# SEQUENCE-STRATIGRAPHIC ANALYSIS OF MIXED CARBONATE-SILICICLASTIC CAMBRIAN SEDIMENTS, CARRARA FORMATION, SOUTHWEST BASIN AND RANGE, CALIFORNIA AND NEVADA

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Submitted to the Department of Earth, Atmospheric, and Planetary Sciences in Partial Fulfillment of the Requirements for the Degree of

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*Dedicated to the memory of Mike Hayes, a friend and colleague who died too young.*

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## ABSTRACT

The Lower to Middle Cambrian Carrara Formation was deposited over about 36,000 $km^2$ on the western passive margin of North America during Early to Middle Cambrian time. Several wide spread processes took place at that time which affected Carrara deposition, including the long-term eustatic Sauk Transgression, rapid passive-margin subsidence, shorter-term regional or eustatic sea level fluctuations, and varying rates of coeval sediment production and delivery into the Carrara depocenter by a cratonal siliciclastic source and an offshore carbonate bank. Mixing of peritidal carbonate and siliciclastic sediments can be resolved in the Carrara at several levels, from alternating laminae to alternating depositional units several tens of meters in thickness (members). Sixteen subtidal to intertidal carbonate lithofacies and five subtidal to nonmarine siliciclastic lithofacies are recognized in the Carrara. The lithofacies combine to produce 23 varieties of generalized meter-scale shallowing-upward cycles (parasequences), including six carbonate varieties, two siliciclastic varieties, and 15 mixed-lithofacies varieties.

A detailed study of the upper 30-50 m of the Jangle Limestone Member of the Carrara Formation at Eagle Mountain, California documents a mix of laterally continuous and discontinuous peritidal carbonate facies and meter-scale shallowing-upward cycles/parasequences. Lateral and vertical changes in facies, cycles and surfaces bounding cycles were described, traced across 1.8 km of continuously exposed outcrop, and correlated to sections in nearby ranges. Subtidal and intertidal facies change laterally over short distances and some cycles and their bounding surfaces do not extent for more than a few hundred meters in a lateral direction. In contrast, many cycles and their bounding surfaces do extend for the 1.8 km of continuous outcrop and can be correlated to nearby ranges with varying degrees of confidence.

Both intrinsic and extrinsic mechanisms controlling sedimentation and stratigraphy are thought to be operating simultaneously and are expressed at different levels of resolution. In the Carrara, members (fourth-order cycles) may be recognized over greater than 200 km along depositional dip and 100 km along depositional strike. Because of this wide-spread occurrence, it is likely that extrinsic mechanisms determine such characteristics as gross lithologies and lateral variations on thickness, and distribution at a member-scale. Some cycles may be correlated across similar distances as the members, whereas others are discontinuous over distances as short as a few kilometers. For meter-scale cycles/parasequences (fifth-order cycles and less than 20 m thick), extrinsic mechanisms are probably the main influence on laterally continuous cycles, whereas either extrinsic or intrinsic mechanisms may be the main influence on discontinuous cycles. The presence of laterally discontinuous cycles among laterally continuous cycles implies that intrinsic factors may override extrinsic factors and influence sedimentation and stratigraphy at the level of fifth-order cyclicity.

Duration of meter-scale cycles may correlate with lateral continuity; cycles of average duration of $10^5$ years are commonly laterally continuous, and cycles with average duration of $10^4$ years are either laterally continuous or discontinuous. Meter-scale cycles of $10^5$ years are not able to record short-term ($10^3$ to $10^4$ years) events in a recognizable fashion because of the small amount of net sedimentation that can be preserved in $10^3$ to $10^4$ years (less than a few tens of centimeters maximum). In contrast, the Carrara meter-scale cycles (average duration of $10^4$ years) form a mosaic of laterally continuous and discontinuous facies and meter-scale cycles because the greater net sedimentation preserves short-term ($10^3$ to $10^4$ years) events in a recognizable fashion. Many autocyclic processes that produce laterally discontinuous facies and cycles occur on these shorter time-intervals.

The nine members of the Carrara, described and correlated using sequence stratigraphic principles, contain three complete and two partial Grand Cycles, ranging from less than 100 to over 200 m in thickness. Sequence stratigraphic correlations provide more detailed delineation of internal geometries of Grand Cycles and allow development of a new sequence stratigraphic model of Grand Cycle formation. In addition, limited observations and published descriptions of the underlying Zabriskie Quartzite and part of the Wood Canyon Formation have been combined with the basal Carrara Formation to form a complete Grand Cycle. A similar approach with the Papoose Lake Member of the overlying Bonanza King Formation allows tentative definition of an uppermost Carrara Grand Cycle.

The proposed sequence stratigraphic model of Grand Cycle development places the sequence boundary at the sharp contact between overlying siliciclastics and underlying carbonates and a Grand Cycle is considered to be one sequence. Sequence boundaries in the Carrara are interpreted as Type 2 boundaries but there is no restriction in the model against the presence of Type 1 sequence boundaries. The minimum accommodation systems tract (**MNAST**), formed during the period of minimum accommodation, has the greatest variation in expression, and this has resulted in much disagreement regarding Grand Cycle origins. If the **MNAST** is thick, it has subtidal and intertidal to nonmarine sediments, predominantly siliciclastics in a progradational stacking of parasequences. If the **MNAST** is thin, it is composed of dominantly subtidal siliciclastics and is difficult to distinguish from the subtidal siliciclastics of the overlying increasing accommodation systems tract (**IAST**). In either case, the siliciclastics may have overrun the bank and shut off carbonate production, or displaced the bank to a more basinward position. During the increase in accommodation, as the rate of accommodation space increased to its maximum, the siliciclastics formed retrogradationally stacked parasequences in the **IAST**. During this same period carbonate sedimentation was re-established offshore and/or began to prograde cratonward. Clearing of the water column as siliciclastics move cratonward may have aided in rejuvenation of carbonate production. Coeval deposition of carbonate and siliciclastic sediments produced the diachronous transitional internal boundary between dominantly siliciclastic sedimentation in the lower parts of Grand Cycles and dominantly carbonate sedimentation in the upper part. As accommodation reached its maximum, the rate of accommodation space decreased significantly during deposition of the maximum accommodation systems tract (**MXAST**). This decrease allowed progradation of both carbonates and siliciclastics in the **MXAST**, but as shown by the preponderance of carbonate sediment in the upper part of Grand Cycles, the carbonate bank prograded more rapidly in the basinward area of the lagoon.

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John Grotzinger has acted as advisor on this thesis and suggested the Carrara Formation as a place in which to explore my ideas on small-scale and large-scale depositional cycles. He has taught me much about many things. In addition to John Grotzinger, my committee included Pete Palmer, Maureen Raymo, and John Southard and I thank them all for reading the thesis and making many useful suggestions for its improvement.

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# CHAPTER 1: INTRODUCTION

## FORMULATION OF THE PROBLEM

Eustatic sea level, vertical tectonic movements, sediment supply, and climate are recognized as the four major controls on depositional geometries (Ingersoll, 1988; Jervey, 1988; Posamentier et al., 1988; Read et al., 1986; Sloss, 1988b), but the mechanisms that cause changes in the rates of these controls are the focus of much controversy in stratigraphy and sedimentology. There is much debate about the major mechanisms that determine depositional geometries at various scales. Are the mechanisms internal to a depositional system (intrinsic) or external (extrinsic)? Do intrinsic and extrinsic mechanisms operate simultaneously or separately in an area? Are they globally wide-spread, restricted to individual basins, or are they localized affecting no more than a part of a basin? Is there a hierarchy of temporal cycles (Milankovitch cycles) that act as a driving mechanism to produce sedimentary cycles, or is there no hierarchy and what we interpret as sedimentary cycles at several sizes really nothing more than a psychological need to impose order on a fractal geometry of depositional units?

Unfortunately, much of our factual data base that should be used to resolve these questions is beset by limitations. We have no method to resolve how time is partitioned in a stratigraphic section between rock and hiatal surface; i.e. we cannot resolve the question of what is actually preserved in a stratigraphic section (Anders et al., 1987; Sadler, 1981; van Andel, 1981). Is the rare and unusual event preserved? Is the section an amalgam of bits and pieces of day-to-day deposition? Is an early depositional episode preserved and most of the rest of time tied up on a hiatal surface that represents sediment bypassing because there is no possibility of sediment preservation? It is difficult to determine the duration of a depositional unit, even if the partitioning of time is ignored, because of uncertainties in the constraints on the boundaries in the geologic time scale. Biostratigraphic controls, though geographically widespread have poor temporal resolution. Radiometric dates have very good local temporal resolution, but are not yet numerous enough to rigorously calibrate the existing biostratigraphic constraints. Lateral continuity or discontinuity of meter-scale cycles over distances from hundreds of meters to tens of kilometers is seldom conclusively demonstrated because of lack of continuous outcrop where depositional units and their bounding surfaces can be walked out. Most studies must rely on correlations made between disjunct stratigraphic sections and/or well logs and it is very rare for correlations to be made with complete confidence. Because of this it is very difficult to prove lateral continuity or lateral discontinuity of cycles. The quality of data is such that different researchers may arrive at opposing conclusions based on the same data (See discussion below).

Given these restrictions on our present ability to interpret controlling mechanisms, it is useful to study relationships between small-scale depositional units and the larger-scale depositional units that are comprised of those small-scale units. Insight into these relationships provides constraints on possible controlling mechanisms and will aid in discriminating between proposed mechanisms. The Carrara Formation is composed of easily recognized meter-scale shallowing-upward cycles that are grouped into larger depositional cycles tens of meters thick. In turn, these depositional cycles tens of meters thick are grouped into still larger depositional cycles 100-200 m thick. Hence, the Carrara provides three levels of depositional cycles to study. Quality and quantity of exposures are very good with complete sections exposed in a number of ranges. In some ranges contacts and bounding surfaces may be walked out for up to several kilometers. The ranges are distributed across both depositional strike and depositional dip directions of the formation and allow detailed reconstruction of the depositional setting on a palinspastic reconstruction (Levy and Christie-Blick, 1989). Because of these reasons, the Carrara provides a good data base with which to begin to study some of these questions.

Lithofacies, described and interpreted in Chapter 2, are divided into carbonate lithofacies and siliciclastic lithofacies. Within those two broad categories, lithofacies are further subdivided into subtidal, intertidal and supratidal group. The vertical arrangement of lithofacies into meter-scale cycles is discussed in Chapter 3 and generalized cycles are developed. In Chapter 4, an example of a mosaic of laterally discontinuous and continuous meter-scale cycles is documented. In turn, the mosaic of meter-scale cycles forms discrete, laterally continuous depositional units that are tens of meters thick. Thus, this example provides constraints that must be explained by any mechanism that is proposed to control the formation of meter-scale cycles. The thicker depositional units are examined in Chapter 5 and the regional distribution, vertical grouping, and lateral changes of generalized facies in those units are analyzed. This analysis provides constraints on the temporal variation of the interaction between rate of accommodation [The combined contribution of eustasy and tectonics producing available space to "store" sediment below sea level] on a passive margin and rates of sediment supply from a carbonate source and a siliciclastic source. The thicker depositional units are grouped into larger units, called Grand Cycles, approximately

100-200 m thick with dominantly siliciclastic sediments in the lower half and dominantly carbonate sediments in the upper half.

## PREVIOUS WORK, PALEOGEOGRAPHY, AND REGIONAL GEOLOGY

The Carrara Formation, of Early to Middle Cambrian age based on trilobite biostratigraphy (Barnes et al., 1962; Barnes and Palmer, 1961; Palmer and Campbell, 1976; Palmer and Halley, 1979), crops out in the Basin and Range Province in southeastern California and southern Nevada, within an area roughly defined by the Last Chance Range (LC), northwest of Death Valley, California; the Groom Range (GR), Lincoln County, Nevada; Frenchman Mountain (FM), near Las Vegas; the Mesquite Mountains (WP; Winters Pass stratigraphic section); and the Panamint Range on the west side of Death Valley (Figure 1). It is a succession 300-500 m thick of mixed nearshore marine carbonate and siliciclastic shelf sediments, whereas to the northwest and north correlative formations are predominantly carbonates. In the White-Inyo Mountains of California and in Esmeralda County, Nevada, the Carrara has been correlated (Figure 2) with all or part of the Saline Valley Formation, the Mule Spring Formation, the Monola Formation, and the Emigrant Formation (Albers and Stewart, 1972; Palmer and Halley, 1979; Palmer and Nelson, 1981; Palmer and Rowland, 1989; Signor and Mount, 1989; Stewart, 1970). To the east and south correlative formations are either of mixed composition or are predominantly siliciclastic. East and north of Las Vegas the Carrara is equivalent to all or parts of the Tapeats Sandstone, Pioche Shale, Bright Angel Shale, Lyndon Limestone, and Chisholm Shale (Longwell et al., 1965; Palmer and Halley, 1979; Palmer and Rowland, 1989; Stewart, 1970; Tschanz and Pampeyan, 1970). South of the Carrara outcrop area correlative formations include the Latham Shale, the Chambless Limestone, and the Cadiz Formation (Palmer and Halley, 1979; Stewart, 1970). These relationships are summarized in Figure 2.

The Carrara Formation has been the focus of a number of studies since Cornwall and Kleinhampl (1961) named the formation and designated the type section near the ghost town of Carrara, Nevada. The general lithology, age, extent of the formation, and regional correlations are described by previous workers (Barnes and Christiansen, 1967; Barnes et al., 1962; Stewart, 1965; Stewart, 1970; Stewart and Barnes, 1966). Trilobite biostratigraphy has refined regional correlations (Barnes and Palmer, 1961; Palmer and Halley, 1979). Important studies of Carrara sedimentology, stratigraphy, and biostratigraphy have been conducted by Bates (1965), Halley (1974), and Palmer and Halley (1979). Halley (1975, p. 287)) pointed out that in

**Figure 1.** Location map showing unrestored positions of the stratigraphic columns measured in this study (solid circles) and four stratigraphic columns measured by Halley (1974) and Palmer and Halley (1979) (open squares). Palinspastically restored positions are shown in Figure 18. Abbreviations: **BR** = Belted Range; **CS** = Chappo Springs; **DR** = Desert Range; **EC** = Echo Canyon; **EM** = Eagle Mountain; **FM** = Frenchman Mountain; **GR** = Groom Range; **LC** = Last Chance Range; **LV** = Las Vegas Range; **MH** = Montgomery Hills; **MR** = Middle Resting Springs Range; **N** = Nopah Range; **NR** = Northern Resting Springs Range; **SH** = Striped Hills; **SR** = Southern Resting Springs Range;**TC** = Titus and Titanothere Canyons; **WP** = Winters Pass.

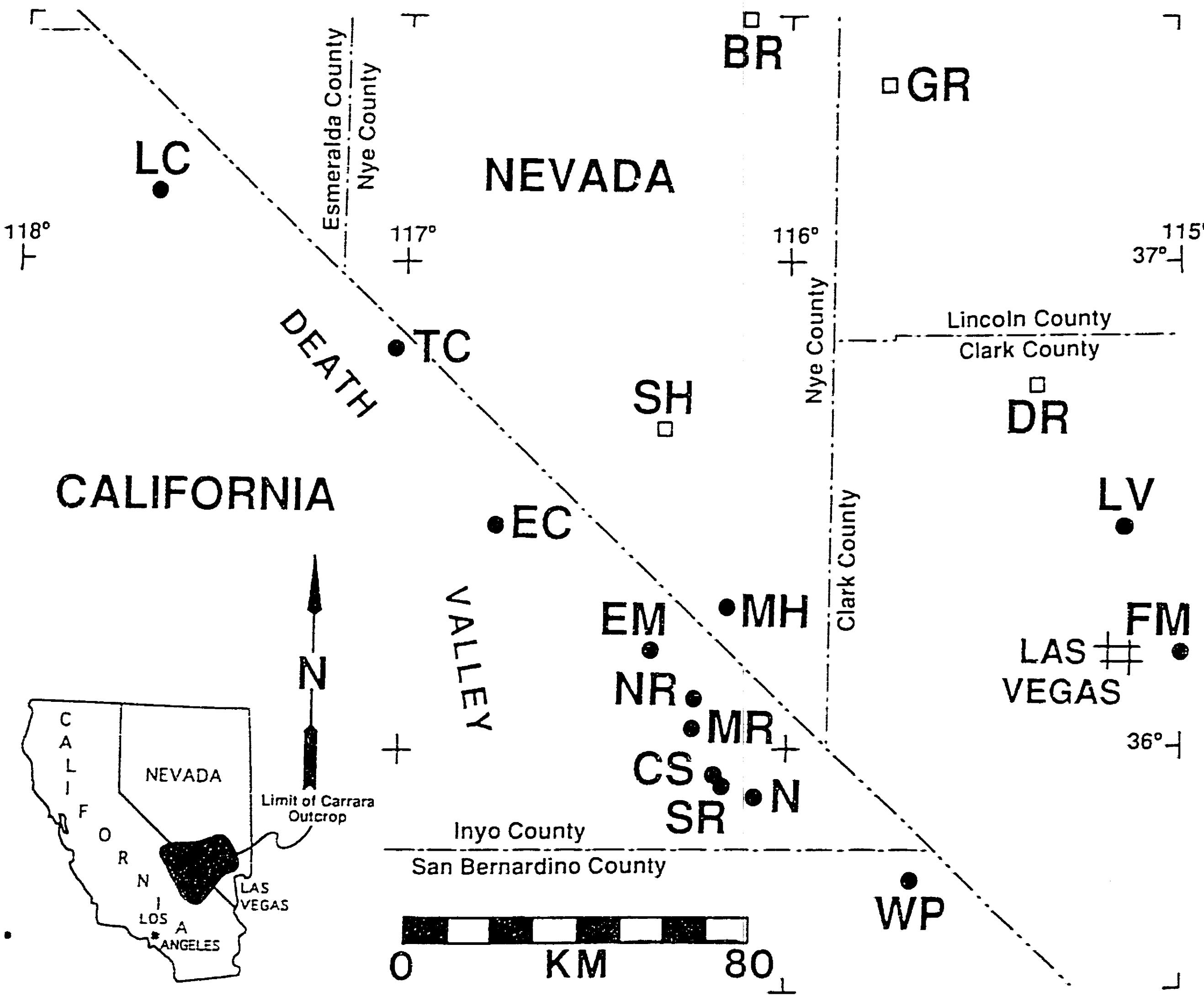
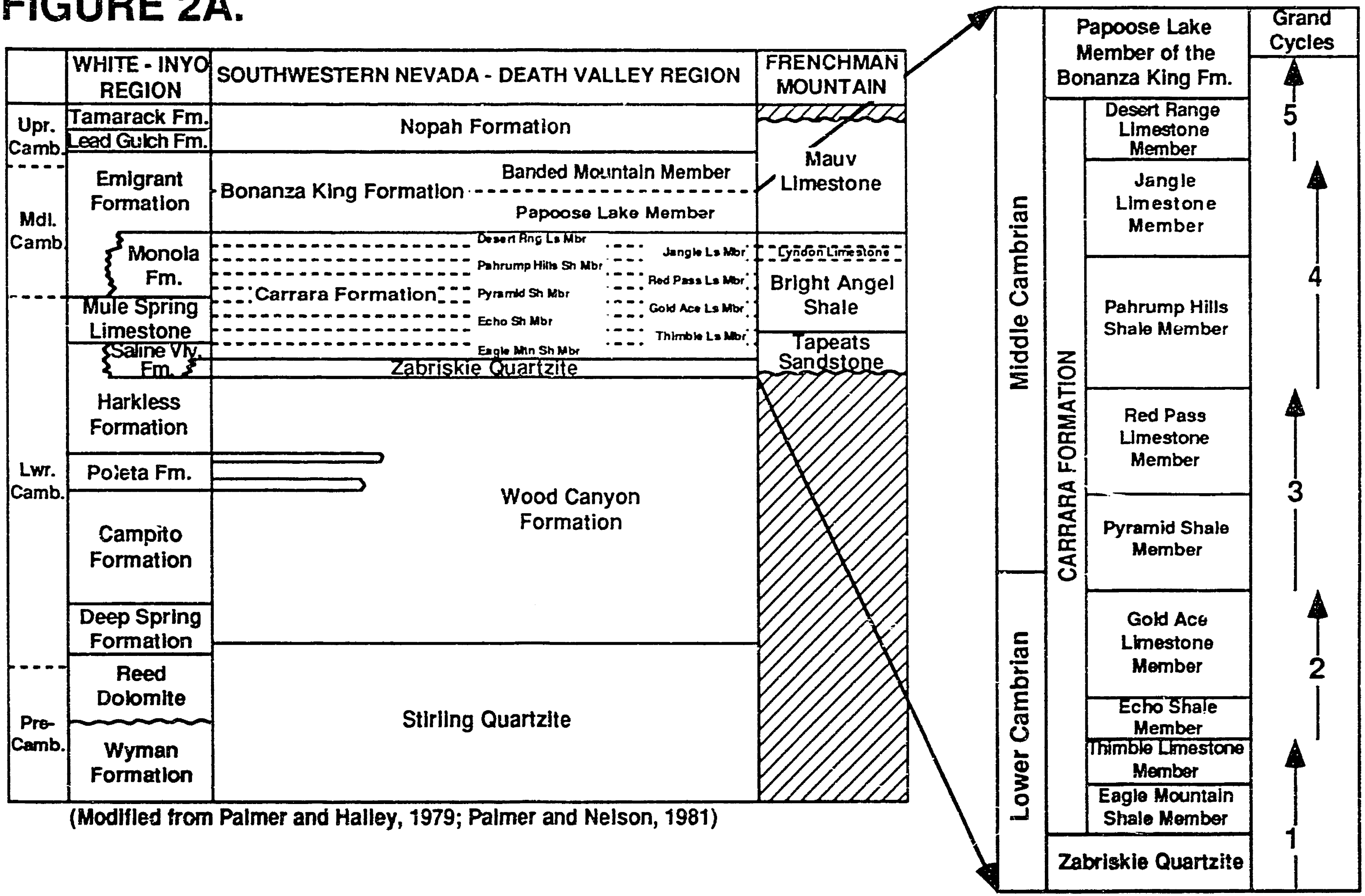

LC
NEVADA
CALIFORNIA
DEATH
VALLEY
Esmeralda County
Nye County
118°
117°
116°
115°
37°
36°
BR
GR
TC
SH
Lincoln County
Clark County
DR
LV
EC
MH
EM
NR
MR
CS
SR
N
FM
LAS VEGAS
WP
Inyo County
San Bernardino County
0
KM
80
CALIFORNIA
NEVADA
Limit of Carrara Outcrop
LAS VEGAS
LOS ANGELES

FIGURE 1.

**Figure 2.** Precambrian through Cambrian stratigraphy of the Death Valley region is presented with generalized regional correlations. **A)** A generalized uppermost Precambrian through Cambrian stratigraphic column in the Death Valley region showing correlative formations to the northwest and the east (from Palmer & Nelson, 1981). The White-Inyo region lies northwest of the limit of the Carrara, and Frenchman Mountain lies at the eastern limit. At Frenchman Mountain, some workers utilize Grand Canyon stratigraphic terminology as shown, however Death Valley terminology is used in this study. The five Grand Cycles and their constituent members and formations, discussed in Chapter 5, are shown on the right. **B)** Regional stratigraphic column with trilobite biozones and the members of the Carrara showing correlative formations to the north, south, east, and west (from Palmer & Halley, 1979).

FIGURE 2A.




(Modified from Palmer and Halley, 1979; Palmer and Nelson, 1981)

# FIGURE 2B.

| Series | Trilobite Biozones | Southern Nevada and Southeastern California | | Marble Mountains, California (to south) | Inyo Mountains, California (to northwest) | Esmeralda County, Nevada (to northwest) | Highland Range, Nevada (to northeast) | Grand Canyon, Arizona (to east) |
|---|---|---|---|---|---|---|---|---|
| Middle Cambrian | *Glossopleura* | CARRARA FORMATION | Desert Range Limestone Member | Cadiz Formation | Monola Formation | Emigrant Formation (part) | Chisholm Shale | Bright Angel Shale |
| | *Albertella* | | Jangle Limestone Member | | | | Lyndon Limestone | |
| | | | Pahrump Hills Shale Member | | | | Pioche Shale | |
| | *Plagiura-Poliella* | | Red Pass Limestone Member | | | | | |
| | | | Pyramid Shale Member | | ? | Mule Spring Limestone | | ? |
| Lower Cambrian | *Bonnia-Olenellus* | | Gold Ace Limestone Member | Chambless Limestone | Mule Spring Limestone | | | Tapeats Sandstone |
| | | | Echo Shale Member | Latham Shale | | | | |
| | | | Thimble Limestone Member | | | | | |
| | | | Eagle Mountain Shale Member | | Saline Valley Formation (upper part) | Saline Valley Formation (upper part) | | |

(Modified from Palmer and Halley, 1979)

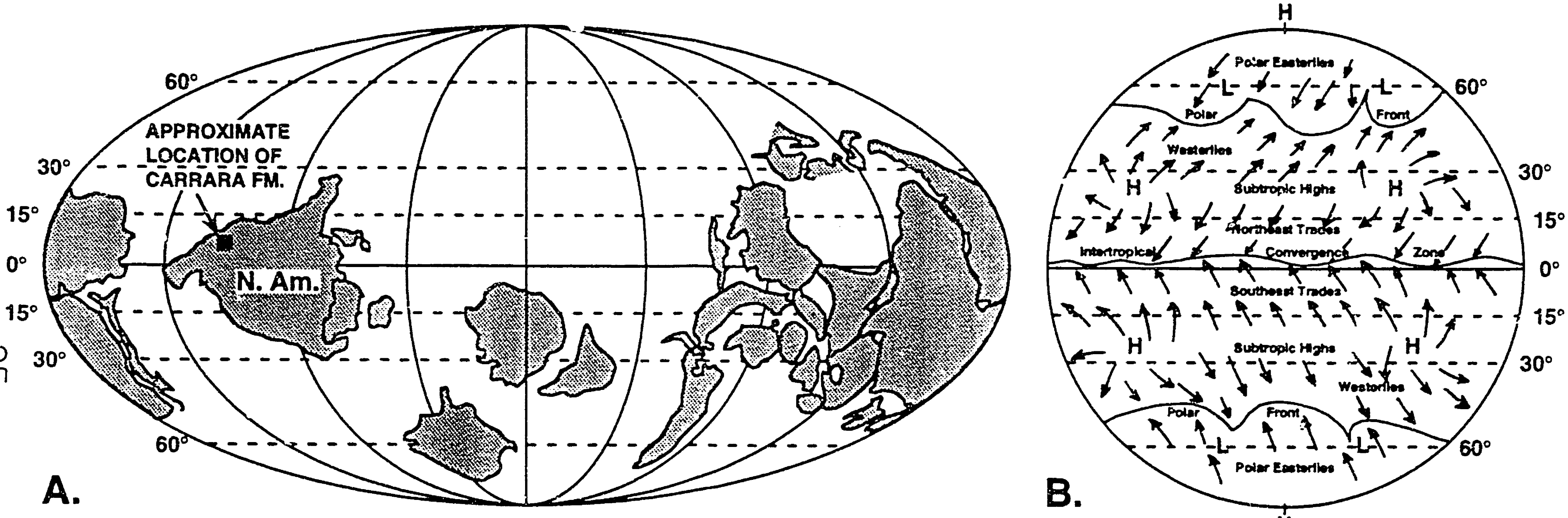
Carrara carbonates "At any one locality the vertical distribution of lithologies ... is more or less random. This ... suggests [deposition as] ... a complex mosaic of ... facies ...". Members defined by Halley (1974) and Palmer and Halley (1979), are used in this paper and are illustrated in the generalized Carrara stratigraphic sections shown in Figure 2. The peritidal carbonate interval described in Chapter 4 corresponds to the upper half of the Jangle Limestone Member of Palmer and Halley (1979) and does substantiate a mosaic distribution of facies and meter-scale cycles in the Carrara.

The Carrara Formation was described by Palmer and Halley (1979) as a collection of Grand Cycles, analogous to the Canadian Grand Cycles of the southern Rockies (Aitken, 1966; Aitken, 1978). Paleogeography of the two areas was similar in that both were mature passive margins in Cambrian time, with a recurrent carbonate bank situated on the outer part of the shelf and a broad, shallow lagoon stretching cratonward from the bank. The lagoon was the main site for deposition of mixed carbonate and siliciclastic sediments. This paleogeography and the extensive area over which the Carrara is exposed have produced one of the better examples of a mixed carbonate and siliciclastic depositional system in North America and, as such, provides excellent field constraints on the major mechanisms determining distribution of carbonate and siliciclastic sediments at the level of members (tens of meters in thickness) and at the level of meter-scale cycles.

Global paleogeography in the Cambrian places North America roughly 90° clockwise from its present orientation straddling the Equator. With this orientation, Carrara deposition is placed at approximately 15° N latitude (McKerrow and Scotese, 1990) on an east-west oriented shelf margin (Figure 3A) (Stewart, 1970; Stewart, 1991; Stewart and Suczek, 1977), in a zone of probable warm, arid climate (Witzke, 1990). Extrapolating from a generalized model of wind and oceanic current circulation patterns on the earth, the general current and wind patterns were probably from east to west (north to south in present orientation) during Carrara deposition (Figure 3B) (Drewry et al., 1974).

A major eustatic rise in sea level, the Sauk Transgression (Sloss, 1963) occurred from the Late Precambrian through the Cambrian and into the Ordovician, and is reflected in long-term changes within the five Grand Cycles of the Carrara. The oldest Grand Cycle contains more coarse-grained siliciclastic sediments, includes a higher percentage of nonmarine deposits in the siliciclastic half-cycle, has siliciclastics that have prograded farther basinward, and has a smaller carbonate half-cycle. There is a general and progressive decrease upwards through the five successive Grand Cycles in the percentage of coarse-grained siliciclastics, the proportion of nonmarine

**Figure 3. A)** Plate reconstruction from McKerrow and Scotese (1990) for the Middle Cambrian. North America is rotated 90° clockwise from its present position which places the passive margin of the Carrara on the northern side of the continent in an east-west orientation at about 15° N latitude. **B)** Schematic diagram of global wind circulation with wind patterns as shown by the arrows (from Drewry et al. 1974). This simple model implies that the passive margin of the Carrara may have been subjected to wind and oceanic currents moving from east to west (north to south in the Holocene configuration).




A. Middle Cambrian Paleogeography

B. Wind Directions

FIGURE 3.

siliciclastics, and the maximum distance of siliciclastic progradation. In addition, throughout the study area there is an increase in the thickness and cratonward extent of each successive carbonate half-cycle. This general progression is reversed somewhat in the Pahrump Hills Shale of the fourth Grand Cycle, leading to speculation that the lower part of the member records the Hawke Bay eustatic fall in sea level although biostratigraphy only restricts the event to occur sometime during deposition of the Zabriskie Quartzite and the Carrara Formation (Palmer, 1981a; Palmer and James, 1980). The Desert Range-Papoose Lake Grand Cycle, the youngest of the five Grand Cycles, has such a limited siliciclastic half-cycle at its base that Palmer and Halley (1979) did not name a separate member for it. In most of the study area the basal siliciclastic part of this Grand Cycle is more of a siliciclastic-rich carbonate than a pure siliciclastic lithology.

Siliciclastic sediments, derived from the craton, range from shales to pebbly sandstones in the Carrara and the underlying Zabriskie Quartzite (Prave, 1992; this paper). Siliciclastics generally become progressively finer to the west and north and, in the Carrara, sandstone is subordinate to shale and siliceous mudstone. Most siliciclastics were deposited in shallow, nearshore environments, probably under conditions of low day-to-day wave energy, though some were deposited in a nonmarine setting, either in a supratidal setting or on a coastal plain. Marine carbonate sediments were mostly produced in relatively shallow subtidal depths, above storm wave base. Intertidal carbonates are subordinate to subtidal lithofacies.

Carrara paleogeography consisted of a recurrent offshore carbonate bank that would build up to the intertidal zone, forming discontinuous tidal islands. The bank allowed development of a broad, shallow, low-energy lagoon that was the site of most of the mixed sedimentation. Periodic decreases in accommodation (falls in relative sea level) adversely affected the bank by either severely restricting the areal extent of the bank or by allowing siliciclastic sediments to rapidly spread so far basinward that they overran the bank and terminated carbonate production completely. As accommodation increased (relative sea level rose), siliciclastic sedimentation was displaced towards the craton, resulting in clear-water conditions and resumption of carbonate production.

## NOTATION

### SEQUENCES AND GRAND CYCLES, PARASEQUENCES AND CYCLES

"Sequence" is used in the sequence-stratigraphic sense, as defined by Mitchum et al. (1977) and Van Wagoner et al. (1987, 1988, 1990) and in the Carrara represents a duration of approximately $10^6$ years (See discussion below). This duration is equivalent to a third-order cycle as defined by Goldhammer et al. (1991; Table 1) and is in agreement with time estimates of sequence duration as discussed in Van Wagoner et al. (1990), Goldhammer et al. (1991), and Mitchum and Van Wagoner (1991). The term "Grand Cycle" is used in the sense of Aitken (1966, 1978) for couplets tens to hundreds of meters in thickness composed of dominantly siliciclastic sediments overlain by dominantly carbonate sediments, with sharp contacts at the bases of shale halves and gradational contacts at the bases of carbonate halves. In this paper a Grand Cycle corresponds to a sequence.

"Parasequence" is also used in the sequence-stratigraphic sense as defined by Van Wagoner et al. (1987, 1988, 1990) for a depositionally related group of facies, deposited under similar conditions over a period of no more than approximately $10^4$ to $10^5$ years. A parasequence records a gradual shoaling of facies and is bounded below and above by parasequence surfaces. It is designated by its lower boundary, i.e., a parasequence bounded below by Parasequence Boundary A and above by Parasequence Boundary B will be designated as Parasequence A. In the Carrara a parasequence represents a duration of approximately $10^4$ years (See discussion below). This duration is equivalent to a fifth-order cycle as defined by Goldhammer et al. (1991; Table 1) and is in agreement with time estimates of parasequence duration as discussed in Van Wagoner et al. (1990), Goldhammer et al. (1991), and Mitchum and Van Wagoner (1991). A "parasequence boundary" is a discrete surface or relatively abrupt interval, a few centimeters or less thick, separating shallower-water facies below from deeper-water facies above. The boundary may be erosional, and it is inferred that it records a diastem. In this study, the terms parasequence boundary and parasequence are used to outline facies relationships and geometries. This usage of parasequence boundary and parasequence follows that defined by Van Wagoner et al. (1987, 1988, 1990). In this context "parasequence" embraces the essence of a "shallowing-upwards cycle" in many carbonate platforms, e.g., James (1984), as well as the "Punctuated Aggradational Cycle" (PAC) of Goodwin and Anderson (1985). In this paper "parasequence" is synonymous with "meter-scale shallowing-upwards cycle". Parasequence terminology is preferred because the accompanying concepts of sequence stratigraphy provide a larger framework in which to place observations.

A hierarchy of "orders of cyclicity" has come into general usage wherein the largest cycle is referred to as a "first-order" cycle and successively smaller cycles are successively designated "second-order", "third-order", etc. Time durations have been assigned to the various levels of cycles, though not with complete uniformity; cf. Busch and Rollins (1984) with Goldhammer et al. (1987). Table 1 uses time duration, cycle

**Table 1.** Comparison of sequence-stratigraphic terminology, Grand Cycle terminology, eustatic or cycle order designation, and range of cycle duration, compiled from several sources.

| Sequence Stratigraphic Terminology | Grand Cycle Terminology | Eustatic Cycle (Order) | Duration (m.y.) |
|---|---|---|---|
| | | First | >100 |
| Supersequence | | Second | 10-100 |
| Sequence | Grand Cycle | Third | 1.0-10 |
| Sequence, Systems tract, Parasequence Set, Cycle | Grand Cycle, Half Cycle of Aitken | Fourth | 0.1-1.0 |
| Systems tract, Parasequence Set, Parasequence, Cycle | Half Cycle of Aitken | Fifth | 0.01-0.1 |
| Parasequence, Cycle | | Sixth | 0.001-0.01 |

Based in large part on Goldhammer, et al. (1991), Van Wagoner, et al. (1990), Mitchum & Van Wagoner (1991), Aitken (1966, 1978, 1981).

**TABLE 1.** Comparision of sequence stratigraphic terminology, eustatic or cycle order designation, and range of cycle duration, compiled from several sources.

orders, and equivalent sequence-stratigraphic terminology essentially as set forth in Goldhammer et al. (1991). These conventions are in general agreement with sequence-stratigraphic designations applied to siliciclastic stratigraphy (Mitchum and Van Wagoner, 1991; Van Wagoner et al., 1990 and most durations assigned to carbonate cycles. Sequences may be either third-order or fourth-order cycles; systems tracts and parasequence sets may be fourth-order or fifth-order cycles; and parasequences may be fifth-order or sixth-order cycles (Table 1). Sequences that are third-order cycles are made up of systems tracts and parasequence sets that are fourth-order cycles, and parasequences that are fifth-order cycles. Sequences that are fourth-order cycles are made up of systems tracts and parasequence sets that are fifth-order cycles, and parasequences that are sixth-order cycles.

**SYSTEMS TRACTS**

Systems tracts are composed of adjacent, coeval depositional systems in a basin or on a shelf and slope of a continental margin (Brown and Fisher, 1977). As such, they are the component parts of sequences, and in turn are made up of parasequences (fifth-order cycles). Hence the duration of a systems tract is between that of a sequence and a parasequence, i.e., a fourth-order cycle with a duration between $10^5$ and $10^6$ years.

The spelling of terms such as "high stand" and "low stand" versus "highstand" and "lowstand" is used to differentiate between a description of where relative sea level is with respect to the craton, "high stand" or "low stand", as opposed to the sequence-stratigraphic term for a particular systems tract, "highstand" or "lowstand". The standard systems tracts designated in sequence-stratigraphic terminology will be abbreviated as follows: "Highstand Systems Tract" = **HST**, "Transgressive Systems Tract" = **TST**, "Shelf-Margin Systems Tract" = **SMST**, and "Lowstand Systems Tract" = **LST**. The standard systems tract names were developed at a time when eustatic sea level fluctuation was considered to be the primary control on stratal geometries (Van Wagoner et al., 1990) and were assigned accordingly, e.g. "highstand" and "lowstand". The "Shelf-Margin Systems Tract", named for a variant of the systems tract deposited during the low stand of sea level, carries an unfortunate and erroneous implication of its position on a shelf due simply to its name. It is not constrained to be situated at the outer edge of the shelf ([Van Wagoner, 1990 #37; p.27]).

Accommodation is the space available below sea level to store sediments (Jervey, 1988; Posamentier et al., 1988; Posamentier and Vail, 1988). As used in this paper, "rate of accommodation" refers to the rate at which accommodation space is added or removed in region. New systems tract names are proposed that refer only to accommodation, without implication as to position of relative or eustatic sea level with respect to the craton. Further, there is no implication as to position on the shelf or in a basin, nor is there any linkage to the nature of the basal sequence boundary. A systems tract deposited during the period of minimum accommodation is the "Minimum Accommodation Systems Tract" = **MNAST**; one deposited during the period of increasing accommodation is the "Increasing Accommodation Systems Tract" = **IAST**; one deposited during the period of maximum accommodation is the "Maximum Accommodation Systems Tract" = **MXAST**; and if a sequence boundary is not formed during the period of decreasing accommodation, but rather sediments are deposited, the resulting systems tract would be the "Decreasing Accommodation Systems Tract" = **DAST**. These new systems tract designations are used in this paper.

## METHODOLOGY

Stratigraphic sections (Appendix 3) were measured using a Jacobs staff with a Brunton compass attached to control dip angle. Beds as thin as a few centimeters were recognized and described. Ten sections were measured through the entire Carrara Formation for this project. An additional three sections were measured through the entire formation by the author and the other three members (S. J. Friedmann, L. Kah, and C. Summa) of the MIT Spring Sedimentology Field Class in 1989. Another eleven stratigraphic sections were measured through parts of the Carrara; nine measured through the upper half of the Jangle Limestone Member were utilized in the detailed study summarized in Chapter 4; one section, measured at Chappo Springs in the southern Resting Spring Range, had only the upper half of the Carrara exposed; and the last section, at the Last Chance Range, California was not completed due to pulled ligaments in the back. However, the upper part of the Last Chance section was combined with an unpublished section from Halley (1974) and an unpublished section provided by I. Montañez and D. Osleger to produce a complete stratigraphic section.

In the Eagle Mountain part of the study (See Chapter 4) facies units, parasequences, contacts between facies units, and parasequence boundaries were traced laterally by walking out features. The information gathered was used to physically connect the nine stratigraphic sections measured across the 1.8 km expanse of outcrop. The cross section of Eagle Mountain (Figure 7) is the result of combining these two data sets. The locations of the nine stratigraphic sections are shown in Figure 8.

Regional cross sections (Plates 1 to 4) and isopach maps (Figure 17) are plotted on the palinspastically restored base map of Levy and Christie-Blick (1989).

Polished slabs (94) and thin sections (30) were examined with binocular and petrographic microscopes to augment field descriptions of various lithologies. Petrographic descriptions are in Appendix 2.

# CHAPTER 2: LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS

## INTRODUCTION

The Carrara Formation is made up of three lithofacies groups; carbonate lithofacies, siliciclastic lithofacies, and mixed carbonate/siliciclastic lithofacies. However, mixed lithofacies can be subdivided into their component carbonate and siliciclastic lithofacies and therefore are not described as a separate group. Lithofacies that are interbedded are noted in the following descriptions, in Table 2, and in Figure 6, which illustrates the variety of shallowing-upwards cycles. Mixing is also characterized by the introduction of siliciclastic grains into carbonate lithofacies or carbonate grains into siliciclastic lithofacies, and these cases are also noted in the lithofacies descriptions and in Table 2.

The common subtidal lithofacies are: fossiliferous wackestone/packstone/grainstone; oolitic grainstone; nodular ribbon rock; well-layered ribbon rock; calcarenite, dolarenite, calcisiltite, and dolosiltite (CDAS lithofacies); shale/mudstone; and siltstone/sandstone. The common intertidal lithofacies are "dolosiltite/calcarenite/calcisiltite and siltstone/sandstone. Less common subtidal lithofacies are calcareous mudstone/wackestone and bioturbated ribbon rock. Less common intertidal lithofacies are calcareous fenestral mudstone, orange dolosiltite, and shale/mudstone. Uncommon subtidal lithofacies are thrombolitic boundstone, oncolitic wackestone/packstone/grainstone, and lithoclast packstone/grainstone. Uncommon intertidal lithofacies are stromatolitic boundstone and calcareous mudstone/wackestone. Supratidal shale/mudstone is also an uncommon lithofacies.

Pervasive recrystallization has affected carbonate lithologies, altering most fine-grained constituents and obscuring much information relating to grain types and textures. This leads to difficulties, in hand sample and in thin section, distinguishing ooids from peloids; *"structure grumeleuse"* mudstone (fine, irregular clotted mudstone without any implication of a thrombolitic origin; Bathurst, 1975) from peloidal packstone/grainstone; original carbonate mud from microspar; rounded mudstone clasts from recrystallized oncoids; and *Girvanella* from *Epiphyton* or *Renalcis*. With the exception of sharp lateral margins of thrombolites, lateral changes between facies are gradual, accomplished by mingling grain types and textures of adjacent facies over distances of tens of centimeters to tens of meters. Vertical contacts between lithofacies are commonly sharp, but may be gradual over a few centimeters to a few tens of centimeters. No channeled deposits are recognized within carbonate lithofacies, hence there are no scoured lateral facies changes. Rare channeled sandstone units may be found within marine shale intervals however. There are several examples of one subtidal

**TABLE 2.** Lithofacies in the Carrara Formation.

## LEGEND:

**Grain types:**
- ooids
- peloids
- undifferentiated ooids & peloids
- oncoids
- general fossils
- trilobites
- hyolithoids
- lithoclasts

↑ = vertical trend changing in upward direction

**Carbonate sedimentary structures and textures:**
- A planar microbial laminae
- A wavy microbial laminae
- R well-layered ribbon rock texture
- NR nodular ribbon rock tecture
- BR bioturbated ribbon rock texture
- stromatolitic boundstone
- T thrombolitic boundstone
- D digitate miocrobial boundstone

**Sedimentary structures:**
- H homogenous beds (no structures)
- current ripples
- climbing current ripples
- flaser ripples
- wave ripples
- W climbing wave ripples
- combined flow rippples
- planar cross beds
- trough cross beds
- hummocky cross beds
- horizontal planar laminae
- wavy parallel laminae
- wavy nonparallel laminae
- W wrinkly laminae
- G gutter casts

**Sedimentary structures:**
- scoured surfaces
- hardgrounds
- load structures
- contorted beds
- burrows
- burrowed-to-bioturbated
- bioturbated
- S soil-churned
- # mudcracks
- tepees
- fenestrae
- microfaulting
- pyrite

**Abbreviations:**

| | | | | |
|---|---|---|---|---|
| bndst = boundstone | mdst = mudstone | wkst = wackestone | pkst = packstone | grst = grainstone |
| w/ = with | % = per cent | sh = shale | sts = siltsite or siltstone | |
| ss = sandstone | aren = arenite | ls = limestone | dol = dolostone or dol- or dolo- or dolomitic | |
| VF = very fine | F = fine | C = coarse | VC = very coarse | M = medium |
| m = meter | cm = centimeter | mm = millimeter | qtz = quartz | crsn = coarsen |
| incr = increase | decr = decrease | ps = parasequence | talc = altered sediments | |

u1, u2, u3 etc. = informal units in shallowing-upwards cycles.
skol = *Slolithos* burrows
CDAS = calcarenite, calcisiltite, dolarenite, and dolosiltite

| LITHOFACIES | LITHOLOGIES & GRAIN TYPES | SEDIMENTARY STRUCTURES | BED THICKNESS (Range only) | VERTICAL TRENDS (In an upward direction) | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| SUBTIDAL CARBONATE FACIES | | | | | |
| BNDST (Uncommon.) | Carbonate mud. | Bulbous heads, squat columns, planoconvex lens w/ convex side down, tabular units, irregular mounds and a reefal complex. | Individual heads & columns: heights 5 - 120 cm & widths 5 - 200 cm. Planoconvex lens: ≈75 cm high & ≈3 m wide. Tabular units: 25 - 190 cm high & > several 10's of m wide. Irregular mounds: ≤ 280 cm high & > 3 m widths. Bioherm complex: ≈ 6.3 m high & ≈ 100 - 150 m wide. | | Calcitic mdst, ribbon rock, Ø dolsts wkst, VF arenite, /⊙ pk/grst, ⊙pk/grst, dolsts and dolsts may be found between heads. |
| MD/WKST (Less common.) | Includes arenitic calcitic wkst & silty mdst. fragments. Ø ⊙≤ 1/2 mm. O≤ 1/8 mm. ≤ 1x1 cm. | Dolsts-filled. H | Bed thickness: ≤ 1 - 10 cm. | None. | pkst, dolsts. |
| Ø WK/PK/ GRST (Uncommon.) | Ø ≤ 1/2 - 4 cm, generally spharoidal, but also cylindrical, ellipsoidal, & discoidal. fragments. ⊙≤ 1/2 - 1 mm. ≤ 1x5 cm. VC & smaller qtz sand grains | | Bed Thickness: 1- 40 cm. | No consistant changes. | Dolsts, mdst, & & heads. Some siliciceous mdst. |
| PK/GRST (Uncommon.) | Muddy & sandy matrix, dolsts matrix, mdst matrix. ls & dol siltite/arenite, ≤ 1/2x1/2 mm - 8x10 cm. ⊙≤ 1/2 mm. Ø≤ 3 cm. O ≤1/4 - 1/2 mm. | | Bed Thickness: ≤ 1- 20 cm. | None. | All 3 varieties of ribbon rock, ls & dol sts/arenite, pk/grst. Generally beds are either composed of small clasts (≤ 1x2 cm) in lenticular beds ≤ 10 cm thick, or of larger clasts in tabular beds 10 - 20 cm thick. |
| WK/PK/ GRST (Common. Also may extend into very lowermost intertidal.) | fragments of trilobites, echinoids, hyolithoids, brachiopods. ⊙≤ 1/4 - 2 mm. Ø≤ 1/2 - 3 cm. ≤ 1 1/2 x 20 cm. VF - C qtz sand grains Unidentified coated grains. | H ≤ 35 cm. at base & internal to unit. rare, at top of bedsets. in one bedset. | Bed Thickness: 1 - 35 cm. | Generally fine & thin, w/ an increase in % dolsts. May extend across several adjacent bedsets. | Dolsts w/in interlaminae, interbeds, & burrow-fills. Some siliceous mdst. Often occurs as ≤1-10 cm thick, lenticular interbeds in siliceous mdst & sh, mostly w/ fragments. Interbedded w/ ss, sts, ⊙ pk/grst. |

**TABLE 2.**

| LITHOFACIES | LITHOLOGIES & GRAIN TYPES | SEDIMENTARY STRUCTURES | BED THICKNESS (Range only) | VERTICAL TRENDS (In an upward direction) | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| SUBTIDAL CARBONATE FACIES | | | | | |
| ⊙ GRST (Common. Also may extend into very lowermost intertidal.) | ⊙ ≤ 1/8 - 2 mm, w/ one occurence of 8 mm. fragments, some coated. ≈ 1x1 mm - ≤ 3x10 cm. ∅ ≤ 2 cm, rare. ≤ 1/8 mm. | 5 - 50 cm. H both at base & internally. very rare. | Bed Thickness: ≤ 1 - 50 cm. | Increase or decrease in % dol-sts, grain size, fragments, & . | Dolsts /coated grain grst, & ls arenite. |
| BR (Less common.) | Liths: mdst, or grst, wkst, rare md/wkst, ∅pk/grst, ⊙grst, calci-sts, calcarenite. ≤ 1/8 mm. ⊙≤ 1/8 - 3/4 mm. ∅≤ 2 cm. fragments. △ rare. | spar-filled & dolsts-filled. H & uncommon. | Bed Thickness: Ls ≤ 1 - 10 cm. Dol ≤ 1 - 6 cm. | Decrease % dolsts, rarely increase % dolsts. | Dolsts in all beds w/in interlaminae, burrow-fills, & irregular, discontinuous patches. Some wkst to grst of ⊙∅ , and some . |
| NR (Common. Also may extend into very lowermost intertidal.) | Liths: pkst, grst, aren/sts (sometimes mixed w/ qtz ss & sts), w/ wkst, mdst (or grst?). fragments. ⊙≤ 1/8 - 1 mm. ≤ 1/8 mm. ≤ 1/4 mm. ≤ 1.5x1.5 - 1x6 cm. ∅≤ 4 cm. △ rare. | H #? Internal ? ≤ 30 cm. rare. very rare. very rare. | Bed Thickness: Ls ≤ 1 - 30 cm. Dol ≤ 1 - 6 cm. | Decrease % dolsts in ≈ 1/2 of bedsets, sometimes increase % dolsts, rarely increase & then decrease % or vice versa. Some beds thin & fine., some beds coarsen & thicken, others increase or decrease amount of burrowing. | Dolsts w/in interlaminae, burrow-fills, & irregular, discontinuous patches. Uncommon occurences of or ∅wk/pkst, ⊙ or pk/grst, VF-Fqtz ss, carbonate arenite, & siliceous mdst. |
| R (Common. Also may extend into lowermost intertidal.) | Liths: grst & aren/sts, rare wkst, qtz ss & sts. ⊙1/8 -1/2 mm. fragments. ≤ 2 mm - 2x15 cm. Some unidentified coated grains. ∅≤ 2 cm. ? | H ≤ 20 cm. uncommon. ? & # both uncommon. rare. Graded beds. | Bed Thickness: Ls ≤ 1/2 - 15 cm. Dol ≤ 0.5 - 8 cm. Rare channels ≤ 20 cm high x 2-to-20 m wide. | Sometimes decrease % dolsts. Rarely fines up. | Dolsts in all beds w/in interlaminae, burrow-fills, & irregular, discontinuous patches. Some arenite, wkst, ⊙pk/grst, ⊙ grst. |
| CDAS LITHOFACIES (Common. Also may extend into lowermost intertidal) | Liths: Generally siltite is dolomitic & arenite is calcitic. Unidentified carbonate grains. Qtz silt & VF sand. ⊙≤ 1/8 - 1/4 mm. ? ≤ 1/4 mm. ∅≤ 1 cm. fragments. rare, ≤ 1/2x10 cm. | flaser, wavy & lenticular. ≤ 25 cm. 5 - 45 cm. #? rare. at base of bedsets. rare & at top of bedsets. | Bed Thickness: ≤ 1 - 45 cm. | Decrease amount of siliciclastics and/or dolsts. Thickens and coarsens.. Overall change from to in some beds. | Calc-arenite & calcists & dolsts often together in one bedset. Often interbedded w/ qtz ss & ⊙grst. Some & pk/grst, calcitic mdst, silty, siliceous mdst & sandy mdst, & sts. |

**TABLE 2. (CONTINUED)**

| LITHOFACIES | LITHOLOGIES & GRAIN TYPES | SEDIMENTARY STRUCTURES | BED THICKNESS (Range only) | VERTICAL TRENDS (In an upward direction) | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| INTERTIDAL CARBONATE FACIES | | | | | |
| ⋒ BNDST (Uncommon. Lowest intertidal.) | Orange dolsts, dol-mdst. Gray is arenite, sts, mdst. F qtz sand grains. ⊙? | ≡A ≋A ≡ Λ? ⦶ ≤ 1x1 mm. ∾ at base of bedsets. | Bulbous (1x1 - 10x10 cm.) to very broad (HxW = 1x5 - 10x55 cm) heads. Intermediate shapes (HxW) 4x10 - 25x40 cm. Synoptic relief generally less than half the height. | From broad up to bulbous. From ⋒ up to ≡A. From ls up to dol. Decrease up in size, e.g. 10x10 cm to 2x2 cm. | ≡A & ≋A dolsts. ⋒ occur twice with ⍑. ⋒ often occur between bedsets of siliceous shale to sh to sts. |
| CALCAREOUS MD/WKST (Uncommon. Lowest intertidal.) | ⊙ 1/8 - 1/4 mm. ⓒ fragments. ⋒ ≤ 1 1/2x2 cm. Ø ≤ 1 cm. | ⦶ ≡ ∿ H | Bed thickness: ≤ 1 cm. | None. | Occasional pk/grst, dolsts. |
| DOLSTS, CALCARENITE & CALCISILTITE (Common. Low intertidal.) | Generally orange, but may be red, tan, cream, brown, green. Unidentified carbonate grains. Unidentified coated grains. Qtz silt & VF sand. O? Ø ≤ 1 cm. ⓒ fragments. ⊙ of dolsts, ≤ 1/2x10 cm. | ∼ ⌒ ≡ ≋W ≋ ∿? ∾ ∿ ⌣ loaded into underlying lithologies. ∿ H ∿–ξ ⋒-like microbial laminae, & incipient ⋒. ≡A # ⦶ ≋A rare. | Bed Thickness: mm-laminated to 20 cm. | Increase in % ≡ in some bedsets, rarely decrease % of ⦶. | Calcitic mdst, calcarenite, calcists, & some ⓒ/⊙/O wk/pkst, ⊙/coated grain pk/grst, and occasional stromatolites. |
| CALCAREOUS ⦶ MDST (Less common. Low to mid intertidal.) | of dolsts & ≡A mdst, ≤ 5X5 mm. ⓒ fragments rare. Ø rare & ≤ 1cm. O? | ⦶ ≤ 2 mm. ≡A discontinuous & indistinct. ≋ ≡ ≤ 1-5 cm. ∼? ∿? # rare. | Bed Thickness: 2 - 215 cm. | Increase in % dolsts or in % ≡A in some beds. | Orange dolsts, & rarely dolarenite or Ø wk/pkst. |
| ORANGE DOLSTS (Less common. Mid to high intertidal.) | Unidentified carbonate grains. Qtz silt & VF sand. of dolsts, ≤ 1/2x10 cm. ⊙ O? ⓒ fragments. | ≡A ≋A ≡ # Λ ⦶ ∾ ∿ ∿ ≠ ⋒-like microbial laminae, & incipient ⋒, ≤ 2x2 cm. ≋ ⌒ uncommon. ∼ uncommon. | Bed Thickness: mm-laminated to 15 cm. | Increase in % calcarenite, sts, or mdst. | Calcitic mdst, calcarenite, calcists, & some ⓒ/⊙/O wk/pkst, ⊙/coated grain pk/grst, and occasional stromatolites. |

**TABLE 2. (CONTINUED)**

| LITHOFACIES | LITHOLOGIES & GRAIN TYPES | SEDIMENTARY STRUCTURES | BED THICKNESS (Range only) | VERTICAL TRENDS (In an upward direction) | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| SUBTIDAL SILICICLASTIC FACIES | | | | | |
| SH/MDST (Most common siliciclastic lithofacies.) | Fissile sh, silty sh, silty mdst, all often chloritic (green, greenish-tan, yellow[illegible]n-green, khaki-green, tan, yellowish-tan, gray, light gray, purple, purple-brown). Finer lithologies often cleaved. | , often only horizontal. ≡ G filled w/ VF qtz ss; ≤ 2x2 cm - 10x30 cm. | Bed Thickness: mm-laminated to 15 cm. | Coarsen & thicken up, often changing to sts &/or ss. Sometimes increase the amount of bioturbation upward, or fine up from mdst to sh. | wk/pk/grst, Ø wk/pkst, M-VF ss, calc- & dolarenite, dolsts. |
| STS/SS (Common.) | Muddy sts, muddy ss, M-VF ss (green, khaki-green, tan, tan-orange, brown, light gray, white, pink). Muddy lithologies often chloritic. O? ≤ 5x10 cm. | 5 - 25 cm. W ≡ 5 - 20 cm. at base of bedsets. | Bed Thickness: ≤ 1/2 - 40 cm. | Coarsen & thicken up most common, but sometimes fine & thin up. Bioturbation may decrease or increase up. | pk/grst, calcarenite, dolsts, silty siliceous mdst. |
| INTERTIDAL SILICICLASTIC FACIES | | | | | |
| SH/MDST (Less common.) | Fissile sh, mdst, silty mdst (red, pink, orange, tan, brown, greenish-tan, green). Often cleaved. | ≡ # , mostly horizontal & ≤ 1 mm diameter. | Bed thickness: ≤ 1/2 - 2 cm. | None. | F-VF ss & calcarenite interbeds. |
| STS/SS (Common.) | Qtz sts & VF - F ss (pink, orange, tan, brown, khaki-green, gray,). | ≡ W H Λ # | Bed thickness: ≤ 1/2 - 25 cm. | None. | Silty siliceous mdst, calc- & dolarenite/siltite, ⊙ grst in interlaminae & interbeds. |
| SUPRATIDAL SILICICLASTIC FACIES | | | | | |
| SH/MDST (Uncommon.) | Blocky, non-fissile sh, slightly silty sh, and not very silty mudstone (red, red-purple, purple, gray-purple). | S # Λ H ≡ & crude, coarse ≡. ? | Bed thickness: ≤ 1/2 cm. | May alternate soil-churned intervals w/ ≡ ? # Λ intervals vertically, on a 1-to-few meter scale. Often a uniform soil-churned texture throughout a bedset. | Dolsts, ss interbeds. S ≡ S Gradational contact. Sharp contact. |

TABLE 2. (END)

facies bounded laterally and vertically by another subtidal facies. For example, at Eagle Mountain, in the upper part of the Jangle Limestone, within Parasequence I (Figures 5 and 8), units of oolitic grainstone and oncolitic packstone/grainstone are enclosed within nodular and bioturbated ribbon rock. This geometry allows comparison of the nature of overlying and underlying contacts versus lateral contacts between the same facies units; sharp, commonly scoured, overlying and underlying contacts contrast with gradual lateral facies contacts. Thus the nature of overlying and underlying contacts between different carbonate subtidal facies cannot be taken as a guide to the nature of lateral contacts between facies.

To aid in clarifying composition of lithologies composed of sand- or silt-sized grains, the terms "sandstone" and "siltstone" are used when referring to siliciclastics and the terms "calcarenite", "dolarenite", "calcisiltite", and "dolosiltite" are used when referring to carbonates. "Siliceous mudstone" denotes a siliciclastic mudrock with noncarbonate silt grains as defined by Blatt et al. (1980, p. 382) and should not be confused with "mudstone" or "carbonate mudstone" used in the sense of Dunham (1962). The terms "bed" and "bedset" are used in the sense of Campbell (1967) and Van Wagoner et al. (1990). Campbell (1967; p. 20) defines "bedset" as follows: "A bedset consists of two or more superposed beds characterized by the same composition, texture, and sedimentary structures." There is no implication of size in this definition, and a bedset may be composed of current-ripple cross-laminae only a few centimeters thick, or of aeolian cross-bedding many meters thick.

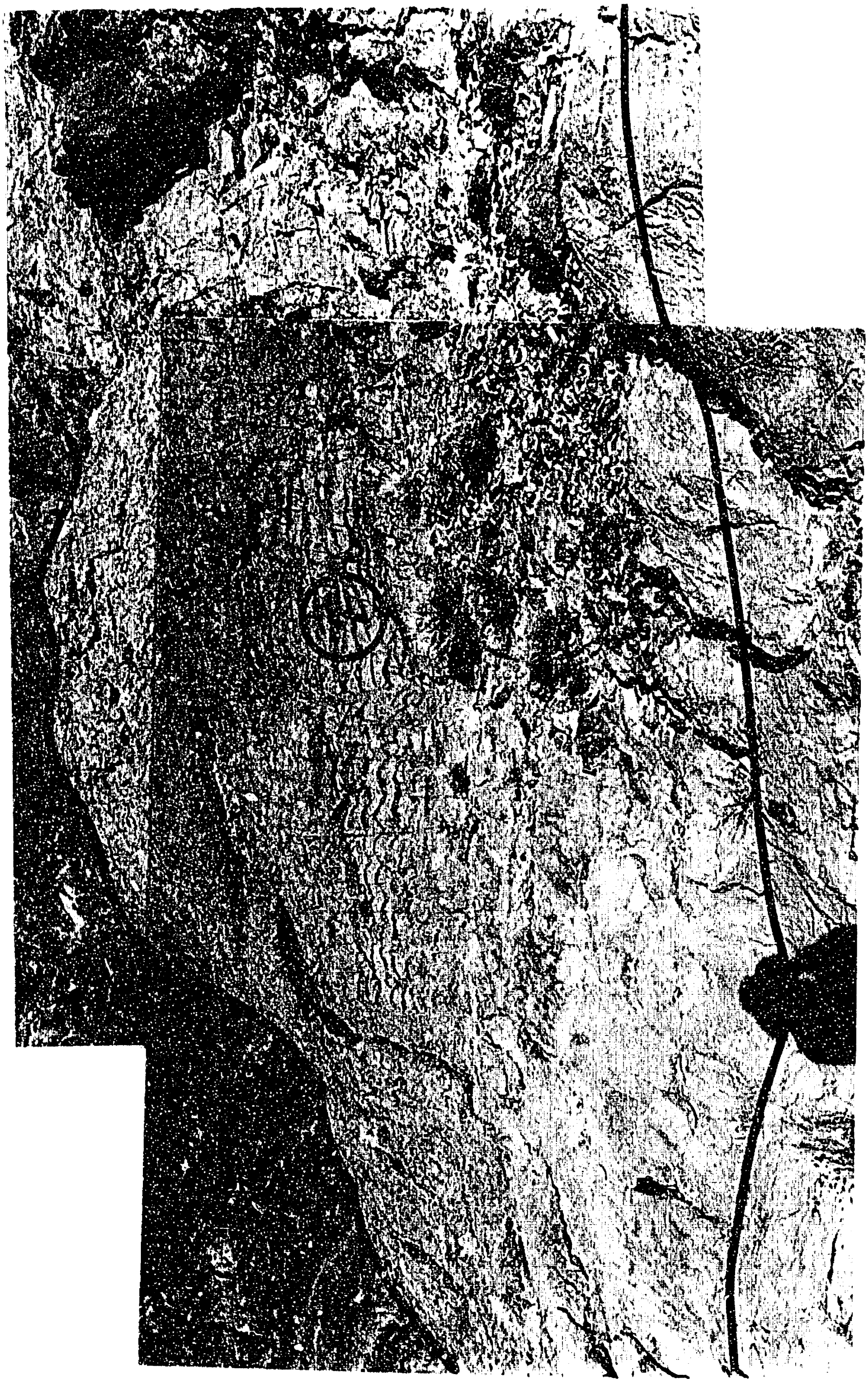
## LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS

### SUBTIDAL CARBONATE FACIES

#### Thrombolitic Boundstone

**Description.**—Although this is a very distinctive facies, especially when units are greater than a meter in thickness, it is not a common facies. Thrombolitic boundstone, commonly found along parasequence boundaries, also may be found to have nucleated on top of packstone and grainstone beds within a parasequence. Thrombolites have sharp contacts with other subtidal facies and may be bounded and overlain by nodular ribbon rock (thin-bedded limestone with dolostone interlaminae; see later discussion in "Subtidal Carbonate Facies" section), calcareous mudstone, oncolitic wackestone with dolosiltite, fossiliferous packstone/grainstone, oolitic packstone/grainstone, or dolosiltite (Figures 6 and 7). At Eagle Mountain, within the upper half of the Jangle limestone thrombolites are usually bounded and overlain by nodular and well-layered ribbon rock (See Chapter 4). Small thrombolitic heads, less than 20 cm high and wide,

**Figure 4.** The south end of the thrombolite boundstone reef complex at the top of Section G (Figure 7). The basal sharp contact with a coarse fossiliferous and clast grainstone is marked by the bottom line. The upper line denotes the "skyline" of the complex, and is not a contact with the dark gray Bonanza King Formation in the background. Within the complex, thrombolite geometries of heads and columns can be recognized, with some laterally linked, as seen to the left of the rock hammer (encircled). Stratigraphic thickness of the complex is 6.3 m and it extends 100 to 150 m to the north.



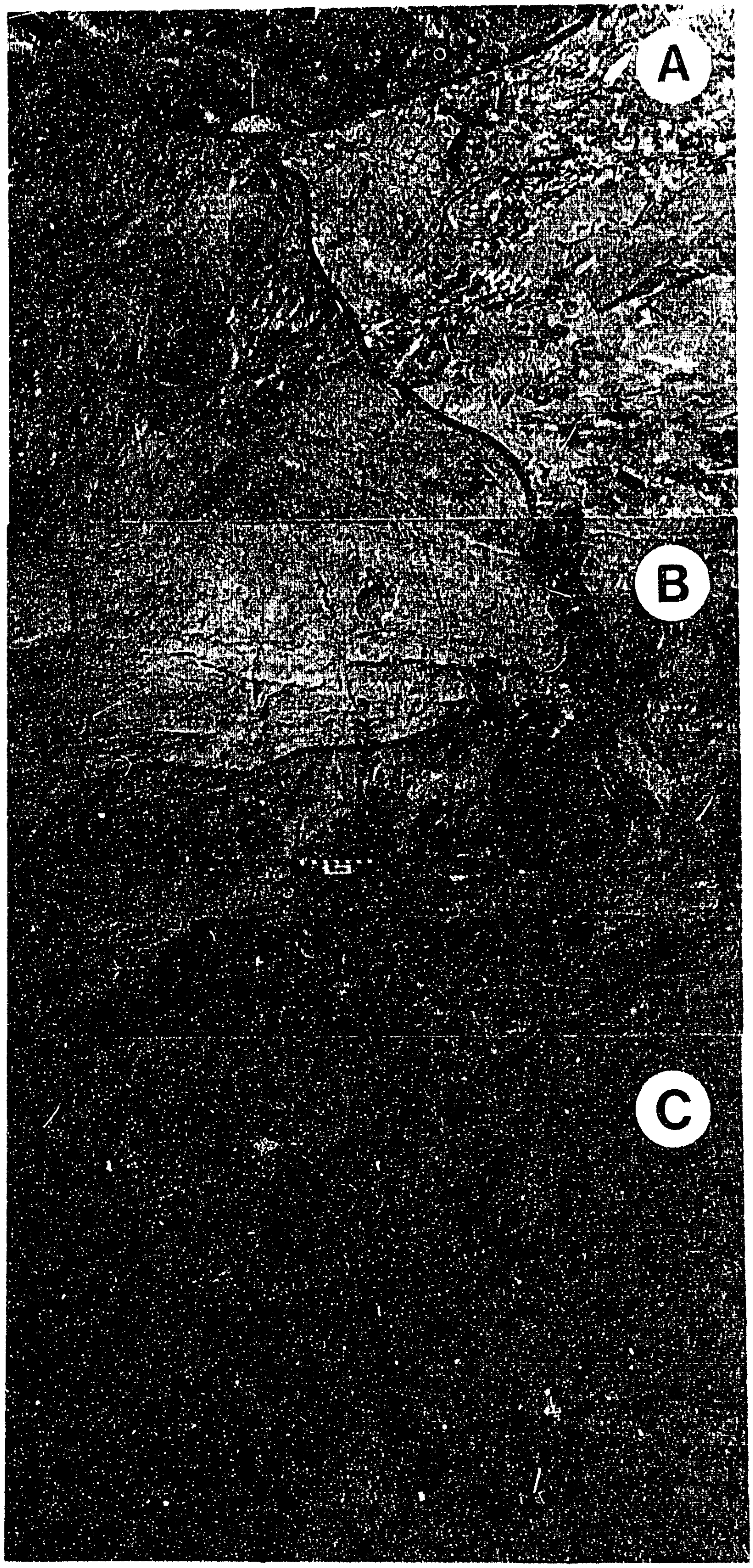

A
B
C

**Figure 5.** Three photographs of lateral facies contacts between thrombolite boundstone and other subtidal facies. **A)** This view shows the sharp lateral contact of the upper part of the thrombolite complex in Section G (Figure 7) with very dolomitic nodular ribbon rock. The large block of thrombolite adjacent to the contact corresponds to the large block in the upper right corner of Figure 4. Again note that the dark gray Bonanza King Formation is in the background and not in contact with the complex. **B)** An small, elongate head rests in sharp contact on fossiliferous ooid grainstone, and with sharp lateral and upper contacts with fossiliferous packstone/grainstone. This head is just above Parasequence Boundary V in Section E. **C)** A sharp lateral contact between thrombolite and an ooid-trilobite-oncoid packstone. Close examination of the thrombolite shows incorporation of the same types of grains into the thrombolite boundstone as make up the packstone. This indicates that the thrombolite and the packstone are contemporaneous. The packstone grades laterally and vertically into nodular ribbon rock over a short distance. The photo was taken in Section E just below Parasequence Boundary III.

also grew along parasequence boundaries in the mixed ooid grainstone and siliciclastic mudstone, siltstone and sandstone of the Red Pass Limestone Member.

Thrombolite morphologies consist of individual bulbous heads, squat columns, a planoconvex lens, irregular mounds, and tabular units. Sizes range from centimeter-wide by centimeter-high heads to a bioherm complex approximately 6.3 m high with an estimated width of 100 to 150 m. Heads and columns range from approximately equal height-to-width ratios, to height-to-width ratios of about 1:3. The planoconvex thrombolite, with the convex side down, is approximately 75 cm high and 3 m wide for a ratio of 1:4. Irregularly shaped mounds have ratios of about 1:1. Ratios for tabular units range from about 1:10 to 1:40. The bioherm complex at Eagle mountain and within the upper half of the Jangle Limestone Member (Figure 7), a large tabular unit, has an approximate ratio of 1:20. Within the bioherm, heads and columns, some laterally linked, can be distinguished by high percentages of brown-weathering dolomite along surfaces (Figure 4). Nodular and well-layered ribbon rock sharply abuts the margins of the bioherm complex, and grain types from the ribbon rock, e.g., ooids, fossil fragments, and oncoids, are incorporated into margins of thrombolite heads. The bioherm has sharp contacts with underlying coarse, fossiliferous and clast-rich grainstone and overlying nodular and well-layered ribbon rock (Figure 5A).

Texturally, thrombolites are recognized by a clotted texture composed of mesoclots (Aitken, 1967; Kennard and James, 1986) and a white and gray mottled coloration caused by white to very light-gray carbonate cement filling original void space. Mesoclots, defined by dark-gray carbonate, range in size from less than 0.1 to 2 mm, and are visible in both hand sample and thin section. Microscopic examination of several samples provided little information pertaining to classification of mesoclots except for some with a "clotted" morphotype similar to that described by Pratt (1984). Pratt (1984) associated this morphotypic end member with *Renalcis*, but aside from this suggested association no conclusive identification of constituents can be made for Carrara specimens.

**Interpretation.**—The closest Modern analogs to ancient thrombolites are the subtidal stromatolites of the Bahamas and in Shark Bay, Australia, which grow on firm to hard substrates (Dill et al., 1986; Dravis, 1983; Playford, 1980). Bahamian subtidal stromatolites grow in clear, agitated waters with salinities between 38 and 40‰ at depths between 1 and 8 m (Dill et al., 1986; Dravis, 1983; Riding et al., 1991). Carrara thrombolites developed on grainstone and dolosiltite, and may indicate early lithification in relatively clear, agitated water. Thrombolites found along parasequence surfaces similarly suggest that clear-water conditions and formation of a firmground (terminology *sensu* Ekdale et al., 1984) or hardground occurred prior to colonization. Parasequence surfaces are thought to form in response to relatively rapid increase in relative water depth, which could temporarily slow or halt sedimentation in an area, creating the necessary conditions for initiation and growth prior to the resumption of sedimentation.

Sharp lateral contacts between thrombolites and surrounding lithologies may either form during contemporaneous deposition or could be the result of burial of previously formed thrombolite heads by a later influx of sediment. However, incorporation of nodular and well-layered ribbon-rock constituents into the thrombolite head implies that both lithologies were forming contemporaneously (Figure 5). It is likely that the depositional surface of a thrombolite head had some small amount, centimeters to tens of centimeters, of relief above the depositional surface of the nodular ribbon rock, but this is not unequivocally shown in the exposures. Similar relationships between thrombolite heads and laterally equivalent lithologies, especially the ribbon-rock group, are reported from Middle Cambrian to Lower Ordovician sediments in the Appalachians (Bova and Read, 1987; Koerschner and Read, 1989; Osleger and Read, 1991).

Thrombolitic boundstone is best developed at the ends of the bioherm complex; possible boundstone clast debris is present in the complex center. This suggests a wave-resistant boundstone wall at either end of the presently exposed part of the complex with storm-generated debris accumulated in the center.

**Mudstone and Wackestone**

**Description.**—One of the less common carbonate facies, this is generally found near the base of shoaling cycles. Carbonate grains consist of unidentified fossil fragments, trilobite pieces, ooids, peloids, lithoclasts, and occasional oncoids scattered throughout beds. Planar horizontal lamination is the only physical sedimentary structure recognized. Dolosiltite-filled burrows are common, as are intervals that are sufficiently burrowed to obliterate other sedimentary structures. Beds are thin, less than 1-10 cm thick. Associated lithofacies are fossiliferous packstone and dolosiltite.

**Interpretation.**—There is little in this facies that is diagnostic of depositional environment. A subtidal assignment is based upon the positioning of mudstone and wackestone units above and below other facies interpreted as subtidal, location near the bases of shoaling cycles, and lack of any structures indicative of subaerial exposure. Preservation of burrows and burrowed-to-bioturbated intervals may be indicative of continuous bioturbation coincident with slow rates of deposition, low levels of depositional energy, or a low frequency of depositional events. These conditions are not uncommon in subtidal environments above storm wave base but below daily wave base (Ekdale et al., 1984).

**Oncolitic Wackestone, Packstone and Grainstone**

**Description.**—Although oncoids are present in many of the the Carrara limestone units, they are volumetrically unimportant, and oncolitic packstone/grainstone is a relatively uncommon lithology. Oncolitic packstone and grainstone is commonly bounded vertically and laterally by ooid grainstone or nodular ribbon rock, but dolosiltite and calcareous or siliceous mudstone also may be present. Occasional small thrombolite or stromatolite heads and digitate microbial growths can be found in association with this facies. Oncolitic packstone/grainstone beds overlying other subtidal lithologies do not have scoured basal contacts. In the few cases where the basal contact of an oncolitic packstone/grainstone bed was scoured, the underlying bed was another oncolitic packstone/grainstone. Oncolitic beds are generally massive but locally contain burrows, planar horizontal laminae, and current ripples.

Carrara oncoids were previously identified to consist of *Girvanella* (Palmer and Halley, 1979), and this identification is accepted. Most oncoids have recognizable laminae that generally contain quartz silt, micrite, and trilobite fragments. Other constituents are ooids, lithoclasts and other oncoids. Nuclei are usually trilobite fragments but may also be ooids or lithoclasts. Some oncoids are so recrystallized that laminae are obscured and differentiation from rounded mudstone or wackestone lithoclasts is difficult.

Some well-laminated oncoids with thrombolitic and stromatolitic digitate columns growing upwards from one side are found overlying Parasequence Boundaries II and III in the Jangle Limestone Member (Figure 7), and these parasequence boundaries can be correlated for several tens of kilometers. They are in discontinuous wackestone to packstone beds 10-25 cm thick. There are also a few instances of these modified oncoids within parasequences that are not recognized laterally. These modified oncoids are similar to the branched oncoids described by Ratcliffe (1988).

**Interpretation.**—Although lateral facies changes between oncolitic packstone/grainstone and oolite or nodular ribbon rock have not been walked out, no obvious channel-form geometries were seen for lateral terminations of the oncolitic packstone/grainstone. This is supported by the unscoured basal contacts of the units. Tucker and Wright (1990) state that biogenic oncoids made by cyanobacteria and/or algae prefer less muddy substrates and relatively clear water. The well-laminated internal structure of individual oncoids is interpreted to indicate frequent overturning during formation of oncoids in subtidal water depths within the photic zone (Dahanayake, 1977; Ratcliffe, 1988). A position within storm wave base would provide sufficient overturning to generate the laminae (Ratcliffe, 1988), although shallower depths are not excluded. Peryt (1981) states that Cambrian *Girvanella* oncoids are indicators of low-energy depositional environments, with low sedimentation rates, in subtidal water depths probably no deeper than a few tens of meters. Digitate thrombolites and stromatolites overgrowing laminated oncoids indicate an additional decrease in agitation and depositional energy below that required for growth of unmodified oncoids (Ratcliffe, 1988; Wright, 1983). Oncoids overlying Parasequence Boundaries II and III at Eagle Mountain (Figure 7) are interpreted to result from a rise in relative sea level associated with boundary formation. Beds of modified oncoids not associated with parasequence boundaries apparently result from a localized decrease in water agitation.

**Lithoclast Packstone and Grainstone**

**Description.**—Another relatively uncommon carbonate lithology, this is present as either thin, commonly lenticular beds within other facies or as separate, tabular to broadly lenticular beds. Matrix sediment in packstones is muddy or sandy. Lithoclasts are commonly composed of calcisiltite and dolosiltite; fine-grained lithologies like carbonate mudstone, shale, and siliceous mudstone are less common. Lithoclasts vary widely in size, from less than 0.5 by 0.5 mm to 8 by 10 cm. In general, thin, lenticular beds contain smaller clasts, less than approximately 2 by 2 cm, whereas the thicker, tabular or broadly lenticular beds also incorporate larger clasts. Ooids, peloids, oncoids, and unidentified fossil and trilobite fragments are also present. Wave ripples in the finest sizes of clasts, and planar horizontal lamination are present. Burrows are also present in many beds. Bed thickness varies from less than 1 cm to 20 cm. Thin, lenticular beds within other facies are generally less than 2 to 3 cm thick, up to a maximum of 10 cm, and are less than a few tens of meters wide. Tabular beds and broadly lenticular beds vary from 5 to 20 cm thick with most between 10 and 20 cm, and are several tens to at least a few hundred meters wide. Associated lithofacies are well-layered ribbon rock, nodular ribbon rock, bioturbated ribbon rock, CDAS lithofacies, and fossiliferous packstone and grainstone.

**Interpretation.**—Sedimentary structures and grain types provide little definitive information to aid in determination of a depositional environment. The suite of sedimentary structures found in this lithofacies also may be found in intertidal facies, although there are no structures indicative of subaerial exposure. Association with a number of lithofacies interpreted to be subtidal is the best argument for a subtidal origin for this facies. Several of the associated lithofacies may also be found in the lowest intertidal zone based on the presence of fenestrae in some units, but fenestrae are not recognized in any of the lithoclast packstones and grainstones.

**Fossiliferous Wackestone, Packstone, and Grainstone**

**Description.**—This common facies is mostly found in two different settings: as thin interbeds in thick intervals of subtidal siliciclastic lithofacies, or as one of several carbonate lithofacies within the lower parts of meter-scale shallowing-upward cycles. Body-fossil fragments are common; most identifiable fossils are trilobite and echinoderm fragments, with a lesser proportion of hyolithoid and brachiopod fragments. Fragments vary widely in size, from very-fine-sand size to trilobite cephala 8-10 cm across. Whole body fossils are very rare; only a few complete trilobites and two unbroken brachiopods were found. Palmer and Halley (1979) also found molluscs, though only in the Groom Range and on the Nevada Test Site. Other grain types in these fossiliferous units consist of unidentified coated grains, lithoclasts, ooids, oncoids, and stringers of very fine to coarse quartz grains.

Beds, especially those less than 10 cm thick, generally have no recognizable physical sedimentary structures and are described as homogeneous. If sedimentary structures are present, horizontal planar lamination, wave ripples, and current ripples are common; trough and hummocky cross-bedding, low-angle planar lamination, and wavy nonparallel lamination (undulatory laminae with wavelengths on the order of centimeters) are less common, and are restricted to the thicker beds. Burrows are present in most beds, and internal scouring can be seen in many bedsets. In one instance, a fossiliferous packstone/grainstone with numerous fenestrae overlies an intertidal microbially laminated fenestral mudstone and underlies a parasequence boundary. Bed thickness ranges from 1 to 35 cm; fossiliferous interbeds in siliciclastic lithofacies generally are less than 10 cm thick, and fossiliferous beds associated with other carbonate lithofacies generally are 5-35 cm thick. Bedsets may fine and thin upwards with an increase in percentage of dolosiltite in interbeds, interlaminae, and burrows. These upward trends may extend across several adjacent bedsets.

Thin fossiliferous beds within siliciclastic mudstone, siltstone, and sandstone are usually lenticular over several tens of meters. Trilobite fragments are the most common grain type, usually with secondary amounts of lithoclasts. Fine-grained siliciclastic sediments make up the matrix in packstone and wackestone. Fossiliferous beds and bedsets associated with other carbonate lithofacies tend to have a more tabular geometry. Associated lithofacies, in addition to siliceous lithofacies, include ooid packstone/grainstone, lithoclast packstone/grainstone, and dolosiltite. Lateral and vertical contacts with adjacent lithologies commonly are sharp but in some cases are gradational. Thrombolitic boundstone may nucleate on fossiliferous packstone or grainstone, and the thrombolitic bioherm complex at Eagle Mountain rests on an unusual unit of this lithofacies (Figure 7). At that location an anomalously thick unit of bedsets, varying from 2.5 to 6 m, extends approximately 850 m laterally and has an overall tabular geometry. This anomalous unit is near the top of Parasequence V, where it extends from north of Section E to several tens of meters south of Section G (Figure 7). The northern lateral contact is gradational with oolitic grainstone, and the southerly lateral contact with nodular ribbon rock is relatively sharp, though partially covered. The contact with underlying oolitic grainstone tends to be sharp and commonly scoured, whereas two different facies, siliciclastic mudstone/siltstone and the thrombolitic boundstone complex, overlie the fossiliferous unit. The contact with mudstone/siltstone varies from sharp to gradational, and the contact with the overlying thrombolitic complex is sharp. Most bedsets contain grains 1–2 mm in diameter and are homogeneous or contain horizontal and low-angle planar lamination.

**Interpretation.**—Most if not all instances of this lithofacies are interpreted to represent subtidal deposition, based on the suite of physical sedimentary structures present. Hummocky cross-bedding is particularly useful as an indicator of subtidal deposition. The presence of mostly horizontal planar lamination for grains of very coarse sand size may be interpreted to indicate either deposition in the low velocity lower plane bed field or deposition in very shallow water where larger bed forms are not able to develop due to shallowness of water depth (Southard and Boguchwal, 1990). Lack of structures indicative of subaerial exposure and association with other lithofacies interpreted to be subtidal also aid in this determination. The one bedset that contains numerous fenestrae is interpreted to be intertidal given its positioning between intertidal mudstone beneath and a parasequence boundary above, and is thought to be emplaced by a storm surge. The fossiliferous packstone and grainstone beds associated with other subtidal carbonate lithofacies also may have accumulated by storm action or by normal currents. The thin, lenticular fossiliferous beds associated with siliciclastics are interpreted as event beds, probably storm-related, that represent winnowed accumulations of fossil debris.

**Oolitic Grainstone**

**Description.**—This is another common lithofacies in the Carrara and it can be found in most members. Ooids range from less than 0.1 mm to 2 mm in diameter and may have either a tangential or a radial fabric. One bedset 2 m thick in the Last Chance Range, California contains ooids from less than 1 mm to 8 mm in diameter arranged in beds 1-30 cm thick with crude horizontal laminae. Other grain types present include coated and uncoated fossil fragments, lithoclasts, rare oncoids, and rounded grains less than 0.1 mm in diameter without discernible internal structure, which may be micritized ooids or peloids.

Common sedimentary structures are trough cross-beds, current and wave ripples, horizontal planar lamination, and scour surfaces within and at the base of bedsets. Relief along these surfaces is normally a few centimeters, and is almost always less than 10-15 cm. In most cases beds show no recognizable sedimentary structures, either because the mode of deposition did not involve traction currents, or more likely, because uniformity of grain size and composition obscure stratification. Planar cross-beds, hummocky cross-beds, contorted bedding and burrowing are less common, and fenestrae are very rare. Bed thickness ranges from less than 1 cm to 50 cm, with the various types of cross-bedding most common in thicker beds. There are not consistent vertical trends within oolitic grainstones. Upward increases and decreases in percentage of dolosiltite, in grain size, and in percentage of fossil fragments and lithoclasts are equally common. Associated lithofacies of dolosiltite, fossiliferous and coated grain grainstone, and calcarenite are present as interbeds and interlaminae. Bounding lithofacies are most commonly nodular ribbon rock or siliceous mudstone, siltstone, and sandstone. CDAS lithofacies and fossiliferous or lithoclast packstone/grainstone bound intervals of oolitic grainstone less commonly. There are also transitions with overlying thrombolites, intertidal fenestral mudstone, and microbially laminated dolosiltite. Parasequence boundaries may overlie or underlie oolitic grainstone. Bedsets of oncolitic packstone/grainstone are in some cases adjacent to oolitic grainstone. Lateral transitions with any of the bounding lithofacies may be gradational.

Bedset geometries of oolitic grainstone are mostly tabular to sheetlike, with thickness varying laterally. Measured widths of individual bedsets at Eagle Mountain (Figure 7) and in the southern Resting Spring Range vary from 150 m to greater than 1.8 km. Commonly as much as about 1.5 m of relief exists along the upper surface, either as preserved bed forms or from erosion. In a few exceptional cases two- and three-dimensional dunes with 10-15 cm of remnant relief are preserved at the top of a bed and can be seen in exposed bedding surfaces and in cross section view as trough cross-beds. An interval of mixed oolitic grainstone with secondary fossiliferous packstone/grainstone and siliciclastic mudstone, siltstone, and sandstone about 65 m thick and 850 m wide was mapped and described in the southern Resting Spring Range. Most bedsets are tabular with almost no variation in thickness. Those bedsets that do vary have flat bases with variation in thickness due to mounding rather than channeling. In one case overlying bedsets fill the low-lying areas on either side of a mound approximately 250 m wide with about 2.5 m of relief, to create a group of bedsets of nearly uniform width across more than 800 m laterally. At the northern end of the area, the group of bedsets thins from about 5 m to 1 m. Although scoured contacts are common within, at the base of, and at the tops of oolitic units, lateral contacts with other lithologies are gradual over decimeters to meters. There is no evidence that laterally discontinuous oolite bodies were emplaced in scoured channels. Rather, laterally equivalent facies, especially nodular ribbon rock, commonly include ooids with the relative amount of ooids decreasing away from the oolitic grainstone body. Geometrically, oolitic grainstone bodies tend to be tabular to planoconvex up rather than planoconvex down or lenticular.

**Interpretation.**—Ooids are usually interpreted as forming in shallow-subtidal, agitated waters (Tucker and Wright, 1990), and there are no indications in Carrara oolites counter to this interpretation. The associated lithofacies forming interbeds and the bounding lithofacies are all interpreted as subtidal facies. The presence of giant ooids in the Last Chance Range is not explained in this study. Sumner and Grotzinger (1993), in a study of Neoproterozoic giant ooids, modeled ooid growth and determined that low supply of nuclei, fast ooid growth rates, higher water velocities, and steep velocity gradients across shoals all favored formation of large ooids. Frequency of storm reworking does not effect size. Without additional research, it is not possible to evaluate which of these factors were important in producing the Carrara giant ooids.

Given the gradational lateral boundaries and geometries, the oolitic grainstone bodies appear to have been local accumulations of ooids with some topographic relief on the sea floor. For example, some of the 1.5 m of relief noted at Eagle Mountain at the top of Parasequence II between Sections D and G (Figure 7) may be due to erosion along the bounding parasequence surface, but it is also probable that at least some if not most of the relief is depositional and represents the depositional surface along a subtidal ooid bar or sand wave. This is supported by the geometric relationship of Parasequence Boundary II relative to the datum, Parasequence Boundary I. Given the interpretation of intertidal-flat deposits immediately beneath Parasequence Boundary I, it is reasonable to assume that the datum was originally nearly planar and approximately horizontal. Further support for the interpretation of relief along Parasequence Boundary II is the presence of intertidal fenestral mudstone at the top of Parasequence II in Section F, essentially on the highest point of the underlying oolite at the top of Parasequence I. The presence of ooids distributed into adjacent facies can also be interpreted as supporting the argument for local topographic highs on some oolitic bodies shedding ooids off into surrounding sediments.

The very rare instances of fenestrae within oolite bedsets may indicate that a particular bedset was deposited in the lowest intertidal zone, perhaps transported there by storm action. Alternatively, fenestrae have been reported to have formed in the subtidal zone (Shinn, 1983), and these instances may be examples of that. There are no other indicators of subaerial exposure in these bedsets, so the interpretation as to intertidal versus subtidal remains equivocal.

**Ribbon Rock Group of Lithofacies**

**General comments.**—"Ribbon rock" is used as a textural term, with the defining characteristic an alternation of centimeter-scale beds and millimeter-scale interlaminae, and composed of coarser and finer grains, respectively. In general, coarser-grained constituents are calcareous and are present in thicker beds. Finer-grained constituents are dolomitic, are commonly silt-sized, and are present in thinner interbeds and interlaminae. In most instances coarser-grained, calcareous constituents make up most of a bedset, though it is not uncommon for the finer-grained, dolomitic constituents to do so. However, in the Carrara, ribbon-rock texture is also present in siliciclastics, in minor quantity, in which case the fine-grained constituent is clay- to silt-sized, and the coarse constituent is silt- to sand-sized. This usage of "ribbon rock" differs from that of Demicco (1983) in that composition is not limited to carbonate grains. Overall, ribbon rock in the Carrara is similar to that discussed by Demicco (1983), except for more pervasive burrowing and a scarcity of sedimentary structures indicative of subaerial exposure.

Pervasive burrowing facilitates subdivision of Carrara ribbon rock into three separate lithofacies based on degree of bioturbation, grain size, and composition of the calcareous component. Where burrowing is minor, the lithofacies is referred to as "well-layered" ribbon rock. Where much of the original bedding is disrupted by burrowing and/or differential pressure solution, the lithofacies is referred to as "nodular" ribbon rock. "Bioturbated" ribbon rock is highly burrowed, to the point that few physical sedimentary structures are recognizable. These three subdivisions are described in the following sections and summarized in Table 2. Nodular ribbon rock is most common and bioturbated ribbon rock is least common. However, at Eagle Mountain, in the upper half of the Jangle Limestone, nodular ribbon rock is most common and well-layered ribbon rock is least common. At that location bioturbated ribbon rock is found only in Parasequence I overlying continuous oolite and underlying nodular ribbon rock, with gradual lateral contacts to the one oncolitic packstone/grainstone unit within (See Figure 7).

The finer-grained component, normally dolosiltite, is present in several different geometries. It is ubiquitous as burrow fill. Interlaminae and interbeds vary in thickness and continuity from discontinuous partings between calcareous laminae to interbeds that are continuous for tens to hundreds of meters. Continuity does not depend on thickness, because some interlaminae are continuous for tens of meters and some interbeds have been disrupted, probably by bioturbation, to the point that they formed a discontinuous series of irregularly shaped blobs only slightly longer than thick. The dolosiltite may have resulted from recrystallization of original carbonate mud (Murray and Lucia, 1967).

A textural, and in some cases compositional, intergradation exists between ribbon rock, especially well-layered ribbon rock, and oolitic grainstone, CDAS lithofacies, oncolitic packstone and grainstone, and fenestral mudstone. This intergradation is especially noticeable where lateral facies transitions are gradational. Gradational transition from a grainstone or carbonate arenite into ribbon rock is marked by an increase in number, thickness, and lateral continuity of finer-grained interlaminae and/or interbeds. If there is a difference in grain types between ribbon rock and adjoining facies, then there is also mixing of grain types in the gradational transition zone.

Wanless (1979) argued that part or all nodular texture in ribbon rock is caused by differential pressure solution and replacement of limestone by dolostone. Because there is ubiquitous, small-scale pressure solution in the Carrara, no attempt has been made to distinguish the contribution of pressure solution versus that of burrowing in formation of nodular texture. Demicco (1983) interpreted ribbon rock of the Upper Cambrian Conococheague Limestone to have formed in both subtidal and intertidal environments. Intertidal ribbon rock of the Conococheague (Demicco, 1983) is commonly mudcracked, whereas Carrara ribbon rock is seldom mudcracked. The few cracks that are present could be syneresis cracks. Because of this, Carrara ribbon rock is interpreted to be subtidal. An environmental interpretation of ribbon-rock texture is the same for siliciclastics as for carbonates, hence the siliciclastic variety will not be discussed separately.

**Bioturbated Ribbon Rock**

**Description.**—Bioturbated ribbon rock is the least common variety of ribbon rock in the Carrara, and overall is a relatively uncommon lithofacies. It is also the only variety that does not have a siliciclastic equivalent. Most bioturbated ribbon rock is composed of either recrystallized peloidal packstone/grainstone or of "*structure grumeleuse*" mudstone (Bathurst, 1975). There are occasional thin and discontinuous associated interbeds of wackestone to grainstone composed of ooids, oncoids, fossil fragments, and/or lithoclasts. Occasionally, beds may be composed of mudstone/wackestone, wackestone, fossiliferous packstone/grainstone, calcisiltite, calcarenite, or oolitic grainstone. Grain types consist of peloids, ooids, fossil fragments (unidentified fragments, trilobites, echinoderms, and hyolithoids), sparse oncoids, and rare lithoclasts. Burrowing was intense and almost always obliterated any original physical sedimentary structures. In most instances the bioturbation was so intense that it is hard to recognize individual burrows. Burrows are not only dolosiltite-filled, as is typical in the other two varieties of ribbon rock, but some are filled with spar cement. Spar-filled burrows are consistently smaller than dolosiltite-filled burrows, never exceeding a few millimeters in diameter. Uncommonly, in some of the packstone/grainstone, carbonate arenite, and carbonate siltite bedsets, burrowing is less intense, allowing preservation of wave ripples and horizontal planar lamination. Bed thickness ranges from less than 1 cm to 10 cm for calcareous lithologies, and from less than 1 cm to 6 cm for dolosiltite interlaminae and interbeds. Within a bedset, there is commonly an upward decrease in the percentage of dolosiltite, resulting in fewer, thinner, and less continuous dolomitic interlaminae and fewer silt-filled burrows. Rarely, there is an increase in the percentage of dolosiltite.

**Interpretation.**—Determination of the original composition of most bioturbated ribbon rock beds, either mudstone or peloid packstone/grainstone, is difficult. The presence of beds of packstone and grainstone composed of nonpeloid grains within bedsets of bioturbated ribbon rock lends support to the interpretation that most, if not all, of these ambiguous bioturbated ribbon-rock beds are made of peloid packstone/grainstones. Spar-filled burrows may be the remnants of burrows that were left open by the organisms that created them, whereas dolosiltite-filled burrows probably represent backfilled burrows. It is possible to have both types of burrows within the same sediment if the sediment is cohesive enough to allow open void space. Either a somewhat dewatered/compacted carbonate mud or a peloid-rich sediment could be sufficiently cohesive to support open burrows.

Bioturbated ribbon rock is thought to represent the lowest-energy depositional environment of the three subfacies and was probably deposited close to the lower limit of storm wave base, where only the largest storms affected the bottom sufficiently to create small bed forms. Because there would be relatively long time intervals between storm-caused agitation of the shelf bottom, organisms were able to churn the sediments sufficiently to destroy all physical sedimentary structures. This interpretation is based on the lack of recognizable physical sedimentary structures, the pronounced burrowing, and the more mud-rich (peloid-rich?) composition. The bioturbated ribbon rock, as the lowest-energy subfacies might also be the deepest-water subfacies of ribbon rock.

**Nodular Ribbon Rock**

**Description.**—This is the most common variety of the ribbon rock group, and overall is a common lithofacies in the Carrara. Nodular ribbon rock, heavily burrowed to the point that most, but not all physical sedimentary structures are obscured, contains many of the same physical sedimentary structures as well-layered ribbon rock. Nodular ribbon rock differs from bioturbated ribbon rock by: 1) the presence of numerous of recognizable physical sedimentary structures due to less intensive burrowing; 2) rarity of small spar-filled burrows and ubiquitous presence of larger, dolosiltite-filled burrows; 3) lower percentage of mud (peloids?); 4) greater diversity of grain types, and; 5) lighter color. Coarser-grained, calcareous lithologies in nodular ribbon rock consist of mudstone through grainstone, calcarenite, and calcisiltite. The fine-grained carbonate lithology is dolosiltite. Grain types vary from fossil fragments (unidentified fragments, trilobites, echinoderms, and hyolithoids) to ooids, peloids, oncoids, and lithoclasts. In addition, siliciclastic siltstone and very fine to fine sandstone are in some cases interbedded with carbonates, usually arenite and siltite.

The most common physical sedimentary structures are horizontal planar lamination, wave ripples, and current ripples. Trough cross-beds, hummocky cross-beds, and nonparallel wavy lamination are relatively uncommon. Cross-beds and ripples are most common in the coarse-grained beds; planar lamination is present in both coarse-grained and fine-grained beds; fine-grained beds are commonly without physical sedimentary structures except for burrows. Burrows are ubiquitous, and burrowed-to-bioturbated texture is common. Complete bioturbation is uncommon. Almost all burrows are backfilled with dolosiltite, though rare, small spar-filled burrows may be found. Homogeneous beds in which no sedimentary structures can be recognized are common and may result from uniform grain size and composition, or bioturbation. Contorted bedding and internal scours are uncommon; digitate microbial growths and mudcracks are rare; and flaser beds, load structures, and fenestrae are very rare. Rare and questionable hardgrounds are present within bedsets.

Bed thickness ranges from less than 1 cm to 30 cm for coarse-grained beds and from less than 1 cm to 6 cm for fine-grained interlaminae and interbeds. Most coarse-grained beds are less than 10 cm thick and most fine-grained interlaminae and interbeds are less than 3 cm thick. Within bedsets there is usually an upward decrease in the percentage of dolosiltite, though sometimes the percent increases upward, and rarely there is first an upward increase followed by a decrease or vice versa. Beds and bedsets may either fine and thin upwards or coarsen and thicken upwards. The amount of burrowing varies upwards.

Associated interbedded lithofacies are fossiliferous wackestone/packstone, oncolitic wackestone/packstone, oolitic packstone/grainstone, lithoclast packstone/grainstone, thrombolitic boundstone, calcarenite and dolarenite, and siliceous mudstone. Lateral transitions to other facies are gradual over tens of centimeters to meters, with the exception of sharp boundaries with thrombolites. Vertical transitions between nodular ribbon rock and other facies vary from sharp to gradual over centimeters to tens of centimeters. Sharp contacts may be scoured, with relief ranging from centimeters to tens of centimeters. At Eagle Mountain, lateral and vertical contacts between nodular ribbon rock and the subtidal lithofacies of oolitic grainstone, CDAS lithofacies, oncolitic wackestone/packstone/grainstone, fossiliferous packstone/grainstone, and thrombolitic boundstone are well exposed and can be walked out. Additionally, transitional lateral contacts, and sharp or gradual vertical contacts between intertidal fenestral mudstone and nodular ribbon rock can also be walked out.

**Interpretation.**—Nodular ribbon rock is interpreted to be intermediate in depositional energy, and hence possibly also water depth, between bioturbated ribbon rock and well-layered ribbon rock. Based upon preservation of physical sedimentary structures, higher percentage of recognizable grain types other than peloids, and lateral transitions into other subtidal facies as well as intertidal facies, nodular ribbon rock is interpreted to have been deposited below the lowest intertidal zone and above storm wave base, possibly even at or just above fair-weather wave base. Bottom sediments were affected often enough by storm (higher-energy) events to result in a mix of physical sedimentary structures and burrows. The very rare fenestrae and the questionable mudcracks might be used to suggest that this facies was occasionally subaerially exposed in the lowermost intertidal zone. However, subtidal fenestrae have been reported (Shinn, 1983) and the questionable mudcracks may be syneresis cracks.

**Well-layered Ribbon Rock**

**Description.**—This is the second most common variety of the ribbon rock group, and overall is a common Carrara lithofacies. Well-layered ribbon rock is composed of centimeter-scale interbeds of limestone and dolostone, with physical sedimentary structures that are not obscured by minor burrowing. Most beds of well-layered ribbon rock are composed of sand-size and silt-size calcite and dolomite grains, commonly with lesser proportions of very fine to fine quartz sand and silt as well as interbeds of sandstone and siltstone. It is not uncommon to have interbedded calcisiltite and dolosiltite, with calcisiltite beds as the thicker "coarse-grained" beds and dolosiltite as thinner "fine-grained" interlaminae and interbeds. Coarse-grained beds are also less commonly composed of fossiliferous wackestone to grainstone, oolitic grainstone, and general packstone and grainstone with a variety of grain types. Ooids, coated grains, trilobite and echinoderm fragments, oncoids, lithoclasts, and possible peloids may be present, in addition to very fine- and fine-sand-sized grains of quartz, calcite and dolomite. Common physical sedimentary structures are horizontal planar lamination, wave ripples, and current ripples. Trough cross-beds and homogeneous beds are less common, whereas hummocky cross-beds are rare. Burrows are common but generally sparse, and are always backfilled with dolosiltite. Burrowed-to-bioturbated texture, load structures, contorted beds, and mudcracks are uncommon, and small channels less than 20 cm high by 2-20 m wide are rare, as are graded beds and questionable fenestrae.

Beds of coarse-grained lithologies range from less than 0.5 to 15 cm thick whereas fine-grained lithologies range from less than 0.5 to 8 cm thick. Most coarse-grained beds are less than 5 cm thick and most fine-grained beds are less than 3 cm thick. Some bedsets show an upward decrease in the percentage of dolosiltite, but to a lesser extent than in nodular ribbon rock. Rarely, bedsets also fine upwards. Associated interbedded lithofacies are calcarenite, fossiliferous wackestone, and siliceous mudstone and shale.

**Interpretation.**—Predominance of physical sedimentary structures over burrows in well-layered ribbon rock indicates that these sediments were deposited in an environment with a more constant state of water motion than was nodular ribbon rock. Wave ripples, current ripples, and trough cross-beds indicate both oscillatory and unidirectional motions were present. Even though grain sizes appropriate for the formation of hummocky cross-bedding are present, hummocky cross-bedding is seldom found, perhaps indicating that purely oscillatory motion was uncommon. Some of the beds of horizontal planar lamination have very broad wavelength (meters to tens of meters) with very low amplitudes (one to a few centimeters), and may be "quasi-planar-laminated" beds similar to those of Arnott (1993). Arnott (1993) ascribed their origin to high-energy, combined unidirectional and oscillatory flows. This combined-flow deposition may explain the rarity of hummocky beds. Because types and sizes of physical sedimentary structures are similar in both well-layered ribbon rock and nodular ribbon rock, it is risky to assume that one lithofacies represents higher maximum energy levels than the other. The lower incidence of preserved burrowing in well-layered ribbon rock may be due to constant water motion versus episodic periods of water motion in nodular ribbon rock. This may be indicative of a generally shallower water depth, probably at or above daily wave base, for deposition of the well-layered ribbon rock.

**Calcarenite, Dolarenite, Calcisiltite, and Dolosiltite (CDAS Lithofacies)**

**Description.**—This heterolithic facies is composed mostly of fine- to very fine-grained calcarenite and mechanically laminated dolosiltite with minor proportions of dolarenite and calcisiltite. It differs from well-layered ribbon rock in that there is not a well-developed interbedding of thinner-bedded, finer-grained lithologies with thicker-bedded, coarser-grained lithologies. However, there can be lateral and vertical intergradation between these two lithofacies. The sand-size and silt-size carbonate grains are not identifiable as to original grain type due to extensive recrystallization. Quartz silt and very fine to fine sand are commonly mixed into the carbonate lithologies. Ooids and fossil fragments (unidentified fragments, echinoderms, and trilobites) are the most common identifiable carbonate grains. Lesser percentages of peloids, oncoids, and lithoclasts are found. Horizontal planar lamination, wave ripples, current ripples, and combined flow ripples, are the most common physical sedimentary structures. Trough and hummocky cross-beds, and flaser, wavy and lenticular bedding (in the sense of Reineck and Wunderlich, 1968) are also common, though in lesser quantity. Parallel and nonparallel lamination is found in some instances. Burrows are sparsely present in most bedsets. Load structures, contorted beds, scours at the bases of bedsets, and burrowed-to-bioturbated and bioturbated zones are uncommon. Fenestrae and questionable mudcracks are rare. Dolosiltite in this facies differs from that in microbially laminated dolosiltite facies by an absence of unquestioned mudcracks and fenestrae and the presence of coarser horizontal lamination, ripple lamination, and trough cross-bedding. Beds range in thickness from less than 1 cm to 45 cm, with most beds in the range 1-10 cm. The thicker beds are generally those with trough and hummocky cross-beds.

Upward vertical trends in bedsets consist of decreasing percentage of dolosiltite and of siliceous lithologies, thickening, coarsening, and an increase in size of sedimentary structures, e.g., from wave ripples up to hummocky cross-beds. Some of these trends may extend across several adjacent bedsets. Calcarenite, calcisiltite, and dolosiltite are generally found together within a single bedset. Carbonate arenite and siltite are also commonly found interbedded with siliceous siltstone and sandstone or with ooid grainstone. Other less common associated lithofacies include carbonate or siliceous mudstone, and fossiliferous packstone/grainstone. Units are tabular, with gradual lateral boundaries with well-layered ribbon rock and oolitic grainstone. Contacts with overlying and underlying facies are sharp or gradual, with variation common along a contact. Overlying oolite is commonly scoured into carbonate arenite and siltite. At Eagle Mountain, where fenestral mudstone overlies CDAS lithofacies the contact between is gradual (Figure 7).

**Interpretation.**—CDAS lithofacies is interpreted as subtidal, deposited above storm wave base, and it is likely that most of it was deposited above fair-weather wave base. This interpretation is based on sedimentary structures indicative of wave reworking and an overall lack of structures indicative of subaerial exposure, such as mudcracks and fenestrae. Hummocky cross-beds and wave ripples indicate the presence of periodic oscillatory flow generated by waves during storms. Some of the horizontal planar lamination is similar to Arnott's (1993) quasi-planar-laminated beds, and may represent combined-flow deposition during storms. A transition across adjacent bedsets from wave ripples to hummocky cross-beds is interpreted as a gradual shoaling from near storm wave base to near fair-weather wave base (Harms et al., 1975; McCubbin, 1982). There appear to be two different energy regimes represented in sediments deposited above fair-weather wave base. Trough cross-beds above the interval of hummocky cross-beds may be interpreted as resulting from deposition above a higher-energy, fair-weather wave base or may be related to unidirectional flow associated with storm events and storm surges. The various ripple structures above hummocky cross-beds and quasi-planar-laminated beds may be interpreted as due to deposition above a lower-energy, fair-weather wave base (Howard and Reineck, 1981). Given the preponderance of ripples over trough cross-beds in this lithofacies and other subtidal lithofacies, it is likely that fair-weather wave energy within the lagoon was relatively low, although storms would have generated high-energy depositional events (Howard and Reineck, 1981).

## INTERTIDAL CARBONATE FACIES

### Stromatolitic Boundstone

**Description.**—Stromatolitic boundstone is uncommon in the Carrara. Dolarenite, dolosiltite, calcarenite, calcisiltite, and calcareous mudstone are the lithologies that make up the stromatolites. Fine quartz sand and possible ooids are minor constituents. Stromatolites are built up of microbial laminae, mostly planar with some wrinkly (i.e., undulatory laminae with wavelengths on the scale of millimeters or less), and uncommon small fenestrae. In the adjacent calcisiltites and dolosiltites planar and wrinkly microbial laminae are also found, as are thicker planar laminae, contorted beds, fenestrae, and possible tepee structures. Scoured surfaces can be found at the bases of some bedsets. The external morphology of stromatolites is not as varied as that of thrombolites. Shapes of heads vary from equant, bulbous heads with a height-to-width ratio of about 1:1 to broad, low heads with ratios of about 1:5. Equant heads range up to about 10 by 10 cm, and broad heads up to about 10 by 55 cm. Heads with intermediate ratios range up to about 25 by 40 cm. Synoptic relief generally was about half the height of the head. Heads are commonly in groups forming both laterally linked (LLH) and vertically stacked (SH) clusters (Logan et al., 1964. Vertically stacked clusters are commonly only a few heads thick, and bedsets do not exceed a meter in thickness. Branching of heads was not noted, though this may be because outcrops are rather fractured with a rough and hackly weathered surface that obscures finer details. Several other upward vertical trends were noted, including change from broad to equant heads, decrease in size of heads, change from stromatolite heads to planar microbial lamination, and change in lithology from limestone to dolostone and vice versa. Associated lithofacies generally are microbially laminated dolosiltite, and thrombolitic boundstone twice is found in the same or adjacent bedsets. Stromatolitic bedsets are commonly bounded above and below by shale to siltstone.

**Interpretation.**—Modern stromatolites have been described from both intertidal and subtidal environments and some authors have discussed criteria to aid in differentiation (Dill et al., 1986; Dravis, 1983; Golubic, 1991; Logan et al., 1974; Playford, 1980). Their criteria, elongation, orientation with respect to the shoreline, mat type, and density are only loosely applicable to the Carrara. Carrara stromatolites are exposed in two-dimensional outcrops and it is not possible to determine if there is elongation of the heads, or what orientation any elongation may have had with respect to the shoreline. The stromatolites are finely laminated with occasional small fenestrae, and Playford (1980) stated that these characteristics are indicative of lower intertidal stromatolites. In addition, the associated microbially laminated lithologies with fenestrae and possible tepee structures are interpreted as intertidal in origin and the intimate association lends support to an intertidal origin for the stromatolites. The vertical trend of stromatolite heads overlain by planar microbial lamination also indicates that the stromatolites may be lower to lowermost intertidal. The two bedsets with associated thrombolites are more ambiguous with respect to differentiating subtidal from intertidal origins, as thrombolites are generally interpreted as subtidal. This may be resolved by interpreting a highest subtidal to very lowest intertidal origin for these two instances.

**Calcareous Mudstone and Wackestone**

**Description.**—This is a very minor lithofacies that is easily overlooked as it is present in thin beds and bedsets, and commonly weathers recessively. Ooids, unidentified fossil fragments, trilobite fragments, lithoclasts and oncoids may be found in the mudstone and wackestone. There is not a wide variety of sedimentary structures, with only horizontal planar lamination, homogeneous beds, burrows and fenestrae present. Bed thickness is 1 cm or less and bedsets are mostly less than 1.5 m thick. No vertical trends were noted, and uncommon thin interbeds of packstone/grainstone and dolosiltite are associated lithologies.

**Interpretation.**—The sedimentary structures found are rather ambiguous as to depositional environment, with fenestrae the most definitive and indicative of an intertidal setting. The general position of bedsets of this lithofacies between subtidal and intertidal lithofacies, coupled with the fenestrae leads to the interpretation of a lowest intertidal setting.

**Dolosiltite, Calcarenite and Calcisiltite**

**Description.**—This is another common, heterolithic facies in the Carrara and may be thought of as forming the middle part of a continuum with the subtidal CDAS lithofacies beneath and the middle-to-high intertidal orange dolosiltite lithofacies above. There can also be intergradation between this lithofacies and the subtidal well-layered ribbon rock lithofacies. The principle grain types are unidentified carbonate grains and unidentified coated grains of fine-sand to silt-size. In addition, there are lesser quantities of quartz silt and very fine sand, ooids, questionable peloids, unidentified fossil fragments, oncoids, and lithoclasts of laminated dolosiltite. A variety of physical sedimentary structures are common, including wave ripples, current ripples, horizontal planar lamination, wavy parallel lamination, and wrinkly lamination. Microbial planar lamination and homogeneous beds are less common. Incipient stromatolites, stromatolite-like microbial lamination, and wrinkly microbial lamination are rare. Other common sedimentary structures include scours and load structures at the bases of bedsets, contorted beds, and burrows. Less common are burrowed-to-bioturbated zones, fenestrae, and mudcracks.

Bed thickness varies from 20 cm to millimeter-laminae. Vertical trends are not common; i.e., an upward increase in abundance of horizontal planar lamination within bedsets is less common, and an upward decrease in the percentage of fenestrae is rare. Commonly two or more constituent lithologies may be found within a bedset. Associated interbedded lithofacies consist of: calcareous mudstone; some wackestone and packstone with fossil fragments, ooids and/or peloids; ooid and/or coated grain grainstone; and occasional stromatolites.

**Interpretation.**—Deposition in the low intertidal is inferred based upon the suite of sedimentary structures present. The lack of trough cross-beds or hummocky cross-beds combined with very common wave ripples and current ripples indicate deposition in shallow and/or low-energy waters or a combination of both. This could be accomplished by either shallow-subtidal or intertidal conditions. The presence of stromatolitic boundstone, microbial lamination, fenestrae and mudcracks argues for an intertidal setting, but because these are not the most common structures, a low-intertidal rather than a high-intertidal setting is preferred. Scours and load structures at the bases of bedsets, combined with contorted beds may record rapid depositional events, possibly during storms.

**Fenestral Calcareous Mudstone**

**Description.**—Light gray, calcitic, fenestral mudstone is only somewhat common, but is easily recognized from a distance by its unusually light color. Lithologically, it is very uniform with a mudstone composition and minor amounts of laminated dolosiltite. Lithoclasts of dolosiltite and microbially laminated carbonate mudstone are uncommon and fossil fragments and oncoids are rare. All three of these grain types are small in size. Some bedsets may be packstone composed of small peloids in a clotted texture, but petrographic evidence is ambiguous. Sedimentary structures are limited to ubiquitous fenestrae and to less common microbial lamination, horizontal planar lamination, and wavy parallel lamination. Mudcracks, questionable burrows, and wave ripples are rare. Fenestrae are filled with bladed and blocky, clear calcite cements and range from irregular to crudely laminoid in geometry. They are interspersed with intervals of discontinuous, poorly defined microbial and mechanical laminae. Laminated intervals have gradual or sharp contacts with fenestral intervals, are mud-dominated, and may contain minor fenestrae. Scattered partial dolomitization, particularly of the laminated intervals, is common.

Recognizable beds vary greatly in thickness, from 2 to 215 cm. However, these unusually thick beds may result from an inability to recognize bed boundaries due to uniform composition. Upward trends are uncommon and consist of an increase in percent dolosiltite or in the concentration of microbial lamination present. Associated interbeds of orange dolosiltite may be present, as might rare interbeds of dolarenite or oncolitic wackestone/packstone.

At several locations (Shadow Mountain, Baxter Mine, and Red Wing Mine in the northern and middle Resting Spring Range (NR, MR); Eagle Mountain (EM); Pyramid

Peak and Echo Canyon (EC) in the southern Funeral Range; Titus and Titanothere Canyons (TC) in the Grapevine Mountains; possibly in the Last Chance Range (LC); see Figure 1) there are substantial intervals (5 to 40 m) of this lithofacies, each made up of a number of bedsets. In some cases it is possible to either walk out the interval until there is a lateral facies change or it is possible to see the lateral change from a distance. At Eagle Mountain, one of these lateral transitions has been documented and the fenestral mudstone interval extends for about 1.8 km south of the subtidal-to-intertidal transition before the outcrop ends (Figure 7). Estimates of the lateral extent of other fenestral intervals made by comparison of topographic maps and photographs taken from a small airplane at low altitude indicate a lateral extent of up to 3 to 5 km before one end of the lithofacies unit appears to terminate by lateral facies change. No large fenestral mudstone unit has been found where it is possible to see both ends terminate by lateral facies change.

The Eagle Mountain interval of fenestral mudstone (maximum of 16 m thick and greater than 1.8 km wide), is thinnest at its northern end where the transition to subtidal nodular ribbon rock is present (Figure 7). The outcrop at the southern end terminates before there is any major change in the mudstone interval, but at the northern end it is possible to walk out the lateral transition into subtidal nodular ribbon rock. The interval thins to the north by loss of the lower part due to lateral facies change into nodular ribbon rock; that is, the uppermost part of the unit extends farther to the north than does the lower part and overlies nodular ribbon rock laterally equivalent to fenestral mudstone to the south. Fenestral mudstone is overlain by either Parasequence Boundary IV or by an intervening facies of intertidal microbially laminated dolosiltite, with a gradual vertical transition over centimeters to decimeters, from mudstone to overlying dolosiltite (Figure 7). Where dolosiltite is present, Parasequence Boundary IV forms its upper surface. Dolosiltite overlies mudstone from south of Section H continuously into the vicinity of Section E, where fenestral mudstone directly underlies Parasequence Boundary IV. A few tens of meters north of Section E dolosiltite is again present and continues to the north of Section D positioned between mudstone and Parasequence Boundary IV. However, north of Section D the dolosiltite thins until at Section C the parasequence surface again rests directly on fenestral mudstone. Most of the stratigraphic thinning in fenestral mudstone is over a lateral distance of approximately 150 m, centered around Section E, and results from stepwise loss of section in the lower part of the unit. As shown in Figure 7, the thinning is in the form of a backstepping series of two steps and three risers to the south, with each step represented by localized Parasequence Boundaries A and B, and the lower two risers represented by gradual lateral facies transitions. The third riser is gently inclined up to the south and represents a gradational parasequence boundary between intertidal fenestral mudstone and subtidal nodular ribbon rock. As such, it may be considered an extension of Parasequence Boundary B. At its northernmost limit, fenestral mudstone grades laterally into nodular ribbon rock over tens of meters. Fenestral mudstone continues to thin northward, becoming increasingly ribbon-rock-like with decreasing fenestrae and an increase in fossil fragments, oncolites, quartz grains, mechanical lamination, burrowing, and dolomite.

**Interpretation.**—The position of fenestral mudstone between subtidal facies and intertidal microbial dolosiltite, in combination with mudcracks and microbial laminae, indicates deposition in an intertidal environment. Because of the lateral transition down depositional dip to nodular ribbon rock, it is probable that fenestrae continue down to lowest intertidal and possibly into the uppermost subtidal environment. Shinn (1983) has reported irregular fenestrae in subtidal facies, but most Carrara fenestral mudstone is probably intertidal based on overall position, laminar fenestrae, microbial laminae, and general absence of body fossils. Poorly defined, very thin and laterally discontinuous laminae interspersed with fenestrae are interpreted to be of microbial origin. The preserved fenestrae in the intertidal fenestral mudstone is indicative of early cementation and little postdeposition-prelithification compaction in the intertidal facies.

Vertical and lateral distribution of laminae and fenestrae was examined for trends at Eagle Mountain between Sections C and G (Figure 7). The main fenestral mudstone interval was subdivided into three subfacies defined by the dominant structure present in each bed: irregular fenestrae, laminoid fenestrae, and microbial laminae. Thickness of each bedset and the nature of contacts between bedsets were logged, and correlations were attempted between five short sections. Laminoid fenestrae should be present in the lower tidal flat and underlie irregular fenestrae of the middle to upper tidal flat in a progradational tidal flat deposit, if Logan's (1974) interpretation of fenestrae morphology indicating position on a modern tidal flat is applicable to the ancient. The microbial-laminae subfacies is similar to the orange-dolosiltite facies overlying fenestral mudstone: because of this, the microbially laminated subfacies is interpreted to be higher on a tidal flat than the fenestral subfacies. However, no patterns were recognized between the three subfacies and bedsets could not be followed for more than a few tens of meters due to gradational lateral facies changes. This is similar to fenestral carbonates in New Mexico described by Tubbett et al. (1965).

Parasequence Boundary IV (Figure 7) is separated from fenestral mudstone by microbial dolosiltite from north of Section D to south of Section H, except in the vicinity of Section E. In Section E a covered interval 1.1 m thick lies between mudstone and overlying nodular ribbon rock. Dolomitic nodular and well-layered ribbon rock more commonly weathers as a recessive interval than does microbial dolosiltite, so the covered interval is interpreted as dolomitic nodular and well-layered ribbon rock deposited in a depression. This depression may have been formed by erosion into microbial dolosiltite during formation of Parasequence Boundary IV, or it may represent a tidal channel on the tidal flat that was filled during the transgression associated with formation of the subsequent parasequence boundary. Aside from this interval, Parasequence Boundary IV is thought to coincide with the former depositional surface of the intertidal flat, sloping down from upper-intertidal microbially laminated dolosiltite to lower-intertidal fenestral mudstone to subtidal nodular ribbon rock.

**Orange Dolosiltite**

**Description.**—Orange dolosiltite is a less common lithofacies. There is a definite continuum with the low-intertidal, dolosiltite-calcarenite-calcisiltite lithofacies, with orange dolosiltite making up the uppermost parts of shoaling cycles. It is made up of predominantly silt-sized, unidentified carbonate grains, with minor quantities of sand-sized carbonate grains, quartz silt and sand, ooids, questionable peloids, fossil fragments, and lithoclasts of laminated dolosiltite. Common physical sedimentary structures include planar and wrinkly microbial lamination, horizontal planar lamination, and wavy lamination. Less common physical structures include incipient stromatolites and stromatolite-like microbial lamination, current ripples, and wave ripples. Mudcracks, tepees, and fenestrae are common sedimentary structures, with scoured surfaces, burrows, contorted beds, and microfaults all less common. Beds range from millimeter-size laminae to 15 cm in thickness, with vertical trends in bedsets including upward increases in percent calcarenite, calcisiltite, or calcareous mudstone. Associated interbedded lithologies are calcareous mudstone, calcisiltite, calcarenite, fossiliferous or oolitic wackestone/packstone, ooid or coated-grain packstone/grainstone, and occasional stromatolites. Orange dolosiltite units tend to be thin and tabular, marked by gradational lower boundaries with other intertidal lithofacies or with subtidal oolitic grainstone, CDAS lithofacies, or nodular ribbon rock. Down-dip lateral terminations with subtidal facies are gradual and intertonguing, as shown in Section E below Parasequence Boundary V (Figure 7). The upper surface is always a parasequence surface in these exposures; no supratidal carbonate lithofacies are recognized.

**Interpretation.**—Microbial laminae, mudcracks, tepees, and fenestrae found in this facies imply episodic subaerial exposure and the lithofacies is interpreted as having been formed on an intertidal flat (Aitken, 1967; Logan et al., 1974). The preponderance of microbial structures over mechanical structures, the lack of common mechanical sedimentary structures besides horizontal planar lamination, the abundance of fenestrae, mudcracks, and tepee structures all indicate that this facies was deposited on the mid- to high-intertidal zone with longer periods of exposure.

### Relative Positions of Fenestral Calcareous Mudstone and Orange Dolosiltite

Planar microbial lamination, wrinkly microbial lamination, and small columnar stromatolitic microbial lamination, fenestrae, ubiquitous mudcracks, and tepee structures, are all indicators of subaerial exposure. When combined in orange dolosiltite, they indicate longer periods of exposure than do the fenestrae, microbial laminae, and rare mudcracks of fenestral mudstone (Ginsburg et al., 1977). Orange dolosiltite may directly overlie a subtidal facies or it may directly overlie intertidal fenestral mudstone, but fenestral limestone directly overlies only subtidal facies. This relative positioning also indicates that, if the shoreline was progradational, fenestral limestone is a lower intertidal facies than is orange laminated dolosiltite, with the caveat that laminated dolosiltite may also be present in the lower intertidal zone without intervening fenestral limestone between the dolosiltite and subtidal rocks.

## SUBTIDAL SILICICLASTIC FACIES

### Mudstone and Shale

**Description.**—This is perhaps the most most common siliciclastic lithofacies and constituent lithologies are shale, silty shale, mudstone, and silty mudstone. Any of these lithologies may be present in a variety of greens, tans, grays, and dark purples, may be chloritic, and are commonly cleaved. Cleavage is less well developed in those lithologies with higher percentages of coarse grains. Outcrops are ordinarily of relatively poor quality as these lithologies tend to weather recessively. Horizontal planar lamination and wavy, nonparallel lamination in the shale and mudstone, and in interbedded siltstone and sandstone are the most common physical sedimentary structures. Wave ripples may be found in interbedded coarser-grained lithologies. Burrows, generally only horizontally oriented, are common, and heavily burrowed intervals are not uncommon. Contorted beds and gutter casts filled with very fine quartz sand are also found. Bed thickness ranges from millimeter-size laminae to 15 cm thick. Bedsets most commonly coarsen and thicken upwards, generally changing to siltstone and sandstone before the trend ends. The intensity of bioturbation decreases upwards in some cases accompanied by fining and thinning within bedsets. Interbedded lithofacies of fossiliferous wackestone to grainstone, oncolitic wackestone/packstone, medium-to-very-fine quartz sandstone, calcarenite and dolarenite, and dolosiltite are common.

**Interpretation.**—Based upon the wave ripples in associated coarser-grained interbeds, the laminae and burrows in all lithologies, presence of gutter casts, and the associated coarser lithologies, this lithofacies is interpreted to have been deposited above storm wave base in a relatively low-energy subtidal setting where episodic higher-energy events had some effect. Some of the horizontal planar lamination in sandstone and siltstone beds may be quasi-planar-laminated beds formed by combined-flow, high-energy storm events (Arnott, 1993). Wave ripples are indicative of deposition above storm wave base, though the lack of larger bed forms implies that the setting was not too high above storm wave base. Horizontal burrows are common in low-energy settings (Ekdale et al., 1984), and the more heavily burrowed intervals may be interpreted as due to lower depositional rates and/or higher rates of burrowing. Gutter casts and the thin, winnowed, coarse-grained interbeds result from episodic higher-energy events, such as storms, that can initiate currents to scour gutters and transport the sands that fill them. These same episodic events can winnow out fine sediments originally deposited with fossil fragments, oncoids, and medium to fine quartz sand, and leave behind lag beds on a generally muddy and silty lagoon floor. Coarsening and thickening up in a bedset or across several adjacent bedsets may reflect progradation of siliciclastic sediments across the lagoon. Fining and thinning upwards may reflect movement of a point-source of siliciclastic sediments farther away from the area, i.e., lateral migration of fluvial/deltaic systems, or may indicate relative deepening during deposition. A decrease upwards in the concentration of bioturbation may reflect increasing long-term sedimentation rates or long-term energy levels in an area.

**Sandstone and Siltstone**

**Description.**—Quartz siltstone and medium to very fine sandstone, both ranging from muddy to clean, in various greens, tans, browns, grays, white, and pink are the characteristic lithologies of this common lithofacies. Muddy siltstone and sandstone are commonly chloritic and may exhibit some cleavage. Scattered fossil fragments including trilobite fragments, questionable peloids, and lithoclasts can also be found. Physical sedimentary structures are common and include flaser ripples, current ripples, wave ripples, combined-flow ripples, horizontal planar lamination, hummocky cross-beds, and trough cross-beds. In addition, climbing wave ripples, though rare, can be found. Scours are common at the base of bedsets. Bioturbation varies from individual burrows to intensely bioturbated intervals. Bed thickness ranges from less than 0.5 cm to 40 cm. Bedsets most commonly coarsen and thicken upwards, but some fine and thin upwards. Bioturbation may either increase or decrease upwards. Associated interbedded lithologies are fossiliferous packstone/grainstone, calcarenite, dolosiltite, and siliceous silty mudstone.

Two sets of channelized sandstones have been recognized. Each set is composed of two channels 1-4 m thick and 50 m or more wide. Both sets are surrounded by silty shale and mudstone interpreted to be subtidal. Internally, one set of channels fines upward from medium to very fine sand, with an increase in percent mud matrix. There are hummocky cross-beds in the lower part of each channel and the upper part is bioturbated. These channels are each about 1 m thick. The second set is made up of a 2 m thick channel and a 4 m thick channel. Internally, each is composed of muddy, very fine sandstone, mostly bioturbated throughout with some horizontal planar lamination.

**Interpretation.**—The suite of sedimentary structures indicates deposition from near storm wave base to above daily wave base. Some of the horizontal planar lamination is probably quasi-planar-lamination of Arnott (1993), resulting from combined flow during storm deposition. Change upwards from ripples, especially wave ripples, to hummocky cross-beds, to trough cross-beds is especially characteristic of a prograding, higher-energy siliciclastic shoreline (Clifton et al., 1971; McCubbin, 1982). Coarsening and thickening upwards in bedsets and groups of bedsets is also indicative of a prograding shoreline. The less common fining and thinning up may be explained by several different causes. Such vertical trends may represent migration of the siliciclastic source away from an area. They may be very broad and shallow subtidal channels with lateral terminations of the channels not recognized due to recessive and slope-forming weathering of the surrounding shale and mudstone. Alternatively, progradation of lower-wave-energy, tidally-dominated, shorelines can produce fining-upward vertical successions of sedimentary structures similar to those seen in these rocks (Howard and Reineck, 1981; Weimer et al., 1982). In almost all instances of fining-up bedsets, subtidal lithofacies are overlain by either a parasequence boundary or by siliciclastic intertidal lithofacies. Vertical changes in the intensity of bioturbation may reflect varying long-term sedimentation rates or changes in the long-term energy level in an area. Low concentration of burrowing would reflect higher sedimentation rates and/or an increase in depositional energy; high concentration of bioturbation would indicate low deposition rates and/or low depositional energy. The two sets of channels are interpreted as subtidal channels, perhaps formed by rip currents during storms.

## INTERTIDAL SILICICLASTIC FACIES

### Mudstone and Shale

**Description.**—A less common lithofacies, the constituent lithologies consist of fissile shale, mudstone, and silty mudstone, and display red, pink, orange, tan, brown, and in some cases green colors. These lithologies may be chloritic and cleaved. Horizontal planar lamination, mudcracks, and burrows may be found in the shale and mudstone, as well as in associated interbeds of fine-to-very-fine quartz sandstone and calcarenite. Current ripples and wave ripples may be found in the siltiest mudstone and in associated sandstone and carbonate arenite. Most burrows are small and horizontal, with less common vertical and inclined burrows. There are some intervals that are burrowed-to-bioturbated. Beds are thin, from 0.5 to 2 cm thick, and no vertical trends were noted in beds or bedsets.

**Interpretation.**—The intertidal interpretation is based on the mix of mudcracks, laminae, and ripples, as well as the position of this facies between subtidal facies below and more diagnostically intertidal and supratidal facies above. The presence of mostly horizontal burrows is characteristic of a *Cruziana* assemblage of trace fossils (Ekdale et al., 1984), which may be present in muddy intertidal flats (Ekdale et al., 1984; Frey et al., 1987). This facies, in comparison to the sandstone-siltstone lithofacies described next, may represent either of two possibilities: it may represent deposition higher on the intertidal flat than the sandstone-siltstone lithofacies, or it may form on a lower-energy tidal flat in a position equivalent to that of the sandstone-siltstone lithofacies.

### Sandstone and Siltstone

**Description.**—This is a common lithofacies, composed of quartz siltstone and very-fine-to-fine sandstone, and may be colored pink, orange, tan, brown, green, or gray. Physical sedimentary structures are horizontal planar lamination, wave ripples, current ripples, combined-flow ripples, some wrinkly lamination, and homogeneous beds. Other common structures are tepees, mudcracks, and fenestrae. Less common structures are load structures, burrows and intervals that are burrowed-to-bioturbated. Beds range from less than 0.5 to 25 cm thick, and no vertical trends were noted. Associated interbeds and interlaminae are composed of these lithologies: siliceous, silty mudstone; dolosiltite-calcarenite-calcisiltite lithofacies; and ooid grainstone.

**Interpretation.**—The combination of ripples, laminae, burrows, mudcracks, tepees, and fenestrae are indicative of intertidal flat deposition. The interbedded dolosiltite-calcarenite-calcisiltite lithofacies, also interpreted as tidal flat deposits, not only contains the same suite of sedimentary structures, but also has microbial structures and laminae indicative of episodic subaerial exposure. Ooid grainstone beds are thin and are interpreted as storm deposits emplaced onto the tidal flat.

## SUPRATIDAL SILICICLASTIC FACIES

### Mudstone and Shale

**Description.**—Recessive weathering, blocky, non-fissile shale, slightly silty shale, and slightly silty mudstone, colored in reds and purples are the lithologies found in this uncommon, though important, lithofacies. Much of the shale and mudstone weathers out in blocky, angular pieces that are commonly slickensided. These intervals are completely disrupted or churned. Mudcracks, tepees, horizontal parallel laminae, and crude thick horizontal parallel laminae are the few sedimentary structures present. There are some questionable burrows, and some intervals in which disruption has destroyed most of the physical structures.

Bed thickness, where it can be recognized is less than 0.5 cm. Churned units alternate vertically, commonly on a meter-scale spacing, with units in which sedimentary structures are present. Contacts between structured intervals and overlying churned intervals are gradational, whereas contacts with underlying churned intervals are relatively sharp. There are uncommon, thin quartz sandstone and dolosiltite interbeds.

**Interpretation.**—A supratidal to coastal plain setting is interpreted for this lithofacies based primarily on the churned character, which is interpreted as formed in paleosol horizons. The blocky, angular weathering and slickensided surfaces have the appearance of cutans and peds in a Bt paleosol horizon (U.S. Department of Agriculture Soil Classification) with well-developed slickensides formed by strong compression and/or by repeated swelling and shrinking of a clayey soil by wetting and drying (Retallack, 1988). The nature of the contacts at top and bottom of structured intervals may be interpreted as due to periods of rapid deposition allowing a relatively sharp contact at the base of a structured interval, followed by long periods of slow to no deposition during which soil processes acted to form the churned intervals. The effect of repeated wetting/drying cycles would be to progressively penetrate deeper into the deposits resulting in the gradational upper contact of the structured intervals.

# CHAPTER 3: GENERALIZED METER-SCALE SHALLOWING-UPWARD CYCLES

## METER-SCALE CYCLES/PARASEQUENCES

### INTRODUCTION

"Meter-scale" shoaling cycles vary in thickness from less than 1 m to about 20 m. It is possible that the thicker cycles are actually composites of several smaller cycles, but it has not been possible to recognize those smaller cycles. Reasons for the inability to differentiate these cycles vary. Recessive weathering of shale and siliceous mudstone results in sloping outcrop, generally partially covered, and prevents detailed observation of subtle changes in surfaces and lithofacies. In addition, some parasequence boundaries record small changes in sea level resulting in subtle facies changes across boundaries. This can result in stacks of similar lithofacies separated by parasequence boundaries with little to distinguish them from event surfaces; e.g., the Gold Ace Limestone Member at Echo Canyon (Plate 1) is composed of thick bedsets of nodular ribbon rock such that any parasequence boundary has the same subtidal lithofacies on either side.

Recognition of subtidal carbonate cycles, in which subtle parasequence boundaries emplace slightly deeper subtidal lithofacies on top of slightly shallower subtidal lithofacies, is critical to the evaluation of stacking patterns that define systems tracts; furthermore, estimates of cycle duration are less accurate, correlation of cycles is more difficult, and interpretation of mechanisms of cycle formation are more problematical. Commonly the boundary is marked by a sharp contact, perhaps with minor scouring, with oncoids with digitate microbial growths, and/or by an abrupt increase in the percentage of dolosiltite above the contact, e.g., in nodular ribbon rock. In thicker siliciclastic parasequences, where outcrop is laterally extensive and well-exposed, these subtle parasequence boundaries can be traced up depositional dip until subtidal overlies intertidal (Van Wagoner et al., 1990). Osleger (1991) recognized meter-scale subtidal carbonate cycles that coarsen upward with a decrease in the intensity of burrowing but was not able to trace them laterally to a point where subtidal overlies intertidal. At Eagle Mountain (Figure 7) this was done for Parasequences III and IV (See Chapter 4).

The 23 shoaling cycles in Figure 6 are generalized and represent a distillation of observed cycles in the various measured stratigraphic sections. The generalized cycles emphasize the wide variation present in the Carrara with respect to vertical succession of facies and lithologies. In addition, any measured cycle may not include top, bottom, or other components of the appropriate generalized cycle. In the summary diagram

**Figure 6.** Generalized meter-scale, shallowing-upwards cycles in the Carrara Formation. Siliciclastic lithologies, shown to the left of the center line, have been grouped into three categories: "shale, mudstone" is closest to the center line, "siltstone" is shown by an intermediate distance from the center line, and "siltstone plus sandstone" has the greatest distance. Carbonate lithologies, shown to the right of the center line, are grouped into "mudstone, wackestone" close to the center line, and "packstone, grainstone and/or siltite, arenite" farther away. Symbols and abbreviations are given in the legend.

**Grain types:**
- ooids
- peloids
- undifferentiated ooids & peloids
- oncoids
- general fossils
- trilobites
- hyolithoids
- lithoclasts

= vertical trend changing in upward direction

**Carbonate sedimentary structures and textures:**
- A planar microbial laminae
- A wavy microbial laminae
- R well-layered ribbon rock texture
- NR nodular ribbon rock tecture
- BR bioturbated ribbon rock texture
- stromatolitic boundstone
- T thrombolitic boundstone
- D digitate miocrobial boundstone

**Sedimentary structures:**
- H homogenous beds (no structures)
- current ripples
- climbing current ripples
- flaser ripples
- wave ripples
- W climbing wave ripples
- combined flow rippples
- planar cross beds
- trough cross beds
- hummocky cross beds
- horizontal planar laminae
- wavy parallel laminae
- wavy nonparallel laminae
- W wrinkly laminae
- G gutter casts

**Sedimentary structures:**
- scoured surfaces
- hardgrounds
- load structures
- contorted beds
- burrows
- burrowed-to-bioturbated
- bioturbated
- S soil-churned
- \# mudcracks
- tepees
- fenestrae
- microfaulting
- pyrite

**Abbreviations:**

| | | | | |
|---|---|---|---|---|
| bndst = boundstone | mdst = mudstone | wkst = wackestone | pkst = packstone | grst = grainstone |
| w/ = with | % = per cent | sh = shale | sts = siltsite or siltstone | |
| ss = sandstone | aren = arenite | ls = limestone | dol = dolostone or dol- or dolo- or dolomitic | |
| VF = very fine | F = fine | C = coarse | VC = very coarse | M = medium |
| m = meter | cm = centimeter | mm = millimeter | qtz = quartz | crsn = coarsen |
| incr = increase | decr = decrease | ps = parasequence | talc = altered sediments | |

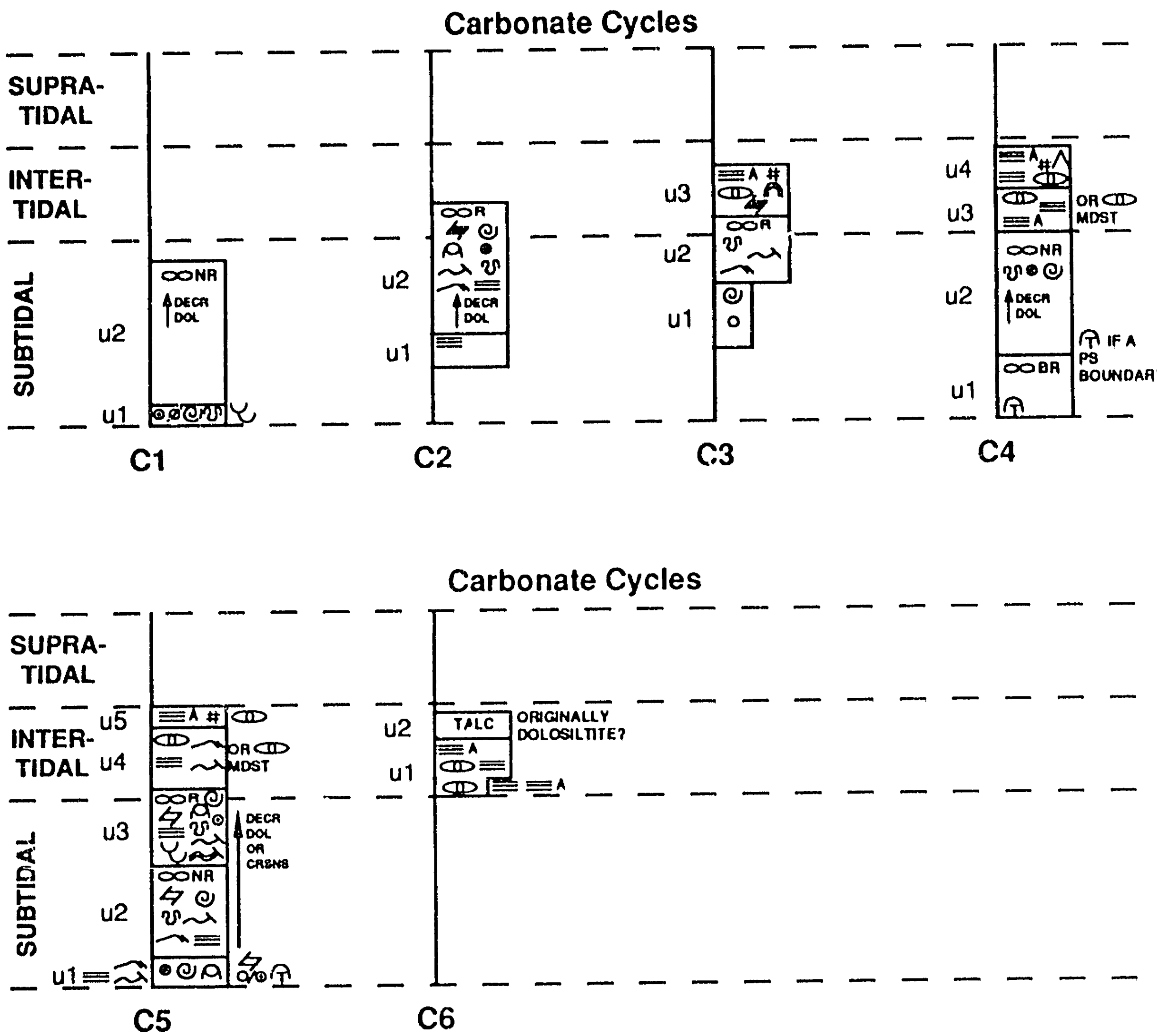
u1, u2, u3 etc. = informal units in shallowing-upwards cycles.

skol = *Slolithos* burrows

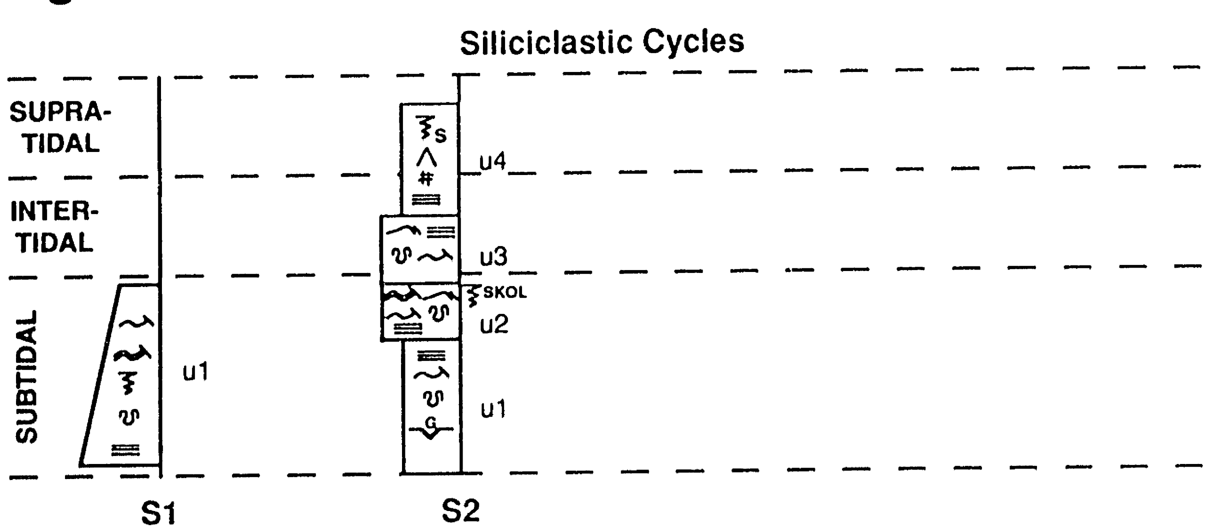
CDAS = calcarenite, calcisiltite, dolarenite, and dolosiltite

**FIGURE 6. LEGEND**

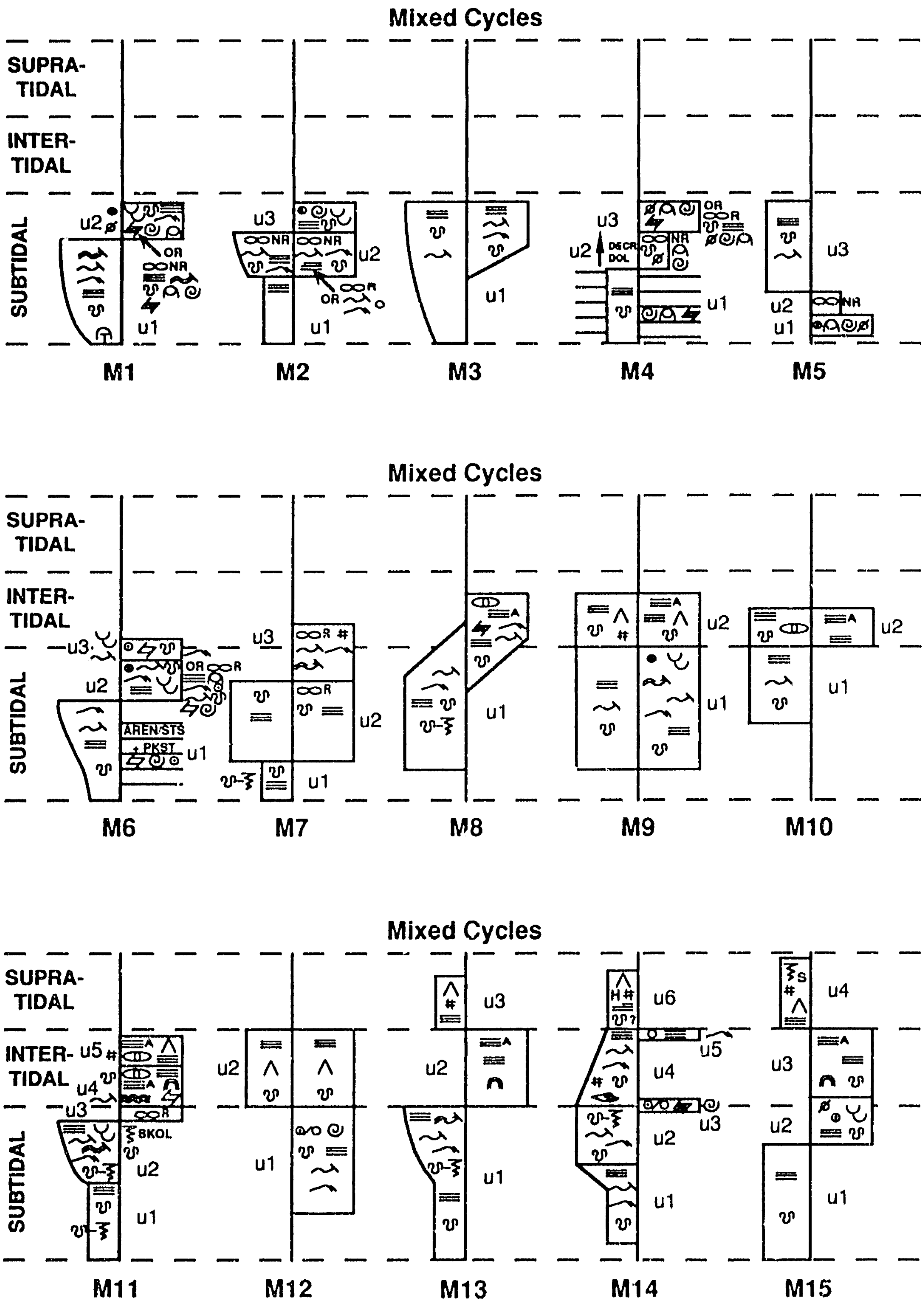
# Figure 6A.




# Figure 6B.



## FIGURE 6C.


Mixed Cycles
SUPRA-TIDAL
INTER-TIDAL
SUBTIDAL
M1
M2
M3
M4
M5
Mixed Cycles
SUPRA-TIDAL
INTER-TIDAL
SUBTIDAL
M6
M7
M8
M9
M10
Mixed Cycles
SUPRA-TIDAL
INTER-TIDAL
SUBTIDAL
M11
M12
M13
M14
M15

(Figure 6), siliciclastic lithologies, shown to the left of the center line, have been grouped into three categories: "shale and/or mudstone" is closest to the center line, "siltstone" is shown by an intermediate distance from the center line, and "siltstone plus sandstone" has the greatest distance. Carbonate lithologies, shown to the right of the center line, are grouped into "mudstone and/or wackestone" close to the center line, and "packstone, grainstone, carbonate siltite, and/or carbonate arenite" farther away. No distinction is made between dolostone and limestone, because this is not important in the Carrara for distinguishing depositional lithofacies or environments. Boundaries between subtidal, intertidal, and supratidal facies are normally gradational, as was previously discussed in the lithofacies descriptions (Chapter 2). Relative thickness of subtidal, intertidal, and supratidal facies as shown on Figure 6 is only schematic and should not be taken as a guide to thickness of a component part of any cycle. Each cycle is bound by parasequence boundaries that record small-scale relative deepening (flooding) events. The cycles are grouped by general lithologies, i.e., clean carbonate cycles (C), clean siliciclastic cycles (S), and mixed cycles (M). Within each group, cycles are arranged by approximate water depth of the uppermost beds, i.e., the uppermost beds in cycle C1 are subtidal, those in C2 are low intertidal, and those in C3 through C6 are high intertidal. Cycles that terminate at about the same level in Figure 6, e.g., cycles M1 through M5, all terminate in about the same water depths.

Each of the generalized cycles is divided into one to six units designated u1 to u6. There is no implication that all units with the same designation, e.g., "u1", have any relationship from one generalized cycle to the next. Within a cycle, a vertical change from one unit to the next coincides with a vertical change from one lithofacies to another. Because the cycles are generalizations, a unit may be composed of one of several possible lithofacies. The various possibilities are discussed for each cycle in the following sections.

No deepening-upward meter-scale cycles were found in the Carrara. Where deepening of the section is recorded, it is brought about by the retrogradational stacking of shoaling cycles, i.e., successive cycles do not shoal to as shallow a depth as did the preceding cycle. Groups of meter-scale cycles may together form larger overall shoaling cycles, i.e., each successive cycle tends to shoal to shallower depths or to have a greater proportion of shallower facies than does the preceding cycle. The Jangle Limestone Member (Plate 3) is made up of two of these larger shoaling parasequence sets. Individual meter-scale cycles may encompass both subtidal and intertidal facies, but those meter-scale cycles in the lower part of a parasequence set tend to have more subtidal facies, whereas meter-scale cycles in the upper part tend to have more intertidal facies (Plates 1 to 4).

Recognition of meter-scale shallowing-upward cycles with both carbonate and siliciclastic sediments demonstrates that deposition of these two sediments was coeval on time scales of parasequence duration. This is reinforced by the regional correlations shown on Plates 1 through 4 which document the widespread zone of mixed lithofacies within the lagoon, located between the carbonate bank and the mainland. Mount (1984) listed four mixing processes that could take place on carbonate-bank-rimmed continental margins with siliciclastics shed from the craton. Only "source mixing", wherein carbonate sediments are second generation, and derived from uplift and erosion of older, lithified carbonate deposits, was not recognized. Evidence for "punctuated mixing", driven by storm events, is present: e.g., deposition of ooids onto siliciclastic intertidal flats. "Facies mixing", driven by diffusion of sediments into adjacent lithofacies belts, was postulated by Mount (1984) to be present across relatively narrow zones. In the Carrara, given the width of the mixed-lithofacies intervals between clean carbonate intervals and clean siliciclastic intervals (Plates 1 to 4), this mixing zone was relatively broad, on the order of 100-200 km down depositional dip. "*In situ* mixing", caused by storm winnowing of fine-grained siliciclastics leaving a coarse lag of death assemblages of calcareous organisms, was commonplace and is recorded by the numerous fossiliferous packstone/grainstone event beds in thick intervals of siliceous shale and mudstone.

In some parasequences, mixing can also be shown to have taken place at the scale of bedsets, beds, and even laminae. This is shown in Figure 6 in mixed cycles M2, M3, M7, M8, M9, and M10. Most commonly the intimate admixtures are found between quartz sandstone and siltstone, and carbonate arenite and siltite. However, other carbonate lithofacies, e.g., ooid grainstone also are associated with siliceous beds. The Red Pass Member oolites (Plate 2) are commonly interbedded with shale to sandstone.

## CARBONATE SHOALING CYCLES

### C1

This is a wholly subtidal cycle, composed only of nodular ribbon rock. The principal characteristic used to pick out parasequences is the vertical trend of decreasing abundance of dolosiltite upsection. At the parasequence surface there is an abrupt increase in percent dolosiltite in the lithology. Commonly the parasequence boundary is a more pronounced surface than other event surfaces within the cycle. In addition to the abrupt increase in dolosiltite, the boundary tends to be traceable across the outcrop. Uncommonly, it may have a concentration of oncoids along it and/or hardground development. The nodular ribbon rock tends to be moderately well burrowed and bioturbated with few recognizable sedimentary structures preserved. There are few interbeds of fossiliferous or lithoclast packstone/grainstone. In some instances, there is an addition of a relatively thin basal bed or bedset of one or more of these lithofacies: oolitic grainstone; oncolitic wackestone, packstone, and/or grainstone; or fossiliferous packstone and/or grainstone. This basal unit is commonly burrowed, may contain cross-beds, and is interpreted as a basal lag. The basal lag provides another criterion to aid in recognition of parasequence boundaries.

**C2**

The basal unit (u1) in this cycle is horizontal planar laminated subtidal CDAS lithofacies. It is overlain by a second unit (u2), a mix of well-layered ribbon rock, fossiliferous packstone/grainstone, lithoclast packstone/grainstone, and/or oolitic grainstone. Some bedsets of carbonate arenite and/or siltite also may be present. Small sedimentary structures present are wave ripples, current ripples, and more horizontal planar lamination. In general, the percentage of dolosiltite tends to decrease upwards. Rare fenestrae may be interpreted to indicate that this cycle can terminate in the lowermost intertidal or be interpreted as of subtidal origin (See discussion in Chapter 2).

**C3**

Three units of varied lithofacies, ranging from subtidal to intertidal compose this cycle. Fossiliferous and/or peloidal mudstone/wackestone make up the basal unit (u1), and well-layered ribbon rock with wave ripples, current ripples, and horizontal planar lamination make up the second unit (u2). The third unit (u3) is made up of a mix of stromatolitic boundstone, the dolosiltite-calcarenite-calcisiltite lithofacies, and/or the orange-dolosiltite lithofacies. The origin of the third unit is very likely intertidal, as shown by microbial lamination, fenestrae, and mudcracks.

**C4**

The basal unit (u1) of this cycle consists of bioturbated ribbon rock and the middle unit (u2) consists of a mix of nodular ribbon rock, fossiliferous packstone/grainstone and/or oolitic grainstone. Bioturbated ribbon rock, the basal unit, is not always present and may be replaced by more nodular ribbon rock. The bottom parasequence boundary of this cycle commonly has thrombolitic boundstone heads growing on it regardless of which variety of ribbon rock overlies it. Overlying the second unit may be either calcitic fenestral mudstone or the dolosiltite-calcarenite-calcisiltite lithofacies (u3). The upper unit (u4) is composed of orange dolosiltite.

**C5**

This carbonate shallowing-upward cycle incorporates five units extending from subtidal to upper intertidal. A basal unit (u1) consists of fossiliferous packstone/grainstone, lithoclast packstone/grainstone, ooid/peloid packstone/grainstone, and/or oolitic grainstone. Sedimentary structures present in the ooid/peloid packstone/grainstone are wave ripples, current ripples, and horizontal planar lamination. A lack of larger sedimentary structures may result from either too low energy-levels, or from grains too small to form larger bed forms regardless of the energy conditions, i.e., at or below about fine sand-size (Southard and Boguchwal, 1990). Many of the ooids and possible peloids are in this size range and this may account for the lack of large bed forms in this unit. The basal oolitic packstone/grainstone represents either ooids transported into the area or ooids formed *in situ* at the start of the parasequence during favorable, but short-term, conditions.

Nodular ribbon rock, which may have interbedded fossiliferous packstone/grainstone and/or lithoclast packstone/grainstone, comprises the second unit (u2). Wave ripples, current ripples, and horizontal planar lamination are preserved in all three lithofacies. The nodular ribbon rock beds tend to be less extensively burrowed than in cycle C1, resulting in preservation of more physical sedimentary structures, and more abundant lithoclast packstone/grainstone interbeds. The third unit (u3), in the uppermost subtidal, is composed of oolitic and/or fossiliferous packstone/grainstone (commonly burrowed and trough cross-bedded), or of well-layered ribbon rock with interbeds of lithoclast packstone/grainstone. An overall coarsening upwards from the second unit to the third is common and is useful in recognizing parasequence boundaries if the intertidal units are not developed within a cycle. The fourth unit (u4) is either fenestral mudstone or the intertidal dolosiltite-calcarenite-calcisiltite lithofacies, whereas the fifth (u5) is the orange-dolosiltite lithofacies.

**C6**

Three units are recognized in an uncommon cycle that only appears in the Jangle Limestone Member at the Last Chance Range, California (Figure 1 and Plate 3A). The basal unit is calcitic fenestral mudstone overlain by orange dolosiltite, with the top unit an altered, talcose, poorly consolidated carbonate that is interpreted to be an altered dolosiltite. It is also possible that the talcose carbonate was originally a shaley carbonate or a carbonate-rich shale, in which case it would form the basal unit of this cycle rather than the uppermost.

## SILICICLASTIC SHOALING CYCLES

### S1

This cycle fines upward from subtidal sandstone to siltstone to mudstone and/or shale. There are two varieties of this fining-upward siliciclastic cycle. In the first variety, sandstone to siltstone is present in the lower half, and the cycle fines upward to mudstone and/or shale in its upper half. The sandstone and siltstone have preserved physical sedimentary structures, mostly wave ripples, whereas the upper, finer-grained half tends to be bioturbated. The fining-upward trend, combined with the increase in bioturbation, may indicate a decrease in sedimentation rate in the upper half. These changes may result from a shift in the point-source of the coarser siliciclastic sediment that moves it farther away from the area measured, or they could result from a deepening of the relative water depths. The preferred interpretation is that the point-source of the coarse sediment moved farther away, as there is no other evidence in this cycle-type or in other cycle-types for deepening of Carrara meter-scale cycles. The second variety fines upward from sandstone to siltstone to a small thickness of mudstone only at the top. Physical sedimentary structures and burrows are found but there are no bioturbated areas. Hummocky cross-beds and wave ripples indicate that oscillatory, wave-induced motion was dominant in this cycle. Possible causes and preferred causes of the fining upward trend are the same as for the first variety.

### S2

A coarsening-upward trend of subtidal lithofacies distinguishes this cycle from the previous one. The lower unit (u1) is siltstone with some mudstone, and sedimentary structures are horizontal planar lamination, wave ripples, gutter casts, and burrows. The overlying unit (u2) is sandstone with hummocky cross-beds, wave ripples, current ripples, horizontal planar lamination, and burrows. Some cycles have tops that are bioturbated with vertical *Skolithos* burrows. The coarsening-upward trend coupled with the change from only wave ripples in the finer unit (u1) to hummocky cross-beds in the coarser may be interpreted as due to progradation and shoaling of a siliciclastic shoreline. The bioturbated tops to some cycles may be interpreted as representing a period of slow sedimentation allowing preservation of large numbers of *Skolithos* burrows. *Skolithos* is interpreted as forming in loose, sandy substrates with a moderately high-energy environment that allows constant sediment movement (Ekdale et al., 1984).

Within some cycles sedimentation continues above the hummocky cross-beds and *Skolithos* burrows, with deposition of rippled and horizontal planar laminated sandstone and siltstone (u3). Although there are no structures indicative of subaerial exposure, this unit is interpreted as high subtidal to low intertidal, in large part because of its position between the second and fourth units, and because the sedimentary structures present are common on low intertidal flats. Above it is the fourth unit (u4), of siltstone to siliceous mudstone with horizontal planar lamination, mudcracks, and tepees that continue into mudstone paleosols. This last unit is interpreted as high intertidal to supratidal.

**MIXED LITHOLOGY SHOALING CYCLES**

**M1**

This is an overall coarsening-upward cycle with the lower unit (u1) composed of siliciclastics and the upper unit (u2) composed of a variety of carbonate lithofacies. In any one cycle, carbonate grains are coarser than siliciclastic grains, and may have been transported into the area of final deposition, or they may have been produced and deposited *in situ*. No fenestrae are found and this cycle is interpreted as entirely subtidal.

The basal siliciclastic unit (u1) exhibits some variation in grain-size and its mode of coarsening upward. All cycles are initially subtidal shale and/or siliceous mudstone with less common small thrombolitic heads growing on the parasequence/cycle boundary. The unit commonly shows a smoothly transitional coarsening-upwards trend, but some coarsen abruptly into siltstone and sandstone. One variety of cycle shows no coarsening in the lower unit and remains shale/mudstone. Sedimentary structures that may be present are hummocky cross-bedding, wave ripples, current ripples, horizontal planar lamination, and burrows.

The upper unit (u2) is a mix of subtidal carbonate lithofacies, but continues the coarsening-upwards trend established in the lower unit. Oolitic grainstone, fossiliferous packstone/grainstone, oncolitic packstone/grainstone, and/or nodular ribbon rock (with hummocky cross-beds and interbeds of fossiliferous and/or lithoclast packstone/grainstone) are all present, and all are burrowed. Oolitic grainstone is the most common carbonate lithofacies. The ooids are coarser-grained than the underlying sandstone, and the change from hummocky cross-beds in the sandstone to trough cross-beds in the oolite is interpreted as coinciding with the change from below fair-weather wave base (hummocky sandstone) to above fair-weather wave base (trough cross-bedded oolite).

**M2**

A basal unit (u1) of laminated siliceous mudstone gives way to a mixed-lithology middle unit (u2) of finely interlaminated and interbedded quartz siltstone and sandstone, plus carbonate arenite and siltite, all with well-layered ribbon rock or nodular ribbon rock texture. Within this unit an overall coarsening-upward trend is evident. The capping unit (u3) is subtidal oolitic grainstone with some fossiliferous packstone/grainstone. Ripples are found in the middle unit and trough cross-beds are found in the top unit, and these two trends can be interpreted as reflecting an upward increase in depositional energy. As in the previous cycle, the upward change in grain-composition and grain-size coincides with the change from below fair-weather wave base to above. Carbonate grains may have been transported into the area or may represent *in situ* carbonate production and deposition.

**M3**

An upward decrease in the proportion of siliciclastic sand and silt with a concomitant increase in proportion of carbonate sand characterizes this cycle. The cycle generally increases in grain size upward, but less commonly may show no change in grain size. The basal part of the cycle may start in siliceous mudstone. Coarsening-upward cycles are composed of siltstone and sandstone with horizontal laminae, wave ripples, and burrows. The upper parts have carbonate arenite interlaminated and interbedded with the siliceous grains. Cycles that don't coarsen upwards lack siliceous mudstone at the base, and contain current ripples in the carbonate arenite. Most diagnostic, however, is the complete replacement of quartz grains by carbonate grains in the upper part of non-coarsening cycles.

**M4**

The lower, dominantly siliciclastic unit (u1) is composed of burrowed and horizontal-planar-laminated, siliceous mudstone and shale, and may have: 1) no interbeds; 2) interbeds of fossiliferous packstone/grainstone; or 3) interbeds of quartz sandstone and siltstone, and fossiliferous and/or lithoclast packstone/grainstone. Interbeds, generally less than 10 cm thick, appear to be event beds or winnowed lag deposits in an environment where the background sedimentation was fine-grained, siliceous lithologies. The carbonate middle unit (u2) is composed of nodular ribbon rock. Within the nodular ribbon rock dolosiltite decreases upwards. The upper unit (u3), with few sedimentary structures, is also carbonate, but may be composed of a number of different lithofacies. It is either well-layered ribbon rock with some oncoids and interbeds of fossiliferous wackestone, or is a fossiliferous, oncolitic, and/or lithoclast packstone/grainstone, generally several tens of centimeters thick.

**M5**

This cycle is one of the more unusual mixed cycles in that the carbonate lithofacies are on the bottom. The basal unit (u1) may be oolitic grainstone, fossiliferous packstone/grainstone and/or oncolitic packstone/grainstone, and is generally several tens of centimeters thick. Some of the thinner (≤10 cm) packstone/grainstones may represent winnowed lags on the parasequence/cycle boundary. The second unit (u2) is nodular ribbon rock of mudstone/peloid packstone (see also discussion in "Bioturbated Ribbon Rock" section), and the overlying siliciclastic unit (u3) is quartz siltstone with horizontal planar lamination, wave ripples, and burrows. Neither lithofacies represents high-energy conditions and this cycle is interpreted as low-energy subtidal throughout.

**M6**

In the siliciclastic lower unit (u1), lithologies coarsen upwards from mudstone/shale to siltstone to sandstone, with common, thin interbeds of carbonate arenite/siltite and fossiliferous or lithoclast packstone. The middle unit (u2) is either an oolitic grainstone or a mix of well-layered ribbon rock and fossiliferous to lithoclast packstone/grainstone. The uppermost unit (u3) is again oolitic grainstone that may contain a moderate percentage of lithoclasts; the unit may extend into the lowest intertidal. The siliciclastic lithofacies have horizontal planar lamination, wave ripples, and current ripples, whereas both carbonate intervals have trough cross-beds in addition to ripples. This increase in size of physical sedimentary structures corresponds to an overall increase in grain-size, and probably reflects an increase in energy in the depositional system.

**M7**

The subtidal, siliceous mudstone/shale of the basal unit (u1) has planar lamination and is burrowed, with some areas burrowed-to-bioturbated. The middle unit (u2) has a well-layered ribbon rock texture with interlaminated and interbedded quartz siltstone-sandstone with carbonate arenite/siltite. Burrows and horizontal planar lamination are the main sedimentary structures. The upper unit (u3), a clean carbonate, is composed of well-layered ribbon rock, in which small hummocky cross-beds, wave ripples, current ripples, and some mudcracks can be recognized. This upper unit is interpreted to have been deposited in both the upper subtidal and the lower intertidal.

**M8**

This cycle grades upward from clean quartz siltstone and sandstone in the base to clean carbonate arenite and siltite in the top, with increasing quantities of carbonate arenite and siltite intermixed into the siliciclastics in the middle. The upper part of the carbonates is intertidal. The transition zone of mixed lithologies not only encompasses parts of both units, but it also spans the change from subtidal to intertidal. The subtidal part of the cycle has horizontal planar lamination, burrows, wave ripples, and current ripples. The intertidal part has horizontal planar lamination, wave ripples, current ripples, some burrows, microbial lamination, and fenestrae.

**M9**

This cycle has interlaminated and interbedded quartz siltstone and sandstone mixed with carbonate arenite and siltite in the subtidal lower unit (u1). In the upper portion of the unit there may be an upward decrease in the proportion of siliciclastic grains. Sedimentary structures in the lower unit tend to change upwards from ripples to hummocky cross-beds to trough cross-beds. Burrows are common and there are some ooids in the carbonate beds. The intertidal upper unit is also of completely interlaminated and interbedded mixed lithologies, with the same siliciclastic and carbonate lithofacies as the lower unit. Sedimentary structures that may be present are horizontal planar lamination, microbial lamination, tepee structures, and some burrows.

**M10**

The lower unit (u1) is subtidal, quartz sandstone and siltstone with horizontal planar lamination, wave ripples, and burrows. The upper unit (u2) is intertidal and consists of mixed siliciclastic sandstone and siltstone with carbonate arenite and siltite. Fenestrae, horizontal planar lamination, microbial lamination, and some burrows characterize the unit.

**M11**

Two subtidal, siliceous units, a subtidal to intertidal(?) carbonate unit, and two intertidal carbonate units compose this cycle. The basal unit (u1) is siliceous mudstone/shale, burrowed and burrowed-to-bioturbated with some planar lamination. The next unit (u2) is part of an overall coarsening-up, subtidal trend and consists of siltstone changing into sandstone, with burrowed-to-bioturbated areas, horizontal planar lamination, wave ripples, current ripples, hummocky cross-beds, and trough cross-beds. The top of the sandstone interval may contain abundant *Skolithos* burrows. The overlying unit (u3) is thin, and composed of well-layered ribbon rock without identifiable grains that may extend into the lowermost intertidal. The first of the intertidal units (u4) has mixed dolosiltite-calcarenite-calcisiltite lithofacies with some stromatolitic boundstone. Sedimentary structures present are fenestrae, microbial lamination, horizontal planar lamination, wavy lamination, some wave ripples, and there may be some burrows in its lower portion. The uppermost unit (u5) is composed of orange dolosiltite with fenestrae, mudcracks, tepee structures, microbial lamination, and some horizontal planar lamination.

**M 1 2**

The subtidal lower unit (u1) of this cycle is mixed oolitic (possibly peloidal) grainstone, fossiliferous packstone/grainstone and/or subtidal carbonate arenite/siltite, with wave ripples, current ripples, and horizontal planar lamination. The intertidal upper unit (u2) is interlaminated and interbedded quartz siltstone and orange dolosiltite with some burrows in the lower part, and tepee structures and horizontal planar lamination in the upper part.

**M 1 3**

The subtidal, basal siliciclastic unit (u1) has the most variability in this cycle. The intertidal carbonate unit (u2) and the siliciclastic upper unit (u3) have little variability. The basal unit (u1) generally coarsens upwards from burrowed, horizontal-planar-laminated, siliceous mudstone/shale, to siltstone and sandstone with some burrowed-to-bioturbated areas, horizontal planar lamination, wave ripples, current ripples, and hummocky cross-beds. The coarsening upward trend can be smooth and transitional, or have an abrupt change from mudstone/shale to siltstone and sandstone. In some cycles, the lower unit does not coarsen up, and is composed of quartz siltstone with burrows and horizontal planar lamination. The intertidal middle unit (u2) is the dolosiltite-calcarenite-calcisiltite lithofacies and may include some stromatolitic boundstone heads. The uppermost unit (u3) is interpreted as supratidal in that it contains siliceous shale/mudstone with mudcracks, tepee structures, horizontal lamination, and is commonly colored in shades of red.

**M 1 4**

This cycle is somewhat complicated in that it is dominantly a siliciclastic cycle, with some thin, carbonate interbeds (units u3 and u5). The lowest unit (u1) of this cycle starts in siliceous mudstone/shale but coarsens rapidly into sandstone in its upper part. Burrows, wave ripples, current ripples, and horizontal planar lamination are found in the unit and it is interpreted as subtidal. Burrowed-to-bioturbated quartz sandstone/siltstone with wave ripples and current ripples make up the next unit (u2) and it is interpreted also as subtidal. These two subtidal units define a coarsening-upward trend, but the intertidal siliciclastic unit (u4) fines upward. This unit is also quartz sandstone/siltstone, with burrows, wave ripples, current ripples, climbing ripples, and horizontal planar lamination, and probably represents deposition on intertidal flats. The third unit (u3), of carbonate interbeds, consists of interbeds of oolitic (possibly peloidal) grainstone between the base of the fourth unit and the top of the second. At the top of the fourth unit, peloidal grainstone (u5) is also interbedded with siliciclastics. These are the only instances of carbonate lithofacies in this cycle and they are likely to have been emplaced as storm deposits. The uppermost unit (u6) is reddish siliceous mudstone/shale with tepee structures, mudcracks, homogeneous beds, horizontal planar lamination, and questionable burrows. It is interpreted as supratidal.

**M 1 5**

In this cycle the lowest unit (u1) is quartz siltstone with horizontal planar lamination and burrows, and is interpreted as subtidal. Overlying it is a second unit (u2), interpreted as mostly subtidal, composed of a mix of oolitic grainstone and oncolitic packstone/grainstone, with burrows and trough cross-beds. When considered together with the lowest unit, the subtidal part of the cycle displays a coarsening-upward trend. The intertidal middle unit (u3) is a mix of the dolosiltite-calcarenite-calcisiltite lithofacies, microbially laminated orange dolosiltite lithofacies, and may include some stromatolitic boundstone heads. The uppermost unit (u4) is interpreted as supratidal in that it contains reddish, siliceous shale/mudstone with disrupted areas separated by horizontal planar lamination, mudcracks, and tepee structures. This unit is interpreted to be paleosols.

# CHAPTER 4: LATERAL CONTINUITY OF FIFTH-ORDER AND FOURTH-ORDER CYCLES

## INTRODUCTION

### FORMULATION OF PROBLEM

A fundamental stratigraphic problem is the differentiation of extrinsic from intrinsic mechanisms in the formation of cyclic stratal patterns. Often, the primary characteristic used to distinguish extrinsic from intrinsic influences is the lateral continuity of the cycle. If a cycle is viewed as laterally continuous, it is most often interpreted as dominated by extrinsic mechanisms; if laterally discontinuous, then dominated by intrinsic mechanisms. Unfortunately, determination of continuity is commonly based on sections measured in isolated outcrops or on widely spaced subsurface well data and must be inferred rather than proven. Consequently, this has lead to opposing interpretations of similar data sets, e.g., see Koerschner and Read (1989, 1990), Kozar et al. (1990), Hardie et al. (1991), and Read et al. (1991).

Demonstration of the actual continuity of cycles is rare. Shallow-water subtidal and peritidal carbonate facies often have been modeled as laterally continuous bodies extending for many tens of kilometers, forming shallowing-upwards cycles that can be correlated over tens to hundreds of kilometers (Ginsburg, 1971; Hardie and Shinn, 1986; Irwin, 1965; Shaw, 1964). Intra- and interbasin studies of cyclicity, investigations of the origins of meter-scale carbonate cycles, and documentation of eustatic fluctuations commonly rely on this model of laterally continuous facies and/or cycles to guide correlations between widely separated areas (Goodwin and Anderson, 1985; Osleger and Read, 1991). Alternative models have been developed that are predicated on lateral discontinuity of facies and cycles (Evans, 1984; Harris, 1984). Some of these rely on Holocene or Pleistocene data (Enos and Perkins, 1977; Enos and Perkins, 1979; Hardie and Garrett, 1977; Roberts et al., 1977), whereas others describe ancient examples, most of which are based on laterally discontinuous outcrop (Kozar et al., 1990; Laporte, 1969; Mazzullo et al., 1978; Pratt and James, 1986; Selg, 1988). Extreme lateral continuity of meter-scale cycles has been shown by Grotzinger (1986a, b), who invoked an extrinsic progradational mechanism. On the other hand, lateral discontinuity of channelized meter-scale cyclic facies has been shown by Waters, Spencer, and Demicco (1989) and Cloyd and Demicco (1990), who invoked intrinsic mechanisms. Pratt and James (1986, p. 332) developed a "tidal island" model for unchanneled cyclic facies to explain "... facies changes [that] can be walked out and observed directly ... and deduced by correlation of closely spaced sections ...".

Koerschner and Read (1990, p. 795) remarked that if local intrinsic processes are responsible for mosaic patterns of facies and cycles, then "... in outcrop sections with flat-lying beds, we would expect to see mosaic-like lateral interfingering of laminate caps with subtidal facies". The present study shows that this is the case in the Cambrian Carrara Formation at Eagle Mountain, California (Figures 2, 7 and 8). This paper presents one of the best documented examples of lateral discontinuity in unchanneled, shallow subtidal and peritidal shoaling-up carbonate cycles. Unchanneled carbonates are characteristic of most shallowing-upward cycles of many geologic ages (Grotzinger, 1989; James, 1984), thus increasing the relevance of this study. In the Carrara Formation, lateral discontinuity of facies, cycles, and cycle boundaries is documented in 1.8 km of laterally continuous outcrop (Figure 9), and correlations are extrapolated to other ranges in southeastern California and southwestern Nevada (Figures 2 and 8).

Stratigraphic, geometric, and sedimentologic data of an interval of carbonates 35 to 50 m thick in the upper half of the Carrara Formation provide a rare opportunity to document lateral discontinuity of cyclic facies. Nine closely spaced stratigraphic sections were measured and described on the west flank of Eagle Mountain, approximately 35 km east of Death Valley, California. Facies contacts and parasequence boundaries were walked out and lateral variations documented, as shown in a cross section of the Eagle Mountain outcrop (Figure 7). Correlations were extended to nearby ranges in a regional north-south cross section extending approximately 55 km south of Eagle mountain (Figure 10). The example described in this paper contrasts sharply with models of peritidal carbonate facies extending laterally for tens of kilometers (Ginsburg, 1971; Grotzinger, 1986a; Grotzinger, 1986b; Hardie and Shinn, 1986; Irwin, 1965; Shaw, 1964).

## APPROACH

This chapter summarizes a detailed study of lateral continuity in meter-scale shallowing-upward cycles. Most of the observations were made in the upper half of the Jangle Limestone Member of the Carrara Formation at Eagle Mountain, California (Figure 8). A mix of laterally continuous and discontinuous facies, fifth-order meter-scale cycles (parasequences), and parasequence boundaries are arranged in a mosaic pattern within a laterally continuous, 35-50 m thick, fourth-order, shallowing-upward cycle. This mosaic pattern is documented in 1.8 km of nearly continuous outcrop at Eagle Mountain. It can also be recognized in a 55 km cross section that extends across several disjunct ranges and is oriented approximately parallel to depositional strike.

Assignment of an order-designation (Table 1) to a depositional unit is dependent on the duration of time represented by that unit and one of its bounding surfaces, either

**Figure 7.** The stratigraphic cross section at Eagle Mountain is of the upper fourth-order parasequence set in the Jangle Limestone Member and shows continuous and discontinuous examples of the following; peritidal carbonate lithofacies, fifth-order parasequences, and parasequence boundaries. Determination of the lateral extent of many parasequences and facies units was made by walking out contacts between stratigraphic sections. The basal surface used to datum the section is a through-going parasequence surface at the top of an intertidal laminated, orange dolosiltite overlain by subtidal oolite, limestone arenites and siltstones, and some ribbon rock. Parasequence Boundary VI also coincides with the Type 2 sequence boundary between the fourth (Pahrump Hills Shale-Jangle Limestone) and fifth (Desert Range Limestone-Papoose Lake) Grand Cycles. There may be several meters of erosion along this surface between stratigraphic columns D and G, but the evidence is equivocal. Heavy lines indicate bounding surfaces of parasequences, Roman numerals I through VI indicate laterally continuous boundaries, and capital letters (A, B, C) indicate laterally discontinuous boundaries. Light lines indicate facies boundaries within parasequences. Parasequence boundaries are sharp and abrupt, whereas facies boundaries within shallowing-upward packages may be either sharp and abrupt or gradational over tens of centimeters. Lateral facies changes are gradual and occur over tens of centimeters to tens of meters. See text for more details.

## INTERTIDAL

Microbial Laminated Dolosiltite

Fenestral Mudstone

## SUBTIDAL

Ooid Grainstone

Oncolitic Packstone & Grainstone

Fossiliferous Packstone & Grainstone

Nodular Ribbon Rock & Well-Layered Ribbon Rock

Bioturbated Ribbon Rock

CDAS Lithofacies

Thrombolite Boundstone

Siliciclastics from Shale to Sandstone

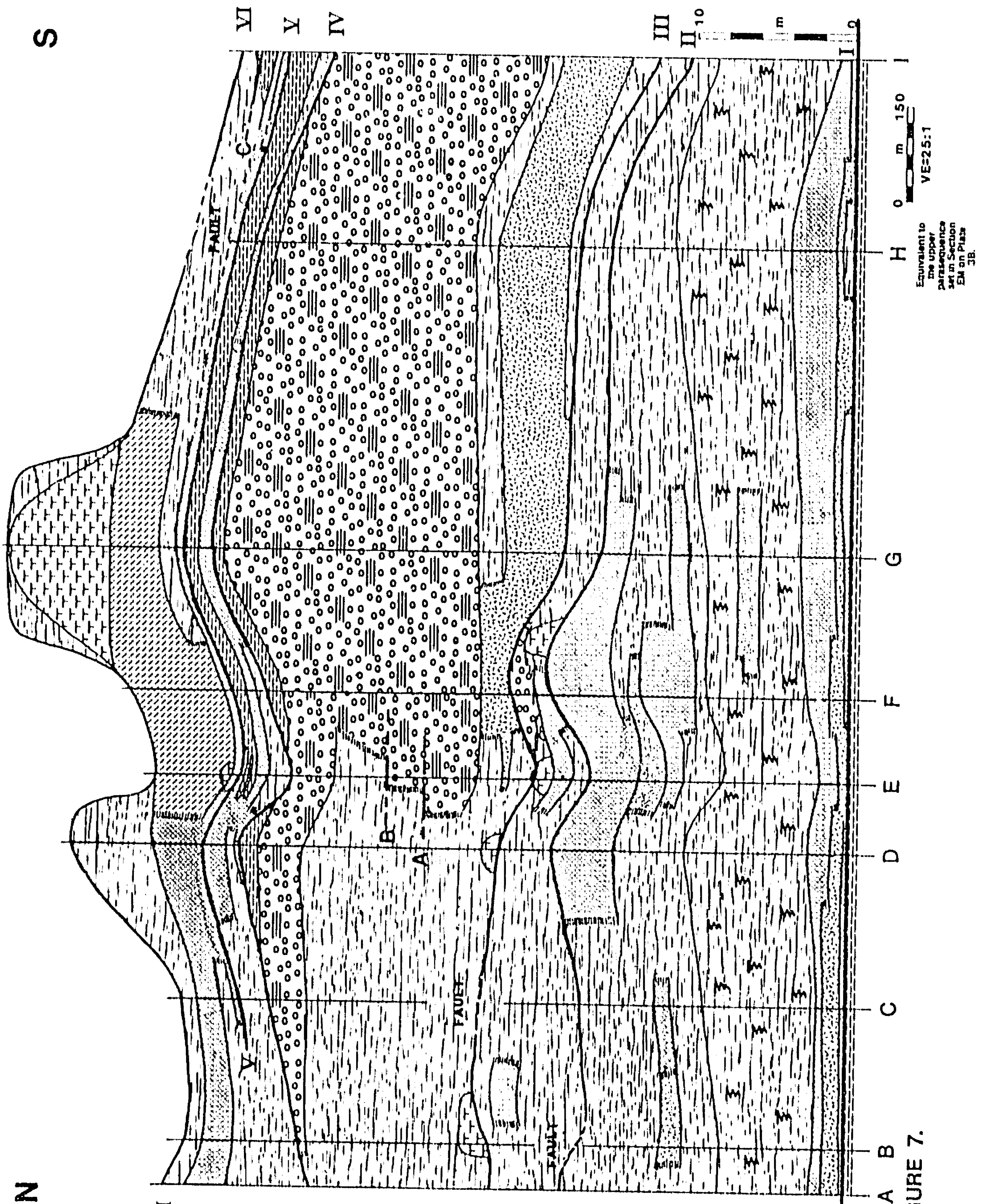
?

No Lithologic Data

Parasequence Boundary

Facies Boundary

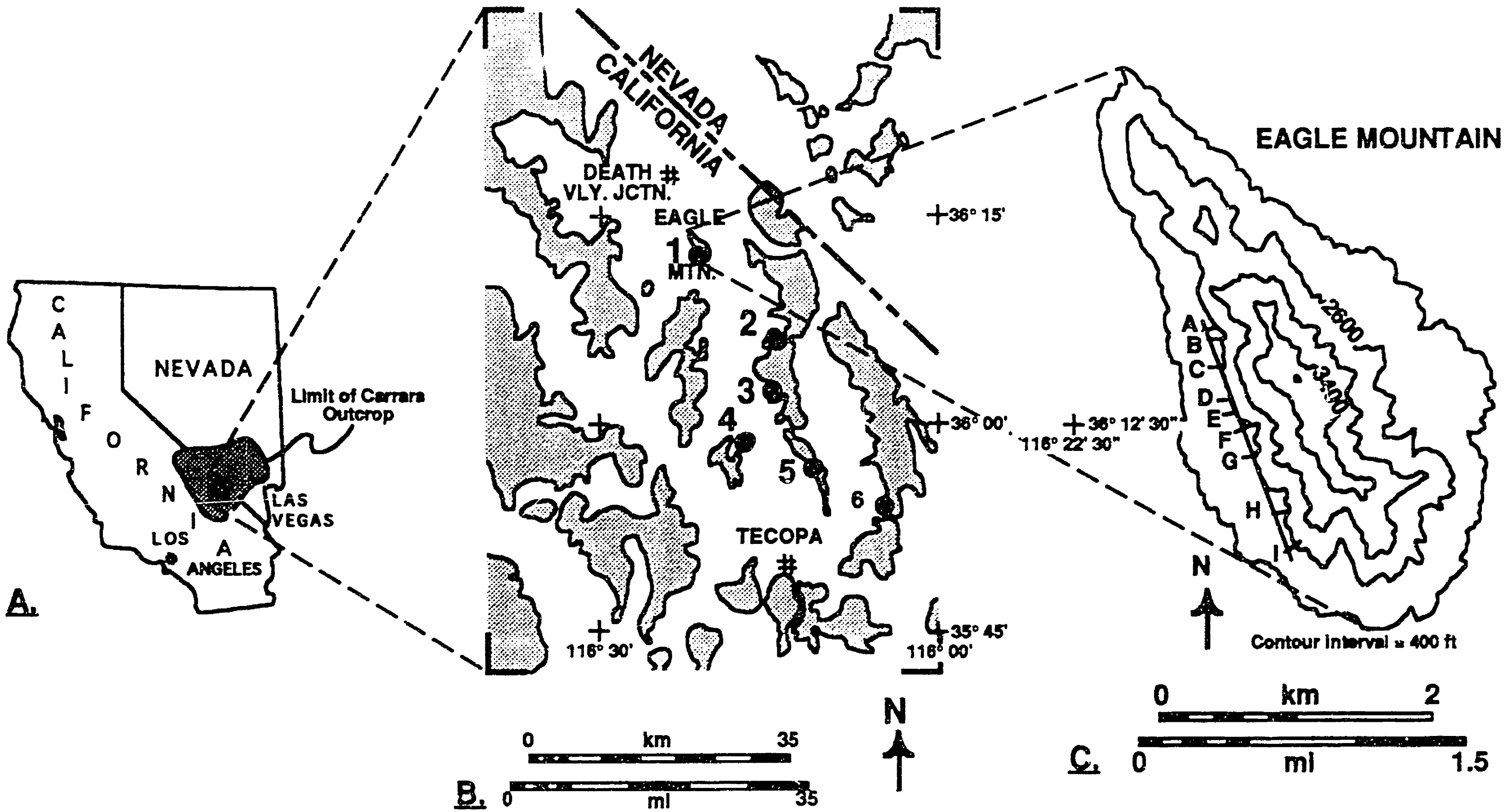
Gradational Lateral Facies Boundary



N
S
VI
V
IV
III
II
I
A
B
C
D
E
F
G
H
FAULT
FAULT
FAULT
10
m
0
0 m 150
VE=25:1
Equivalent to the upper parasequence set in Section EM on Plate 3B.


FIGURE 7.

**FIGURE 8.** Location maps showing the extent of the Carrara Formation (A), the location of Eagle Mountain and the area encompassed in the regional cross section (B), and the location of the Eagle Mountain cross section (C). **A)** The limit of Carrara Formation outcrops are shown on a nonpalinspastic base map of California and Nevada. **B)** Stratigraphic sections one through six, measured in the region immediately east of Death Valley, comprise the regional cross section in Figure 10. Eagle Mountain, the site of detailed lateral and vertical descriptions in the Carrara is at location one. Ranges, mountains and hills are outlined and shaded on a nonpalinspastic base map. **C)** The topographic enlargement of Eagle Mountain provides exact positions of the nine stratigraphic sections portrayed in the cross section in Figure 7. The line of the cross section projects between sections A and I, and also approximates the panoramas in Figure 9.



A.
C A L I F O R N I A
NEVADA
LOS ANGELES
LAS VEGAS
Limit of Carrara Outcrop
B.
NEVADA
CALIFORNIA
DEATH VLY. JCTN.
EAGLE MTN.
TECOPA
1
2
3
4
5
6
36° 15'
36° 00'
35° 45'
116° 30'
116° 00'
N
0 km 35
0 mi 35
EAGLE MOUNTAIN
2600
3400
A
B
C
D
E
F
G
H
I
36° 12' 30"
116° 22' 30"
N
Contour interval = 400 ft
C.
0 km 2
0 mi 1.5


FIGURE 8.

**Figure 9.** Two overlapping photographic panoramas present approximately 2 km of the west face of Eagle Mountain and delineate the area of the cross section in Figure 7. The delineated interval, the upper half of the Jangle Limestone Member, is approximately 35 to 50 m thick. The upper panorama shows the northern end and the lower shows the southern. Sections E, F, and G are repeated in each half and solid lines mark the approximate boundaries of the interval of the Carrara discussed in this paper. The flat area in the foreground is the Zabriskie Quartzite (ZQ) underlying the Carrara (C). The lower, more siliciclastic-rich part of the Carrara crops out in the flat area and in the slopes below the interval of study. The more dominantly carbonate-rich, upper part of the Carrara crops out from slightly below the delimited interval into the lower part of the steep dark gray slopes. The Bonanza King Formation (BK), overlying the Carrara Formation, comprises most of the dark gray limestone. Formation boundaries are highlighted with dotted lines between sections G and H in the lower panorama.

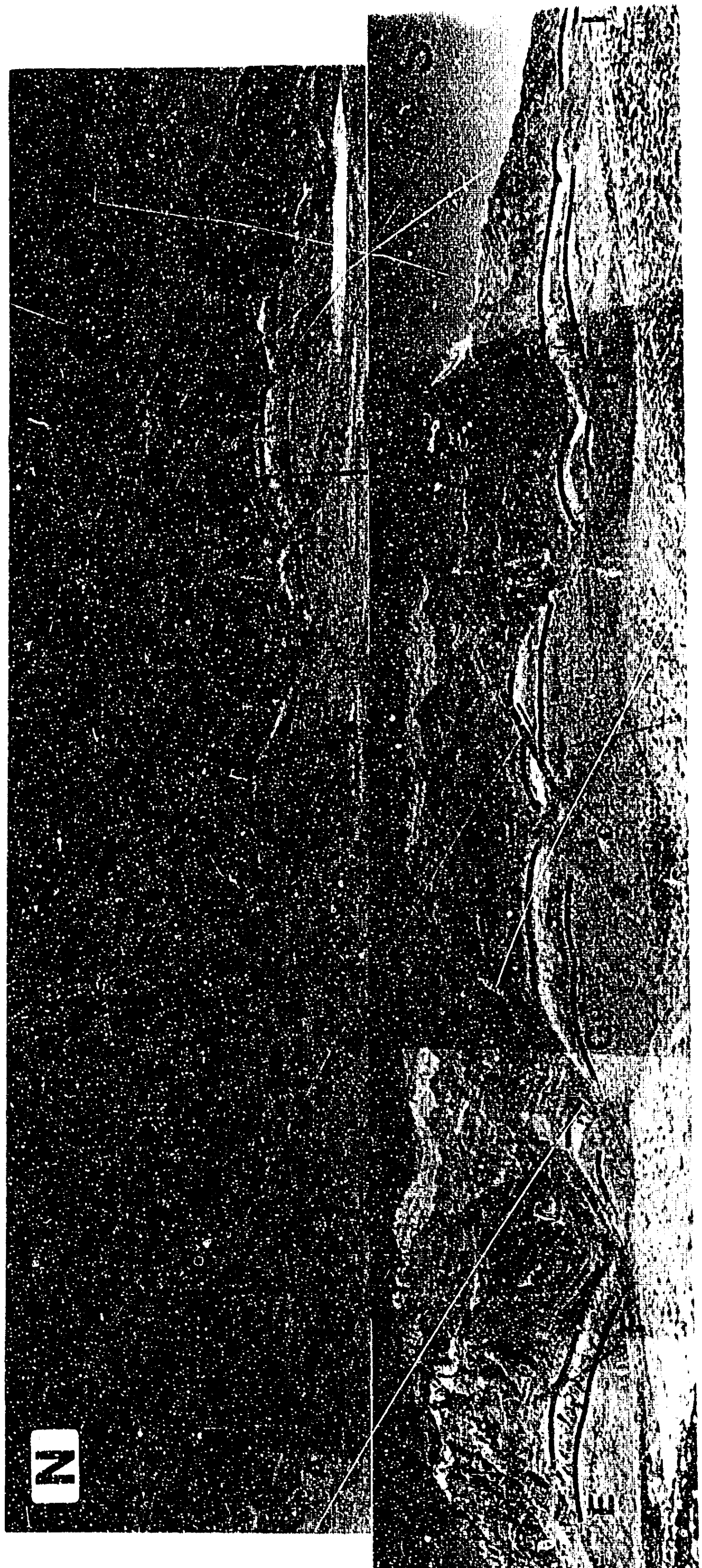

N

**Figure 10.** The regional cross section of the upper part of the Jangle Limestone Member extends across 57 km, approximately parallel to depositional strike. Section 1 represents a composite of the Eagle Mountain cross section (Figure 7). Facies that are interbedded on a scale too fine to be resolved in this cross section are indicated by alternating patterns within a facies unit, e.g., the base of section 2. Parasequence boundaries are labeled as in Figure 7. Five additional discontinuous parasequence boundaries (D through H) are recognized and Parasequence Boundary II cannot be correlated south of Section 2. The mosaic pattern of continuous (Roman numerals) and discontinuous (capital letters) fifth-order parasequences and facies documented at Eagle Mountain (Figure 7) also fits the data in the regional cross section, even though contacts cannot be physically traced between stratigraphic sections. Note also the discontinuity of intertidal facies, evidence of the island-like character of the exposed portions of the carbonate bank. Abbreviations beneath the column locations tie to the location map (Figure 1), the isopach maps (Figure 18) and the regional cross sections (Plates 1 to 4).

## INTERTIDAL

Microbial Laminated Dolosiltite

Fenestral Mudstone

## SUBTIDAL

Ooid Grainstone

Oncolitic Packstone & Grainstone

Fossiliferous Packstone & Grainstone

Nodular Ribbon Rock & Well-Layered Ribbon Rock

Bioturbated Ribbon Rock

CDAS Lithofacies

Thrombolite Boundstone

Siliciclastics from Shale to Sandstone

No Lithologic Data

Parasequence Boundary

Facies Boundary

Gradational Lateral Facies Boundary

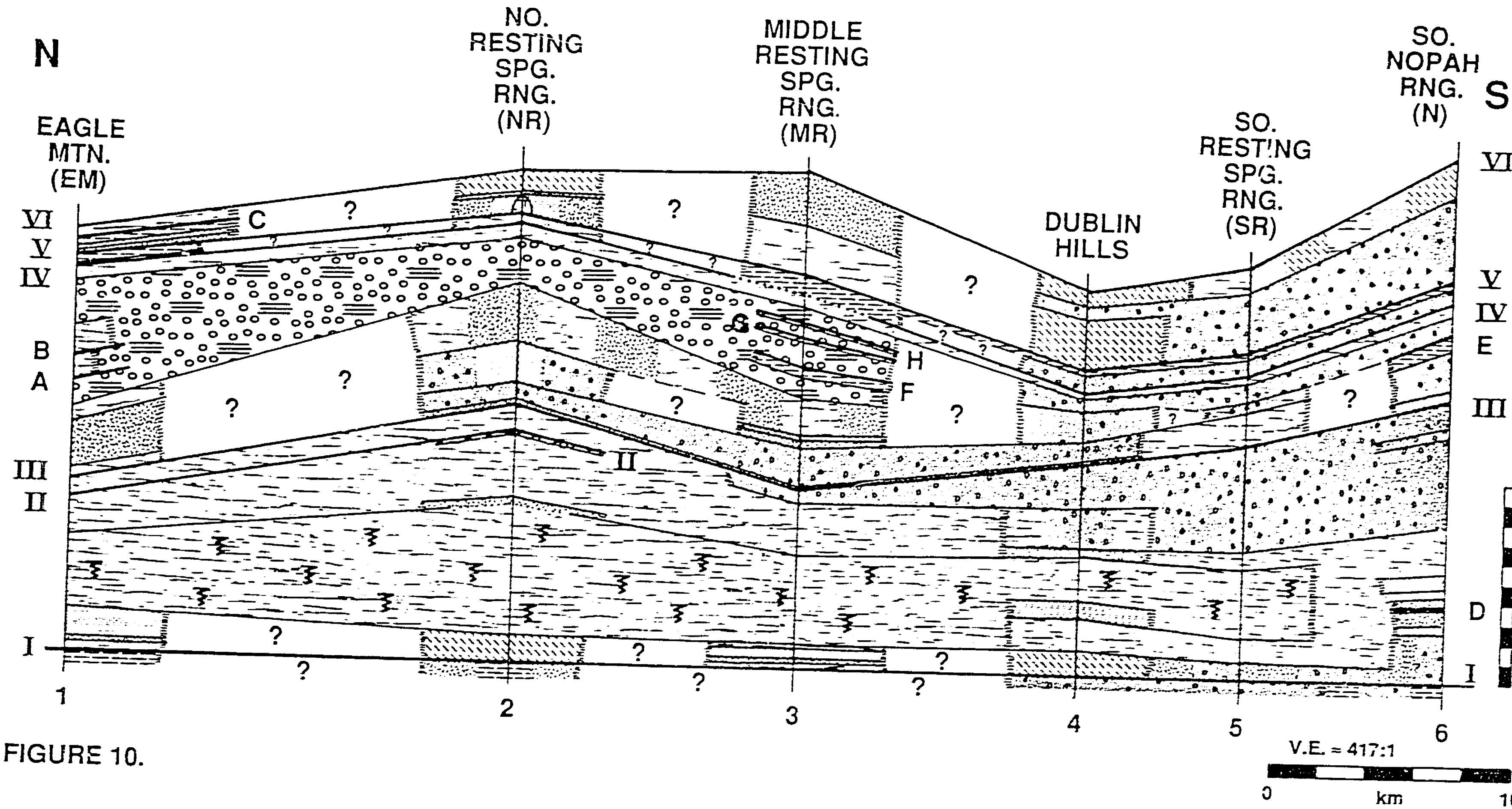

N
S
EAGLE MTN. (EM)
NO. RESTING SPG. RNG. (NR)
MIDDLE RESTING SPG. RNG. (MR)
DUBLIN HILLS
SO. RESTING SPG. RNG. (SR)
SO. NOPAH RNG. (N)
VI
V
IV
B
A
III
II
I
C
G
H
F
E
D
?
1
2
3
4
5
6
20
m
0
V.E. = 417:1
0
km
10

FIGURE 10.

upper or lower. Partitioning of time between sediment, hiatal surfaces within the unit, and the bounding surface of the unit is presently an intractable problem (Anders et al., 1987; Sadler, 1981; van Andel, 1981), but knowledge of the partitioning is not necessary to assign an order to a depositional unit. There are large uncertainties associated with many of the stratigraphic boundaries in the geologic time scale (Harland et al., 1990; Harland et al., 1982) and there are uncertainties in dating most sedimentary formations (See discussion in Chapter 1). As a consequence of these uncertainties, estimates of the duration of sedimentary cycles, especially third-order to sixth-order cycles, are rough approximations at best. Nevertheless, an attempt is made with the Carrara database to estimate an average duration for the meter-scale shallowing-upward cycles and for the parasequence sets, systems tracts, and sequences into which those cycles are arranged.

Within a parasequence, a consistent stacking relationship between two intertidal facies allows determination of relative positions of facies on an intertidal flat. An example of this is provided by fenestral mudstone, which is consistently overlain by microbially laminated dolosiltite, thus allowing the conclusion that fenestral mudstone is a lower intertidal facies than microbially laminated dolosiltite assuming the parasequence is progradational. In contrast, subtidal facies are not arranged in a consistent vertical succession (Halley, 1975) and commonly are positioned laterally to one another (Figures 7 and 10). Consequently there is no obvious ranking of subtidal facies with respect to relative water depths. This lack of predictable succession of subtidal facies makes it difficult to outline shoaling cycles. Markov analysis is used to test for a nonrandom succession with grouped and ungrouped lithofacies. Tests with ungrouped lithofacies are inconclusive but grouped lithofacies produce results that indicate a nonrandom succession.

The various peritidal lithofacies that compose the meter-scale cycles discussed in this chapter have been described in Chapter 2 and are summarized in Appendix 1. Generalized meter-scale shallowing-upward cycles have been described in Chapter 3 and carbonate cycles C1-C5 can be found in the upper part of the Jangle Limestone at Eagle Mountain. Lateral variation of lithofacies within a pair of bounding parasequence surfaces is common and produces lateral change from one generalized cycle-type to another. This can be seen by comparison of Figure 6 with Figure 7. Because of this lateral variation, recognition of bounding surfaces (parasequence surfaces) is an integral part understanding and analyzing meter-scale cycles. Criteria are developed to distinguish bounding surfaces from event surfaces.

Correlations at Eagle Mountain are described and the mosaic pattern documented at Eagle Mountain. Correlations are extended from Eagle Mountain to several ranges to the south. A mix of laterally continuous and laterally discontinuous facies and parasequences is also recognized in these correlations. Possible mechanisms that may control development of the mosaic pattern are discussed and speculations, based on the Eagle Mountain data, are made regarding a possible correlation between duration of meter-scale cycles and their lateral continuity. A survey of literature on meter-scale cycles indicates that the observations made at Eagle Mountain and in the Carrara may apply to other formations.

## DURATIONS

Rough calculations, based on age data summarized in Table 1 of Levy and Christie-Blick (1991) and in Bowring et al. (in press), lead to an estimate of approximately $10^4$ years per meter of stratigraphic thickness in the Carrara Formation and an average duration of $10^6$ years per Grand Cycle/sequence. These values are in agreement with estimates of net subsidence rates of 80-100 m/m.y. for this region during the latest Proterozoic to early Ordovician given in Sloss (1988a). The age of the Cambrian/Precambrian boundary is currently undergoing revision, and because of this two different estimates of the boundary will be used in the following discussion. Use of either of these two different boundary ages does not substantially alter the first-order estimates of duration of cycles and Grand Cycles. Levy and Christie-Blick (1991) use dates from the Harland et al. (1982, 1990) time scales; a 570 ± 14 Ma age for the Cambrian/Precambrian boundary, a 540 ± 14 Ma age at the boundary between Lower and Middle Cambrian (10 m above the contact between the Gold Ace Limestone Member and the Pyramid Shale Member), and a 523 ± 18 Ma age at the boundary between Middle and Upper Cambrian (in the middle member of the overlying Bonanza King Formation). These dates, although not obtained directly on strata of the Death Valley region, are tied into the area using biostratigraphy. Recent work by Bowring et al. (in press) has provided new U-Pb dates that suggest an approximate age of 544 Ma for the Cambrian/Precambrian boundary. No new dating has been done on the Cambrian/Ordovician boundary, and the estimate of 505 ± 16 Ma is used in most of the calculations that follow.

If the rough assumption is made that time is proportional to stratigraphic thickness for the Middle Cambrian part of the stratigraphic section at one location on the passive margin, then the Levy and Christie-Blick (1991) dates allow one estimate of a duration of approximately 3.8 m.y. for the Middle Cambrian part of the Carrara. Thickness values used in these calculations are from the central part of the area of Carrara outcrop, in the vicinity of the Spring Mountains, Nevada and the Nopah Range and Funeral Range, California. This estimate of duration is arrived at as follows:

- The Carrara is approximately 307 m thick, minus 10 m that are Lower Cambrian, for a total of 297 m.
- The Papoose Lake Member of the Bonanza King Formation is 475 m thick.
- The Middle Cambrian part of the Banded Mountain Member of the Bonanza King Formation is 540 m thick.
- This gives a total Middle Cambrian thickness of 297 + 475 + 540 = 1312 m.
- The Middle Cambrian had a duration of 540 Ma - 523 Ma = 17 m.y.
- Assuming that time is proportional to stratigraphic thickness, then the duration of the Middle Cambrian part of the Carrara is (297 m) + (1312 m) x 17 m.y. ≈ 3.8 m.y.

The Harland et al. (1982, 1990) dates give a total duration for the Cambrian of 65 m.y., and durations (and percent of total) of each epoch as follows: Early Cambrian = 30 m.y. (≈ 46%); Middle Cambrian = 17 m.y. (≈ 26%); Late Cambrian = 18 m.y. (≈ 28%).

If the Bowring et al. (in press) estimate of 544 Ma for the Cambrian Precambrian boundary is used, and the proportionate division of time for the epochs is retained, then the Middle Cambrian duration decreases to 10 m.y., and the second estimate of duration of the Middle Cambrian part of the Carrara becomes approximately 2.3 m.y. This value is arrived at as follows:

- Duration of the Cambrian is 544 Ma - 505 Ma = 39 m.y.
- Duration of the Early Cambrian is 0.46 x 39 m.y. ≈ 18 m.y., and the boundary between Early and Middle Cambrian is 544 Ma - 18 m.y. = 526 Ma.
- Duration of the Middle Cambrian is 0.26 x 39 m.y. ≈ 10 m.y. and the boundary between Middle and Late Cambrian becomes 526 Ma - 10 m.y. = 516 Ma.
- Duration of the Middle Cambrian part of the Carrara (using the same thickness values of Levy and Christie-Blick (1991)) is (297 m) + (1312 m) x 10 m.y. ≈ 2.3 m.y.

Bowring et al. (in press) also suggest an age of 520 Ma for the boundary between Early and Middle Cambrian. This pick leaves approximately 15 m.y. to be divided between the Middle and Late Cambrian epochs. If the slightly older date of 510 ± 10 m.y.

(Harland et al., 1990) for the Cambrian/Ordovician boundary is used, then there is only 10 m.y. for both the Middle and Late Cambrian epochs. If the least amount of time for the duration of the Middle Cambrian is used, 5 m.y., then a third estimate for duration of the Middle Cambrian part of the Carrara would be

(297 m) + (1312 m) x 5 m.y. ≈ 1.1 m.y.

The first two values for the duration of the Middle Cambrian part of the Carrara produce average, first-order estimates of 1.3 x $10^4$ and 0.78 x $10^4$ years per meter of stratigraphic thickness, respectively and the third estimate yields an estimate of 0.37 x $10^4$ years per meter (= duration of Middle Cambrian part of Carrara + thickness of Middle Cambrian part of Carrara). These estimates do not differentiate between contributions of tectonic subsidence rate and eustatic sea-level change to accommodation rate, nor do they reflect an average accommodation rate. It must be emphasized that this average value of $10^3$ -$10^4$ years per meter of sediment is not an absolute, and is only a first-order approximation. The thickness of the Carrara tends to average between 400 and 500 m in this area, and represents an along-strike transect of the Cambrian passive-margin shelf. Total duration estimates for the Carrara (Lower Cambrian + Middle Cambrian portions) range from 1.5 m.y. (= 400 m x 0.37 x $10^4$ yr/m) to 6.5 m.y. (= 500 m x 1.3 x $10^4$ yr/m). If the approximation of four Grand Cycles/sequences in the Carrara (three complete and two partial) is made, then each Grand Cycle/sequence has an average duration between 0.4 m.y. (= 1.5 m.y. + 4) and 1.6 m.y. (= 6.5 m.y. + 4), or ≈ $10^5$ -$10^6$ years.

## MARKOV ANALYSIS AND RELATIVE WATER DEPTHS OF SUBTIDAL FACIES

Markov analysis (Davis, 1986) is a mathematical test to determine if there is preferential, nonrandom succession present in a string of data. It has been commonly used in sedimentology and stratigraphy to test for predictable facies successions (Carr, 1982; Morrow and Labonte, 1988; Powers and Easterling, 1982). The analysis tests whether the next facies ("state", in statistical terminology) can be predicted given the current facies (state) by attempting to disprove the hypothesis that a given set of observed facies transitions is random. Because parasequence boundaries are an integral part of meter-scale cycles (parasequences), the parasequence boundary surface is included as a possible state for Markov analysis. Transitions from one facies or parasequence boundary to the next facies were tabulated for each of the nine stratigraphic sections at Eagle Mountain and combined into a table of observed transitions. Transitions were recorded such that a facies was not recognized as succeeding itself; i.e., a transition from one bed of "Facies A" to other of "Facies A" is

**Table 3.** Embedded Markov analysis of ten states (seven subtidal lithofacies, two intertidal lithofacies, and parasequence boundaries) does not disprove the hypothesis of random lithofacies transitions. Abbreviations are as follows: **ML** = microbial laminated dolosiltite; **FEN** = calcareous fenestral mudstone; **OOID** = oolitic grainstone; **FOSS** = fossiliferous packstone and grainstone; **ONC** = oncolitic packstone and grainstone; **NRR** = nodular ribbon rock; **BRR** = bioturbated ribbon rock; **CDAS** = calcarenite, calcisiltite, dolarenite, and dolosiltite; **THRM** = thrombolitic boundstone; **PSB** = parasequence boundary; **Marg Prob Vector** = Marginal Probability Vector; **RT*MPT** = Row Total multiplied by Marginal Probability Vector; **Exptd-Diag** = Row Total from the Hypothetical Expected Transition Frequencies matrix minus the diagonal cell value for that row; **Obs** = Row Total from the Observed Transition Frequencies matrix; **Obs Trans Freq** = Observed Transition Frequencies; **Hyp Exp Trans Freq** = Hypothetical Expected Transition Frequencies. (See Davis, 1986 for expanded explanation of Markov Analysis.)

**Observed Transition Frequencies**

| | ML | FEN | OOID | FOSS | ONC | NFR | BFR | CDAS | THRM | PSB | Row Total | Marg Prob Vector |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ML | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 20 | 0.10 |
| FEN | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 10 | 0.05 |
| OOID | 6 | 0 | 0 | 2 | 2 | 9 | 9 | 6 | 2 | 6 | 42 | 0.20 |
| FOSS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 0.01 |
| ONC | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 4 | 0.02 |
| NFR | 1 | 8 | 15 | 0 | 1 | 0 | 0 | 4 | 0 | 21 | 50 | 0.24 |
| BFR | 0 | 0 | 0 | 0 | 1 | 9 | 0 | 0 | 0 | 0 | 10 | 0.05 |
| CDAS | 1 | 1 | 10 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 16 | 0.08 |
| THRM | 0 | 0 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 2 | 8 | 0.04 |
| PSB | 0 | 0 | 15 | 0 | 0 | 21 | 0 | 6 | 5 | 0 | 47 | 0.22 |

Total Transitions 210 — 1.000

**Expected Transition Frequencies**

| | ML | FEN | OOID | FOSS | ONC | NFR | BFR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|---|---|---|---|
| ML | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| FEN | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| OOID | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| FOSS | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| ONC | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| NFR | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| BFR | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| CDAS | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| THRM | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |
| PSB | 0.10 | 0.05 | 0.20 | 0.01 | 0.02 | 0.24 | 0.05 | 0.08 | 0.04 | 0.22 |

**Transpose of Marginal Probability Vector**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.085 | 0.039 | 0.205 | 0.012 | 0.016 | 0.264 | 0.043 | 0.066 | 0.031 | 0.24 |

**To Calculate the Embedded Expected Transition Probabilities:**
**Hypothetical Observed Transition Frequencies**

| | ML | FEN | OOID | FOSS | ONC | NFR | BFR | CDAS | THRM | PSB | Row Total | RT * MPT | Marg Prob Vector |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ML | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 22 | 2 | 0.085 |
| FEN | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 10 | 0 | 0.039 |
| OOID | 6 | 0 | 11 | 2 | 2 | 9 | 9 | 6 | 2 | 6 | 53 | 11 | 0.205 |
| FOSS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 0.012 |
| ONC | 0 | 0 | 1 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 4 | 0 | 0.016 |
| NFR | 1 | 8 | 15 | 0 | 1 | 18 | 0 | 4 | 0 | 21 | 68 | 18 | 0.264 |
| BFR | 0 | 0 | 0 | 0 | 1 | 9 | 1 | 0 | 0 | 0 | 11 | 0 | 0.043 |
| CDAS | 1 | 1 | 10 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 17 | 1 | 0.066 |
| THRM | 0 | 0 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 2 | 8 | 0 | 0.031 |
| PSB | 0 | 0 | 15 | 0 | 0 | 21 | 0 | 6 | 5 | 15 | 62 | 15 | 0.240 |

Total Transitions 256 — 1.000

**Hypothetical Expected Transition Probabilities**

| | ML | FEN | OOID | FOSS | ONC | NFR | BFR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|---|---|---|---|
| ML | 0.007 | 0.003 | 0.018 | 0.001 | 0.001 | 0.022 | 0.004 | 0.006 | 0.003 | 0.020 |
| FEN | 0.003 | 0.002 | 0.008 | 0.000 | 0.001 | 0.010 | 0.002 | 0.003 | 0.001 | 0.009 |
| OOID | 0.018 | 0.008 | 0.042 | 0.002 | 0.003 | 0.054 | 0.009 | 0.014 | 0.006 | 0.049 |
| FOSS | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 | 0.003 | 0.000 | 0.001 | 0.000 | 0.003 |
| ONC | 0.001 | 0.001 | 0.003 | 0.000 | 0.000 | 0.004 | 0.001 | 0.001 | 0.000 | 0.004 |
| NFR | 0.022 | 0.010 | 0.054 | 0.003 | 0.004 | 0.069 | 0.011 | 0.017 | 0.008 | 0.063 |
| BFR | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| CDAS | 0.006 | 0.003 | 0.014 | 0.001 | 0.001 | 0.017 | 0.003 | 0.004 | 0.002 | 0.016 |
| THRM | 0.003 | 0.001 | 0.006 | 0.000 | 0.000 | 0.008 | 0.001 | 0.002 | 0.001 | 0.007 |
| PSB | 0.020 | 0.009 | 0.049 | 0.003 | 0.004 | 0.063 | 0.010 | 0.016 | 0.007 | 0.058 |

**Hypothetical Expected Transition Frequencies**

| | ML | FEN | OOID | FOSS | ONC | NFR | BFR | CDAS | THRM | PSB | Row Totals Exptd-Diag | Row Totals Obs | Chi-Squared (row) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ML | 1.88 | 0.85 | 4.52 | 0.26 | 0.34 | 5.80 | 0.94 | 1.45 | 0.68 | 5.29 | 20 | 20.00 | 5.48 |
| FEN | 0.85 | 0.39 | 2.05 | 0.12 | 0.16 | 2.64 | 0.43 | 0.66 | 0.31 | 2.40 | 10 | 10.00 | 0.02 |
| OOID | 4.52 | 2.05 | 10.89 | 0.62 | 0.82 | 13.97 | 2.26 | 3.49 | 1.64 | 12.74 | 42 | 42.00 | 8.72 |
| FOSS | 0.26 | 0.12 | 0.62 | 0.03 | 0.05 | 0.79 | 0.13 | 0.20 | 0.09 | 0.72 | 3 | 3.00 | 0.00 |
| ONC | 0.34 | 0.16 | 0.82 | 0.05 | 0.06 | 1.05 | 0.17 | 0.26 | 0.12 | 0.96 | 4 | 4.00 | 0.00 |
| NFR | 5.80 | 2.64 | 13.97 | 0.79 | 1.05 | 17.92 | 2.90 | 4.48 | 2.11 | 16.34 | 50 | 50.00 | 0.07 |
| BFR | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 8 | 10.00 | 0.29 |
| CDAS | 1.45 | 0.66 | 3.49 | 0.20 | 0.26 | 4.48 | 0.72 | 1.12 | 0.53 | 4.09 | 16 | 16.00 | 0.00 |
| THRM | 0.68 | 0.31 | 1.64 | 0.09 | 0.12 | 2.11 | 0.34 | 0.53 | 0.25 | 1.92 | 8 | 8.00 | 0.01 |
| PSB | 5.29 | 2.40 | 12.74 | 0.72 | 0.96 | 16.34 | 2.64 | 4.09 | 1.92 | 14.90 | 47 | 47.00 | 0.24 |

Total Transitions 208

**Chi-Squared Intermediate Values**
[(Obs Trans Freq - Hyp Exp Trans Freq)2/Hyp Exp Trans Freq]

| | ML | FEN | OOID | FOSS | ONC | NFR | BFR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|---|---|---|---|
| ML | | | | | | 5.80 | | | | 30.57 |
| FEN | | | | | | | | | | |
| OOID | | | | | | 1.77 | | | | 3.56 |
| FOSS | | | | | | | | | | |
| ONC | | | | | | | | | | |
| NFR | 3.97 | | 0.08 | | | | | | | 1.33 |
| BFR | | | | | | | | | | |
| CDAS | | | | | | | | | | |
| THRM | | | | | | | | | | |
| PSB | 5.29 | | 0.40 | | | 1.33 | | | | |

(10-1)*(10-1)-10=71 Deg. of Freedom => X2 @ 20% - 81

Chi-Squared Value 68.91

TABLE 3.

not counted. This method of tabulating transitions requires that a modified version of Markov analysis, embedded Markov analysis, be used (Davis, 1986; Powers and Easterling, 1982). The reader is referred to Davis (1986) for an in-depth discussion of Markov analysis methodology.

Initially, analyses were made using ten possible states; seven subtidal facies, two intertidal facies, and parasequence boundaries (Table 3). The inclusion of parasequence boundaries as one possible state incorporates the concept of a parasequence as the fundamental unit of cyclicity and allows analysis of facies on a parasequence-by-parasequence basis. Bioturbated ribbon rock is common enough in the upper Jangle Limestone to distinguish as a separate state. Well-layered ribbon rock is rare in this part of the Carrara and is grouped with nodular ribbon rock. Results of these tests indicated that the hypothesis of random facies transitions could not be disproved.

Transitions were also tabulated and analyzed by grouped facies for a total of six possible states; four groups of subtidal facies, one intertidal group, and parasequence boundaries (Table 4). The four groups of subtidal facies are: packstone and grainstone regardless of grain types; all varieties of ribbon rock; calcarenite, dolarenite, calcisiltite, and dolosiltite (CDAS lithofacies); and thrombolite boundstone. Grouping of different facies changed the tabulation of transitions slightly by allowing a state to succeed itself; i.e., "Facies $A_1$" (a member of "Facies Group A") might be succeeded by "Facies $A_2$" ( another member of "Facies Group A"), and this would be recognized and tabulated. When a state is not allowed to succeed itself, the "upper-left-to-lower-right" diagonal of the matrix is filled with zeros and the embedded Markov test is used. If a state is allowed to succeed itself, then this diagonal has nonzero values and the standard Markov test is used rather than the embedded test. Markov analysis on this data set disproves the hypothesis of random successions (Table 4) for groups of similar facies, thus indicating that there is some predictable arrangement of facies groups.

Diagrammatic representation of transition probabilities for the grouped data from Table 4 is shown in Figures 11A and 11B, with the probability for a transition given next to the arrow going from one state to the next. The probabilities are for transition from one state *up* to the next in a vertical section, not for transition from one state *down* to the previous one. The probability of going from one facies in the intertidal group to another is 0.143, whereas the probability of going to a parasequence boundary (PSB) is 0.857. Facies in the ribbon-rock group are most likely to overlie a parasequence boundary (0.447); those in the packstone/grainstone group are second most likely (0.319). Intertidal facies never overlie parasequence boundaries, as shown by the lack of an arrow from parasequence boundaries to the intertidal group. The difficulty of setting up the subtidal parts of ideal shoaling cycles can now be appreciated by examination of Figure 11A. Any one of the four subtidal facies groups may overlie a parasequence surface; any of the subtidal facies groups, except thrombolites, may overlie two or more of the other subtidal groups; facies in the packstone/grainstone group and the ribbon-rock group may overlie other facies within their own group; parasequence boundaries may overlie any of the subtidal groups except the CDAS lithofacies group; and intertidal facies may overlie any of the subtidal groups except thrombolitic boundstone.

Figure 11B shows only those transitions with a probability greater than 0.300, an arbitrary choice to help clarify the most likely transitions. The packstone/grainstone group and the ribbon-rock group are most likely to overlie parasequence boundaries; the packstone/grainstone group is most likely to overlie the CDAS lithofacies group; the ribbon-rock group is most likely to overlie thrombolites or packstone/grainstone group; and parasequence boundaries are most likely to overlie the ribbon-rock group. As can be seen on the two cross sections (Figures 7 and 10), parasequences remain subtidal over a most of their length; this is reflected in Figure 11B, where there is a higher probability for a parasequence boundary (0.350) to overlie the ribbon-rock group than for intertidal facies (0.150) to overlie the ribbon-rock group.

Inclusion of the intertidal group and of parasequence boundaries as two of six states makes it easier to disprove the hypothesis of random successions. This is because the intertidal facies group is always overlain by itself or a parasequence boundary, and a parasequence boundary (at Eagle Mountain) is always overlain by subtidal facies. These relationships were already known from the consistent vertical successions observed. A third, and more stringent, analysis was made using only the four subtidal facies groups, thereby removing the effect of obvious transitions (Table 5 and Figures 11C and 11D). Parasequence boundaries were not used as a possible state, but a transition from one facies group to another was not counted if a parasequence boundary lay between. This again allowed subtidal facies groups to be tested parasequence by parasequence. The results of this third analysis (Table 5 again disproved the hypothesis of random transitions; the results are schematically shown in Figures 11C and 11D. Possible transitions from subtidal group to subtidal group remain the same as before, but probabilities for transitions are somewhat different from those calculated in Table 5 because transitions to intertidal facies and parasequence boundaries have been removed. Application of the arbitrary probability cutoff of 0.300 again emphasizes the most likely subtidal transitions and is shown in Figure 11D. It is now seen that there are two additional likely transitions besides those shown in Table 5 and Figure 11B: the ribbon-

**Table 4.** Standard Markov analysis of six states (four subtidal lithofacies groups, one intertidal lithofacies group, and parasequence boundaries) disproves the hypothesis of random lithofacies variations. Abbreviations are as in Table 3, with additions that follow: **INTR** = group of both intertidal lithofacies; **PK/GR** = group of all packstone and grainstone lithofacies; **RR** = group of all varieties of ribbon rock; **Fixed Prob Vect** = Fixed Probability Vector; **Exptd** = Row Total from the Expected Transition Frequencies matrix.

**Observed Transition Frequencies**

| | INTR | PK/GR | FR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|
| INTR | 4 | 0 | 0 | 0 | 0 | 24 |
| PK/GR | 6 | 5 | 21 | 6 | 3 | 8 |
| FR | 9 | 17 | 9 | 4 | 0 | 21 |
| CDAS | 2 | 10 | 4 | 0 | 0 | 0 |
| THRM | 0 | 1 | 5 | 0 | 0 | 2 |
| PSB | 0 | 15 | 21 | 6 | 5 | 0 |

| Row Total | Fixed Prob Vect |
|---|---|
| 28 | 0.13 |
| 49 | 0.24 |
| 60 | 0.29 |
| 16 | 0.08 |
| 8 | 0.04 |
| 47 | 0.23 |

Total Transitions: 208 | 1.000

**Expected Transition Probabilities**

| | INTR | PK/GR | FR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|
| INTR | 0.13 | 0.24 | 0.29 | 0.08 | 0.04 | 0.23 |
| PK/GR | 0.13 | 0.24 | 0.29 | 0.08 | 0.04 | 0.23 |
| FR | 0.13 | 0.24 | 0.29 | 0.08 | 0.04 | 0.23 |
| CDAS | 0.13 | 0.24 | 0.29 | 0.08 | 0.04 | 0.23 |
| THRM | 0.13 | 0.24 | 0.29 | 0.08 | 0.04 | 0.23 |
| PSB | 0.13 | 0.24 | 0.29 | 0.08 | 0.04 | 0.23 |

**Expected Transition Frequencies**

| | INTR | PK/GR | FR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|
| INTR | 3.77 | 6.60 | 8.08 | 2.15 | 1.08 | 6.33 |
| PK/GR | 6.60 | 11.54 | 14.13 | 3.77 | 1.88 | 11.07 |
| FR | 8.08 | 14.13 | 17.31 | 4.62 | 2.31 | 13.56 |
| CDAS | 2.15 | 3.77 | 4.62 | 1.23 | 0.62 | 3.62 |
| THRM | 1.08 | 1.88 | 2.31 | 0.62 | 0.31 | 1.81 |
| PSB | 6.33 | 11.07 | 13.56 | 3.62 | 1.81 | 10.62 |

**Row Totals**

| Exptd | Obs | |
|---|---|---|
| 7.00 | 4.00 | 1.29 |
| 5.65 | 9.00 | 1.98 |
| 6.92 | 4.00 | 1.23 |
| 16.00 | 16.00 | 0.00 |
| 8.00 | 8.00 | 0.00 |
| 5.42 | 11.00 | 5.74 |

**Chi-Squared Intermediate Values**
**[(Obs Trans Freq - Exp Trans Freq)/Exp Trans Freq]**

| | INTR | PK/GR | FR | CDAS | THRM | PSB |
|---|---|---|---|---|---|---|
| INTR | | 6.60 | 8.08 | | | 49.37 |
| PK/GR | 0.05 | 3.71 | 3.33 | | | 0.85 |
| FR | 0.11 | 0.58 | 3.99 | | | 4.09 |
| CDAS | | | | | | |
| THRM | | | | | | |
| PSB | 6.33 | 1.39 | 4.09 | | | 10.62 |

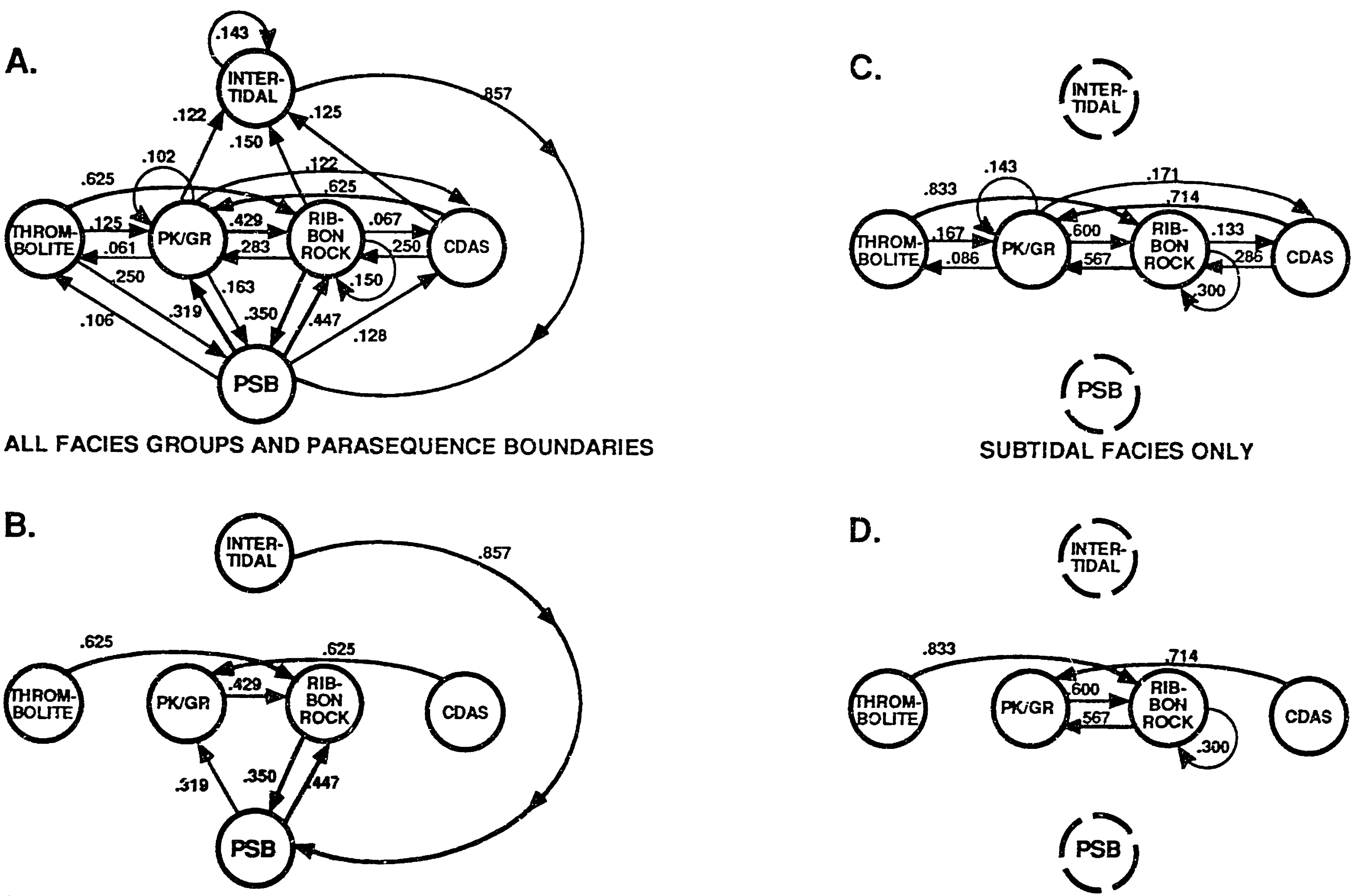
TABLE 4.

(7-1)*(7-1)=36 Deg. of Freedom => X2 @ 5% ~ 50.96

Chi-Squared Value: 113.41

**Figure 11.** Diagrammatic representation of observed transition probabilities for grouped facies data. The diagrams are more fully explained in the text. For each diagram: the basal circle represents parasequence boundaries (PSB); the middle tier of circles represents subtidal lithofacies including, from the left, thrombolitic boundstone (THROMBOLITE), all packstone and grainstone lithofacies (PK/GR), all varieties of ribbon rock (RIBBON ROCK), and calcarenite, calcisiltite, dolarenite, and dolosiltite (CDAS); the top circle represents all intertidal lithofacies (INTERTIDAL). **A)** All observed transition probabilities between all facies groups and parasequence boundaries. Calculations presented in Table 4 indicate that these transitions are non-random. **B)** The same data as in (A), but highlighting only those transitions occurring ≥ 30% of the time. The most likely transitions are: ribbon rock (0.447) or packstone/grainstone (0.319) overlying parasequence boundaries; ribbon rock overlying packstone/grainstone (0.429); a parasequence boundary overlying ribbon rock (0.350); packstone/grainstone overlying CDAS lithofacies (0.625); ribbon rock overlying thrombolitic boundstone (0.625); a parasequence boundary overlying intertidal lithofacies. As can be seen in (A), intertidal lithofacies do overlie subtidal lithofacies, but these transitions are not shown in (B) because probabilities are less than 0.300. **C)** All observed transition probabilities between subtidal lithofacies groups only. Lithofacies transitions across parasequence boundaries are not counted, nor are transitions to or from intertidal lithofacies. Calculations presented in Table 5 indicate that these transitions are non-random. **D)** The same data as in (C), but highlighting only those transitions present in ≥ 30% of cases. This analysis indicates that the most likely transitions between subtidal lithofacies groups are: thrombolitic boundstone overlain by ribbon rock (0.833); CDAS lithofacies overlain by packstone/grainstone (0.714); packstone/grainstone overlain by ribbon rock (0.600); ribbon rock overlain by packstone/grainstone (0.567); and one variety of ribbon rock overlain by a different variety of ribbon rock (0.300).

FIGURE 11.




A. ALL FACIES GROUPS AND PARASEQUENCE BOUNDARIES

B. ALL FACIES GROUPS AND PARASEQUENCE BOUNDARIES

C. SUBTIDAL FACIES ONLY

D. SUBTIDAL FACIES ONLY

**Table 5.** Standard Markov analysis of four states (four subtidal lithofacies groups) disproves the hypothesis of random facies variations. Abbreviations are as in Tables 3 and 4.

**Observed Transition Frequencies**

| | PK/GR | FR | CDAS | THRM |
|---|---|---|---|---|
| PK/GR | 5 | 21 | 6 | 3 |
| FR | 17 | 9 | 4 | 0 |
| CDAS | 10 | 4 | 0 | 0 |
| THRM | 1 | 5 | 0 | 0 |

| | Row Total | Fixed Prob Vect |
|---|---|---|
| PK/GR | 35 | 0.41 |
| FR | 30 | 0.35 |
| CDAS | 14 | 0.16 |
| THRM | 6 | 0.07 |
| Total Transitions | 85 | 1.000 |

**Expected Transition Probabilities**

| | PK/GR | FR | CDAS | THRM |
|---|---|---|---|---|
| PK/GR | 0.41 | 0.35 | 0.16 | 0.07 |
| FR | 0.41 | 0.35 | 0.16 | 0.07 |
| CDAS | 0.41 | 0.35 | 0.16 | 0.07 |
| THRM | 0.41 | 0.35 | 0.16 | 0.07 |

**Expected Transition Frequencies**

| | PK/GR | FR | CDAS | THRM |
|---|---|---|---|---|
| PK/GR | 14.41 | 12.35 | 5.76 | 2.47 |
| FR | 12.35 | 10.59 | 4.94 | 2.12 |
| CDAS | 5.76 | 4.94 | 2.31 | 0.99 |
| THRM | 2.47 | 2.12 | 0.99 | 0.42 |

**Row Totals**

| Exptd | Obs | |
|---|---|---|
| 2.47 | 3.00 | |
| 7.06 | 4.00 | 3.38 |
| 8.24 | 4.00 | 2.18 |
| 6.00 | 6.00 | 0.00 |

**Chi-Squared Intermediate Values**
**[(Obs Trans Freq - Exp Trans Freq)2/Exp Trans Freq]**

| | PK/GR | FR | CDAS | THRM |
|---|---|---|---|---|
| PK/GR | 6.15 | 6.05 | 0.01 | |
| FR | 1.75 | 0.24 | | |
| CDAS | 3.11 | | | |
| THRM | | | | |

# TABLE 5.

**(4-1)*(4-1) = 9 Deg. of Freedom => X2 @ 5% ~ 16.92**

**Chi-Squared Value** 22.86

rock group may also be overlain by more units of the ribbon-rock group or by the packstone/grainstone group.

The difference in results of Markov analysis on ten states versus six states or four states may be due to an insufficient number of transitions to test accurately for ten states, whereas there are sufficient transitions to test for six or four states.

## STRATIGRAPHIC BOUNDING SURFACES

### INTRODUCTION

The term "surface" is used to refer to an inferred break in sedimentation that can be recognized in a stratigraphic section. Bounding surfaces can be arranged in a hierarchy that generally reflects increasing duration of time incorporated into the surface and increasing areal extent of the boundary. Hence, bounding surfaces can vary from those between laminae to those between supersequences (Campbell, 1967; Mitchum et al., 1977). Time in bounding surfaces between laminae, laminasets, and beds is measured in seconds to years (Campbell, 1967) and can be considered as geologically instantaneous. Time in bounding surfaces between bedsets, facies, and parasequences is measured in minutes to $10^5$ years (Van Wagoner et al., 1990). Time in the bounding surfaces of larger-scale packages of sediments, e.g., parasequence sets, systems tracts, sequences, and sequence sets, varies from $10^3$ years to $10^7$ years (Mitchum et al., 1977; Van Wagoner et al., 1990). More in-depth discussions may be found in papers by Campbell (1967), Mitchum et al. (1977), and Van Wagoner et al. (1990). Bounding surfaces between bedsets, facies, and parasequences are critical to this study and will be described and interpreted.

Surfaces between laminae, laminasets, beds, and bedsets can be thought to encompass a geologic instant (Campbell, 1967). Examples include the surface formed in the few seconds between deposition of one lamina and the next, or the surface that marks months to decades between one episode of storm-generated scour and deposition and the next. The surface between laminae has an areal extent measured in square centimeters to square meters, whereas the storm-generated surface has an areal extent measured in square kilometers to hundreds of square kilometers (Campbell, 1967; Van Wagoner et al., 1990). These bounding surfaces can be thought of as event surfaces and will be referred to as such in this chapter.

Within a shoaling-upward cycle or parasequence, surfaces between facies record the decades or longer required to replace a deeper-water facies with a shallower-water facies. These surfaces are either sharp or gradual and often are diachronous within a parasequence. Over lateral intervals of a few meters to hundreds of meters, facies boundaries record brief periods of time, less than a few hundred years, and can be viewed as geologically instantaneous events; hence facies boundaries can be viewed as event surfaces. Though diachronous when viewed across the lateral extent of a parasequence, facies boundaries can be thought of as coincident with numerous smaller event surfaces.

Parasequence boundaries differ in that they form over time spans of $10^2$ to $10^4$ years. They record an *apparently* fast relative rise in sea level because of the abrupt superposition of deeper water facies over shallower water facies. In most cases a thin to nonexistent deposit is preserved during relative rise and there is often no noticeable scour or thin lag deposits (Figures 12A and 12B). Areal extent of a parasequence boundary can range from square kilometers to thousands of square kilometers (basinwide) (Goodwin and Anderson, 1985; Van Wagoner et al., 1990).

## BOUNDARIES THAT ARE NOT DISTINCT SURFACES

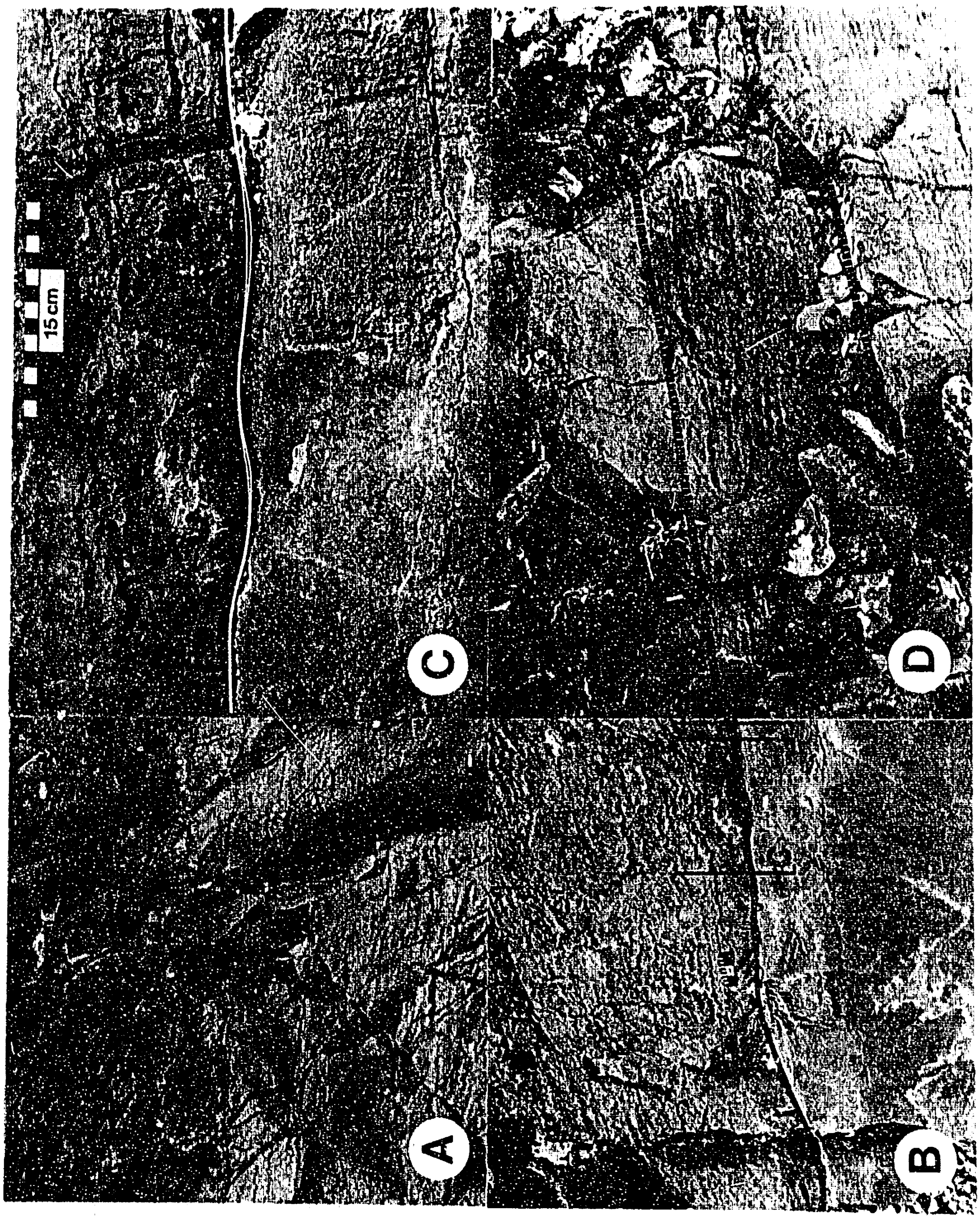
Boundaries between facies are not always distinct surfaces: commonly they may be gradational over centimeters to meters, reflecting a gradual change from one adjacent facies to another. Such a change may be from one to another subtidal facies, or from a subtidal facies to an intertidal facies. Rarely, gradual parasequence contacts are recognized that show a gradual change from a shallow-water facies to a deeper-water facies over a vertical distance of centimeters to several tens of centimeters, and laterally over meters to tens of meters (Figure 12D). A gradual parasequence boundary indicates that continuous deposition during the relative rise in sea level was preserved, and it is likely that deposition was able to keep up, or almost keep up, with the change in relative sea level.

## EVENT SURFACES

Event surfaces are commonly sharp, represent a period of nondeposition, possibly with scour, and may record a change from one facies to another. Event surfaces between bedsets of the same facies, e.g., nodular ribbon rock facies or fenestral limestone facies, are not correlative between sections. Although the origin of at least some of these surfaces may be due to storms that must have affected the entire area of the Eagle Mountain outcrop, it is not possible to correlate the surfaces laterally for more than a few hundred meters. A possible explanation for this lack of lateral continuity of event boundary surfaces could be formation by localized scour and deposition during storms as well as by normal day-to-day deposition.

Event surfaces between different facies are recognizable and correlative because of differing facies across the surface. If one facies progrades over another, the contact between the two, considered over lateral distances of meters to kilometers, coincides

**Figure 12.** Parasequence boundaries. Relative positions of sections, lithofacies, and parasequence boundaries are shown on Figure 7. **A)** Parasequence Boundary B, located just south of Section E at the top of the lower tongue of intertidal fenestral limestone. Subtidal ribbon rock overlies this scoured parasequence boundary. Note that this scoured flooding surface cannot be recognized down local depositional dip (north) in Section D, nor can it be recognized up local depositional dip (south) in Section F. Closer to Section F the flooding surface is much more of a gradational contact over several centimeters vertically (see Figure 12D). **B)** Another photo of the same parasequence boundary taken approximately 25 to 50 meters down local depositional dip (north) of Figure 12A. Note that the fenestral limestone beneath the parasequence is less laminated here than in the previous photo, probably due to a lower topographic position on the intertidal flat. Also note lateral variation in amounts of burrowing and orange dolosiltite in the overlying ribbon rock facies. The position of Figure 12C is indicated by the square brackets. **C)** A close-up of Parasequence Boundary B and the intertidal fenestral mudstone overlain by subtidal nodular ribbon rock. **D)** Uncommonly, gradual parasequence contacts are recognized that show a gradual change from a shallow-water facies to a deeper-water facies over a vertical distance of centimeters to several tens of centimeters, and laterally over meters to tens of meters. The local depositional updip terminus of Parasequence Boundary B, located between Sections E and F is shown in a close-up that includes the termination of a ribbon rock tongue. The pencil lies across the upper gradational facies contact, the lower gradational contact is Parasequence Boundary B, and within a meter of the right side of the photo all ribbon rock is gone and only fenestral limestone is present.


15 cm
A
B
C
D

with numerous smaller event surfaces. Where two facies are separated by an event surface, either there is a shoaling of facies or both facies represent equivalent water depths. A deepening across the surface defines a parasequence boundary and is discussed in the next section.

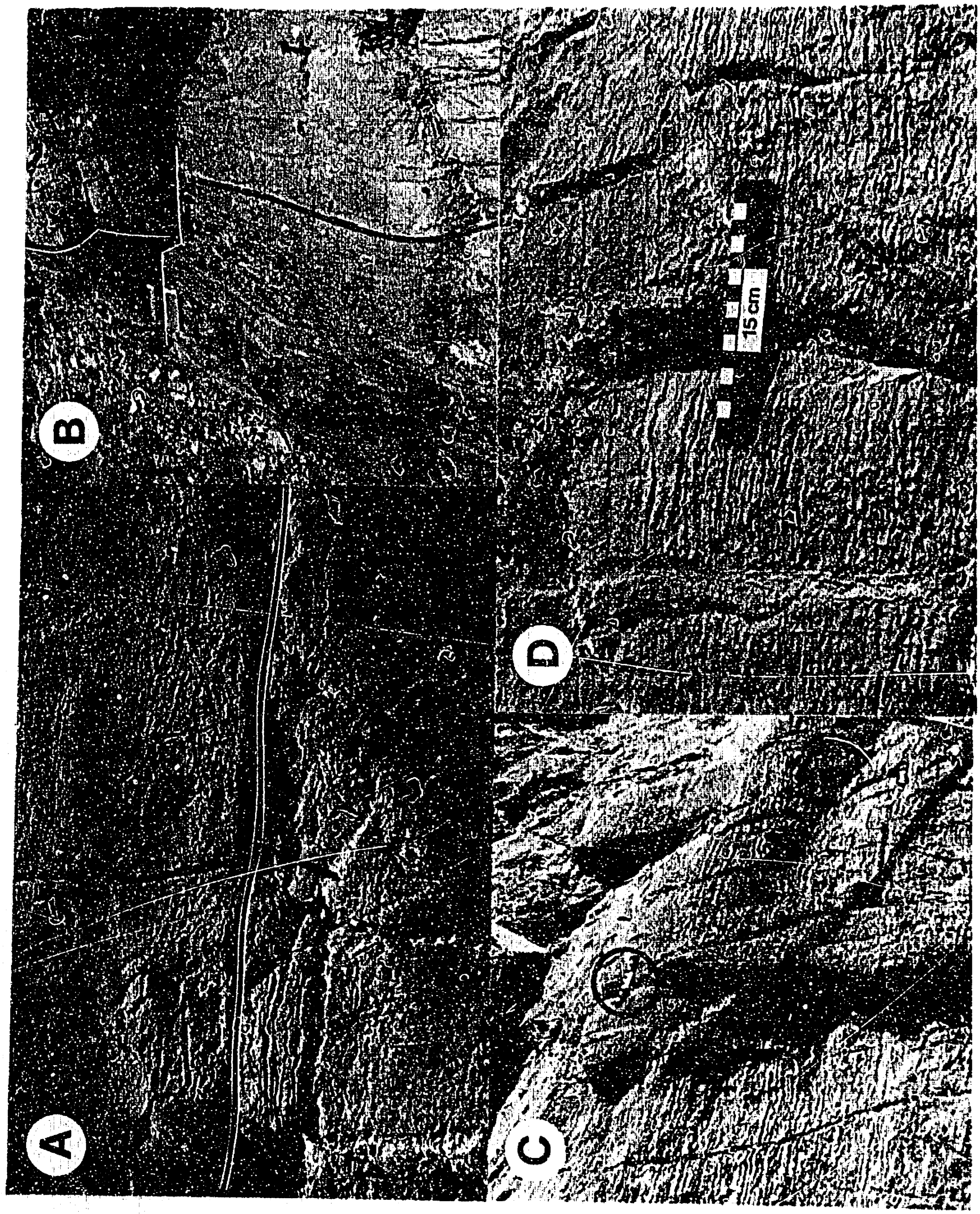
The nature of the surface between facies changes laterally, so a bounding surface may be sharp in one location and gradual over one to several centimeters in another. This variation is a result of the amalgamated character of the surface, due to localized and episodic scour and deposition during a slow progradation of one facies over another. Figure 13 shows three different locations along the amalgamated event surface at the base of the large fenestral limestone unit. A sharp contact is shown in Figures 13A and 13B, with nodular ribbon rock beneath the fenestral mudstone in Figure 13A (located between Sections E and F) and CDAS lithofacies beneath the fenestral mudstone in Figure 13B (located south of Figure 13A and just north of Section F). This lower surface becomes gradational at Section F and remains so to Section I (Figures 13C and 13D), where the lower facies changes from a CDAS lithofacies to nodular ribbon rock. Figure 13 also illustrates shoaling across an amalgamated event surface from subtidal nodular ribbon rock and CDAS lithofacies to intertidal fenestral mudstone.

Event surfaces separating different facies of similar water depth share the same characteristics as those that separate shoaling facies. Figure 14A shows the event surface separating oolitic grainstone from overlying nodular ribbon rock located just above Parasequence Boundary I at Section A. The event surface is sharp along its entire length, with evidence of some localized scour. Irregularity in the contact beneath the scale in Figure 14A is due to local microfaulting and some pressure solution along the surface. Figure 14B shows intertidal fenestral mudstone gradually changing to intertidal microbially laminated dolosiltite located just below Parasequence Boundary IV and a few meters south of Section D. This event surface tends to be gradual across much of the outcrop.

## PARASEQUENCE SURFACES

At Eagle Mountain six parasequence surfaces can be traced across most or all of the outcrop. These are designated in Roman numerals I through VI (Figure 7). These six parasequence boundaries bound five parasequences that range in thickness from about 1 to 20 m. Five of these six parasequence boundaries can also be correlated tentatively to several of the nearby ranges across distances of tens of kilometers (Figure 10). The sixth boundary, Parasequence Boundary II, can be correlated only 18 km to Section 2 (Figure 10). Three other parasequence surfaces recognized at Eagle Mountain are designated Parasequence Boundaries A, B, and C. Although obvious in vertical section due

**Figure 13.** Lateral variation along an amalgamated event surface is illustrated. The photographs are located stratigraphically above Parasequence Boundary III, at the base of the large fenestral mudstone interval, and are located geographically between Sections E and F (Figure 7). The surface is sharp in (A) and (B), but gradational in (C) & (D). Nodular ribbon rock underlying fenestral mudstone in (A), (C), and (D), contrasts with mixed calc- and dolarenite/siltite underlying mudstone in (B) and illustrates lateral facies change. Shallowing is also demonstrated as there are subtidal to lowest intertidal facies overlain by intertidal fenestral mudstone. **A)** A locally sharp facies contact (solid line) between nodular ribbon rock and overlying intertidal fenestral limestone is located between Sections E and F. The same contact in Sections F and G is gradational over a few tens of centimeters (Figures 13C and 13D). The lower part of the fenestral limestone changes laterally to ribbon rock down local depositional dip and to the north of Section E. **B)** A sharp facies contact between mixed CDAS lithofacies (to the left of the solid line), and overlying fenestral limestone (to the right of the line); located just north of Section F at the base of the fenestral limestone. **C)** A gradational facies contact over several centimeters between nodular ribbon rock below and fenestral limestone above; located at the base of the fenestral limestone in Section H. The scale is located close to the top of the nodular ribbon rock. Fenestrae begin appearing in the nodular ribbon rock 10 to 20 cm below the scale. **D)** A close-up of the area around the scale in Figure 13C.


A
B
C
D
15 cm

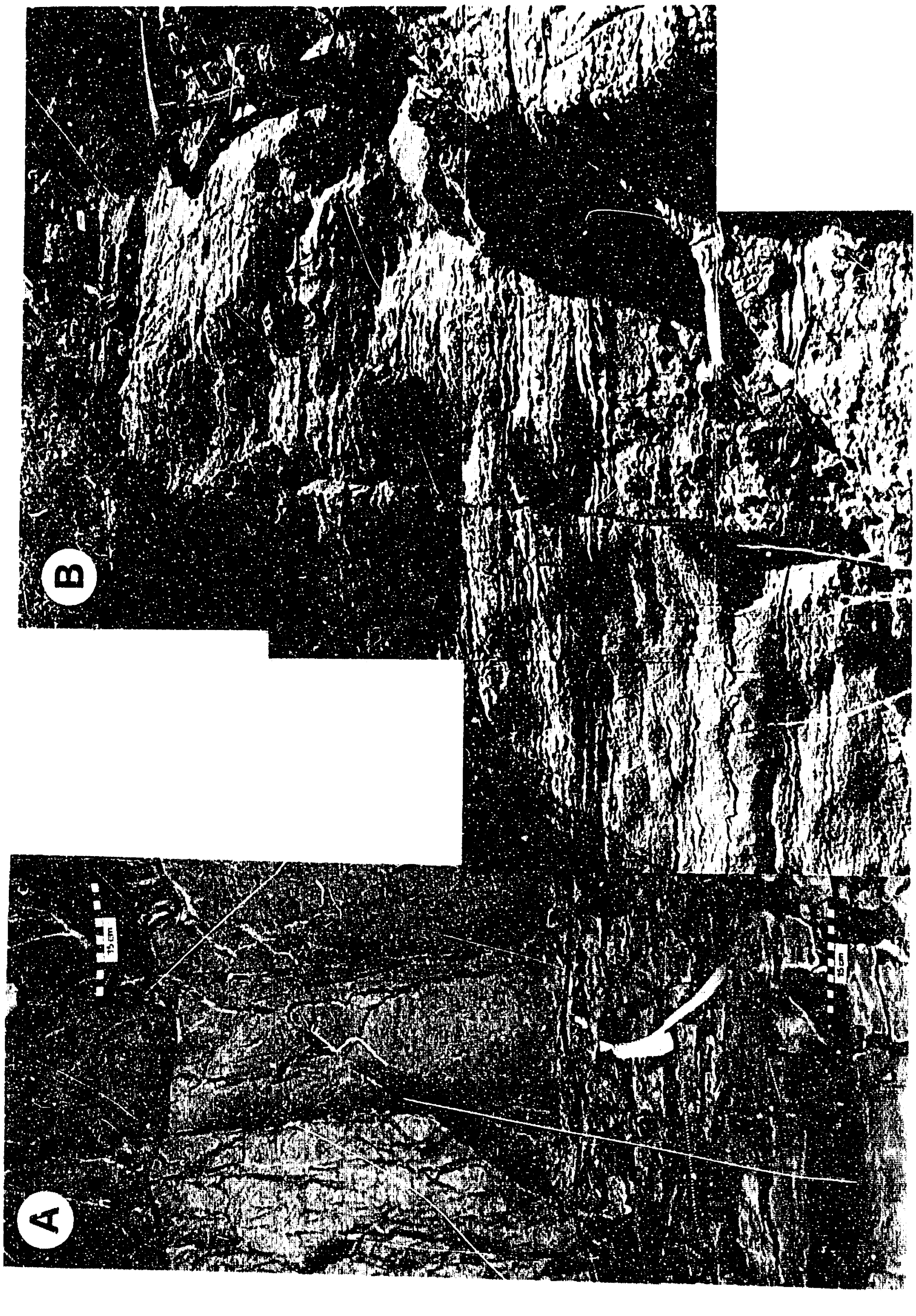
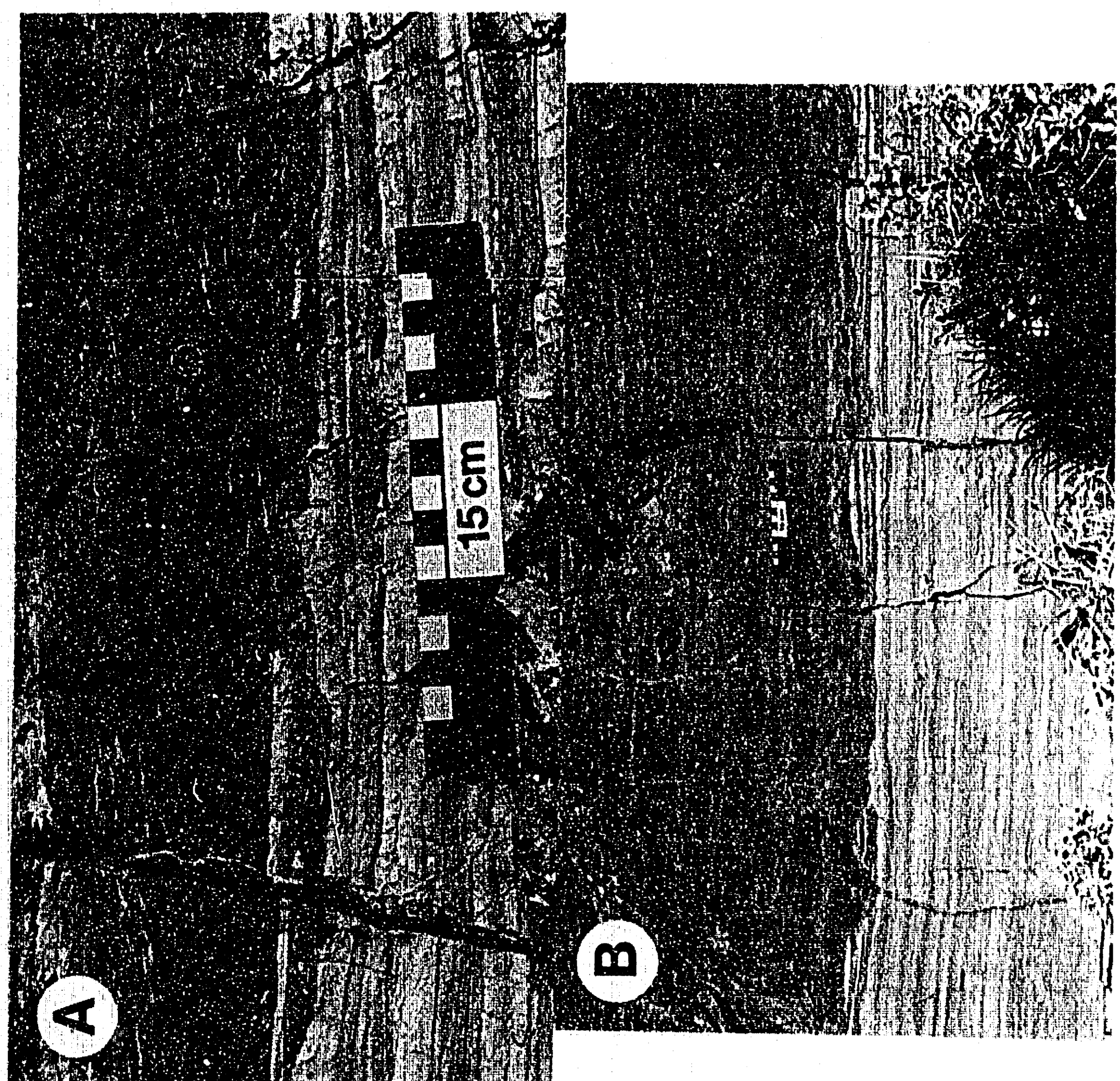

B
A

**Figure 14. A)** Two sharp facies contacts between subtidal facies, the lower between mixed calcarenite and dolarenite and overlying ooid grainstone, and the upper between the grainstone and overlying nodular ribbon rock are shown in this photo. These lithologies are found just above Parasequence Boundary I at Section A (Figure 7). The upper contact is probably scoured. **B)** Gray fenestral mudstone interbedded with orange laminated dolosiltite in a very gradational vertical contact between the two intertidal facies, located just below Parasequence Boundary IV and a bit south of Section D. The fenestral limestone is in a lower intertidal position than is the dolosiltite.

**Figure 15.** Parasequence boundaries with subtidal facies overlying and slightly scoured into intertidal microbial-laminated dolosiltite. The apparent depth of scour in each case is only a few centimeters. However, scour at any single location along a parasequence boundary cannot be used to predict scour laterally along the boundary, nor is it an indicator of lateral extent of a boundary. **A)** Subtidal ooid grainstone scoured 1 to 2 cm into intertidal orange laminated dolosiltite characterizes laterally continuous Parasequence Boundary IV located between Sections E and F (Figure 7). Note the numerous, platy rip-up clasts of dolosiltite incorporated into the basal few decimeters of ooid grainstone. **B)** Laterally discontinuous Parasequence Boundary C near the top of Section I is more deeply scoured by subtidal, oncolitic nodular ribbon rock cutting up 5 cm into intertidal orange laminated dolosiltite.


A
15 cm
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to juxtaposition of subtidal over intertidal facies, the surfaces cannot be traced laterally for more than a few hundred meters and cannot be distinguished in adjoining areas where there are only facies of similar water depth, i.e., subtidal over subtidal facies or intertidal over intertidal facies. This contrasts with the numbered, laterally continuous parasequence boundaries that can be traced through such areas.

Parasequence boundaries that cannot be traced for more than a few hundred meters have characteristics similar to those that can be correlated for tens of kilometers. Vertical nature and characteristics of a parasequence boundary do not predict extent of lateral continuity. Such attributes as extent of scouring, hardgrounds, subtidal microbial structures, magnitude of deepening across the boundary, and the facies above and below the boundary are not predictors of lateral continuity.

**Interpretation**

**Scouring.**—Carrara parasequence boundaries are almost always sharp and commonly accompanied by minor erosion. In rare instances the surface may be diffuse over a vertical distance of several centimeters resulting in a gradational contact between the two facies. Lateral variation along scoured boundaries is represented by changes in depth of scouring along the surface. Two parasequence boundaries with a minimum of several centimeters of scour are illustrated in Figure 15. Figure 15A shows 1-2 cm of scour on Parasequence Boundary IV, a surface that can be traced across Eagle Mountain and can be tentatively correlated to nearby ranges. However, comparison of Sections D and E (Figure 7) shows a minimum of approximately one meter of scour along Parasequence Boundary IV. Scour associated with Parasequence Boundary C near Section I (Figure 15B) is approximately 5 cm deep, greater than scour on Parasequence Boundary IV (Figure 15A). However, Parasequence Boundary C cannot be confidently correlated to the north at Eagle Mountain. Hence, the depth of scour recognizable at one location is not a reliable indicator of the total scour on the boundary, nor is it a reliable indicator of lateral continuity of that surface.

**Hardgrounds.**—In the upper half of the Jangle Limestone Member of the Carrara at Eagle Mountain there is little evidence for hardgrounds along parasequence boundaries. Few truncated grains or burrows and no encrusting organisms or expansion features were recognized along the many sharp contacts. Sediments overlying a parasequence surface commonly contain clasts of the underlying facies, especially where the underlying facies is microbially laminated orange dolosiltite (Figure 15A). However, production of clasts would not require sediments to be previously cemented, because binding of sediment by microbial mats with dewatering and drying would probably be sufficient to allow the sediment to behave cohesively during rip-up, transport, and

**Figure 16.** Digitate microbial growths on oncoids are found along Parasequence Boundary III (Figure 7). Thrombolitic internal morphologies occur most frequently, although rare stromatolitic morphologies also are found. The oncoids apparently ceased moving prior to the initiation of the digits. Oncoids with digitate growths are also found along Parasequence Boundary II, and sparse quantities occur along surfaces that are not interpreted as parasequence boundaries.


15 cm

redeposition over short distances (Hardie and Ginsburg, 1977). Thus hardgrounds as defined by the criteria of James and Choquette (1983) are absent on both laterally continuous and laterally discontinuous parasequence surfaces.

**Microbial structures.**—Some parasequence surfaces are marked by growth of microbial structures, including thrombolites and modified oncoids with digitate growths that have thrombolitic and/or stromatolitic texture. Thrombolites are thought to preferentially colonize hardgrounds or firmgrounds, by comparison with the Holocene (Dill et al., 1986; Dravis, 1983; Playford, 1980). It is deduced from this that subtidal parasequence surfaces on muddy lithologies may have become firmgrounds or hardgrounds. This inferred firmness of originally muddy sediments may have developed during a time of lowered environmental energy (as inferred from modified oncoids; see discussions in Chapter 2 and below) and decreased sedimentation rates that accompanied increased water depth. Additionally, thrombolites on parasequence boundaries imply preferential colonization of sites with a low concentration of disseminated mud in the water column and a firm substrate (Aitken, 1967; Dill et al., 1986; Dravis, 1983; Playford, 1980; Pratt and James, 1982; Pratt and James, 1986). Thrombolites are found on laterally continuous Parasequence Boundaries II and III, on discontinuous Parasequence Boundary C, and on surfaces that are not interpreted as parasequence boundaries, so thrombolites cannot be used as indicators of lateral continuity of a parasequence surface.

Well-laminated oncoids are interpreted to have grown in agitated subtidal waters, but modification by one-sided growth of digitate thrombolites and stromatolites requires that environmental energy levels be decreased so as to no longer turn over oncoids (Ratcliffe, 1988; Wright, 1983). Modified oncoids can be seen along laterally continuous Parasequence Boundaries II and III (Figures 7 and 16), where digitate growths grew up from oncoids that apparently ceased to be moved. However, sparse numbers of modified oncoids have also been found on surfaces not interpreted as parasequence boundaries, suggesting that they may not be useful as an indicator of laterally continuous parasequence surfaces.

**Deepening.**—Magnitude of relative deepening across a parasequence boundary is difficult to decipher in Carrara rocks because no absolute water depths can be assigned to these subtidal facies. One can only note whether subtidal facies overlie subtidal facies or intertidal facies. Subtidal facies are juxtaposed on intertidal facies in parts or all of Parasequence Boundaries I, III, IV, V, A, B, and C (Figure 7). Hence both discontinuous and continuous parasequence boundaries place subtidal facies over intertidal facies, indicating lack of prediction of lateral continuity. No discontinuous parasequence

**Figure 17.** Looking north at Section A with the lower part of the section to the left. The dark gray outcrop on the upper right corner is a part of the Bonanza King Formation in the background. The outcrop at the far left side of the photo corresponds to about the middle of the nodular ribbon rock below Parasequence Boundary II shown on Figure 7. The three lines on the left side correspond to Parasequence Boundaries II, III, and IV. The next two lines mark the sharp bottom and top boundaries of the oolite unit near the top of the section. The dotted line on the far right is the approximate location of Parasequence Boundary VI, which is obscured by vegetation in this picture. Parasequence Boundary V cannot be carried into Section A. An abrupt increase in the percentage of dolosiltite occurs across Parasequence Boundaries II, III, and IV and aids in identifying the parasequence boundaries. The change is most pronounced across Parasequence Boundary IV.

surfaces have been recognized that only juxtapose subtidal facies on subtidal facies throughout their lateral extent.

**Facies.**—Parasequence Boundaries A, B, and C are recognizable where different facies are present on either side of the boundary but are not traceable laterally where the same facies is above and below the boundaries. Other parasequence surfaces that have the same facies above and below, e.g., parts of Parasequence Boundaries II, III, IV, and V (Figure 7), are easily traceable across the outcrop. In nodular ribbon rock, an attribute that helps to identify and trace these surfaces is a gradual up-section decrease in the percentage of dolosiltite in the unit underlying the surface coupled with an abrupt increase in the percentage of dolosiltite in the first unit overlying the surface. An example of this is shown in Figure 17 with Parasequence Boundaries II and IV. The increase in dolosiltite is apparent by the darker color of the more dolosilt-rich unit above the boundary. In discontinuous parasequence boundaries, no vertical trends or changes in lithologic character delineate the parasequence boundary. Presence of similar or different facies on either side of a parasequence boundary cannot be used as a *predictor of lateral continuity.*

**Alternative correlations.**—If an abrupt increase in percentage of dolomite across a surface is taken as an unambiguous criterion to delineate a parasequence boundary, then tenuous correlations of the three discontinuous parasequence boundaries can be made across Eagle Mountain. Although it was not possible to trace Parasequence Boundaries A, B, and C in the field, application of this criterion results in tenuous correlations from section to section. In addition an argument can be made for inserting two more tenuous parasequence boundaries within Parasequence I, one between the upper two oolite units and one at the top of the basal oolite. If these tenuous parasequence boundaries are correct, then most occurrences of oolitic grainstone would be near the top of the subtidal part of parasequences, implying that the oolitic grainstone facies is shallower than most nodular ribbon rock. These tenuous correlations are not accepted because none could be proven in the field by lateral tracing on the outcrop.

## CORRELATIONS

### LOCAL CORRELATIONS AT EAGLE MOUNTAIN

Detailed correlations of peritidal facies, parasequences, and parasequence surfaces across the 1.8 km length of almost continuously exposed outcrop have demonstrated that all of these features can change or terminate within the length of the outcrop (Figure 7). Facies, especially the subtidal facies, tend to undergo gradual lateral change on this scale. This is well illustrated in the middle part of the outcrop belt in Parasequences I, II, and III. Overall deposition is of nodular ribbon rock with occasional localized facies of oolitic grainstone, oncolitic packstone/grainstone, CDAS lithofacies, and thrombolitic boundstone. These localized facies extend from under 100 m to over 1 km laterally and vary in thickness from less than 1 m to over 4 m. Event surfaces between facies coalesce to form boundaries separating overlying and underlying facies, and boundaries can extend the entire 1.8 km of the outcrop. However, the change from gradual to sharp to scoured boundaries implies that any single event surface may not extend laterally for more than a few hundred meters. Parasequence surfaces, generally assumed to be laterally continuous, recognizable, and correlative on scales ranging from kilometers in extent to basinwide, also have been shown not to be recognizable or traceable for distances of more than a few hundred meters in some cases, e.g., Parasequence Boundaries A, B, and C . Parasequence Boundary V can be correlated across most of the 1.8 km of outcrop but is unrecognizable at its northern limit, where it separates nodular ribbon rock from nodular ribbon rock.

## REGIONAL CORRELATIONS FROM RANGE TO RANGE

Confident correlations of thicker intervals can be made without the benefit of continuous outcrop and can be carried for distances of tens of kilometers or more (Plates 1-4). For example, the entire 40-m interval discussed in this chapter, equivalent to the upper half of the Jangle Limestone Member, can be correlated with confidence into adjacent ranges (Palmer and Halley, 1979; Chapter 5 of this paper). However, the Eagle Mountain data on peritidal facies, parasequences, and parasequence boundaries show that it is risky to extrapolate finer-scale correlations, i.e., units within this 40-m interval, because such features may not extend laterally for more than a few hundred meters, and characteristics observable in a vertical section are not accurate predictors of the lateral extent of these features.

A regional cross section (Figure 10; not based on the palinspastic restoration of Levy and Christie-Blick, 1989), shows the lateral extent of and variability in peritidal facies, parasequences, and parasequence surfaces extrapolated 55 km south from Eagle Mountain to the southern Nopah Range. The regional cross sections for the entire Carrara Formation, Plates 1 to 4, are based on the palinspastic map of Levy and Christie-Blick (1989), and show a 45 km separation between Eagle Mountain and the southern Nopah Range. In the palinspastic restoration, sections measured at Eagle Mountain, the Resting Springs Range, the Dublin Hills, and the Nopah Range are restored into an approximate NNW-SSE-oriented plane, i.e., mostly parallel to depositional strike but with a component of depositional dip. Restoration allows about 20 kilometers of depositional dip (east-west) separation between Eagle Mountain and the southern Nopah Range and about 40 km of depositional str'.e (north-south) separation.

As can be seen on the regional cross section (Figure 10), Parasequence Boundaries I and III-VI are carried approximately 55 km to the south to Section 6, but Boundary II cannot be correlated farther than Section 2, 18 km south of Eagle Mountain. In Sections 3 and 6, Parasequence Boundaries D through H can be recognized by facies changes across flooding surfaces but cannot be correlated into adjacent sections. These are analogous to Parasequence Boundaries A, B, and C at Eagle Mountain (Figure 7, Sections E and I). No facies unit recognized at Eagle Mountain can be correlated the entire distance to the south, although bioturbated ribbon rock may be correlative for approximately 45-50 km to Section 5. The basal unit of ribbon rock in Section 2 has undergone some diagenetic alteration and may be either bioturbated ribbon rock or nodular ribbon rock. Fenestral mudstone is recognized in Sections 2 and 3, approximately 30 km south of Eagle Mountain, and may have formed as a continuous subaerially exposed carbonate island or bank. Aside from these two facies units, most other facies differ from section to section without predictable order; further, numbers of facies between parasequence boundaries do not remain constant. Thus, it can be seen that the pattern formed by a mixture of laterally continuous and discontinuous facies, parasequences, and parasequence boundaries as documented at Eagle Mountain, can be applied to a regional cross section comprising sections measured in adjacent ranges.

Siliciclastics, from mudstone to very fine sandstone, increase towards the south, substantiating regional correlations of the mixed carbonate/siliciclastic Carrara with the siliciclastic Latham Shale, the Chambless Limestone and the mixed-lithology Cadiz Formation (Palmer and Halley, 1979; Stewart, 1970). Siliciclastics, more prevalent in the upper half of the study interval, are present in both lower and upper parts of parasequences. The siliciclastics tend to be subtidal and to be overlain by intertidal laminated dolosiltite. An exception to this is present below Parasequence Boundary I, at the base of Sections 4, 5, and 6, where intertidal siliciclastics are interbedded with intertidal carbonates.

## CONTROLLING MECHANISMS

### INTRINSIC PROCESSES

An intrinsic process is any influence on a depositional system that is internal to and dependent of the depositional system. Intrinsic processes may exert a spatially and temporally continuous influence throughout a depositional system, e.g., depositional energy gradients on a sloping shelf, effects of long-term and stable currents, or position

**Table 6.** A summary of papers dealing with models for shallowing-upwards cycles. The table is divided into the following sections: intrinsic models; extrinsic with intrinsic influence; extrinsic, dominantly eustatic; and extrinsic, dominantly tectonic.

| MODELS FOR SHALLOWING-UPWARD CYCLES | | | | |
|---|---|---|---|---|
| MODELS | SIZE/DURATION OF CYCLES | LATERAL CONTINUITY | FIELD EVIDENCE | COMMENTS |
| **INTRINSIC:** All models depend on changing sediment production/accumulation rates and lag times coupled with continuous subsidence. | | | | |
| Algeo & Wilkinson, 1988 **(Phanerozoic** stat data base.) | Most **1 to 20 m** cycles will have durations in range of **20 to 400 Ka** due to interactions of sed'n rates, subsidence & dynamics of sed. systems | Not directly addressed, but implicit that not laterally continuous over broad areas because not extrinsic control. Does recognize lateral continuity & Milankovitch influence of Carboniferous cyclothems. | Statistical data base, not outcrop work. | "... average cycle thickness is the best predictor of average cycle period, ..." (p316). See Goldhammer, et al., 1990 for opposite conclusion. |
| Bosellini & Hardie, 1973 **(Upr Perm)** | 32-46 cycles ave **3-4.5 m**, w/o discussion of duration. | Over ≈ 16,000 $km^2$. Does not discuss lateral continuity nor correlatability. | 2 measured sections w/ observations at several other sites. No discussion of outcrop quality. | 1) Cycles are gypsum over dolomite (shallow subtidal to supratidal)<br>2) Prefers Ginsburg's tidal flat carbonate factory model but also mentions 2 other mechanisms:<br>• sporadic subsidence, perhaps associated w/ block-faulting<br>• eustasy w/ continuous subsidence. |
| Cloyd, Demicco, & Spencer, 1990 **(Mid-Upr Camb)** | **0.5 to 1.5 m** w/ no discussion of duration. Interval studied is 10 m thick. | Cycles continuous across outcrop except for one that terminates w/in the 1 km long face. Infer that crevasse splay & levee fining-up cycles change laterally **w/in a few km** to channel bar grst deposits. | 2 continuous outcrops forming a corner w/ sides of 1 km & 0.7 km. Contacts walked out as well as covered w/ continuous photomosaics. | Channel bar grainstone deposits (ave 1.4 m thick) and crevasse splay/levee fining-up cycles both intrinsic due to fluvial processes acting in tidal channels. |

| | | | | |
|---|---|---|---|---|
| Demicco & Mitchell, 1982 **(Upr Camb)** | **2-12 m** peritidal cycles (& unrecognized subtidal cycles) in two groups w/ no discussion of duration. | "Layercake" correlatibility of cycles, though there is variation in numbers of cycles from section to section across ≈ 1000 $km^2$ (balanced xsctn). | 6 strat sections w/ discontinuous & thrust outcrop. | Favors carbonate factory for intrinsic origin of cycles. |
| Ginsburg, 1971, 1982 (Abstracts); Hardie 1986 (Model) | 1971: **≤ few 10s m.** Doesn't discuss duration of cycles. | Not stated. At least continuous bands of sub-environments | Model only. No field data. | The tidal-flat/carbonate-factory model. Area of carbonate production decreases to shut off sedimentation. |
| Hardie, Dunn, & Goldhammer, 1991 (Models & **Mdl-Upr Camb**)<br><br>(Discussion of Koerschner & Read, 1989) | Presents 3 models of alternate mechanisms to generate 4th/5th-order cycle rather than Milankovitchian eustasy:<br>1) 1-D **model** of **random** relative **sea level fluctuations** w/ random Markov successions generated **<1-10 m** cycles w/ ave duration of **45.5 Ka.**<br>2) 2-D **model** of **Ginsburg-type autocyclicity** generated **<1-10 m** cycles that prograded **200 200-500 km down-dip** w/ durations of **50-150 Ka.**<br>3) **Episodic subsidence:** large-magnitude **earthquakes** on passive margins have **recurrence intervals** of in **$10^3$-$10^5$ yr** range; could affect **areas ≥ 100 x 800 km**; have **vertical movement** in range of **0.5-2+ m.** | Lateral continuity of field data not discussed. | Not addressed. Mainly a discussion of data of Koerschner & Read, 1989. | 1) Argues that while Milankovitchian eustasy is likely operating, the "... effects are not legible in the Cambrian record and are hidden by other more dominant influences on carbonate sediment accumulation." (p645).<br>2) Discusses intrinsic and episodic subsidence mechanisms.<br>3) See Koerschner & Read, 1989 & Kozar, et al., 1990 |
| Havard & Oldershaw, 1976. **(Mid-Upr Dev)** | From **0.7 to 6 m** w/ avg of 2 m. Doesn't discuss duration of cycles. | Back-reef area **22 x 34 km.** | 5 cored wells | Uses model of Mossop, 1973 (unpublished thesis), 1979 . See 'Mossop, 1979'. |

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| Kozar, Weber & Walker, 1990 **(Mdl-Upr Camb)**<br><br>(Discussion of Koerschner & Read, 1989) | **Meter-scale** cycles w/ durations **between 20 & 200 Ka.** | "Our observations ... suggests that, on a meter scale, lithofacies stack in an unpredictable pattern. Individual stacked cycles (i.e. genetic cycles) are not correlative among closely-spaced stratigraphic sections. This strongly suggests that the meter-scale 'cycles' in any one outcrop are due to local effects." (p790). | Not addressed. Mainly a discussion of data of Koerschner & Read, 1989. | 1) Discusses Ginsburg autocyclicity, esustasy, tectonic processeses, and intrinsic processes due to local interplay of subenvironments.<br>2) Though eustasy operating, for 4th/5th order cycles "... meter-scale stacking patterns ... are more reasonably explained as products of vertical accretion and rapid migration of ... environments in respose to sediment production, tidai variations, and wave and storm activity." (p791).<br>3) "... the best method for distinguishing one end-member model from another involves the temporal correlation of similar cycles over wide geographic areas." (p794)<br>4) See also Koerschner and Read, 1989 & Hardie, et al., 1991 |

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| Laporte, 1967, 1969 **(Upr Sil-Lwr Dev)** | Doesn't talk about size of cycles. Doesn't discuss duration of cycles. Views formations as gross facies units w/ each representing a general depositional environment: Manlius **(7.5-15 m)** =intertidal; Coeymans **(6-30 m)**= agitated subtidal; Kalkberg **(15-30 m)** = quiet subtidal; N. Scotland **(15-45 m)** = quiet subtidal. | 1969: w/in Manlius Fm, "local tidal flats" that migrated across subtidal facies formed "...a complex facies mosaic of supratidal, intertidal & subtidal units." (p116). Overall viewed each fm as a facies belt w/ belts migrating w/ time to produce overall deepening. Shelf **approximately 135 km wide.** | Discontinuous outcrop | Did not try to break out or explain small shoaling cycles, but did recognize their existence: 1967: "Detailed examination ...reveals that, ... lithologically ...is neither homogeneous nor randomly variable." (p76). "... environmental conditions ... fluctuating continuously ... w/ ... result ... facies ... repeatedly shifted laterally &, ... vertically." (p77). Anticipated tidal island model of Pratt & James, 1986: there was not a progressive parallel migration of facies, but rather supratidal, intertidal, & subtidal present in a relatively small area at any one time, & hence facies migrated more irregularly as "...small islands of low relief ..." (1967, p90-1). |
| Matti & McKee, 1976 (Abstract discussing model) | Not stated. Doesn't discuss duration of cycles. | No comments on lateral extent. | Model. No field data. | Restates Ginsburg's tidal flat factory model, but depth of carbonate production increases to shut off sedimentation. |
| Mazzullo, et al., 1978 **(Upr Camb - Lwr Ord)** | Cycles ave **13.9 & 15.1 m** in the 2 formations (≈ 140 m total thickness), however their cycles are made up of smaller cycles they did not break out. No discussion of duration. | Cycles cannot be correlated between sections due to facies "... complex of peritidal shoals interrupted by shallow carbonate shelves." that formed a "... mosaic that resulted from the independent and non-contemporaneous lateral migration of ... shoals and ... shelves."(p113) | 27 outcrops, 10 quarries & 1 core scattered across ≈ 35 km x 10 km. | Applies modification of Irwin's (1965) model for epeiric sea sedimentation, though w/ an **apparent** primary emphasis on the intrinsic nature of the cycles. |

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| Mossop, 1979<br>**(Lwr Ord)** | Average **3.5 m** thick. Doesn't discuss duration of cycles. | Some beds can be traced for approximately **15 km** and "... possible to make reasonable correlations between sections ... **20 or 30 km apart**, ..." (p25). Sabkha system extends approximately **300+ km** along **strike & 110 km wide** (p29). | Outcrop (cliff-face) 18 km long (Fig. 23) in addition to much other outcrop. | He wasn't looking at cycles. Model is intrinsic for evaporites & carbonates w/ lag built in, though he does discuss effects of local/temporal fluctuation in subsidence rates on the intrinsic model. |
| Pratt and James, 1986<br>**(Lwr Ord)** | Tidal islands w/ height of a few m develop as a response to "... variable local rates of sediment accumulation." (p338). Doesn't discuss duration of cycles. | Lateral <u>facies</u> changes observed directly over 100's m (p316). tidal islands **≤ 10 km laterally** & only a few km to a **few 10's km** apart at times (p335). | "...facies changes can be walked out & observed directly ... and deduced by correlation of closely spaced sections; ..." (p332). | Differs from other intrinsic models in requiring laterally discontinuous facies for at least the intertidal facies. |
| Selg, 1988<br>**(Lwr Camb)** | Cycles **20 m** thick that shoal then deepen, i.e. (bottom to top) restricted lagoon to intertidal to subaqueous "spillover oolites". Doesn't discuss duration of cycles. | Approximately **15 x 30 km**? States that "Lithofacies change rapidly, vertically as well as laterally, in a very disordered way.". | Five isolated blocks in approximately 15 x 30 km. | States that there is no facies changes on stable clastic tidal flat area to east nor on platform to west. With stability on either side, 'cycles' between must be intrinsically driven. |
| Spencer & Demicco, 1989; Demicco & Spencer, 1989 (Model) | **Meter-scale** cycles w/ **25 Ka** duration in model. | Not addressed. | Model. | 1) Sea level variations of 2 cm to 20 m used.<br>2) 2 & 20 cm variations may be intrinsically caused by:<br>• variable local or regional tectonic subsidence,<br>• isostatic adjustment<br>• episodic compaction dewatering<br>• sediment production<br>• sediment distribution |
| Waters, Spencer, & Demicco, 1989<br>**(Mid-Upr Camb)** | 15 cycles **1-2.5 m** thk, w/o addressing duration. Interval discussed is 21 m thick. | All cycles continuous across outcrop. Can see lateral transition in the 5 km outcrop from channel deposits to overbank deposits w/in cycles. | ≈ 5 km long continuous outcrop, V-shaped plan geometry. 14 strat sections measured, photomosaics of key areas, & many contacts walked. | Cycles interpreted as channelized tidal flat deposits w/ some barrier beach deposits and some subtidal deposits. Origin of channelized fining-up tidal flat cycles due to fluvial processes acting in tidal channels. |

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| Wilkinson, 1982 (Conceptual model) | **< 1 - several 10s of meters** w/ abrupt flooding surface at base. Does not discuss duration. | "... individual component facies as well as individual cyclic sequences may cover exceedingly wide geographic areas, commonly extending **tens of kilometers** across shallow epicontinental shelves." (p190). | Conceptual model. | Discusses 2 end-member mechanisms (p192 and following):<br>• "Non-uniform variation in the position of relative sea level ..."<br>• "Intrinsic variation in rates of sediment production and deposition ..."<br>In a discussion (p195) of his Fig. 4, Wilkinson makes a one-to-one comparison of meter-scale cyclicity w/ cyclic seismic sequences to argue against validity of seismic statigraphy. Unfortunately he is comparing $4^{th}/5^{th}$ order cycles (1-10 m thick & $10^4$-$10^5$ yr duration) w/ $3^d$ order cycles (several 10s to 100s m thick & $10^6$-$10^7$ yr duration). |
| Wilkinson, Opdyke & Algeo, 1991 (**Phan.** stat. data base) | "metre-scale". Duration not addressed. | Not addressed. | Stat. data base, not field work. | 1) Hol. & Phan. cycles are same thickness & must have been deposited at same rates. Since Phan. cycles have longer apparent durations, most of time must be in bounding surfaces (70-97% of duration).<br>2) "... allocyclic models ... more-or-less continuous deposition during episodic sea-level rise ... intrinsic models generally presuppose invariant sea level and rapid deposition during an even smaller fraction of cycle period." (p1096) |

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| Wong and Oldershaw, 1980 **(Upr Dev)** | "... 20 cycles in 26 m of section" & range from **0.7 to 2.7 m** w/ **avg of 1.6 m** (p411, 420). Doesn't discuss duration of cycles. | Only w/in reef interior, approximately **5 x 20 km** (3 x 12 mi) (Fig 1). | 5 cored wells. | Cyclicity is due to variation in rates of sediment production. Hi rates produce tidal flats which prograde inward, reducing area of sediment production which shuts off production/progradation letting subsidence have upper hand until return to optimum conditions for high sediment production & restart the cycle (p421). |
| **EXTRINSIC w/ INTRINSIC INFLUENCE:** Eustatic, including Milankovitch variation, coupled with continuous subsidence. Various intrinsic mechanisms generate smaller cycles. | | | | |
| Brett & Baird, 1986 **(Mdl Dev)** | **Minor cycles** are **0.5-3 m** thick, **$4^{th}$-order**, of **100-225 Ka** duration, equivalent to PACs, & may be extrinsic & intrinsic. **Major cycles** (14-15) are **3-20 m** thick, also **$4^{th}$-order**, of **400-500 Ka** duration, are only extrinsic, & symmetric (transgressive-regressive) or asymmetric depending on position on shelf. Group is **90-200 m** thick & **6-7 Ma** total duration. | "... single units [≈ 1-20 m from Fig. 2] can be traced [**along depositional strike**] for **tens of kilometers without** substantial change in thickness, lithology, or fossil content. However, ... **across depositional strike, abrupt changes** are observed." (p432). Minor cycles "... may or may not be basinwide in extent." (p434). "... virtually all of the larger-scale, and many smaller-scale, facies cycles can be traced continuously across the entire outcrop belt from very shallow-water... into the deeper trough areas and into the western ... shelf ... Hence ... widespread and probably basinwide." (p441). | 4 sections measured across ≈ 200 km of discontinuous outcrop. | 1) The authors use 'order designations' of Busch & Rollins, 1984 (See entry this table), which do not agree w/ those used in this table. The authors '$5^{th}$- & $6^{th}$-order cycles' have durations that are assigned to $4^{th}$-order cyclcity in this table, i.e. durations in the $10^5$-$10^6$ yr range. 2) Extrinsic process is eustasy. **Intrinsic processes** includes **local episodic tectonics & delta progradation.** 3) Authors show no detailed cross sections to document cycle-by-cycle correlations. 4) Equates thickness w/ duration. |

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| Busch & Rollins, 1984 (Penn) | **5-30 m** thick $4^{th}$-order cycles. $2^{nd}$-order (**65 Ma**) to $4^{th}$-order (**400 Ka**) cycles recognized in a stacked hierarchy. $4^{th}$-order cycles (**100-225 Ka**) (PACs) recognized but not discussed. | $4^{th}$-order cycles correlated through 4 sections over **200 x 240 km**. | Not really discussed but 4 sections shown. | 1) Their '$5^{th}$-order cycles' w/ duration of 400-450 Ka, are placed in the $4^{th}$-order category in this table, as are their '6th-order cycles' w/ durations of 100-225 Ka.<br>2) "... fifth-order [400-450 Ka] T-R [transgressive-regressive] units are best explained by ... extrinsic dominance with some concomitant intrinsic influence. The number of T-R units between two marker beds is generally constant, but an occasional "extra" unit is ... viewed as the result of an intrinsic process." (p473). The primary mechanisms are extrinsic Milankovitch-driven eustasy & climate. **Intrinsic mechanisms include basin tectonics, and fluvial-delta processes.** |

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| Goldhammer, Dunn & Hardie, 1990 **(Triassic & Pleistocene)** | **Triassic Latemar: 8-20 Ka** duration, bundled 5:1 into megacycles ($4^{th}$-order) of '$10^5$ **yr'** duration.<br>LPF: ≈ 2 Ma & 250 m total w/ **≈ 10 m/$4^{th}$**-order cycle<br>LCF: ≈ 90 m total w/ 73 cycles ave **1.24 m/$5^{th}$**-order cycle<br>TF: ≈ 6 Ma & 120 m total w/ 295 cycles ave **0.4 m/$5^{th}$**-order cycle<br>UCF: ≈ 210 m total w/ 230 cycles ave **0.96 m/$5^{th}$**-order cycle<br>**Pleistocene of Florida:** 6 cycles/400 Ka =ave. duration of ≈ **67 Ka.**<br>**Pleistocene of Great Bahamas Bank:** 15 subtidal cycles w/ soil caps (ave ≈ **2.7 m**) in a total of 3.2 Ma = ave. duration of ≈ **213 Ka**<br>**Triassic Dolomia Principale** subtidal facies: **0.15-5 m, ave 1.5 m/cycle, ave duration 24-40 Ka.** Capped w/ tepees of 1-3 diagenetic cycles **0.25-2 m** thick or w/ soil-breccias **0.2-1 m** thick. Resultant condensed megacycles **1-4 m** thick of **$4^{th}$-order** duration.<br>**Triassic Lofer Facies:** (see Fischer, 1964) 61 shoaling peritidal cycles, **<1 m - 28 m** (192 m total), that **are not** bundled and **cannot** be resolved into megacycles or Milankovitchian rhythms despite ave. cycle duration of ≈ **50 Ka.** | Not really addressed. Latemar massif 5-6 km across. Lofer Facies much more widespread, though lateral continuity of facies/cycles not discussed. | Not really addressed. Dolomia Principale includes a 55 m section measured in detail. Lofer Facies of the Dachsteinkalk was examined at three locations. | 1) Composite eustasy invoked for Triassic Latemar & Dolomia Principale. Pleistocene of southern Florida is also controlled by composite eustasy, but the $4^{th}$-order ($10^5$ yr) sea level fluctuations are greater amplitude than (& dominate) the $5^{th}$-order ($10^4$ yr) and the $3^{d}$-order ($10^6$ yr) fluctuations. **Intrinsic episodic & localized tectonic subsidence** is invoked to explain the Triassic Lofer Facies, though composite eustasy (like so. Florida Pleist.) would produce similar patterns (but no large scale glaciation recognized during Triassic)<br>2) Modelling (p 555 & Fig. 22) indicates that "... cycle thickness does not reflect cycle duration or periodicicty." See Algeo & Wilkinson, 1988 for opposite conclusion.<br>3) See also Cisne, 1986. |

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| Heckel, 1986; Boardman & Heckel, 1989 (Desmoinesian-Virgilian; i.e. **Mdl-Upr Penn**) | Cycle thickness not given. Duration of 55 cycles calculated in several different ways, but range **44-600 Ka**/cycle (1986), placing them in $4^{th}/5^{th}$-order cycles. | Not discussed, except for correlation of 29 out of 41 cycles for **600 km** (1989). | Not discussed directly, but includes outcrop & core. | 1) Have 12/41 (=29%) non-correlation between areas 600 km apart. Cycles that don't correlate are explained as being lower on shelf, hence w/o lateral equivalents.<br>2) Heckel (1986) argues for different durations for different sizes of cyclothems. One of his calculations for duration assumes all cyclothems are same & gives range of 145-218 Ka. This is likely the correct assumption, as cyclothems can be grouped into a hierarchy of cycles a la Goldhammer, et al., 1990.<br>3) Boardman & Heckel (1989) invoke **intrinsic delta lobe switching** for a few cyclothems. |
| Irwin, 1965 (Model) | Size & duration not discussed. | Broad facies belts that would be laterally continuous for 10s to 100s of km. | Conceptual model. | Invokes sea level change for major changes, but also allows for **intrinsic** smaller-scale "minor fluctuations" due to "... **local** changes in the **rate of subsidence** [extrinsic] or emergence in relation to the **rate of deposition** [intrinsic] ; ..." |
| Osleger, 1991 (**Upr Camb**) | **0.6 to 12.0 m.** No age constraint & doesn't discuss duration of cycles. | No statement regarding lateral correlatability. | Measured sections. | Overall a eustatic control on cycle formation, but invokes **intrinsic wave-sweeping** of shelf to prevent subtidal cycles from shoaling into intertidal. |

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| Strasser, 1988 **(Lwr Cret)** | **'≈ 20 Ka'** cycles ≈ **0.2 to 1.5 m**, bundled ≈ 5:1 into **'100 Ka'** cycles, in turn bundled ≈ 4:1 into **'400 Ka'** cycles. **See Comments.** | '20 Ka' cycles don't always correlate well but can carry the bounding surfaces of the '100/400 Ka' cycles ≥ 200 km. | Lots of sections across platform, but doesn't really address how much outcrop is laterally continuous or traceable. | 1) No age control on cycle duration. Has assigned durations to cycles based on Milankovitch freqs.<br>2) His smallest-sized cycles don't carry laterally and he states that facies change laterally and may reflect **intrinsic processes acting locally**, "... commonly change laterally in the same outcrop & do not correlate with other sections." (p380)<br>3) Invokes **intrinsic discontinuous islands** shoaling up to intertidal outboard of lagoon a la Pratt & James |
| **EXTRINSIC:** Eustatic, including Milankovitch variation, coupled with continuous subsidence | | | | |
| Bechstädt & Schweizer, 1991 **(Upr Triassic)** | **3$^{d}$-order cycles** (3), **50-100 m** thick, ≈**2 Ma** duration; comprised of shoaling **4$^{th}$-order** cycles (4 in carbonate part, ≤ 20 **m?**; 4-5 in siliciclastic part, **1.5-16.5 m?**), ≈ **250 Ka** duration. **5$^{th}$-order** cycles, ≈ **0.5-8 m?**, recognized but not dealt with in detail. | Outcrop over ≈ **100 x 500 km.** **5$^{th}$-order** cycles "... cannot be correlated for more than a **few kilometers.**" (p250). "Subcycles [**4$^{th}$-order**] are less clear and are **difficult to correlate within the rest of the carbonate interval ....**" (p246-8), but in **siliciclastics** are "... **present throughout th study area.**" (p260). Distinct lateral facies changes w/in 4$^{th}$-order cycles (p260). **3$^{d}$-order** cycles correlated over **hundreds of km** (p256). | > 60 strat sections, though only parts of 10 shown. No other discussion regarding quality of field data. | 1) Carbonates (30-80 m) in the shelf margin systems tract, & siliciclastics (20-40 m)in the transgressive & highstand systems tracts.<br>2) Prefers eustatic mechanism for 3$^{d}$/4$^{th}$-order cycles but can't disprove large-scale intraplate deformation. |
| Bertrand-Sarfati & Moussine-Pouchkine, 1988 **(Upr Prot**, 890 ± 35 to 775 + 52 Ma) | Quite variable cycle thickness, **≤ 1 m to 38 m.** (≈ 28 to 202 Ma for deposition of ≈775 m of seds, though taking 890-775 = 115 Ma or 775/115 ≈ 6.7 m/Ma or ≈ **150 Ka/m**). Gives neither the number of cycles nor duration values. | Stromatolite 'facies sequences' (3-38 m) laterally continuous **30 to 1000+ km.** (p257). Other shoaling cycles, ≤1 to 5(?) m, & siliciclastic units, ≤ 10 m, are of less lateral extent, **1 to 10s km** (p269), & make up facies mosaics (p269) | Discontinuous outcrop for correlations over 30 km, but may have more continuous outcrop on some areas . | Deals w/ an approximately 800 Ma epeiric carbonate platform. Interprets stromatolite units as reflecting widespread flooding of platform. Picks base of cycles at base of stromatolite units. |

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| Borer & Harris, 1991 **(Upr Permian;** upr Guadalupian = Kazanian) | **3d-order cyle, ≈ 150 m thick & 1.2-2 Ma** duration, made up of 5-6 **large cycles** typically **30 m** thick (9-15 m dol + 9-18 m of couplets of sts/ss & dol) w/ **≈400 Ka** duration. Couplets are **small cycles (2-9.2 m?)**, of 1-4.9 m sts/ss + 1-4.3 m of dol, w/ duration of ≈ **100 Ka**. Three couplets + thick dol unit make a 4:1 bundle in a large cycle. Smaller shoaling depositional cycles ≤ **2m** (≈ **20-40 Ka** duration?) seen w/in small cycles, w/in thicker siliciclastic intervals, & w/in thicker carbonate intervals, but are more problematical as to duration & relation to eustasy. | Area under study is ≈ **15 km** in dip direction & ≈ **200 km** along a curving basin margin. A schematic cross section, Figure 32, shows **updip termination** of 100 Ka carbonate units into 400 Ka siliclastic units over ≈ **15-30 km** (p 765-6). "... relative continuity of facies along strike but a high degree of variability in a dip direction." (p769). Carbonate wedges can pinch out in 0.4 to 2+ km updip (p769-70) | 9 cores, 2 subsurface cross-sections, & 4 strat sections/outcrops. | 1) Composite eustasy w/ Milankovitchian frequencies invoked.<br>2) Estimates of duration of Yates Fm. varies from 0.5-2.0 Ma. Authors prefer 2.0 Ma duration for several reasons. If 0.5 Ma estimate is correct, then have large cycles = 100 Ka, small cycles = 20 Ka.<br>3) Reservoir-scale heterogeneity controlled by interaction between 2 Ma & 400 Ka eustactic fluctuations. Heterogeneity w/in a reservoir unit is controlled by 100 Ka eustatic fluctuations (p776-7 & Fig. 39). |
| Bova & Read, 1987 **(Lwr Ord)** | **1-7 m** peritidal & **30-100 m** (20-110 m?) subtidal only. long-term subs rates of ≈ 4 cm/1 Ka & cycle duration of **140-200 Ka** | Tidal flat progradation of **300+ km** (p724). Lateral discontinuity of cycles due to differential subsidence along mature passive margin. Also recognizes lateral change of facies & cycle type. | Discontinuous outcrop correlation. | 1-D computer modeling. |
| Connolly & Stanton, 1992 (Desmoinesian-Missourian; i.e. **M-Upr Penn)** | ≈ **4-7.5 m** of mixed carbonate/siliciclastics, w/ duration ≈ **352 Ka** | Correlate for 1500 km. | 3 sections: 50 km apart & 1500 km apart. Sparse fossil control. | Have ≈ 8/60 (=13%) non-corr between '50 km' sections & ≈ 11/38 (=29%) non-corr between '1500 km' sections. These cycles are more like 4th order cycles/parasequences than regular parasequences. |
| Elrick, Read, & Coruh, 1991 **(Lwr Miss)** | **6 to 40 cm** couplets (ls/argillite) w/ **>3 Ka** duration bundled into 4 **'8-40 m thk' 3d/4th Order** sequences. Couplets recording storm/no storm Milankovitch 'harmonic' cycles. | ≥ ≈ 100 m as seen in cutcrops ≈ 100 m wide. | Outcrops ≈ 100 m wide. | 1) Spectral analysis to derive < 3 Ka duration.<br>2) Storm/no storm climatic cycles tied to Milankovitch 'harmonics'.<br>3) Not a 20 Ka duration for bundles, but no age assignment to 3d/4th Order sequences. |

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| Elrick & Read, 1991 **(Lwr Miss)** | $5^{th}$ **Order** cycles: **0.3-10.0 m** & **30-110 Ka** bundled into 3 $3^{d}/4^{th}$ **Order** sequences **20-220 m** w/ no duration given. | In field & model, number & type of cycles vary updip & downdip over distances < 30 km. | Measured sections > 30 km apart. 2D model. | $5^{th}$ Order cycles do not correlate well; updip due to decreased accommodation & downdip due to water too deep & decreased sed'n rates. |
| Fischer, 1964 **(Upr Triassic)** | Approximately 0.5 to 14.5 m in thickness for the 35 cycles he measured (Figs 3, 4, 6). Member C can range from ≤ 1 m to 20 m (p131), so 300 cycles probably range from approximately **1 m** to **≤ 25 m** (max). Ave. cycle duration ≈ **50 Ka** (20-100 Ka) (p144 & 146) and are bundled ≈ 6-8:1 into '**megacycles**' of **120-800 Ka** (p147-8). | Approximately **20 x 35 km**? Cycle cont/discontinuous not really addressed. Favors eustatic driver, so at least **basin-wide**? Facies continuity/discontinuity not addressed either. | Outcrop of four discontinuous blocks extends over approximately 20 x 35 km. | 1) <u>Vertical sequence:</u><br>dissolution surf<br>subtidal facies<br>intertidal facies<br>residual paleosol<br>dissolution surf<br>2) Fischer interpreted cycles to be deepening-up. Goldhammer, Dunne & Hardie, 1990 reinterpret cycles as shoaling-up, recognizing that some of the cycles are analogous to Latemar cycles w/ exposure surfaces on subtidal facies.<br>3) <u>See also Cisne, 1986</u> |
| Goldhammer, Dunn & Hardie, 1987 **(Middle Triassic)** | **0.1 to 5 m, avg of 0.65 m.** ≈ **10-15 Ka** duration, bundled 5:1 into **megacycles** (4-6 cycles/grp) w/ '**$10^5$ yr**' duration. | Doesn't address lateral continuity. | Outcrop is approximately 5 km across. Also modeled using outcrop as goal. | Approximately 10-15 Ka duration. bundled into 5-cycle groups (4-6 cycles/group). Subtidal facies w/ dolomitic vadose diagenetic cap. |
| Goldhammer, Oswald, & Dunn, 1991 (Desmoinesian; i.e. **Mdl Penn)** | $3^{d}$ **-order: 200⁺ m** & **2-3 Ma** duration.<br>$4^{th}$**-order:** 29 in basin but only 8 on shelf, ave. **30 m** & ave . **138-345 Ka** (mean of 257 Ka) duration.<br>$5^{th}$**-order:** Total not stated in basin but only 34 on shelf, bundled a maximum of 9:1, ave. **6.1 m** & ave **15-38 Ka** (mean of 29 Ka) duration. | Data collected over ≈ **80 km E-W by ≈ 30 km N-S.**<br>$4^{th}$**-order:** Bounding exposure surfaces correlated >110 km, & "... lack of abrupt lateral thickness changes of the regionally correlative sequences." (p396).<br>$5^{th}$**-order:** "... are apparently regionally correlative, ..." (p394). | Outcrop, 1 measured section, 1 published section, 5 cores, & 46 well logs. | 1) Discusses possible tectonic mechanisms but prefers a hierarchy of stacked $3^{d}$ to $5^{th}$ order Milankovitchian eustasy.<br>2) Data (≤9:1)doesn't discriminate between long eccentricity:obliquity (413 Ka:34 Ka or ≈ 12:1) & short eccentricity:precession (100 Ka:17.4 Ka or ≈ 5.7:1). |

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| Goodwin and Anderson, 1985, 1988, & Anderson & Goodwin, 1990 **(Upr Sil-Lwr Dev)** | Cycles average ≤ **1 - 5 m** thick. 25 PACs over 2 Ma = **80 Ka**/PAC (Rondout-Kalkberg). [Goodwin & Anderson, 1988: **$10^4$ yr**/PAC. Anderson & Goodwin, 1990: **$10^4$ -$10^5$** yr/PAC] | Bounding surfaces cont **(10's km)**, but have lateral facies changes between boundaries. (p519). Correlations w/in Helderberg basin of ≥ **300 km** (1985, p525). | Correlation between discontinuous outcrops. | Their Fig 8 (p523) shows differing numbers of PACs in each of three wide-spread sections. |
| Grotzinger, 1986a, b, c **(Lwr Prot.**, 1.89 Ga) | Cycles **1-15 m** thick. Duration **18-30 Ka**, w/ max range of 18-90 Ka. Modeled w/ 24 Ka. **($10^5$ year/cycle**. See Comments) | Continuous **along strike ≥ 200+ km, ≥ 120 km perpendicular to strike.** | Walked out 10's km in strike direction. | 140-150 cycles. Bowring and Grotzinger (1992) reported new radiometrioc dates that result in recalculated cycle durations of 72 to 120 Ka with a maximum range of 72 to 360 Ka. |
| Hardie & Shinn, 1986<br>**(Upr Camb)**<br>**(Lwr Ord)**<br>**(Lwr Ord)**<br>**(Upr Sil)**<br>**(Upr Perm)**<br>**(Upr Triassic)** | Several data sets w/ calculated durations but no thicknesses:<br>•Demicco Ph.D.: mean **70-110 Ka** (range 30-220 Ka).<br>•Nguyen Ph.D.: mean **145 Ka** (range 35-260 Ka).<br>•Goldhammer (unpub): mean **100-130 Ka** (range 20-300 Ka).<br>•Tourek Ph.D.: mean **30 Ka** (range 8-60 Ka).<br>•Bosellini & Hardie, 1973: mean **65 Ka** (range 5-125 Ka).<br>•Bosellini & Hardie (unpub): mean **24-40 Ka** (range 0-92 Ka). | Continuity & correlatability not discussed. | Not discussed. | Data set part of a general discussion of ancient tidal flat deposits. 3 mechanisms discussed:<br>• intrinsic mechanisms<br>• eustasy,especially w/ Milankovitch frequencies<br>• tectonic pulses related to block or wrench faulting. |

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| Hardie, Bosellini, & Goldhammer, 1986 **(Triassic)** | 3 intervals; subtidal w/ supratidal caps; durations based on 2 different time-scales:<br>• Dolomia Principale: 250-1500 m total; ≈ **1-12 m w/ mean of ≈ 3-4 m**; mean duration of **40 Ka** (0-92) **or 24 Ka** (0-76).<br>• Durrenstein: ≤ 800 m total; **mean 2 m**; no duration.<br>• Latemar: ≈ 400 m total; ≈ 550 cycles; **0.1 -5 m, w/ mean < 1 m**; mean duration **10 Ka** (0-32.5) **or 17.5 Ka** (0-62.5).<br>• Recalculated duration of Fischer, 1964: **means of 40 Ka** (10-73) **& 53 Ka** (13-93). | Continuity & correlatability not discussed. Dolomia Principale extends over 20,000 $km^2$. | Not discussed. | Preferred mechanism is eustasy at Milankovitch frequencies w/ occasional drops below platform for several cycles resulting in 'missed beats'. Proposed alternate mechanism of occasional platform block uplift (tectonics) to remove platform from depositional realm & have prolonged exposure. |
| Jervey 1988 (Model) | Modeled sequence-level intervals **10s to 100s m** thick (fig 6, p51). **4 Ma** duration for model (p. 53). | 150-240 m thick & **160-960 km** laterally for sequences (p56). | 2D model. | Oriented towards sequences, not parasequences. |
| Koerschner & Read, 1989 **(Mdl-Upr Camb)** | ≤ 400 cycles in ≈ 26 Ma, **1-7 (5?) m** thick, ave duration of ≈ **65 Ka.**<br>Elbrook Fm: 4 strat sections<br>247 ± 20 cyc., 2.44 m & 60.7 Ka<br>273 ± 25 cyc., 1.95 m & 54 Ka<br>193 ± 22 cyc., 2.2 m & 77 Ka<br>126 ± 24 cyc., ≈ 2.15 m & 130 Ka<br>Conococheague Fm: 4 strat sectns<br>201 ± 16 cyc., 2.98 m & 54.7 Ka<br>247 + 20 cyc., 2.42 m & 44.5 Ka<br>227 ± 35 cyc., 2.09 m & 48 Ka<br>148 + 29 cyc., ≈ 1.79 m & 74 Ka | "... can be traced as far as the individual outcrops extend (up to a few hundred meters)." & "K. Walker (pers. comm.) shows that laminites in the Upper Knox in Tennessee can be traced in cores for a minimum of 2.4 km." & "We believe that the outcrop data suggests that the laminites are regionally extensive and not the product of random mosaic shoals." (p655-6). | 4 unconnected sections/formation stretched out across ≈ 130-150 km, w/ outcrops ≤ a few hundred meters wide. | 1) Discusses & dismisses intrinsic mechanisms & episodic subsidence, prefering Milankovitchian eustasy.<br>2) See discussions by Kozar, et al., 1990 & Hardie, et al., 1991 |
| Mitchum, et al. 1977 (Model) | Modeled sequence-level intervals generally **10s to 100s m** thick; duration of **1-10 Ma.** | Those that are several 10s m thick, if continuous can be traced on seismic lines for 10s or 100s km. | Seismic data, well data, and model. | Can exist to finer sizes, ≤ meters & shorter time durations 100s Ka (p56-7). Oriented towards sequences, not parasequences. |

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| Osleger & Read, 1991. **(Upr Camb)** | **5th Order: 0.4 to 12.0 m & ave. ≈ 96 Ka.** Bundled 4:1 to make<br>**4th Order: 15-45 m & ave. ≈ 440 Ka.**<br>**3d Order: 220 m & ≈ 4.8 Ma.** | Correlates 5th Order, etc by Fischer plots from Utah to Appalachians. | Discontinuous outcrop in Appal. but "... cycles can be tracked as subparallel bands for many kilometers along the mtn flank & meter-scale deep subtidal cycles can be correlated between outcrops greater than 45 km apart (Fig. 5),..." (p1228) | 1) Age estimates ≈ 40 to 150 Ka, but with 50% error becomes ≈ 20 to 225 Ka.<br>2) Key Point is that his 5th Order cycles do not carry 1-to-1 on his Fischer plots. He explains this by 'missed beats' and amalgamated cycles. I would ascribe this to intrinsic influence at this scale while the similar overall curve shape does reflect the influence of eustatic events (i.e. we agree on this pt) at the coarser scale.<br>3) peritidal cycles basically limited by amt of accommodation space available, but subtidal cycles limited by sedimentation rates.<br>4) Argues that occurrence of both peritidal & subtidal cycles prohibits intrinsic mechanisms but I don't agree. |
| Posamentier, et al. 1988; Posamentier & Vail, 1988 (Conceptual model) | Doesn't discuss scale of cycles. However is focused on sequences & systems tracts. | Not stated. | 2D model. | 'Higher freq eustatic cycles may be associated w/ parasequence sets or parasequences.' (p122, 1988a). |

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| Van Wagoner, et al. 1987, 1988, 1990 (**Mesozoic & Cenozoic** examples) | 1990: **10 to a few 100s ft** thick (Table 1), 10s to a few 1000 sq mi of lateral extent, **$10^2$ to a few $10^4$ yrs** duration (Tbl 1). Parasequence surface: "... of local to basinal extent..." (p10) | 1990: **10s to a few 1000 sq mi** of lateral extent (Table 1). parasequence surface: "... of local to basinal extent..." (p10). "However, parasequence [PS] boundaries usually cannot be easily correlated regionally with widely spaced well control. For this reason, and because PS distribution is very sensitive to sediment supply, PS boundaries usually are not good surfaces for regional correlation of time & facies." (p13). e.g. PS 17 m thick, PS surface traced approximately 24 km in outcrop along depositional dip. parasequences 10 & 6 m thick, traced for approximately 19 km in outcrop along depositional dip (p13-15). Lateral facies changes w/in a PS & lateral terminations updip & downdip (p15). PS '... lose their identity basinward by thinning, shaling out, & downlapping accompanied by stratal thinning onto an older PS, PS set, or sequence boundary.' Correlated 10's mi down-dip before becoming unrecognizable (p15). | Continuous and discontinuous outcrop, well data, seismic data | 1) Deals w/ siliciclastics only, but much of general concepts applicable to carbonates. Parasequences originally defined in siliciclastics.<br>2) Mechanisms:<br>• delta-lobe switch;<br>• relative sea-level rise by subsidence;<br>• eustasy (p17 & p42). 5th-order cycles of eustasy (10's of Ka) (p42). Can be 4th-order (approximately 120 Ka) as well (p48, 1990). |
| **EXTRINSIC:** Tectonic, i.e. variable subsidence rates. | | | | |
| See also Goldhammer, et al., 1990; Hardie, et al., 1991. | | | | |

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| Aigner, 1984 **(Mid Triassic)** | Shoaling cycles **1 - 7 m** thick on carbonate ramp. **Average 3 m** thick. Duration: 80 m of rock for 5 Ma to give 'net accommodation/sed rate' = 16 cm/$10^4$ yr or ≈ **60-440 Ka/cycle or ave. ≈ 185 Ka/3-m cycle**. (p152)] | " ... correlated over several **10's of km** ..." (p139). " ... both parallel & oblique to strike ... ' (p141). Do have lateral change of facies & of shoaling cycle type (p139, 141). " ... seem to be caused by mechanisms that operate at least on a regional scale." (p139). Some "... cycles ... are traceable for at least **100 km across strike** and for **more than 250 km along strike**." (p147, referring to a German book). . | "... abundance of quarry sections, ... traced laterally & their facies changes examined across, ... several 10's of km." Possibly noncontinuous outcrop. | Compares w/ PACs but does not think all are basin-wide, due to local development & to cycle amalgamation. (p147-9, fig 11). Mechanism thought to be tectonic |
| Atwater, 1987 **(Holocene)** | **0.5-2.0 m**, w/ ≥ 6 events in 7000 yr for a recurrence interval for earthquakes of magnitude 8-9 of **≈ 1 Ka**. | Can cause subsidence over area ≤ **≈ 170 x 950 km**. | Field measurements. | Subsidence associated w/ great (magnitude 8 to 9) subduction earthquakes. |
| Cisne, 1986 **(Upr Triassic)** | **≈ 40 Ka** recurrence interval (duration) w/ displacements of a **few meters**. | ≤ **≈ 100 km**, w/ Lofer cycles in the Dachstein **≈ 20 km**. | Model w/ Lofer cycles as example. | 1) Stick-slip faulting as the driving mechanism coupled w/ continuous sea level rise.<br>2) See also Fischer, 1964 & Goldhammer, et al., 1990. |
| Cloetingh, et al. 1985; , 1986 (Model) | Doesn't refer to thicknesses of deposits, rather just talks about sea level fluctuations. 1986: Sea level fluctuations of **10'S m** over **millions of yrs** (p617). 1985: **100 - 200 m** over $10^6$ - $10^7$ **yrs** | 1986: No mention of lateral extent. 1985: Lateral extents of approximately **150 km**. | Model & measurement of intraplate stress. | |
| Karner 1986 (Model) | **10 - 100 m** of vertical motion. 2[d] to 5[th] order sea level changes. | Basin widths of **100 km** or **greater**. | Model & measurement of intraplate stress. | Looking at 2[d] & 3[d]-order Vail sequences, & may also explain PACs (p581) & 4[th]/5[th] order cycles (p581). |
| Palmer and Halley, 1979; Halley, 1975 **(Lwr & Mid Camb)** | 1975: Dealt w/ Grand Cycles (**approximately 100 m**) only & did not discuss duration. | over **10's km**, in thicker grouping than this paper. 1975: Describes facies distribution as "complex mosaic" & states that bank had localized shoaling to form offshore carbonate islands (p287). | Mostly section to section correlation w/o walking intervening terrane. | Prefers variable subsidence rate. |

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| Pitman, 1978 (Model) | Dealt w/ sea-level change on duration of **$10^7$ yrs**, i.e. $2^{nd}/3^{d}$-order cycles. | Eustatic. | Model. | Relates sea-level change to changes in spreading rates (volumes) of mid-ocean ridges. |

**TABLE 6. (END)**

of sediment influx into a basin. These sorts of stable intrinsic processes may result in either laterally continuous facies and parasequences, e.g., offshore, shoreface, and foreshore facies on a wave-dominated shoreline, or may produce laterally discontinuous facies, e.g., channelized deposits or tidal islands. Some intrinsic processes are commonly localized in their effects on a depositional system in both time and areal extent. Localized processes may be responsible for many lateral facies changes and for short lateral extent of parasequence boundaries, and would include storm accumulations, preferential accumulations of coarser-grained and finer-grained components by tidal or other currents, influence of relict topography on subsequent sedimentation (Boss et al., 1991; Rasmussen et al., 1991), or biological control on facies. Many localized processes operate on time spans shorter than the duration of fifth-order cycles.

Several models are listed in Table 6, including one of the earliest, Ginsburg's (1971) tidal-flat "carbonate factory" model. All models listed involve changes in sediment production rates, a time lag in sediment production, and continuous subsidence. The two most commonly invoked intrinsic models for carbonate shelf depositional systems are Ginsburg's tidal flat/carbonate factory model (Ginsburg, 1971; Hardie and Shinn, 1986) and Pratt and James' (1986) tidal island model. Ginsburg's tidal flat/carbonate factory model may produce laterally extensive facies and parasequences if the flat is sufficiently large. Pratt and James' (1986) tidal island model was developed as an alternative to Ginsburg's to explain discontinuous facies and shoaling cycles in the rock record. A localized intrinsic process like the tidal island model removes the problem of having to prograde tidal flats hundreds of kilometers in 10-40 Ka (Koerschner and Read, 1989; Koerschner and Read, 1990) by substituting numerous small peritidal shoal complexes for a single large one.

Drummond and Wilkinson (1993) have developed a one-dimensional computer model of an intrinsic process on a carbonate shelf dependent on amplitude of the sea-level cycle, sedimentation rate, and subsidence rate. The model can produce more than one shallowing-upward, meter-scale carbonate cycle per sea-level cycle. The sea-level period (100 Ka) is held constant on all runs of their model, but when more than one sedimentary cycle is produced the apparent period of that sedimentary cycle is in the range of fifth-order cycles ($10^4$ years). Because of the dependence on subsidence rate, the number of sedimentary cycles produced during one sea-level cycle may vary along the dip direction of a shelf. This is shown in their Figure 7, a compilation of several one-dimensional runs that vary only by subsidence rate, and are used to simulate deposition down depositional dip along a shelf. Their one-dimensional model produces a mix of laterally continuous and laterally discontinuous meter-scale cycles somewhat analogous to the Carrara.

## EXTRINSIC PROCESSES

An extrinsic process is any influence on a depositional system that is external to and independent of the depositional system. Extrinsic processes may exert a short-term, episodic influence, e.g., episodic subsidence (Aigner, 1984; Atwater, 1987; Cisne, 1986; Karner, 1986), or they may exert influence throughout the duration of the cycle, e.g., eustatic cycles with Milankovitch frequencies (Fischer, 1964; Fischer, 1982; Goldhammer et al., 1987; Goldhammer et al., 1990; Goldhammer et al., 1991; Grotzinger, 1986a; Grotzinger, 1986c; Koerschner and Read, 1989; Osleger, 1991; Osleger and Read, 1991; Read et al., 1986).

Variation in eustatic sea level or in subsidence rates are the most commonly invoked extrinsic controls on facies and cycle development, and are summarized in Table 6. Eustatic sea-level fluctuations are usually modeled as driven by glacial or climatic mechanisms, commonly with Milankovitch orbital forcing frequencies (Fischer, 1964; Fischer, 1982; Goldhammer et al., 1987; Goldhammer et al., 1990; Goldhammer et al., 1991; Grotzinger, 1986a; Grotzinger, 1986c; Koerschner and Read, 1989; Osleger, 1991; Osleger and Read, 1991; Read et al., 1986). Variation in rates of tectonic subsidence and uplift have recently been modeled as resulting from intraplate stress (Atwater, 1987; Cloetingh, 1986; Cloetingh et al., 1985; Karner, 1986) or stick-slip faulting (Cisne, 1986). No new extrinsic controls on sedimentation and stratigraphy are proposed here. In general, the influence of any of these processes is likely to be widespread and of long duration in a depositional system, producing laterally extensive facies and parasequences whenever extrinsic processes dominate. However, Goldhammer et al. (1990) have modeled late Pleistocene eustasy and shown that certain configurations of composite eustatic signals may produce laterally discontinuous facies and cycles. This is discussed in more detail later in the section "Holocene/Pleistocene Mosaic Facies Patterns".

## SIMULTANEOUS OPERATION OF INTRINSIC AND EXTRINSIC MECHANISMS

Intrinsic processes may operate simultaneously with extrinsic processes and may occasionally dominate over long-term extrinsic processes in an area, resulting in occasional deposition of laterally discontinuous facies and parasequences within a group of laterally continuous facies and parasequences (Boardman and Heckel, 1989; Brett and Baird, 1986; Busch and Rollins, 1984; Goldhammer et al., 1990; Goldhammer et al., 1993; Heckel, 1986; Irwin, 1965; Osleger, 1991; Strasser, 1988). In the case of meter-scale parasequences, it is likely that intrinsic and extrinsic processes operate simultaneously and either may be the dominant control on deposition in an area. Localized intrinsic processes operate on short time frames, producing discontinuous parasequences within intervals of continuous or discontinuous parasequences. An example of this, though in siliciclastics, is the development by intrinsic processes of 16 lobes in the Mississippi Delta over the past 6000 years (Frazier, 1967). This has occurred during a period of constant sea-level rise that is on the scale of a fifth-order extrinsic cycle. In the rock record, each lobe would be interpreted as a single intrinsically driven, laterally discontinuous sixth-order parasequence that represents a shorter time duration than does the enveloping fifth-order parasequence set. For carbonate sediments, the tidal island model of Pratt and James (1986), or any other intrinsic mechanism that could form localized shoaling, should operate during basinwide or greater sea-level change at the parasequence scale, and would probably operate at a shorter time scale. Goldhammer et al. (1993) have described and modeled Lower Ordovician platform carbonates that are composed of third-order to fifth-order cycles. They have used computer modeling and time-series analysis to develop an approximation of their outcrops using eustatic and tectonic controls on second-order and third-order cycles, and mix of eustatic and intrinsic processes on fourth-order and fifth-order cycles.

## IS THE DETERMINATION OF AN INTRINSIC VERSUS AN EXTRINSIC MECHANISM DEPENDENT ON THE PERCEIVED CORRELATABILITY OF CYCLES?

Table 6 indicates that in general, cycles that are not considered to be correlative are assigned intrinsic depositional mechanisms and, if correlatable, then extrinsic mechanisms are invoked. This is most clear in studies, listed in the "Extrinsic w/ Intrinsic Influence" section of Table 6, which argue that the dominant controlling mechanism is extrinsic, but that occasional cycles, laterally discontinuous and often thinner, are the result of intrinsic processes. This same inference is also made in this chapter. There are several exceptions to this "rule of thumb". Ginsburg (1971, 1982) stated that there may be continuous bands of subenvironments developed by his intrinsically driven carbonate-factory model. Demicco and Mitchell (1982) invoked Ginsburg's model and described a "layer-cake" correlatability to their parasequences. Several studies and models recognize a lack of correlatability for some or all of their cycles, but still propose extrinsic mechanisms for cycle formation (Table 6: Aigner, 1984; Bechstädt and Schweizer, 1991; Bertrand-Sarfati and Moussine-Pouchkine, 1988; Borer and Harris, 1991; Bova and Read, 1987; Elrick and Read, 1991; Goldhammer et al., 1990).

Determination of whether formation of an individual parasequence and its bounding parasequence surface was controlled by intrinsic or extrinsic mechanisms may be inferred by deciphering the lateral extent of the parasequence bounding surfaces through correlation. This situation in peritidal carbonates is analogous to distinguishing between a deltaic parasequence (delta lobe) and its bounding surfaces caused by eustatic change (extrinsic process) from one caused by fluvial avulsion (intrinsic process). The surfaces formed by an extrinsic process should extend over an area greater than the lobe, whereas the bounding surfaces formed by an intrinsic process should coincide with the lobe. Unfortunately, because determination of lateral continuity is commonly limited by outcrop quality, in most instances this cannot be proven. Laterally discontinuous parasequences may be the result of intrinsic processes or of composite eustasy similar to that found during the late Pleistocene.

## HOLOCENE/PLEISTOCENE MOSAIC FACIES PATTERNS

Workers in Quaternary carbonate environments have long recognized mosaic-like areal distributions of facies in a variety of depositional settings (Enos and Perkins, 1979; Hardie and Garrett, 1977; Roberts et al., 1977). Models have been advanced for and against the premise that modern mosaics will lead to mosaic facies patterns in the rock record. Arguments for a resultant sheetlike pattern of distribution include: 1) some facies, e.g., channels in tidal flats, migrate laterally over broad areas and rework those areas leaving behind little or no trace of other facies; 2) much information in Holocene sediments that allows specification of numerous facies will not be recognized in the preserved record, causing many modern facies to be grouped together in the rock record producing a sheetlike facies. The opposite point of view states that Holocene facies mosaics will be preserved as recognizable lithofacies mosaics (Evans, 1984; Harris, 1984). It is likely that at different times and places both end-member views can be found to be applicable.

Mosaic distributions of facies do not allow a definitive decision as to whether small-scale cyclicity is controlled by intrinsic or extrinsic processes. Pleistocene and Holocene facies mosaics have formed under conditions of large-scale eustatic change, e.g., in the range of 80-150 m fluctuations (Matthews, 1984), and therefore the presence of mosaics in the rock record does not rule out the possibility of a dominant extrinsic control during deposition. In an attempt to understand why the distinct patterns of eustatically controlled cycles in the Triassic Latemar Formation (Goldhammer et al., 1987) are exceptional in the rock record, Goldhammer et al. (1990) modeled distributions of facies, cycles, and cycle boundaries that are similar to those of upper Pleistocene deposits in south Florida using composite eustatic fluctuations. They found that there is a critical difference when amplitudes of fourth-order sea-level fluctuation ($10^5$ years duration) are greater than those of third and fifth-order sea-level fluctuation ($10^6$ and $10^4$ years), allowing the fourth-order signal to dominate. Such a configuration of composite eustasy is characteristic of the upper Pleistocene. This situation is in marked contrast with the eustatic configuration thought to be characteristic of the Triassic during deposition of the Latemar Formation (Goldhammer et al., 1987), when amplitudes of third-order cycles were greater than those of fourth and fifth-order cycles, allowing the third-order signal to dominate. The principal reason for the difference in configuration of composite eustasy between the Pleistocene and the Triassic is that the Pleistocene was a time of waxing and waning of large-scale continental glaciation, whereas the Triassic was not.

Modeling by Goldhammer et al. (1990) shows that a dominant 100 Ka signal tends to produce more of a mosaic of cycles and facies with less widespread lateral continuity similar to the upper Pleistocene. Fifth-order cycles that result from dominant eustatic 20-40 Ka sea-level fluctuations (nonglacial periods) should generally be laterally continuous, at least in a depositional strike direction (lateral facies changes within cycle boundaries may be present). In contrast, fifth-order cycles that are embedded in a mosaic geometry resulting from dominant 100 Ka fluctuations (glacial periods) may not be laterally continuous and may not be readily recognizable, in part because many fifth-order cycles are not deposited ("missed beats" of Goldhammer et al., 1990).

Fourth-order cycles are generally more laterally continuous, whether they are comprised of meter-scale, fifth-order cycles (nonglacial periods) (Bechstädt and Schweizer, 1991; Strasser, 1988) or are individual meter-scale (or thicker) cycles, e.g., cyclothems (glacial periods) (Boardman and Heckel, 1989; Borer and Harris, 1991; Connolly and Stanton, 1992; Elrick and Read, 1991; Goldhammer et al., 1991; Heckel, 1986). Perhaps fourth-order cycles are more "buffered" against the vagaries of localized intrinsic processes, i.e., can incorporate them without loss of lateral continuity, because of the much shorter duration of intrinsic processes.

## APPLICATION TO THE CARRARA

In the Carrara there are both laterally continuous and laterally discontinuous cycles and facies: any given subtidal or intertidal facies, or fifth-order shoaling cycle (parasequence), with thickness of 1-20 m, may extend laterally for distances as short as a hundred meters or as long as a few tens of kilometers in a strike direction. Similar observations of localized facies and shoaling cycles have been reported in other areas

(Pratt and James, 1986; Sargeant, 1975; Wong and Oldershaw, 1980). This contrasts with other studies of peritidal carbonate facies in which facies belts and cycles have been correlated for tens to hundreds of kilometers (Aigner, 1984; Goodwin and Anderson, 1985; Grotzinger, 1986a; Grotzinger, 1986b).

Unpublished work of the author, as well as work of Bates (1965) and Palmer and Halley (1979) has shown that larger-scale units (Palmer and Halley's (1979) members) in the Carrara, some of which may be described as overall fourth-order shoaling cycles (parasequence sets and systems tracts), can be correlated with a high degree of confidence over tens to hundreds of kilometers. The entire 35-to-50-m thick interval discussed in detail in this chapter forms one of these larger fourth-order shoaling cycles, and it can be correlated throughout most of the approximate 36,000 $km^2$ of the Carrara outcrop belt. Sequence-stratigraphic analysis and correlation of the entire Carrara Formation indicate that parasequence sets (fourth-order cycles), systems tracts (fourth-order cycles), and sequences (third-order cycles) are laterally extensive (Plates 1-4). Therefore in the Carrara different scales of cyclicity have different ranges of lateral continuity; fourth-order cycles have longer lateral continuity and can be correlated with greater confidence, whereas fifth-order cycles may have shorter lateral continuity and can be correlated with less confidence.

At Eagle Mountain, within the 1.8 km interval of nearly continuously exposed outcrop, intertidal facies have been shown to interfinger laterally with subtidal facies. This type of lateral change is predicted by Koerschner and Read (1990) to develop if local intrinsic processes are responsible for mosaic patterns of facies and cycles. Most of the intervals of peritidal facies capping fifth-order shoaling cycles are not laterally continuous across the Eagle Mountain outcrop, and correlation of these intervals to adjacent ranges indicates that most cannot be correlated across all ranges. The pattern of mixed laterally continuous and laterally discontinuous facies and cycles documented at Eagle Mountain can be applied to correlations between adjacent ranges.

## INTERPRETATION

The Carrara Formation contains a mosaic of laterally continuous and discontinuous fifth-order cycles. This mosaic can be interpreted in at least three ways: (1) It is the result solely of a dominant 100 Ka eustatic signal (extrinsic process) such was present in the upper Pleistocene. (2) It may be a response to the shelf-wide intrinsic process modeled by Drummond and Wilkinson (1993). (3) It may represent a mix of extrinsic processes to account for the laterally continuous cycles, with occasional local intrinsic processes producing interspersed, laterally discontinuous cycles. The first interpretation is not reasonable because there are no glacial periods recorded during deposition of the Carrara (Frakes et al., 1992). It is not possible to distinguish the Drummond and Wilkinson (1993) model from the third interpretation at this time. The third interpretation is favored because it encompasses both local intrinsic processes and more widespread intrinsic and extrinsic processes, it explains why most fifth-order cycles are continuous, and lateral transitions can be seen between intertidal and subtidal facies in some of the discontinuous cycles, as might be expected with the operation of local intrinsic processes (Koerschner and Read, 1990, p. 795). Examples of more continuous fifth-order parasequences include Parasequences I, III, IV, and V shown on both cross sections (Figures 7 and 10). Parasequence Boundaries I, III, IV, V, and VI are laterally continuous across most or all of the regional cross section. Note that Parasequence II merges with Parasequence I south of Section 2 on the regional cross section (Figure 10) and that north of Section B on the Eagle Mountain cross section (Figure 7) Parasequence V merges with Parasequence IV due to the termination of a recognizable surface for Parasequence Boundary V. However, correlations from range to range have a moderate degree of uncertainty, with the exceptions of Parasequence Boundaries I and VI, which between them define and bound an overall fourth-order shoaling cycle of 40-50 m, i.e., a parasequence set. Examples of laterally discontinuous parasequence boundaries include boundaries A, B, and C in the Eagle Mountain cross section, and boundaries D, E, F, G, and H in Sections 3 and 6 of the regional cross section.

Although the tidal island model (Pratt and James, 1986) does not fit the Carrara exactly, it provides a reasonable general mechanism to explain laterally discontinuous, fifth-order, peritidal parasequences. The observed disjunct distribution of intertidal deposits in the Carrara can be accounted for by a series of peritidal islands distributed along the course of the outer carbonate bank. Local intrinsic processes also explain the observed lateral change from intertidal facies to subtidal facies demonstrated at Eagle Mountain. It is likely that the tidal island mechanism was operating simultaneously with extrinsic processes during Carrara deposition.

Fourth-order cycles (parasequence sets and systems tracts) and third-order cycles (sequences) can be correlated across much of the areal extent of the Carrara (Plates 1-4). This greater continuity of lower-order cycles is interpreted to be due to the long-term dominance of extrinsic processes. Thicker intervals in the Carrara, representing dominance of longer-term extrinsic processes (third-order and fourth-order cycles), are composed of thinner facies units and parasequences (fifth-order cycles) produced by both intrinsic and extrinsic process. Aitken's (1978) revised study of Canadian Grand Cycles noted this possibility and suggested that extrinsic processes may be expressed at a coarser scale than are intrinsic processes. The Carrara demonstrates that at the 1-to-

20-m scale of fifth-order parasequence development, both intrinsic and extrinsic processes may impress themselves upon the depositional and stratigraphic record.

## SPECULATION REGARDING LATERAL CONTINUITY AND DURATION OF METER-SCALE CYCLES

If most localized intrinsic processes operate on time scales of $10^3$ to $10^4$ years and are the main cause of discontinuous facies and meter-scale cycles in nonglacial periods, then localized intrinsic processes may not be recognizable in fourth-order meter-scale cycles. However, such processes may be recognizable fifth-order meter-scale cycles. Groups of fifth-order meter-scale cycles may form mosaics of laterally continuous and laterally discontinuous facies and fifth-order cycles arranged into fourth-order cycles. It is suggested that 1-to-20-m thick parasequences with durations of approximately $10^5$ years, i.e., fourth-order cycles, are laterally continuous because of the interaction between long duration and thickness. Fourth-order meter-scale cycles may not record short-term ($10^3$ to $10^4$ years) events recognizably because of the small net thickness of sediment, several centimeters to a few tens of centimeters, that can be preserved in $10^3$ to $10^4$ years. In contrast, the fourth-order cycles of the Carrara are several tens of meters thick and recognizably record a mosaic of laterally continuous and discontinuous facies and fifth-order meter-scale cycles. Carrara meter-scale parasequences with durations of approximately $10^4$ years, i.e., fifth-order cycles, are more likely to record processes on time scales of $10^3$ to $10^4$ years recognizably. This is because of the greater net thickness of sediment, several tens of centimeters to a few meters, that can be preserved in $10^3$ to $10^4$ years. Another way to express this is that the Carrara acted as a high-speed strip-chart recorder that was able to record far more detail about short-term stratigraphic events.

A general test of the hypothesis that most fourth-order cycles (100 Ka to 1 Ma duration) are laterally continuous regardless of thickness and that fifth-order cycles may be either laterally continuous or discontinuous can be made. However, to test this hypothesis a study must resolve the duration of cycles, record cycle thicknesses, and correlate cycles and facies laterally. Although many studies have been made on cyclicity (see Table 6 for a partial listing), most have not noted all three of these characteristics. Several studies in Table 6 have discussed these points, and a very brief summary of these papers, in the same order they are entered in Table 6, is presented in Table 7. As can be seen in Table 7, there is a definite trend to support the hypothesis that the duration of a meter-scale cycle correlates with its lateral continuity.

**Table 7.** A summary of papers dealing with meter-scale cycles, each of which includes information on duration, thickness and lateral continuity. The table is broken into three parts based on duration: 1) cycles of greater than 100 k.y. duration; 2) cycles of 65-100 k.y. duration; and 3) cycles of less than 50 k.y. duration. The breakdown emphasizes the difference in lateral continuity between cycles of less than 50 k.y. duration and of greater than 100 k.y. duration. The papers listed in this table are included in Table 6. Grotzinger (1986a, c) calculated that Rocknest meter-scale cycles had durations in the range of 18-51 k.y., i.e., fifth-order cycles. However, acquisition of additional U-Pb zircon ages in the Wopmay orogen ([Bowring, 1992 #301]) has led Grotzinger to revise his cycle durations to approximately 72-120 k.y. or greater (Grotzinger, personal communication, 1993). Hence the 1-to-20-m thick cycles of the Rocknest are now thought to be fourth-order cycles.

**Table 7.**

**DURATIONS GREATER THAN 100 K.Y.**

| STUDY | DURATION | THICKNESS | CORRELATABILITY |
|---|---|---|---|
| Brett and Baird, 1986 (Middle Devonian) | 400 to 500 k.y. | 3 to 20 m | Traced tens of km along strike, with abrupt changes perpendicular to strike, likely that **cycles extend basinwide**. |
| ditto | 100 to 225 k.y. | 0.5 to 3 m | ditto |
| Busch and Rollins, 1984 (Pennsylvanian) | 400 k.y. | 5 to 30 m | Correlated over **200 x 240 km.** |
| Boardman and Heckel, 1989; Heckel, 1986 (Middle to Upper Pennsylvanian) | 145-218 k.y. | Cycle **thickness not given** | 71% of cycles correlated **600 km.** |
| Strasser, 1988 (Lower Cretaceous) | 400 k.y. | 1 to 30 m | Correlated over **200 km.** |
| Bechstädt and Schweizer, 1991 (Upper Triassic) | 250 k.y. | 1.5 to ≤ 20 m | Can be correlated throughout **100 x 500 km** study area. |
| Borer and Harris, 1991 (Upper Permian) | 400 k.y. | typically 30 m | Relatively continuous **along strike (200 km)** but have **updip terminations over 15-30 km.** |
| Connolly and Stanton, 1992 (Middle to Upper Pennsylvanian) | 352 k.y. | 4 to 7.5 m | 71% correlated for **1500 km** & 87% correlated for 50 km. |
| Goldhammer et al., 1991 (Middle Pennsylvanian) | 138 to 345 k.y. | Average 30 m | Correlated **> 110 km.** |
| Osleger and Read, 1991 (Upper Cambrian) | 440 k.y. | 15 to 45 m | Correlates from Utah to Virginia, **approximately 2800 km.** |
| Aigner, 1984 (Middle Triassic) | Average of 60 Ka per meter of rock, to give range of **60 to 440 k.y.** for cycles | 1 to 7 m | Correlated some cycles **≥ 250 km parallel to strike** and **≥ 100 km perpendicular to strike.** |

Table 7. (End)

DURATIONS BETWEEN 65 AND 100 K.Y.

| STUDY | DURATION | THICKNESS | CORRELATABILITY |
|---|---|---|---|
| Strasser, 1988 (Lower Cretaceous) | 100 k.y. | ditto | Correlated over 200 km. |
| Borer and Harris, 1991 (Upper Permian) | 100 k.y. | 2 to 9.2 m | Relatively continuous along strike (200 km) but have updip terminations over 15-30 km. |
| Anderson and Goodwin, 1990; Goodwin and Anderson, 1985; Goodwin and Anderson, 1988 (Upper Silurian to Lower Devonian) | 80 k.y.(1985), $10^4$ years (1988), $10^4$ to $10^5$ years (1990) | Average ≤ 1 to 5 m | Correlated over ≥ 300 km. |
| Bowring and Grotzinger, 1992; Grotzinger, 1986a; Grotzinger, 1986b; Grotzinger, 1986c (Proterozoic, 1.9 Ga) | 72 to 120 k.y. or greater duration | 1 to 15 m | Correlated along strike for ≥ 200 km and perpendicular to strike for ≥ 120 km. |
| Koerschner and Read, 1989 (Middle to Upper Cambrian) | Average 65 k.y. duration | 1 to 7 m thick | Much debate regarding the continuity of cycles, cf. Kozar et al., 1990. |
| Osleger and Read, 1991 (Upper Cambrian) | 96 k.y. | 0.4 to 12 m | approximately 2800 km, but 96 Ka cycles do not correlate one-to-one. |

DURATIONS LESS THAN 50 K.Y.

| STUDY | DURATION | THICKNESS | CORRELATABILITY |
|---|---|---|---|
| Strasser, 1988 (Lower Cretaceous) | 20 k.y. | 0.2 to 1.5 m | Don't always correlate well, may reflect localized intrinsic processes. |
| Bechstädt and Schweizer, 1991 (Upper Triassic) | 5th-order cycles, duration not given | 0.5 to 8 m | Correlated only a few km. |
| Borer and Harris, 1991 (Upper Permian) | 20-40 k.y. | ≤ 2 m | Do not correlate well. |
| Elrick and Read, 1991 (Lower Mississippian) | 30-110 k.y. duration, fifth-order | 0.3 to 10 m | Number and type of cycle vary updip and downdip over < 30 km. |
| Goldhammer et al., 1991 (Middle Pennsylvanian) | 15 to 38 k.y. | Average 6.1 m | "... are apparently regionally correlative, ...". |

## SUMMARY

The 40 to 50 m thick interval of the upper half of the Jangle Limestone Member of the Carrara Formation has been shown to be made up of subtidal and intertidal carbonate facies arranged into shoaling-upward fifth-order cycles that together make up an overall shoaling fourth-order cycle. Markov analysis applied to the facies data shows that there are several possible preferred vertical successions of groups of subtidal facies within fifth-order parasequences but cannot resolve any preferred vertical successions of individual facies, probably due to an insufficient number of facies transitions in the data set composed of individual facies. Parasequence boundaries, defined as surfaces that record abrupt, small-scale flooding events, must be identified and recorded as one of the possible states used in Markov analysis. In addition, their recognition is crucial in delineating fifth-order parasequences and in defining a sequence-stratigraphic interpretation. Parasequence surfaces in the Carrara are commonly sharp and often scoured, have few hardgrounds preserved along them, in some cases are marked by oncolites with digitate microbial growths or by thrombolites growing off of them, and separate shallower-water facies below from deeper-water facies above, including subtidal over intertidal facies and the subtler cases of deeper subtidal over shallower subtidal facies or lower-intertidal over higher-intertidal facies.

Detailed lateral correlations between nine stratigraphic sections measured in 1.8 km of nearly continuously exposed outcrop at Eagle Mountain have shown that facies and fifth-order parasequences form both laterally continuous and laterally discontinuous units. The laterally continuous facies and parasequences extend across the entire 1.8 km outcrop and can be correlated a few tens of kilometers to other ranges. The discontinuous facies and parasequences may be as short as a few hundred meters. This pattern of a mosaic of mixed continuous and discontinuous cycles is also seen in the regional cross section made up of six stratigraphic sections distributed across a trend subparallel to depositional strike, extending approximately 55 km (approximately 45 km palinspastically restored). The lateral transition from intertidal facies to subtidal facies that is well exposed at Eagle Mountain indicates that, for at least some of the laterally discontinuous cycles, localized intrinsic processes are probably the mechanism responsible for their formation (Koerschner and Read, 1990). The tidal island model (Pratt and James, 1986) is a reasonable intrinsic mechanism for these laterally discontinuous peritidal fifth-order cycles.

Any one of three different general models can explain the mix of continuous and discontinuous fifth-order cycles: (1) The mosaic is solely the result of a composite eustatic signal dominated by the large amplitude of the fourth-order period. (2) The mosaic is the result of the widespread intrinsically driven model of Drummond and Wilkinson (1993). (3) The mosaic is a result of occasional short-term, localized intrinsic processes superimposed on persistent, longer-term, and more widespread extrinsic processes. The third model is preferred because it encompasses the lateral continuity of third-order and fourth-order parasequence sets, systems tracts, and sequences seen in the Carrara as well as the tidal-island-type discontinuous parasequences, as demonstrated at Eagle Mountain.

It is proposed that Carrara fifth-order meter-scale cycles may record short-duration ($10^3$ to $10^4$ year), localized intrinsic processes that cause discontinuous meter-scale cycles and facies, whereas fourth-order meter-scale cycles with durations of $10^5$ years cannot record such short-term processes recognizably. Examination of lateral continuity of fourth-order cycles in the Carrara (parasequence sets and members, tens of meters thick) reveals that these cycles can be correlated for over 110 km in a strike direction and for over 200 km perpendicular to strike. This lateral persistence of fourth-order cycles is thought to reflect a dominant influence of long-term extrinsic processes, perhaps 100 Ka and 400 Ka Milankovitch orbital cycles or some unknown tectonic process that operates on this time span. Examination of similar studies in the literature indicates that these relationships can be applied to many different formations and are not unique to the Carrara.

# CHAPTER 5: SEQUENCE-STRATIGRAPHIC MODEL OF GRAND CYCLES

## INTRODUCTION

### FORMULATION OF THE PROBLEM

Clarification and understanding of the depositional geometries within and between Grand Cycles provide constraints on the mechanisms that control accommodation and sediment supply. In most stratigraphic studies made at any scale, it is difficult to separate tectonic influence from eustatic influence with respect to the lateral and vertical arrangement of facies and cycles. Because of this the contributions of tectonics and eustasy are commonly combined and are termed "accommodation" (Jervey, 1988; Posamentier et al., 1988; Posamentier and Vail, 1988). Accommodation is the amount of vertical space available below sea level in which to deposit sediments, and accommodation may be added to or removed. The lateral and vertical arrangement of facies and cycles reflects the interplay through time between changes in rate of accommodation and changes in rate of sediment supply.

With Grand Cycles, there is the added complication of two sediment sources, one carbonate and the other siliciclastic, separated geographically along depositional dip. The two sediment sources respond through time in different ways to changes in accommodation and to each other. This chapter briefly reviews the four major controls on deposition, presents Carrara isopach data, reviews previous work on Grand Cycles, develops a sequence-stratigraphic model of Grand Cycle formation in terms of the interplay between changes in rate of accommodation and changes in rates of sediment supply from a carbonate sediment source and a siliciclastic sediment source, provides a detailed description of lateral and vertical distribution of lithofacies groups within Carrara Grand Cycles, and applies the new model to Carrara Grand Cycles.

### OVERVIEW OF FOUR MAJOR CONTROLS ON DEPOSITION OF THE CARRARA FORMATION

#### Climate

The influence of climate on shallow-marine stratigraphy and sedimentation is widely recognized (Berger et al., 1984; Duff et al., 1967; Einsele et al., 1991; James, 1984; Tucker and Wright, 1990). However, studies of cause-and-effect relationships between climate and shallow-marine stratigraphy and sedimentation either cover specific aspects of the relationships and produce results that are relatively restricted (Hardie, 1977; Koltermann and Gorelick, 1992), or have been generalized and relatively nonspecific (Dalrymple et al., 1985; Drewry et al., 1974; Lees, 1975; Lees and Buller, 1972). Climatic effects, aside from development of ice ages, that may influence carbonate and siliciclastic sedimentation include fluctuations between wet and dry climates, warm and cool mean annual temperatures, and variations in strength and duration of winds. Increase in precipitation may increase siliciclastic sediment flux into the shallow-marine environment and thereby dilute carbonate sedimentation (Gardulski et al., 1986; Roof et al., 1991) and/or decrease carbonate production by lowering salinity of lagoonal waters (Lees, 1975; Lees and Buller, 1972). Warmer climates may increase carbonate productivity (Lees, 1975; Lees and Buller, 1972), but may also increase weathering rates on the craton and thereby increase siliciclastic flux (Koltermann and Gorelick, 1992). A change to a warm and wet climate would likely have a different impact on a mixed carbonate-siliciclastic depositional system than would a change to a warm and dry climate, but whether either change would favor carbonate production over siliciclastic flux is an open question. Changes in wind strength and duration would affect carbonate lithofacies and depositional patterns (Hine and Neumann, 1977) but could also deliver variable quantities fine-grained siliciclastics into an area of mixed carbonate and siliciclastic deposition (Dalrymple et al., 1985; Drewry et al., 1974). In short, there is little hard data to relate a particular climatic effect to a specific response in stratigraphy/sedimentation. For any of these climatic changes to affect Carrara Grand Cycles, they must operate over time durations from approximately $10^4$ to $10^6$ years, i.e., over durations that would affect sedimentation patterns at the scale of both meter-scale cycles and Grand Cycles (see discussion of cycle duration below).

One aspect of the influence of climate on sedimentology that has been well studied is the Milankovitch signature in Pleistocene deposits (Berger et al., 1984; Hays et al., 1976). Alternation of glacial/interglacial periods occurred at Milankovitch frequencies (Hays et al., 1976), and it has been hypothesized (Hays et al., 1976; Roof et al., 1991) that changes in the earth's insolation caused by orbital perturbations (Milankovitch cycles) have had a major affect on the climate. There has been much disagreement as to how orbital perturbations specifically affect climate. Hays et al. (1976) made the assumption that the geological record is the "output" of the climate system, and successfully performed mathematical analyses that recognized Milankovitch frequencies in that "output". Hence, it has been demonstrated that climate reacts at Milankovitch frequencies during times of widespread glaciation and climate cannot be ruled out as a possible cause of cyclic sedimentation. This is especially so for meter-scale (1 to 20 m) cycles because these have been shown by Algeo and Wilkinson (1988) to have probable durations in the range of Milankovitch frequencies from approximately 20 k.y to 400 k.y. However, there is much disagreement about the specific responses of climate to orbital perturbations; e.g., Berger et al. (1992; p. 561-2) state that "... a considerable amount of the climatic variance is driven *in some way* by insolation changes brought about by changes in the earth's orbit" [italics added for emphasis]. In addition, there is also little agreement regarding how sedimentation responds to a given climatic change, e.g., "... suitable mechanisms for coupling variation in ... insolation to sedimentation changes are difficult to find" (Berger, et al, 1992, p. 562). Hence, it is not possible at this time to model climatic fluctuations and the response of stratigraphy and sedimentation to account for the alternation of carbonates and siliciclastics in the Carrara at the level of either meter-scale cycles or Grand Cycles. The climatic influence may be indirectly accounted for in sediment flux at all times and in eustatic fluctuations during glacial epochs. Witzke (1990) stated that the general climate for the region of Carrara deposition during the Cambrian was a zone of probable warm, arid climate. Paleosols in the Pahrump Hills Member of the Carrara only indicate repeated wetting and drying of the soil which does not contradict the general statement of Witzke (1990).

**Tectonics**

Episodic pulses of tectonic subsidence or uplift occurring on a time scale of approximately $10^5$ to $10^6$ years over distances on the scale of continental passive margins may be invoked to explain cyclicity on the scale of Cambrian Grand Cycles. Episodic tectonic pulses may be responsible for changing rates of siliciclastic sediment influx, producing periods of high influx (siliciclastics dominate) alternating with periods of low siliciclastic influx (carbonates dominate). The nature of the tectonic pulses might be periodic subsidence of the shelf, uplift of the siliciclastic source area, or tilting of the craton with simultaneous subsidence of the shelf and uplift of the source terrane. However, the tectonic setting of the Carrara is a mature passive margin (Stewart, 1970; Stewart, 1991; Stewart and Suczek, 1977) and geophysical modeling (R1 and R2 analysis) indicates that subsidence followed an exponential decay pathway, characteristic of dominance by thermal subsidence (Bond and Kominz, 1984; Bond et al., 1988; Bond et al., 1989; Levy and Christie-Blick, 1991), rather than episodic subsidence. Earlier Grand Cycle correlations (Palmer, 1981b) have suggested that many of the Cambrian Grand Cycles can be correlated around North America. R2 analyses performed on coeval Grand Cycles in the Southern Canadian Rockies, the Great Basin, and Virginia and Tennessee (Bond et al., 1988; Bond et al., 1989) have also suggested synchroneity of Grand Cycles. Further, Bond et al. (1988, 1989) suggested that third-order eustatic fluctuations might be the most plausible mechanism, though tectonic mechanisms were not ruled out. A tectonic mechanism must be able to provide fluctuations in subsidence rate with a duration of approximately $10^5$ to $10^6$ years, with a vertical scale of approximately 10 to 100 m, and be essentially coeval on both sides of the North American craton to explain successfully the observed characteristics and correlations of Grand Cycles.

Horizontal lithospheric stresses have been modeled to produce vertical movements of approximately 10 to 100 m over durations of a few million years (Cloetingh, 1986; Cloetingh, 1988; Cloetingh et al., 1985; Karner, 1986). The models presented can affect areas at least a few hundred kilometers across but may not produce uniform vertical movement along a basin or passive margin due to inhomogeneities in the lithosphere and/or to differing response between the center of a basin and its margins (Cloetingh, 1986; Cloetingh, 1988; Cloetingh et al., 1985; Karner, 1986). Cloetingh (1988; p. 26) stated that "... stress provinces can vary in size from that of an entire lithospheric plate to that of a small part of a plate" and indicated that there are no theoretical reasons why the stress field could not be uniform across a plate. If the stress field is uniform, then basins at either side of a plate would respond in phase to changes in the stress field and synchronous onlap/offlap patterns would develop along the margin of the plate. However, Cloetingh (1988) did not provide examples of uniform stress fields across large plates, rather he cited examples of large plates with compressive stress fields at one end and tensile stress fields at the other. Compressive stress produces a vertical response opposite to that of a tensile stress field (Cloetingh, 1986; Cloetingh, 1988; Cloetingh et al., 1985), and would not produce synchroneity of passive-margin response around continent. At this time, models of horizontal lithospheric stress as a mechanism for producing third-order fluctuation in relative sea level do not sufficiently address the apparent synchroneity of North American Grand Cycles.

A recent model invoking subduction of oceanic crust as a cause of subsidence of the overriding continental plate (dynamic topography) provides a possible mechanism for plate-wide, coeval tectonic subsidence (Gurnis, 1990; Gurnis, 1992; Gurnis, 1993 (submitted)) with a vertical scale of up to hundreds of meters over durations of $10^7$ to $10^8$ years. This model requires subduction of oceanic crust under continental crust, but Gurnis (1993, submitted) presented data that indicate there may have been sufficient subduction around North America during the Cambro-Ordovician to account for the apparent synchroneity of Grand Cycles. Gurnis' (1993, submitted) rates of subsidence would be great enough to account for the stratal thickness of the Grand Cycles, but he did not indicate whether the mechanism would cause the fluctuation in subsidence rates on the time scale of $10^5$ to $10^6$ years necessary to explain internal and external stratigraphic geometries of Grand Cycles. Consequently, though the model is intriguing and may prove applicable in the future, it currently is more appropriate for explaining first-order and second-order fluctuations in accommodation rather than third-order fluctuations.

**Sediment Supply**

For the Carrara Formation, sediment supply must consist of two major sources, one for siliciclastics and the other for carbonates which introduce sediments into the study area throughout Carrara deposition. Siliciclastics were derived from the craton to the east and south of the outcrop area, as shown by the presence of time-equivalent siliciclastic strata to the east and south (Stewart, 1970; Stewart, 1991; Stewart and Suczek, 1977). An *in situ* source of carbonate sediments was located along the edge of the continental margin and was a major recurring carbonate bank, in part represented by age-equivalent carbonate strata to the northwest (Palmer and Halley, 1979; Stewart and Suczek, 1977) and by parts of the Carrara itself (Palmer and Halley, 1979; this paper). Craton-sourced siliciclastics tended to accumulate landward of and prograde out to the carbonate bank. Periodically the bank was overrun by siliciclastics, terminating carbonate deposition and resulting in large-scale interleaving of siliciclastics and carbonates on a member scale that led Palmer and Halley (1979) to apply Aitken's (1966) Grand Cycle model to the Carrara.

**Eustasy**

From the Late Precambrian into the Ordovician, a major eustatic rise in sea level occurred, the Sauk Transgression (Sloss, 1963). Shorter-duration eustatic fluctuation has been suggested by previous studies (Aitken, 1989; Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Chow and James, 1987; Grotzinger, 1986a; Grotzinger, 1986b; Mount et al., 1991; Mount and Rowland, 1981) as the main mechanism that determined position and geometry of dominant sediment types in Grand Cycles. However, most studies, including an earlier study on the Carrara (Halley, 1974; Palmer and Halley, 1979), have ascribed deposition of the siliciclastics to high stands of sea level and deposition of part or all of the carbonates to low stands of sea level (Aitken, 1966; Aitken, 1989; Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Chow and James, 1987). Geophysical modeling (R2 analysis) by Bond et al. (1988, 1989) has indicated that these shorter-term fluctuations in accommodation may have been approximately synchronous in North America and indicate a possible eustatic cause for Grand Cycle development.

**Figure 18.** Isopach maps drawn on the palinspastic reconstruction of Levy and Christie-Blick (1989). Contour intervals are not standardized, but have been chosen as necessary to highlight trends in the data. **A)** Locations of stratigraphic columns measured in this and previous studies. The lower map is the isopach of the total thickness of the Carrara. **B)** Isopach maps of the first Grand Cycle/sequence (Zabriskie Quartzite-Eagle Mountain Shale-Thimble Limestone). The upper left map is total thickness, the second (in a clockwise progression) is of clean carbonate sediments, the third is of clean siliciclastic sediments, and the fourth is of the mixed lithofacies interval. Shaded values do not fit the isopach contour values. This layout is used in each set of maps for each Grand Cycle/sequence. **C)** Isopach maps for the second Grand Cycle/sequence (Echo Shale-Gold Ace Limestone). **D)** Isopach maps for the third Grand Cycle/sequence (Pyramid Shale-Red Pass Limestone). **E)** Isopach maps for the fourth Grand Cycle/sequence (Pahrump Hills Shale-Jangle Limestone). **F)** Isopach maps for the fifth Grand Cycle/sequence (Desert Range-Papoose Lake Member). See text for additional discussion.

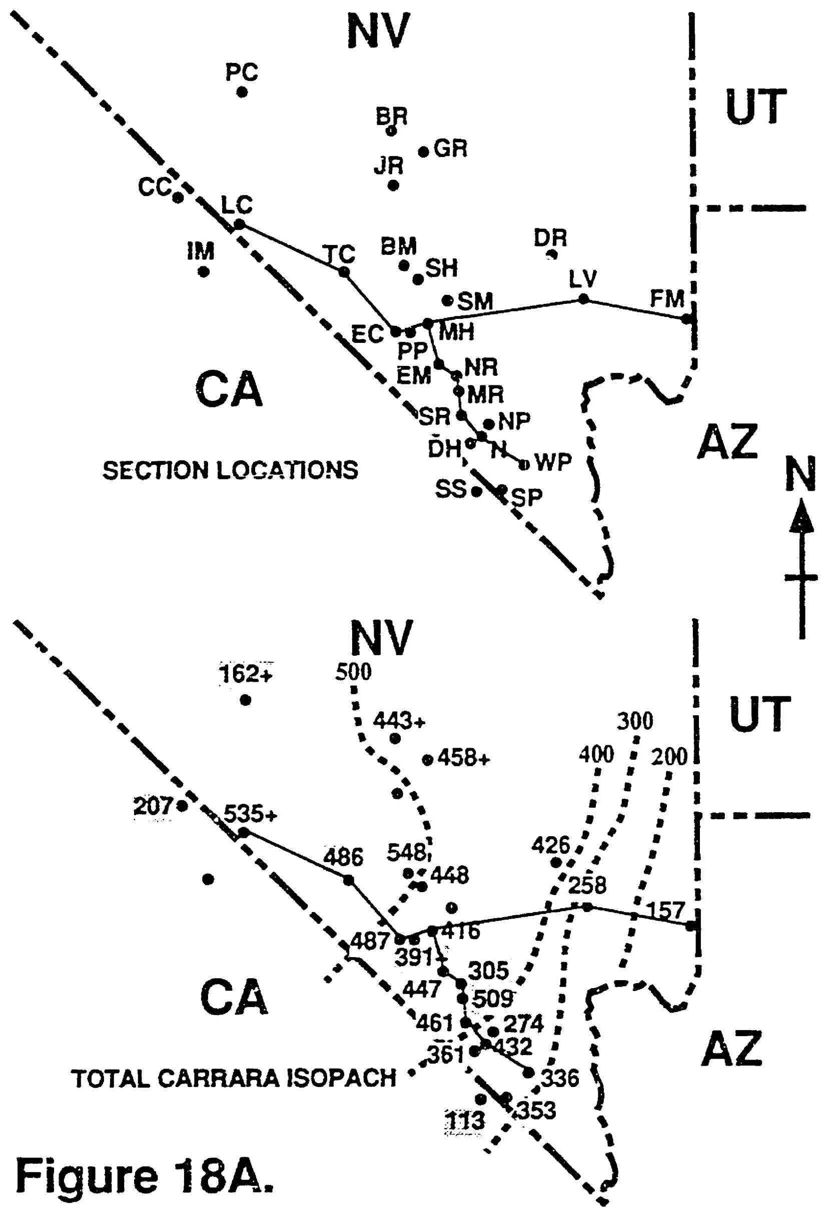



Figure 18A.

| LOCATIONS: | ADAMS | HALLEY | BATES |
|---|---|---|---|
| | (total thickness in meters) | | |
| BM = Bare Mtn. | | | 548 |
| BR =Belted Rng. | | 443+ | |
| CC = Cucomongo Cyn. (Mule. Spg Ls.+) | | 207 | |
| DH = Dublin Hills | | | 361 |
| DR = Desert Rng. | | 426 | |
| EC = Echo Cyn. | 487 | 443 | 507 |
| EM = Eagle Mtn. | 447 | 400 | 360 |
| FM = Frenchman Mtn. | 157 | | |
| GR = Groom Rng. | | 458+ | |
| IM = Inyo Mtns. | | | |
| JR = Jangle Ridge | | | |
| LC = Last Chance Rng. | 535+ | 500 | |
| LV = Las Vegas Rng. | 258 | 217 | |
| MH = Montgomery Hills | 416 | 343+ | 432 |
| MR = Mdl. Resting Spg. Rng. | 509 | | 430 |
| N = Nopah Rng. (90-1) | 432 | 363+ | |
| NP = No. Panamint Rng. | | | 274 |
| NR = No. Resting Spg. Rng. | 305 | | |
| PC = Paymaster Cyn. (Mule. Spg Ls.+) | | 162+ | |
| PP = Pyramid Peak | | 391+ | |
| SH = Striped Hills | | 448 | |
| SM = Spring Mtns. | | | |
| SP = So. Panamint Rng. | | | 353 |
| SR = So. Resting Spg. Rng. | 461 | (298+) | 365 |
| SS = Salt Spg. Hills | | | 113 |
| TC = Titanothere Cyn. | 486 | 460 | 497 |
| WP = Winters Pass | 336 | | |

NOTES: 1. Base map locations from the palinspastic restoration of Levy and Christie-Blick (1989). State boundaries are not restored.
2. Palmer and Halley (1979) locations 'PH' and 'RS(S)' are equivalent to this paper's locations 'MH' and 'MR' respectively.
3. If multiple intervals of a lithofacies occur in a Grand Cycle, then the thicknesses are summed and the total is plotted.
4. The Chappo Springs (CS) section, located 3 km north of the southern Resting Spring Range (SR) section & shown on Plates 3 and 4, is not placed on the maps due to scale limitations.
5. Abbreviations used on maps include: "F" indicates a fault in that interval has removed section; "NM" indicates that the interval was not measured; "+" indicates only part of an interval was measured.
6. Shaded numbers do not fit contours.
7. Isopach values picked off stratigraphic sections. Values picked off Plates 1 to 4 will vary due to paper stretch & limitations of drafting.

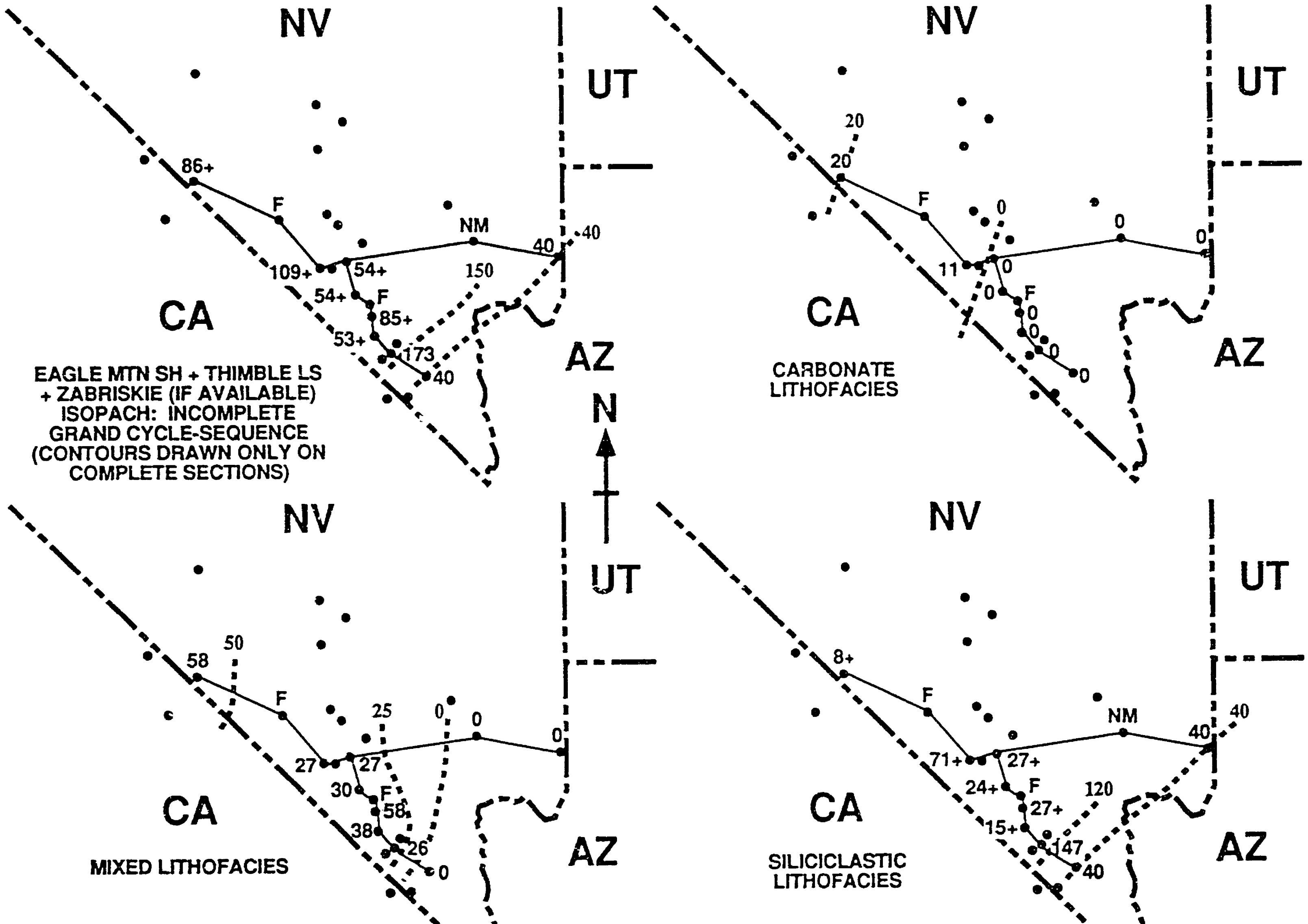

NV
UT
CA
AZ
86+
F
NM
40
·40
109+
54+
54+
F
85+
150
53+
173
40
EAGLE MTN SH + THIMBLE LS
+ ZABRISKIE (IF AVAILABLE)
ISOPACH: INCOMPLETE
GRAND CYCLE-SEQUENCE
(CONTOURS DRAWN ONLY ON
COMPLETE SECTIONS)
N
NV
UT
CA
AZ
20
20
F
0
0
0
11
0
0
F
0
0
0
0
CARBONATE
LITHOFACIES
NV
UT
CA
AZ
58
50
F
25
0
0
0
27
27
30
F
58
38
26
0
MIXED LITHOFACIES
NV
UT
CA
AZ
8+
F
NM
40
40
71+
27+
24+
F
120
27+
15+
147
40
SILICICLASTIC
LITHOFACIES

Figure 18B.

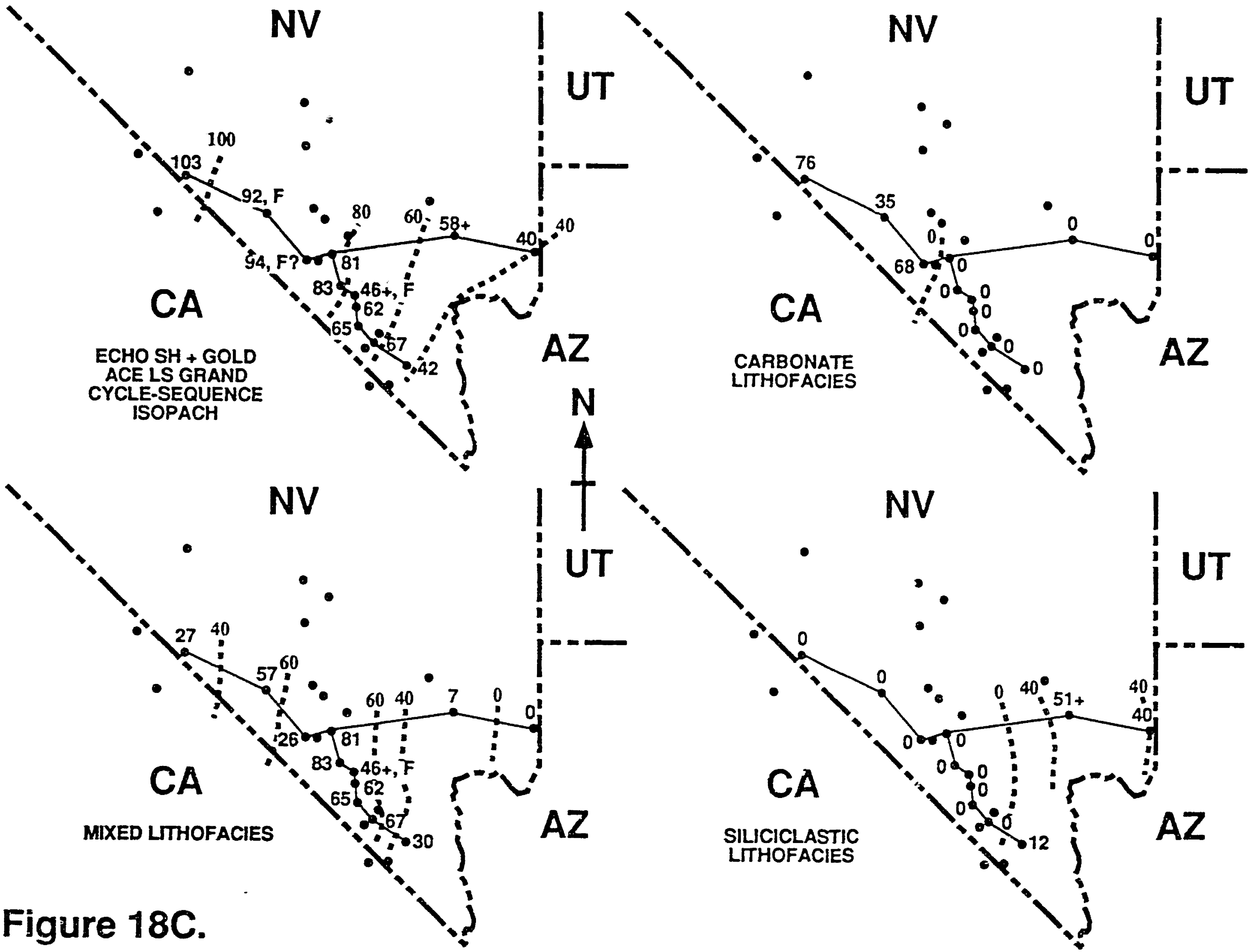

NV
UT
CA
AZ
ECHO SH + GOLD ACE LS GRAND CYCLE-SEQUENCE ISOPACH
CARBONATE LITHOFACIES
MIXED LITHOFACIES
SILICICLASTIC LITHOFACIES
N

Figure 18C.

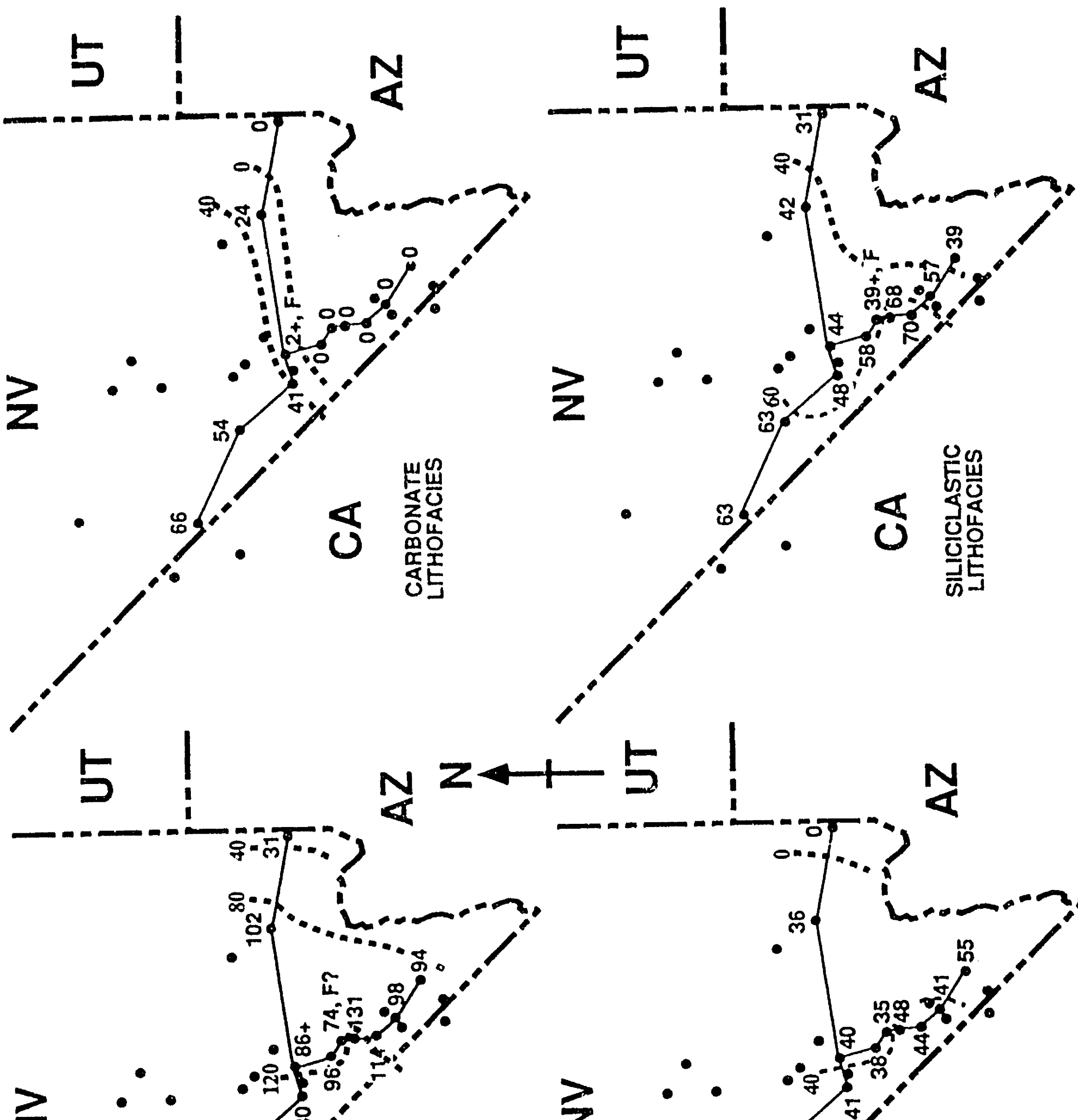

NV
UT
AZ
CA
N
PYRAMID SH + RED PASS LS GRAND CYCLE-SEQUENCE ISOPACH
CARBONATE LITHOFACIES
SILICICLASTIC LITHOFACIES
MIXED LITHOFACIES

Figure 18D.

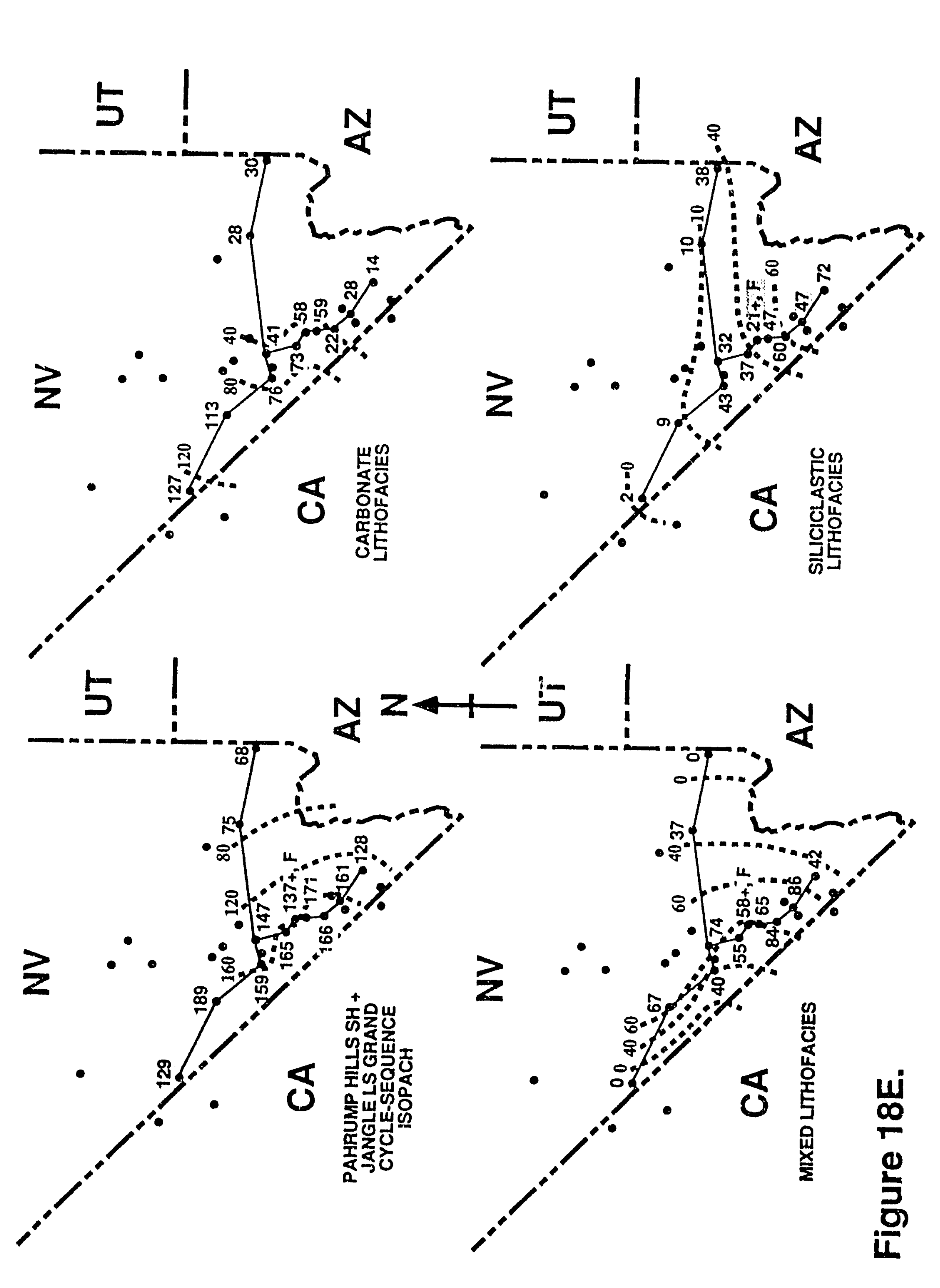

PAHRUMP HILLS SH +
JANGLE LS GRAND
CYCLE-SEQUENCE
ISOPACH
CARBONATE
LITHOFACIES
MIXED LITHOFACIES
SILICICLASTIC
LITHOFACIES
NV
UT
AZ
CA
N

Figure 18E.

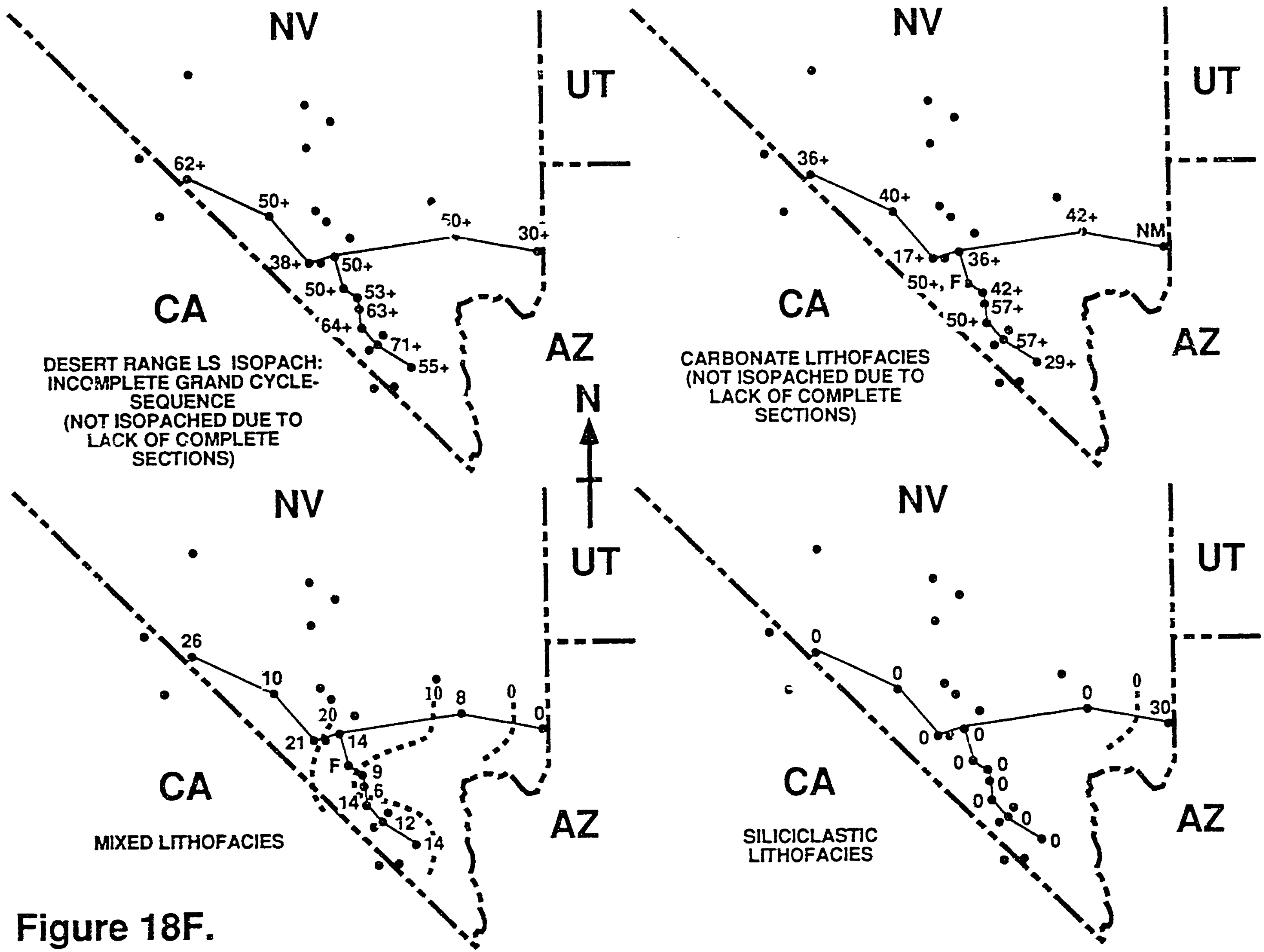

NV
UT
CA
AZ
DESERT RANGE LS ISOPACH:
INCOMPLETE GRAND CYCLE-SEQUENCE
(NOT ISOPACHED DUE TO LACK OF COMPLETE SECTIONS)
CARBONATE LITHOFACIES
(NOT ISOPACHED DUE TO LACK OF COMPLETE SECTIONS)
N
MIXED LITHOFACIES
SILICICLASTIC LITHOFACIES

Figure 18F.

**Summation**

For study of the Carrara Grand Cycles it must be acknowledged that climatic fluctuations, episodic tectonics, and eustatic fluctuations cannot be isolated and tested. Hence, a more general model utilizing variation in accommodation (Subsidence + eustatic fluctuation: see Jervey, 1988; Posamentier et al., 1988; Posamentier and Vail, 1988) combined with interactions between outer-shelf carbonate sediment production and siliciclastic sediment flux from the craton is developed. Although the paleogeography of the Carrara placed the carbonate sediment source down depositional dip from the siliciclastic sediment source, the model should work equally well for cases in which the two sources were separated along depositional strike.

## ISOPACH DATA PLOTTED ON A PALINSPASTIC BASE MAP

**DISCUSSION**

Isopach data has been plotted on the palinspastic base map of Levy and Christie-Blick (1989) for each of the Grand Cycles in the Carrara (Figures 18A through 18F). For each Grand Cycle, four different values have been plotted: total thickness (sequence thickness); thickness of clean carbonate lithofacies; thickness of mixed lithofacies; and thickness of clean siliciclastic lithofacies. Thickness of members has not been plotted because of the blurring of member boundaries caused by the presence of transitional mixed lithofacies intervals. Member isopach maps also tend to obscure sequence stratigraphic and chronostratigraphic relationships because of the lithostratigraphic nature of member designations. In a Grand Cycle with several intervals of a lithofacies group, the value plotted represents the sum of the intervals. Contour intervals are variable, and are chosen to best display trends in the data.

Isopach values for the Carrara as a whole include thickness values reported by Halley (1974) and by Bates (1965) as well as the values measured for this study. Isopach contours run approximately north-south, with thinning to the east. Thinning seems to become relatively abrupt in the vicinity of the Desert Range and Las Vegas Range (Figure 18A). The basal Grand Cycle, composed of the Zabriskie Quartzite, the Eagle Mountain Shale, and the Thimble Limestone, was only partially isopached because the Zabriskie was measured in its entirety in just three stratigraphic sections. Those three sections, Frenchman Mountain (FM), Winters Pass (WP), and the Nopah Range (N) indicate a very rapid thinning of the section east of the Nopah Range. Prave (1992) shows a similar relationship in his study of the Zabriskie. Isopach contours for this Grand Cycle are oriented northeast-southwest and thin to the southeast, which differs from other Grand Cycles and from the Carrara as a whole. However, this anomaly may only reflect the paucity of data for the lower part of the Grand Cycle.

Isopachs of the next three Grand Cycles, Echo Shale-Gold Ace Limestone, Pyramid Shale-Red Pass Limestone, and Pahrump Hills Shale-Jangle Limestone, are oriented the same as the isopachs of the entire Carrara, i.e., essentially north-south with thinning to the east. The final Grand Cycle, the Desert Range Limestone-Papoose Lake Member of the Bonanza King, was not isopached due to a lack of measured sections through the Papoose Lake. Within Grand Cycles, general trends vary for each of the lithofacies groups: carbonate lithofacies thin to the east and south; siliciclastic lithofacies thin to the west and north; and the mixed lithofacies group will either thin to the east, or will thin to both east and west. The isopach maps serve to summarize the lateral interrelationships between the carbonate bank to the west and north and the siliciclastic cratonal source to the south and east that are displayed in more detail on the cross sections (Plates 1 through 4).

## INTERPRETATION

Isopach maps of the entire Carrara and of the individual Grand Cycles/sequences provide insight to the orientation and evolution of the passive margin during Carrara deposition. Isopach maps of thinner time-slices than sequences are not practical because of limited confidence of parasequence correlations within Grand Cycles (see discussion below). However, isopachs of the clean carbonate interval within a Grand Cycle highlight the position and eastern extent of the carbonate bank. Isopachs of the clean siliciclastic interval emphasize the principal direction of the siliciclastic source, e.g., a greater thickness in the south than in the east probably is due to a higher percentage of siliciclastics derived from the south than from the east, or vice versa. The eastern limit of the isopachs of the mixed lithofacies interval delineates the maximum cratonal influence of carbonate sedimentation. The western limit delineates the maximum basinal influence of siliciclastic sedimentation. The position of the "0 meters" isopach line delineates the region of mixed sedimentation in the lagoon. All of this aids in understanding the changing paleogeography during Carrara Grand Cycle deposition and facilitates comparison between Carrara Grand Cycles.

The relatively consistent north-south orientation of the Carrara isopachs and Grand Cycle isopachs (Figures 18A through 18F) indicates that the general north-south orientation of the passive margin postulated by Stewart (1970, 1977, 1991) applies to the region of Carrara deposition. Further, the trends exhibited by the isopachs of lithofacies groups within each Grand Cycle support the interpretation of two sediment sources, a siliciclastic source from the craton to the east and south, and a carbonate source from an offshore carbonate bank situated to the west and north. The back-bank lagoon was the "mixing area" for the two varieties of sediment and this is clearly shown by thinning to both east and west of the mixed isopachs of the Echo Shale-Gold Ace Limestone Grand Cycle and the Pahrump Hills Shale-Jangle Limestone Grand Cycle. Isopachs of the mixed interval in the basal Grand Cycle (Zabriskie Quartzite-Eagle Mountain Shale-Thimble Limestone), the Pyramid Shale-Red Pass Limestone Grand Cycle, and the Desert Range Limestone-Papoose Lake Member Grand Cycle show only thinning to the east, which may reflect an offshore position for the main part of the carbonate bank outside of the region examined. Isopachs of carbonate lithofacies and of siliciclastic lithofacies do not provide more specific information regarding orientation of the carbonate bank or the principal source area of the siliciclastics.

### SPECULATION

Halley (1974) reported an unusual thickness (94 m) of dark shale (without carbonate interbeds) in the Pahrump Hills Shale in the Groom Range overlain by a thin Jangle Limestone (21.5 m). Both these values are at odds with the isopach data farther to the south (Figure 18E), and may be related to the House Embayment of eastern Nevada and western Utah (Rees, 1986). If this speculative association is correct, then not only is the southern limit of the embayment extended, but the age of initiation is also extended from middle Middle Cambrian to early Middle Cambrian (Rees, 1986). In addition, the presence of platform carbonates (Jangle Limestone and the Bonanza King Formation) may indicate that the platform built out and over the early margin of the embayment.

## CARRARA STRATIGRAPHY

### INTRODUCTION

Five Grand Cycles are recognized to be partially or completely encompassed by the Carrara Formation, and the variation within and between those five cycles has led to development of the model just described. Two of the Grand Cycles, the Zabriskie Quartzite-Eagle Mountain Shale-Thimble Limestone and the Pahrump Hills Shale-Jangle Limestone, are interpreted to have siliciclastic **MNAST** deposits at their bases. The presence of the **MNAST** places these two cycles into an uncommon group of Grand Cycles that includes the Gog Sandstone and the Arctomys-Waterfowl Grand Cycle of Aitken (1978). The other three Grand Cycles, the Echo Shale-Gold Ace Limestone, the Pyramid Shale-Red Pass Limestone, and the Desert Range Limestone-Papoose Lake Member of the Bonanza King Formation, either have no **MNAST** deposits or very thin **MNAST** deposits that cannot be distinguished from the thicker siliciclastic **IAST** deposits. This results in placement of the transgressive surface on or very close to the sequence boundary at the base of the Grand Cycle. These three Grand Cycles are typical and resemble most other Grand Cycles described in the literature (see Table 8).

The series of five Grand Cycles that are present in the Carrara record the interactions of two very different sources of sediments; a cratonal source of siliciclastic sediment that has been transported into the study area, and an offshore source of carbonate sediment that has also been transported into the study area, but was, at times, also produced within the study area. These two sources were operating on a rapidly subsiding passive margin during a time of long-term eustatic sea level rise (Bond et al., 1988; Levy and Christie-Blick, 1991; Sloss, 1963; Sloss, 1988a; Stewart, 1970; Stewart, 1991), and this setting affected each of the sediment sources differently. In addition, shorter-term accommodation fluctuations, possibly eustatic in origin, are also believed to have affected sedimentation (Bond et al., 1988), again acting somewhat differently on each source. More detailed descriptions of the geometries and responses within each Grand Cycle follow, but general trends will be discussed first.

In the basal Grand Cycle (Wood Canyon-Zabriskie-Eagle Mountain-Thimble) (Plate 1 and Figure 18B), siliciclastics appear to have been introduced from both the east and the south in equal proportions; carbonates were relatively thin and somewhat distal to the study area. In the second Grand Cycle (Echo-Gold Ace) (Plate 1 and Figure 18C), the siliciclastics were the less important sediment, and were derived predominantly from the east. The third Grand Cycle (Pyramid-Red Pass) (Plate 2 and Figure 18D) is relatively balanced in the proportions of carbonates to siliciclastics; siliciclastics again appear to be derived equally from south and east. The carbonate bank, however, was better developed in the northern part of the field area with little change in its western position. The fourth Grand Cycle (Pahrump Hills-Jangle) (Plate 3 and Figure 18E) also is balanced in its proportion of carbonates to siliciclastics, and once again the main source area for siliciclastics was located to the south. The carbonate bank remained well established in the northern position, though it narrowed near the end of the Grand Cycle due to siliciclastics derived from the southern source area. The fifth and last Grand Cycle (Desert Range-Papoose Lake) (Plate 4 and Figure 18F) is almost entirely carbonate sediments, except for the basal 5 to 30 m which are mostly mixed lithofacies. Siliciclastic sediments were again derived from the east and south, with perhaps a greater contribution from the east as shown by the 30 m of clean siliciclastics at Frenchman Mountain (FM) versus the second tongue of mixed lithofacies that is present in the upper part of the Jangle Limestone at Winters Pass (WP). These were the last siliciclastic sediments to be deposited in the Death Valley region for the next several hundred meters of section (Stewart, 1970). Overall, the five Grand Cycles recorded an increasing contribution of carbonate sediments at the expense of siliciclastic sediments, and this was the result of the long-term eustatic rise flooding the craton. The changing importance of a southern versus an eastern source for the siliciclastics may reflect changing fluvial patterns on the craton.

One other general trend encompassed by at least the first four Grand Cycles involves a progressively greater percentage of intertidal lithofacies in each successive Grand Cycle. The first two Grand Cycles have almost no intertidal lithofacies, whereas the third contains intertidal lithofacies in both the mixed and clean carbonate intervals. The fourth Grand Cycle contains intertidal facies in intervals of all three lithofacies groups, and is especially noteworthy for containing nonmarine shale/mudstone red beds that are interpreted to be paleosols. The fifth Grand Cycle has not been examined above the basal few meters of the Papoose Lake Member, and the published literature does not address subtidal versus intertidal lithofacies. In the Desert Range Limestone, intertidal lithofacies are found in both mixed and carbonate intervals, but the basal part of the Papoose Lake is subtidal. Lithology aside, intertidal lithofacies are present lower in this Grand Cycle than in the bottom three, and at comparable levels to the fourth. The trend of increasing proportion of intertidal deposits may continue into the fifth Grand Cycle.

This trend may result from the overall repositioning of the carbonate bank from mostly outside to mostly within the study area. It would be easier for bank sediments to have built into the intertidal zone than for lagoonal sediments to have done so because the bank is thought to have had topographic relief above the lagoon (Aitken, 1966; Aitken, 1968; Aitken, 1978; Aitken, 1981; Palmer and Halley, 1979). As more of the study area was represented by bank deposits, a higher percentage of intertidal deposits would have been recorded in the sections. A second effect that may influence this trend is decreasing rates of tectonic subsidence as the margin ages (Bond et al., 1988; Levy and Christie-Blick, 1991), i.e., as subsidence decreases it is easier for sediments to build to intertidal range. These effects may have been working in tandem to produce this trend. However, decreasing subsidence rates may not have affected lateral distribution of intertidal lithofacies within a single Grand Cycle. As position changes along a dip transect of the margin towards the hinge line (eastward), the subsidence rate decreases. Instead of the predicted increase in intertidal deposits to the east, the dip cross sections (Plates 2A, 3A, and 4A) show that the percentage of intertidal lithofacies within a Grand Cycle tended to decrease towards the hinge line.

### Speculation Concerning the Hawke Bay Event

The Hawke Bay Event, a proposed, major eustatic fall at or near the boundary between the Early and Middle Cambrian (Palmer, 1981b; Palmer and James, 1980) should be recognizable within the interval of Zabriskie-Carrara-Bonanza King sedimentation. The fall would be expected to coincide with one of the sequence/Grand Cycle boundaries and there should be a well developed **MNAST** above the boundary. As discussed below, there are two Grand Cycles associated with the Carrara that have well-developed **MNASTs**, i.e., the first Grand Cycle composed of the Zabriskie Quartzite and the Eagle Mountain Shale and Thimble Limestone members of the Carrara, and the fourth Grand Cycle composed of the Pahrump Hills Shale Member and the Jangle Limestone Member.

The Zabriskie Quartzite is within the *Wanneria* trilobite subzone of the *Bonnia-Olenellus* biozone and the Pahrump Hills-Jangle Grand Cycle is within the *Albertella* trilobite biozone immediately below the *Glossopleura* biozone (Figure 2B). Published trilobite biostratigraphic data (Palmer, 1981b; Palmer and James, 1980) place the Hawke Bay Event above the *Wanneria* subzone and below the *Glossopleura* biozone, effectively excluding the Zabriskie from involvement in the Hawke Bay Event. However, unpublished biostratigraphic data (A. R. Palmer, personal communication, 1993) extend the possible range of the event down into the *Wanneria* subzone. This new constraint allows placement of the Hawke Bay Event at the sequence boundary marking the base of the Zabriskie-Eagle Mountain-Thimble Grand Cycle. Thus the most significant influx of siliciclastics in the Zabriskie-Carrara-Bonanza King interval appears to coincide with a eustatic fall.

In much of eastern North America, the Hawke Bay Event is represented by a major erosive unconformity that encompasses the upper *Bonnia-Olenellus* biozone, the *Plagiura-Poliella* biozone, and the *Albertella* biozone, as well as parts of the *Glossopleura* biozone (Palmer and James, 1980). In the region of Carrara deposition, this time interval is represented by over 500 m of marine sediments. The lack of development of a Type 1 sequence boundary at the Hawke Bay Event may be a result of a combination of long-term, eustatic rise during the Cambrian (Sloss, 1963) combined with a high subsidence rate (80 to 100 m/m.y.) associated with this region during the Cambrian (Sloss, 1988a). Both of these would act to moderate the effects of a short-term eustatic fall.

**Regional Cross Sections and Correlation Strategy**

Note that there are only two regional cross section lines and that they form a crude T-shape on the palinspastic base map (Figure 18). Plate 1 shows the first and second Grand Cycles; Plate 2 shows the third; Plate 3 shows the fourth; and Plate 4 shows the fifth. Cross sections oriented approximately parallel to depositional dip (east-west) are designated as Plates 1A, 2A, 3A, and 4A; cross sections oriented approximately parallel to depositional strike (north-south) are designated as Plates 1B, 2B, 3B, and 4B. The two northernmost stratigraphic sections on the strike cross sections (Plates 1B to 4B), MH and EC, are found in the middle of the dip cross sections (Plates 1A to 4A), and are the tie-points between strike and dip cross sections.

The correlations used in this study, and shown on Plates 1 through 4, are not lithostratigraphic correlations. Because of this, they do not follow formation and member boundaries exactly, as can be clearly seen on Plate 1A where the Tapeats Sandstone/Zabriskie Quartzite at Frenchman Mountain (FM) is in part correlated with the Eagle Mountain Shale and the Thimble Limestone, as well as with the Echo Shale and Gold Ace Limestone in stratigraphic sections measured to the west. In addition, Zabriskie Quartzite underlies the Eagle Mountain Shale in the western stratigraphic sections. Less striking examples can be seen in Plate 3A between the Pahrump Hills Shale and the Jangle Limestone, as well as in Plate 2B between the Pyramid Shale and the Red Pass Limestone.

Correlations in this study are guided by recognition of regionally extensive surfaces (sequence boundaries) that define regionally extensive depositional packages (Grand Cycles/sequences). Within depositional packages, lateral changes in lithofacies are expected because they mimic lateral changes in depositional environments that are seen on a regional basis. Although only sequence boundaries and gross lithofacies group boundaries are shown on the cross sections (Plates 1 through 4), smaller-scale parasequence boundaries were used to guide placement of many of the facies boundaries. On Plate 3, two parasequence set boundaries are marked and it can be seen that they subdivide lithofacies groups and offset lithofacies boundaries. Parasequence correlations have not been shown for two reasons: 1) they are too numerous and close together, and obscure the overall internal stratigraphy of Grand Cycles; and 2) Variably discontinuous, fifth-order cycles (parasequences) in the Carrara reduce the confidence level of parasequence boundary correlations given the spacing of stratigraphic sections. Figure 10, approximately parallel to depositional strike, is a cross section of part of the upper Jangle Limestone Member that does utilize parasequence correlations and shows both discontinuous and continuous fifth-order cycles.

Sequence stratigraphic correlations attempt to approximate chronostratigraphy at levels above and below the resolution of biostratigraphy. Biostratigraphic (trilobite) correlations (Palmer and Halley, 1979) are not violated by the Grand Cycle/sequence-level stratigraphic correlations implemented in this study. However, most of the fine-scaled correlations are made at a level below resolution of trilobite biostratigraphy. Chronostratigraphic aspects of correlations within Grand Cycles emphasize coeval centers of carbonate and of siliciclastic deposition with the lagoonal area of mixing between.

**Member Descriptions**

Members of the Carrara Formation were defined by Halley (1974), and Palmer and Halley (1979) as lithostratigraphic units, with each member composed mainly of carbonate or siliciclastic lithofacies. Their member designations are followed in this paper. As can be seen on Plates 1 through 4, within a Grand Cycle, there is normally an interval of mixed carbonate-siliciclastic lithofacies between basal clean siliciclastic lithofacies and upper clean carbonate lithofacies. However, the clean siliciclastics may not have extended laterally to the carbonate bank (e.g., Echo Shale Member) and the clean carbonates may not have extended across much of the lagoon (e.g., the Thimble Limestone Member (Plate 1A)). The transitional interval blurs the contact between members within a Grand Cycle and has made designation of members difficult and somewhat arbitrary in some sections. This is noted in the following lithofacies discussions. There is less difficulty in defining contacts between members of the successive Grand Cycles because of sharp juxtaposition of clean siliciclastic lithofacies overlying clean carbonate lithofacies.

Carbonate members generally are more pure and less of a mixed lithofacies to the north and west, whereas siliciclastic members are more pure and less of a mixed character to the south and east. These lateral changes may make it more difficult to pick out sequence/Grand Cycle boundaries in some areas. This is most noticeable in Plate 1B in the middle part of the cross section where mixed lithofacies are on either side of the sequence boundary between the two Grand Cycles, resulting in a somewhat arbitrary placement of the boundary. In general, within a Grand Cycle, member boundaries do not coincide with time lines but are time-transgressive (Aitken, 1981; Palmer and Halley, 1979; this paper, see Plates 1 to 4).

On the cross sections (Plates 1 through 4), an attempt has been made to assign lithostratigraphic member designations, but these assignments are somewhat arbitrary. A strict adherence to member designations tends to obscure sedimentologic and chronostratigraphic relationships within Grand Cycles. Because of this, the member picks on the cross sections are de-emphasized and should be used primarily in comparing this study to previous studies on the Carrara.

## FIRST SEQUENCE/GRAND CYCLE: ZABRISKIE QUARTZITE-EAGLE MOUNTAIN SHALE-THIMBLE LIMESTONE

### A Brief Review of the Zabriskie Quartzite

Prave (1992) divided the Zabriskie Quartzite into two members, the lower Resting Springs Member and the upper Emigrant Pass Member. The base of the Resting Springs Member is defined to lie on top of a thick, intensely *Skolithos*-bioturbated sandstone ("piperock"). The member is made up of an overall coarsening-upward series of siliciclastic units, ranging from marine shale to sandstone and up into braid-plain sandstone. A transgressive lag deposit separates the lower member from the Emigrant Pass Member. The upper member of the Zabriskio Quartzite is composed of interbedded subtidal and possibly some intertidal (Prave, 1992) sandstone, siltstone, mudstone, and shale (Halley, 1974; Palmer and Halley, 1979; Prave, 1992). Beneath the clean quartzites of the Zabriskie and above the last carbonates in the Wood Canyon, are a few tens of meters of marine shale to sandstone (Plate 1B: base of the Nopah Range (N)) lithostratigraphically assigned to the Wood Canyon Formation (Prave, 1992; Stewart, 1970). In this paper, those siliciclastics are part of the basal Grand Cycle, and are informally grouped with the Zabriskie in most discussions.

### Eagle Mountain Shale

**Lithology.**—The lithologic marker used to distinguish the contact of the Eagle Mountain Shale with the underlying Zabriskie Quartzite is defined to be the top of the last clean quartzite greater than one meter in thickness. This definition of the Carrara/Zabriskie contact allows recognition and differentiation of the upper member of the Zabriskie where it crops out. However, the lithostratigraphic boundary between the Zabriskie Quartzite and Carrara Formation is strongly time-transgressive (Plate 1), becoming younger to the south and east. The Eagle Mountain Shale Member of the Carrara Formation is dominated by shale and siliceous mudstone with less common thin sandstone and siltstone interbeds in its lower part. Shoaling cycles, where they can be distinguished, are typically of type S2, with less common S1 cycles. Overlying the clean siliciclastics are more shale and mudstone, with thin interbeds of fossiliferous packstone/grainstone, arranged in shoaling cycle-type M4. For the purpose of this discussion of lithofacies, the top of the member is not picked across most of the study area (Plates 1A and 1B) because it is within the mixed carbonate-siliciclastic lithofacies interval. On the cross sections, most of the mixed interval is lithostratigraphically designated as the Eagle Mountain Shale.

**Lateral Change.**—In the most western and northern location, the Last Chance Range (LC), the member is marked by mixed carbonate and siliciclastic lithofacies arranged into cycle-type M4. At Titus/Titanothere Canyon (TC) the member is removed by faulting. At the most southern location, Winters Pass (WP), and at the two most eastern locations, the Las Vegas Range (LV) and Frenchman Mountain (FM), the member has changed laterally to sandstone and is no longer distinguishable from the Tapeats Sandstone/Zabriskie Quartzite. These relationships are shown on the dip-section, Plate 1A and on the strike-section, Plate 1B.

**Thimble Limestone**

**Lithology.**—This is the smallest and least laterally extensive carbonate member of the Carrara (Plates 1A and 1B). Clean carbonate lithofacies, mostly subtidal nodular ribbon rock, are found only in the uppermost part of the member and only at the northwestern part of the study area at the Last Chance Range (LC) and Echo Canyon (EC). It is likely that if the basal part of the Titus/Titanothere Canyons (TC) section were not faulted, clean carbonates would also be present there. Lithofacies are arranged into cycle-types C1 (nodular ribbon rock), and the subtidal part of C5 (nodular and well-layered ribbon rock). In the lower parts of the member, carbonate and siliciclastic lithofacies are mixed and essentially indistinguishable from the upper parts of the Eagle Mountain Shale Member and marked by cycle-type M4. Overall, the mixed lithofacies interval of the combined Eagle Mountain Shale-Thimble Limestone has shale and siliceous mudstone as the background sediment, with carbonate interbeds that are mostly fossiliferous (commonly trilobite debris) and/or lithoclast packstones. Only at the Last Chance Range (LC) and Echo Canyon (EC) are there approximately equal proportions of siliciclastic and carbonate lithofacies. In the upper part of the member, additional lithofacies include CDAS lithofacies, oolitic grainstone, well-layered and nodular ribbon rock, and oncolitic packstone/grainstone, arranged in mixed cycle-types M1, M3, M5, and M11. An upper contact for the Thimble Limestone and for the top of the Grand Cycle in the region of mixed lithofacies is somewhat arbitrarily picked at either an oncolitic and fossiliferous packstone 1-to-2 m thick, or at the top of one of the thicker carbonate units.

**Lateral Change.**—The clean carbonates quickly change laterally to the south and east into mixed lithofacies and as correlations are carried farther, the Thimble Limestone changes to the sandstone of the Zabriskie/Tapeats (Plate 1). Halley (1974) and Palmer and Halley (1979) have also reported these lateral and vertical variations in the Thimble Limestone. Further, they assign the mixed lithofacies to the upper part of the Eagle Mountain Shale and state that it is difficult to differentiate between Eagle Mountain Shale and Echo Shale if the Thimble Limestone is missing. This report concurs for lithostratigraphic designations, but recognizes that the upper part of the Eagle

Mountain Shale, where not overlain by clean carbonates, is isochronous with the Thimble Limestone.

**Type 2 Sequence Boundary**

A basal Type 2 sequence boundary is recognized at the top of the last subtidal fossiliferous packstone/grainstone in the upper Wood Canyon. This uppermost part of the Wood Canyon is a mix of subtidal carbonate and siliciclastic sediments, and is overlain by fine-grained subtidal siliciclastic sediments that coarsen up into Zabriskie sandstones. This sequence boundary is similar to the sequence boundary between the Echo Shale-Gold Ace Grand Cycle and the Pyramid Shale-Red Pass Limestone Grand Cycle (Plates 1 and 2) that is discussed in a later section. Although the contact was examined in the Nopah Range (N) and at Winters Pass (WP), no attempt was made to study the contact or the overlying Wood C :nyon/Zabriskie at other locations.

**An Alternate Interpretation of the Zabriskie Quartzite**

Prave (1992) developed a sequence stratigraphic model in which each Zabriskie member, the lower Resting Springs Member and the upper Emigrant Pass Member, form parts of different sequences. He interpreted the lower Resting Springs Member, composed of braid-plain siliciclastics overlying marine siliciclastics, as a **HST (MXAST)** separated from its underlying **TST (IAST)**, uppermost Wood Canyon Formation deposits, by an intensely bioturbated sandstone thought to be a condensed interval. The sequence boundary between the Resting Springs Member and the overlying Emigrant Pass Member is a "transgression surface" characterized by a transgressive lag that records flooding of the braid plain environment. This transgressive surface is interpreted to coincide with a Type 2 sequence boundary. The nearshore marine siliciclastics of the Emigrant Pass Member form a retrogradational stack of thin parasequences; hence, the member is interpreted as a **TST (IAST)**. The Eagle Mountain Shale Member of the Carrara is also viewed as part of this **TST (IAST)**.

A less complex interpretation of the Resting Springs Member is preferred. The surface between the Zabriskie members interpreted by Prave (1992) as a combination sequence boundary/transgressive surface, is reinterpreted as a transgressive surface only and not as a sequence boundary. The Resting Springs Member is reinterpreted as a **MNAST** and only one Grand Cycle/sequence is recognized in the Zabriskie in the Montgomery Hills/Resting Spring Range/Nopah Range area. Either interpretation of the lower Zabriskie is compatible with the sequence stratigraphic interpretation of the Carrara Formation proper. Only in the larger viewpoints of regional, multi-formational stratigraphy and of sequence stratigraphic models of Grand Cycles does the lower Zabriskie interpretation become important.

**Minimum Accommodation Systems Tract**

The facies succession of the Zabriskie (Prave, 1992), shoreface overlain by braid-plain and separated from overlying nearshore deposits by a flooding surface, does not show evidence of the basinward shift in facies needed to define a Type 2 sequence boundary. However, the progradational stacking of lithofacies and parasequences in the Resting Springs Member (Prave, 1992) reflects progradational stacking patterns common in **MNASTs** (Posamentier and Vail, 1988). Zabriskie outcrops generally contain more than one significant bed of *Skolithos*-bioturbated sandstone ("piperock"). This indicates that caution should be used in defining a maximum flooding surface based on this lithofacies. However, Prave (1992, p. 512) maintains that a distinctly thicker unit "... occurs only at that particular stratigraphic position (although thinner piperock beds are present in the lowermost Zabriskie Quartzite and uppermost Wood Canyon Formation) ...". The transgressive surface with its lag deposits separates the **MNAST** from the overlying **IAST**.

The documented widespread nature of the Resting Springs Member indicates that the carbonate bank was not established within the study area during deposition of the **MNAST**. Further, the lack of carbonate interbeds in the member indicates that if the bank was active outside the study area, it was at a sufficient distance that carbonate sediments could not be transported into the area during times of marine deposition.

**Increasing Accommodation Systems Tract**

The Emigrant Pass Member of the Zabriskie Quartzite exhibits a retrogradational stacking of parasequences (Prave, 1992) as does the Eagle Mountain Shale Member of the Carrara Formation (Plate 1). The retrogradational stacking in the Emigrant Pass Member is not illustrated in Plate 1 because of a lack of measured stratigraphic sections through the member. However, the retrogradational nature of the Eagle Mountain Shale can be seen in the dip cross section, Plate 1A. Between the western locations (LC and EC) in the lowermost part of the cross section, mixed lithofacies assigned to the Eagle Mountain Shale are seen to laterally interfinger with sandstone of the Zabriskie. Stratigraphically above this, the mixed lithofacies laterally interfinger with shale-rich siliciclastics that are also assigned to the Eagle Mountain Shale. Farther to the east, the shale-rich siliciclastics are inferred to laterally grade into sandstone of the Zabriskie/Tapeats in the vicinity of the Las Vegas Range (LV) and possibly as far east as Frenchman Mountain (FM). This series of lateral changes, as recorded in the succession of lithofacies groups, defines a retrogradational stacking of lithofacies, and though not shown, of parasequences as well. The retrogradational stacking does not show very well on the strike cross section, Plate 1B, except in the lateral transition from the shale-rich siliciclastic interval of the Eagle Mountain Shale into the sandstone and shale of the Zabriskie that is seen between the Nopah Range (N) and Winters Pass (WP).

An overall dominance of carbonate over siliciclastic deposition in the mixed lithofacies interval at the Last Chance Range (LC) indicates that carbonate bank deposition was active outside the study area during the early **IAST**. The active bank was also close enough to act as a source of carbonate sediments for the western end of the study area.

**Maximum Accommodation Systems Tract**

The Thimble Limestone Member and the upper part of of the Eagle Mountain Member of the Carrara Formation make up the **MXAST**. Clean carbonate lithofacies of the Thimble Limestone are exposed over a relatively small part of the study area and this is interpreted to be due to deposition of most the carbonate bank north and west of this area. The clean carbonate lithofacies interval is not seen in locations to the east and south of Echo Canyon (EC) and only at the Montgomery Hills (MH) is the laterally equivalent mixed interval sufficiently rich in carbonates to be considered part of the Thimble Limestone. Farther to the north and west, at the Last Chance Range (LC), the mixed interval beneath the carbonate lithofacies interval is predominantly carbonate. Clean carbonate lithofacies of the bank are interpreted to have existed northward and westward of this location. Late in the **MXAST**, the final progradation of the bank away from its center and towards the craton apparently was not able to extend past the Montgomery Hills area.

**A Comment Concerning the Type Section of the Thimble Limestone**

Correlations in this study indicate that approximately the basal 60 m of Carrara have been removed by faulting at this location. There are no reports of trilobites from this locality (Palmer and Halley, 1979; their Plate 17), hence trilobite biostratigraphy can not resolve which part of the lower Carrara is missing. The missing section may include the lower part of the Gold Ace Limestone, and this would explain the anomalously thin clean-carbonate interval. It is possible that the anomalously thick, mixed-interval at the base of the section includes parts of the Echo Shale, Thimble Limestone, and Eagle Mountain Shale. The quality of outcrop precludes determination of exactly where and how many faults slice the section. For simplicity, it has been assumed that all of the Eagle Mountain Shale and Thimble Limestone have been removed, and the entire mixed interval is assigned *in toto* to the Echo Shale.

This location is the type section for the Thimble Limestone as reported in Halley (1974). Unfortunately, it is affected by the structural removal of the base of the Carrara, making it possible that the true Thimble Limestone is not even exposed in this area. In addition to this, Halley improperly located the position of his measured section, reporting that it was on the "... east slope of hill 5229, SW1/4 section 18, T. 13 S., R. 46 E., Grapevine Peak, Calif.-Nev., 15' quadrangle." (Halley, 1974; p. 359). This hill is topped with quartzite and not with carbonates. The correct location is the east-facing slope immediately west of hill 5229.

## SECOND SEQUENCE/GRAND CYCLE: ECHO SHALE-GOLD ACE LIMESTONE

### Echo Shale

**Lithology.**—The clean siliciclastic portion of this member is restricted to Winters Pass (WP), the Las Vegas Range (LV) and Frenchman Mountain (FM) in the most southern and eastern parts of the study area (Plates 1A and 1B). It is very similar to the basal part of the Eagle Mountain Shale with shale and siliceous mudstone as dominant lithofacies, and lesser proportions of sandstone and siltstone interbeds. Over the rest of its extent the member is composed of a mix of carbonate and siliciclastic lithofacies that is very similar to the mixed lithofacies of the Eagle Mountain Shale-Thimble Limestone. Within the mixed interval cycle-types C5, S2, M1, M4, and M5 are present. No attempt is made to pick a top contact to this member in areas where there are not overlying clean carbonate lithofacies of the Gold Ace Limestone. This is again due to the transition zone between Echo Shale and Gold Ace Limestone. On the cross sections, most of the mixed interval is lithostratigraphically designated as Echo Shale.

In the middle of the mixed interval at Eagle Mountain (EM), approximately 20 m of subtidal, muddy siltstone mixed with carbonates are present and can be tentatively correlated to approximately 3 m of siltstone at the northern Resting Spring Range (NR). These siltstones are the only coarse siliciclastics within the member, aside from interbedded thin sandstone and siltstone event beds. Sandstone in the basal 15 m of the section at Titus and Titanothere Canyons (TC) may be part of the Zabriskie Quartzite in fault contact with the Echo Shale.

**Lateral Change.**—At least part of the Echo Shale Member is laterally equivalent to the Zabriskie Quartzite/Tapeats Sandstone at the Las Vegas Range (LV) and Frenchman Mountain (FM). At Winters Pass (WP) (Plate 1B) a basal tongue of shale and siliceous mudstone lies above the Zabriskie/Carrara boundary. That tongue is assigned to the Echo Shale, although part of the underlying Zabriskie sandstone may be chronostratigraphically equivalent to the Echo Shale. The lower part of the mixed lithofacies above the tongue is also likely to be part of the Echo Shale, but again no attempt is made to determine the position of the member boundary between Echo Shale and Gold Ace Limestone in a mixed lithofacies interval. All the mixed interval is lithostratigraphically designated as the Echo Shale. On the strike section, Plate 1B, the area between the Montgomery Hills (MH) and Nopah Range (N) is entirely of the mixed lithofacies in both the Echo Shale and the Gold Ace Limestone. Consequently, no attempt is made to precisely place the boundary between members. To the west and north there is an overall increase in the abundance of carbonate lithofacies in the mixed interval.

**Gold Ace Limestone**

**Lithology.**—Clean subtidal carbonates are present at the northern and western parts of the study area and are arranged into C1 cycles of nodular ribbon rock (Plates 1A and 1B). Beneath the clean carbonates is the mixed lithofacies interval, and at Last Chance Range (LC) and Echo Canyon (EC) the contact between clean carbonates and mixed lithofacies may be considered to be the contact between the Gold Ace Limestone and underlying Echo Shale. At Titus and Titanothere Canyons (TC), the mixed interval is about twice as thick as at the other two locations, hence its upper half may be chronostratigraphically equivalent with the Gold Ace Limestone, even though lithostratigraphically it is designated as Echo Shale. Across the rest of the study area, the clean carbonates are replaced by the upper part of the mixed interval; lithofacies and cycle types are discussed above. One additional carbonate lithofacies that is seen in the Gold Ace is fossiliferous mudstone interbedded with siliceous mudstone.

**Lateral Change.**—The lateral extent of clean carbonate lithofacies in the Gold Ace Limestone is approximately equal to that of the Thimble Limestone, however the clean carbonates of the Gold Ace are up to 3.5 times thicker. In addition the laterally equivalent part of the mixed interval extends farther to the east and south, i.e., to the Las Vegas Range (LV) and to Winters Pass (WP), where the top 7 to 8 m of clean carbonates is lithostratigraphically designated Gold Ace Limestone. Coeval shale and siliceous mudstone at Frenchman Mountain (FM) pass laterally down-dip into mixed lithofacies and clean siliciclastics at the Las Vegas Range (LV). At the Montgomery Hills (MH), equivalent strata consist only of mixed lithofacies, though heavily siliciclastic (Plate 1A). Within 17 km, the section is almost entirely clean carbonates as at Echo Canyon (EC).

**General Comment**

This Grand Cycle is somewhat questionable in that it might be better classified as a fourth-order cycle within a third-order Grand Cycle that encompasses all members from the top of the carbonates of the Upper Member of the Wood Canyon to the top of the Gold Ace Limestone. The problem arises from the observation that two Grand Cycles are easily split out of the section in the outer bank area, i.e., along Grand Cycle boundaries at the top of the Thimble Limestone and at the top of the Gold Ace Limestone. However, in the mixed lithofacies of the back-bank lagoon it becomes very difficult to divide the section. Palmer (1981b), in a discussion of the correlatability of Grand Cycle tops, noted that in eastern Tennessee there is a possible Lower Cambrian cycle top within the *Olenellus* zone between the Shady Formation and the Rome Formation (his Grand Cycle "W" in stratigraphic column R). This cycle top is in the same trilobite biostratigraphic interval as the Grand Cycle boundary at the top of the Thimble Limestone, i.e., located between the top of the Wood Canyon carbonates and the top of the Gold Ace Limestone. However, Palmer (1981b) also noted that there were no other recognized Cordilleran Grand Cycles at this biostratigraphic position. This implies that unless sedimentologic, tectonic, and eustatic conditions are all favorable, a Grand Cycle may not form, and that continent-wide correlations of Grand Cycles must be done very carefully.

**Type 2 Sequence Boundary**

The sequence boundary separating the Thimble Limestone from the overlying Echo Shale marks the beginning of the second Grand Cycle/sequence. In the lagoon, as represented on the strike section (Plate 1B) by the area from the Montgomery Hills (MH) to the Nopah Range (N), it is difficult to pick the sequence boundary. This is partly due to the lack of clean carbonate lithofacies in this area, but is also due to the lack of a definitive sequence boundary surface. The lack of a definite surface indicates that sedimentation in the lagoon was not interrupted for any appreciable interval of time. This is consistent with a Type 2 boundary forming between the Grand Cycles, and also may reflect continued bank deposition in a distal position. The decrease in accommodation (fall in relative sea level) that marks the initiation of this Grand Cycle may be more aptly thought of as a stall in the increase of accommodation (rise in relative sea level).

**Minimum Accommodation Systems Tract**

Within the study area, there is little evidence for or against a **MNAST** in this Grand Cycle. Clean siliciclastic lithofacies are only found in the easternmost locations, the Las Vegas Range (LV) and Frenchman Mountain (FM), and the southernmost location, Winters Pass (WP) (Plate 1). This limited exposure does not allow definitive recognition of either a progradational or retrogradational stacking pattern of lithofacies and parasequences to aid in differentiation between a **MNAST** and a **IAST**. If a **MNAST** is deposited, then it is likely restricted to no more than the basal 10 to 20 m of the Grand Cycle, is composed only of marine lithofacies, and is lithostratigraphically part of the Echo Shale. As such, it would be very difficult to distinguish from the **IAST**. Because of the widespread presence of the mixed lithofacies interval at the base of the Grand Cycle, it is inferred that the carbonate bank remained active, though outside the study area, during **MNAST** and/or **IAST** deposition. This inference does not preclude the possibility of a hiatus in sedimentation during much or all of the time of the **MNAST**. Such a hiatus would result in placement of the transgressive surface on or very close to the sequence boundary.

**Increasing Accommodation Systems Tract**

An interpretation of retrogradational stacking of lithofacies and parasequences can be made based upon the vertical change from clean siliciclastics to mixed lithofacies that is recorded at Winters Pass (WP) and the Las Vegas Range (LV) (Plate 1). Note that this interpretation avoids the question of whether the clean siliciclastic interval alone represents a progradational or retrogradational stacking (**MNAST** versus **IAST**). If the **MNAST** is not present in this Grand Cycle, then the **IAST** will incorporate the clean siliciclastic interval at the southern and eastern parts of the study area, as well as the lower portion of the mixed lithofacies interval. In the study area, the clean carbonate interval has a relatively restricted areal distribution (Plate 1). Its thickness of approximately 70 m in the area from the Last Chance Range (LC) to Echo Canyon (EC) indicates that the position of the carbonate bank was relatively stable during much of the Grand Cycle. It is possible that part of the clean carbonate interval belongs in the **IAST**. The relative stability of the bank over most of its duration precludes definitive differentiation of **IAST** and **MXAST**.

**Maximum Accommodation Systems Tract**

The clean carbonate interval comprises the Gold Ace Limestone. Much or all of this interval forms the **MXAST** in the northern and western part of the study area. The part of the mixed interval, assigned to the Echo Shale, that is laterally equivalent to the Gold Ace Limestone forms the **MXAST** to the east and south. In the Las Vegas Range (LV), only the upper seven meters of section are mixed lithofacies and this represents the greatest cratonward progradation of mixed deposition in the lagoon. It is interpreted to have occurred during the latest highstand, when the rate of accommodation decreased (Figure 19). At least part of the shale-rich interval of siliciclastics at Frenchman Mountain (FM) is assigned to the **MXAST**. The measured stratigraphic section at Titus/Titanothere Canyons (TC) records an anomalously thin interval of clean carbonates and an anomalously thick interval of mixed lithofacies. The anomalous thickness values may be due to faulting at the base of the section.

## THIRD SEQUENCE/GRAND CYCLE: PYRAMID SHALE-RED PASS LIMESTONE

### Pyramid Shale

**Lithology.**—Whereas the previous two siliciclastic members are dominantly subtidal shale and siliceous mudstone, the Pyramid Shale contains a moderate percentage of subtidal, and some intertidal, siltstone and sandstone. Only subtidal facies are found in the lower, clean siliciclastic interval that extends across the entire dip section (Plate 2A) to the Last Chance Range (LC). S2 shallowing-upwards cycles are most common, with lesser numbers of S1 cycles. Poor outcrop quality in thick shale/mudstone intervals precludes the delineation of thinner cycles. The mixed lithofacies interval, though present, is richer in carbonates than has been seen in previous members, and in most instances would be grouped with the overlying Red Pass Limestone Member. At the Las Vegas Range (LV), intertidal sandstone is more common than subtidal ooid grainstone, fossiliferous packstone/grainstone, and lithoclast packstone/grainstone. Hence, at that location the mixed interval would be assigned to the Pyramid Shale Member. A variant on shallowing-upwards cycle M14, with a basal subtidal carbonate packstone/grainstone overlain by intertidal sandstone/siltstone can be found in this mixed interval.

**Lateral Change.**—Three of the thickest sandstone and siltstone intervals in the Pyramid Shale are present in the clean siliciclastic interval at the Last Chance Range (LC) and Titus and Titanothere Canyons (TC) (Plate 2A). This is somewhat unexpected as these two locations are in the most down-dip positions. However, the distribution may be due to episodic lateral movement of fluvial-deltaic systems on the craton side of the lagoon that resulted in a non-uniform distribution of sands and silts. This interpretation is reinforced by concentrations of sandstone and siltstone in the middle of the strike section (Plate 2B) at the Resting Spring Range (NR, MR, and SR) and Nopah Range (N).

At the top of the Pyramid Shale, over 20 m of clean siliciclastics at Eagle Mountain (EM) are interpreted to change laterally to mixed lithofacies at the Montgomery Hills (MH) (Plate 2B). To the south at Winters Pass (WP), 25 m of mixed lithofacies are present at the base of the member. Subtidal shale/mudstone forms the dominant lithofacies, with interbeds of fossiliferous packstone/grainstone. Placement of the boundary between the Gold Ace Limestone and the overlying Pyramid Shale is ambiguous at Winters Pass (WP) and this part of the section may correlate with the Gold Ace Limestone.

### Red Pass Limestone

**Lithology.**—The Red Pass Limestone can be divided into a lower, mixed lithofacies interval and an upper clean carbonate interval. An additional mixed interval is present at the top of the section at the Las Vegas Range (LV) above the clean carbonate interval. The faulted-out interval of the member at the Montgomery Hills (MH) is interpreted to have been a clean carbonate interval. This is based on lateral correlations between the clean carbonate interval at Echo Canyon (EC) to the west and the clean carbonate interval at the Las Vegas Range (LV) to the east. Many of the various carbonate lithofacies can be found in the mixed lithofacies and the clean carbonate intervals. Common to both are ooid grainstone, nodular ribbon rock, fossiliferous packstone/grainstone, subtidal CDAS lithofacies, low intertidal dolosiltite-calcarenite-calcisiltite lithofacies, rare subtidal mudstone/wackestone, rare thrombolitic boundstone, and rare stromatolitic boundstone. In the mixed interval, additional carbonate lithofacies include lithoclast packstone/grainstone, and subtidal-to-lowest-intertidal well-layered and nodular ribbon rock, in addition to subtidal siliciclastic sandstone, siltstone, and shale/mudstone. Additional lithofacies found only in the clean carbonate interval include bioturbated ribbon rock, calcic fenestral mudstone, rare oncolitic packstone, and rare mid-to-high-intertidal, microbially laminated, orange dolosiltite. The most common carbonate lithofacies in both intervals are nodular ribbon rock and ooid grainstone. Nodular ribbon rock is more common in the clean intervals than is oolitic grainstone, but the situation is reversed in the mixed interval. Shallowing-upwards cycles exhibit a variety of styles in the mixed interval, including cycle-types C1, C2, S2, M1, M3, M4, M5, M7, M9, M11, and M13. In the clean carbonate interval cycle-types C1, C3, C4, and C5 are present.

**Lateral Change.**—To the south and east the base of the mixed interval is generally found higher in the stratigraphic section. This is particularly noticeable in Plate 2B between the Montgomery Hills (MH) and Eagle Mountain (EM), and between the Nopah Range (N) and Winters Pass (WP). Clean siliciclastics replace both mixed lithofacies and clean carbonates between the Las Vegas Range (LV) and Frenchman Mountain (FM) on the dip section (Plate 2A). However, an 18 m interval of mixed lithofacies is present at the top of the section at the Las Vegas Range (LV), displacing clean carbonates to the west. Within the mixed interval, siliciclastics decrease in abundance from east to west, forming a majority of the interval at the Las Vegas Range (LV) (and designated as Pyramid Shale), but making up a minority of the interval at all other locations. The clean interval extends updip in the line of Plate 2A to somewhere between the Las Vegas Range (LV) and Frenchman Mountain (FM), but ends between the Montgomery Hills

(MH) and Eagle Mountain (EM) in the strike section (Plate 2B). Interestingly, there is a greater abundance of ooids off the main part of the carbonate bank (the clean interval) and within the lagoon (the mixed interval).

**Type 2 Sequence Boundary**

In most locations without the Gold Ace Limestone the basal sequence/Grand Cycle boundary is placed at the contact between mixed lithofacies and overlying clean siliciclastic lithofacies (Plate 2). No erosion or evidence for subaerial exposure was recognized along the contact, and whereas there is a relatively abrupt change from mixed to clean siliciclastic deposition across the contact, the depositional environment remains marine. These features imply that a Type 2 boundary separates the two Grand Cycles. At Eagle Mountain (EM) and the Montgomery Hills (MH), the boundary has been drawn more than 10 to 30 meters above the contact between mixed and clean siliciclastic deposits. At Eagle Mountain, there is a final 10 cm thick, trilobite packstone at the boundary, and the underlying shale, though without carbonate interbeds, contains numerous trilobite fragments. The overlying shale is devoid of both carbonate interbeds and trilobites. At the Montgomery Hills (MH), the boundary pick is less justified as there are no trilobites found in the upper 12.5 m of the preceding Grand Cycle and there is no final carbonate interbed at the boundary. The pick for the boundary is based more on a consideration of maintaining thickness for the two Grand Cycles. The contact could be moved down by the 12.5 m with little affect on the overall stratigraphic interpretation. At Winters Pass (WP), the sequence boundary pick is also somewhat arbitrary and could easily be moved from its present position at the top of the 8-m thick carbonate bedset to the top of the last carbonate interbed 25 m above. Again, much of the reason for the pick is maintenance of relative thickness along the strike cross sections.

**Minimum Accommodation Systems Tract**

As with the previous Grand Cycle, there is not definitive evidence for or against the presence of a **MNAST** at the base this Grand Cycle. However, in this cycle the clean siliciclastic interval, the Pyramid Shale Member, does extend across all of the study area and tends to be greater than 40 m thick. Retrogradational stacking of the siliciclastic interval has been interpreted to be present between the Montgomery Hills (MH) and Eagle Mountain (EM) (Plate 2B). If correct, this indicates that at least the upper part of the siliciclastic interval should be assigned to the **IAST**. It appears likely that the decrease in accommodation (fall in relative sea level) associated with initiation of this sequence was of sufficient amplitude and/or duration to allow distribution of siliciclastic sediments across a wide area. Given this and the thickness of the siliciclastic interval, it is likely that part of it was deposited during the **MNAST**.

However, without recognition of either a transgressive surface within the interval to mark the change from **MNAST** to **IAST**, or additional stratigraphic sections down depositional dip to demonstrate a change from a progradational to retrogradational stacking of lithofacies and parasequences, a definitive assignment can not be made.

As in the first Grand Cycle, the lack of carbonate interbeds indicates that if the carbonate bank remained active at the start of this Grand Cycle, then it did so at a great enough distance to not distribute carbonate sediments into the study area.

**Increasing Accommodation Systems Tract**

As discussed above, at least the upper part of the Pyramid Shale was deposited during the **IAST**. Laterally equivalent parts of the mixed lithofacies interval, especially at Echo Canyon (EC) and the Montgomery Hills (MH) (Plate 2B), and the lower parts of the mixed interval in other locations (Plate 2A and 2B) were also deposited during the **IAST**. Because much of the mixed interval is predominantly carbonate, it is lithostratigraphically assigned to the Red Pass Limestone Member. The presence of the carbonate interbeds again is indicative that the carbonate bank was re-established early in the **IAST**, and within distance to contribute carbonate sediments to the study area.

**Maximum Accommodation Systems Tract**

The clean carbonate interval, assigned to the Red Pass Limestone, is interpreted to have been deposited entirely during the **MXAST**. In the strike cross section (Plate 2B), this interval grades laterally into mixed lithofacies between the Montgomery Hills (MH) and Eagle Mountain (EM). However, in the dip cross section (Plate 2A) the clean carbonate interval extents east of the Las Vegas Range (LV). This represents a substantially greater expansion eastward for the carbonate bank than in the previous two Grand Cycles, but expansion to the south was not significantly greater. At the Las Vegas Range (LV), in the uppermost part of the **MXAST**, an interval of mixed lithofacies overlies the carbonates. Rapid progradation commonly coincides with the late **MXAST** because the rate of accommodation is becoming increasingly negative (Figure 19). If basinward progradation of the siliciclastics took place at a greater rate than cratonward progradation of the carbonate bank, then a geometry such as this could develop. However, as seen in the previous two Grand Cycles, it is just as likely that the net rate of progradation of carbonates is greater than that of siliciclastics.

## FOURTH SEQUENCE/GRAND CYCLE: PAHRUMP HILLS SHALE-JANGLE LIMESTONE

### Pahrump Hills Shale

**Lithology.**—Multiple tongues of clean siliciclastic and mixed lithofacies intervals in combination with lateral facies changes make the Pahrump Hills Shale the most complex siliciclastic member in the Carrara. The lithostratigraphic boundary with the overlying Jangle Limestone Member can be placed at the top of the mixed interval that comes in on top of the upper three nonmarine tongues of clean siliciclastics (Plates 3A and 3B). Between Echo Canyon (EC) and the Las Vegas Range (LV) to the east (Plate 3A), the lower half of the overlying Jangle Limestone changes laterally to a mixed interval that is lithostratigraphically designated as the Pahrump Hill Shale Member. The depositional dip cross section (Plate 3A) shows intertonguing between clean carbonates and the mixed interval at the Montgomery Hills (MH).

Lithofacies found in the clean siliciclastic tongues are subtidal shale to sandstone with minor quantities of intertidal shale through sandstone, as well as supratidal shale/mudstone. This is the only siliciclastic member in which a demonstrable supratidal lithofacies is found. Blocky weathering, slickensides, churning, mudcracks, and small tepee structures indicate development of a supratidal paleosol. Intertidal lithofacies are associated with supratidal shale/mudstone, though few of them have mudcracks. In many instances there are thin (≤ 10-15 cm), intertidal dolosiltite beds at the bases of parasequences in the supratidal mudstone. S2 shallowing-upward cycles are almost exclusively found in the clean siliciclastic intervals. Rare S1 cycles can be found. The supratidal shale/mudstone is involved in S2 cycles, as well as mixed cycles with minor to moderate numbers of carbonate beds, i.e., cycles M13 through M15. Most of the siliciclastic supratidal lithofacies intervals ("NON-MAR") delineated on Plates 3A and 3B have been drawn to emphasize changes in lateral extent of this lithofacies. The lithofacies boundaries commonly are parallel to parasequence boundaries, and upper lithofacies boundaries coincide with parasequence boundaries. In addition, because the lithofacies intervals drawn on the cross sections commonly encompass two or more parasequences minor carbonate units (basal parts of parasequences) may be contained within a supratidal siliciclastic interval.

A great variety of siliciclastic and carbonate lithofacies can be found in the mixed lithofacies interval. Subtidal and intertidal siliciclastic shale to sandstone are present. All subtidal and intertidal carbonate lithofacies, except bioturbated ribbon rock and calcareous fenestral mudstone, appear in this interval. Low-intertidal stromatolitic boundstone is more common than elsewhere in the Carrara, and crops out in distinctive orange-to-gray ledges that can be correlated for tens of kilometers. Intertidal carbonate lithofacies are moderately common throughout the tongues of mixed lithofacies, and are more common in this member than in previous members. At Titus and Titanothere Canyons (TC) they make up most of the outcrop.

Shallowing-upward cycles (parasequences) in the mixed intervals also show a wide variation, with cycle-types C1 to C3, C5, S2, M1 to M6, and M8 to M15 present.

**Lateral Change.**—The overall pattern of lateral lithofacies change was again dominated by easterly- and southerly-derived siliciclastics, whereas carbonates were derived from the west and north. In the basal part of the dip section (Plate 3A), two tongues of clean siliciclastics, separated by a mixed tongue, appear to onlap the basal sequence boundary to the east. The onlap may be real and due to an increase in accommodation (rise in relative sea level) or may be apparent and due to a point source which localized siliciclastics between the Las Vegas Range (LV) and the Titus and Titanothere Canyons (TC) area, with a thinner, but contemporaneous, mixed section at the Las Vegas Range (LV) and a thicker equivalent section to the west. The other clean siliciclastic interval is mainly restricted to the Frenchman Mountain (FM) area and is interpreted to be younger. Only the upper part of this interval extends to the west at least as far as the Las Vegas range (LV) area.

The lower mixed interval intertongues with and grades eastward into the lower clean siliciclastic tongues (Plate 3A). It is, in part, overlain by the middle tongue of supratidal rock and the down-dip equivalent subtidal sandstone with some mixed carbonates. The equivalent sandstone extends past the Last Chance Range (LC) for an undetermined distance. The upper mixed interval crops out at the Las Vegas Range (LV), grades eastward into clean siliciclastics and westward into clean carbonates at the Montgomery Hills (MH) and Echo Canyon (EC) areas.

Intertonguing relationships are more complex in the strike section (Plate 3B). The lowest clean siliciclastic tongue extends across the entire section, as does the overlying mixed tongue. However, the second siliciclastic tongue grades laterally to the south into the lowest mixed tongue and extends northward to Echo Canyon (EC). Two thin tongues of supratidal shale/mudstone stretch from the south to Eagle Mountain (EM) and to the middle Resting Spring Range (MR) and overly the second siliciclastic tongue. They are overlain by, and grade laterally into, the second mixed tongue that passes through the Nopah Range (N) but does not continue to Winters Pass (WP). The third (middle) supratidal tongue overlies the second mixed interval tongue and reaches as far north as the Montgomery Hills (MH). North of there, it grades laterally into mixed lithofacies and sandstone. Overlying the middle supratidal tongue is the upper interval (third tongue) of mixed lithofacies, and it also extends across the width of the cross section. However, at the southern end, two thin tongues of supratidal shale/mudstone are present, the lower (fourth) tongue is present at locations as far north as Chappo Spring (CS) in the southern Resting Spring Range, and the upper (fifth) tongue is present only at Winters Pass (WP).

**Jangle Limestone**

**Lithology.**—Clean carbonate lithofacies intervals and mixed lithofacies intervals intertongue in the Jangle Limestone Member. In addition, at Winters Pass (WP) the northern terminus of a clean siliciclastic tongue crops out, underlain by a clean carbonate interval and overlain by a mixed interval. The Jangle contains the greatest variety of carbonate lithofacies, with examples of each of the 15 carbonate lithofacies in clean carbonate intervals, whereas the mixed intervals lack only bioturbated ribbon rock, stromatolitic boundstone, and intertidal mudstone/wackestone. Mixed intervals also contain shale/mudstone and siltstone/sandstone that are mostly subtidal facies with subordinate intertidal facies. Intertidal carbonate lithofacies are common, and are present in all mixed intervals and in the three upper clean carbonate tongues, but are lacking in much of the basal clean tongue. The middle two tongues of clean carbonates grade laterally into a mixed lithofacies interval and this, combined with the lack of intertidal lithofacies in the lowest clean carbonate tongue, allows subdivision of the Jangle Limestone into two fourth-order shallowing-upward cycles composed of fifth-order shallowing-upward cycles. This subdivision can be recognized at all locations except Frenchman Mountain (FM) where siliciclastics are contemporaneous with the lower fourth-order cycle (Plate 3A). The clean siliciclastic interval at Winters Pass (WP) is composed of subtidal shale to sandstone.

Fifth-order shallowing-upward cycles also show a wide range of variability, with all six of the carbonate cycles present in the clean carbonate tongues, cycle S2 present in the clean siliciclastic interval at Winters Pass (WP), and cycle-types C1, C3, C5, S2, and M1 to M9 present in the mixed intervals. In addition, cycle-types M13 and M15 are present, though without supratidal shale/mudstone.

**Lateral Change.**—The common pattern of siliciclastics derived from the east and south in conjunction with carbonates derived from the west and north repeats in the Jangle Limestone, but is somewhat complicated by the presence of the two fourth-order shallowing-upwards cycles within the member. Three tongues of clean carbonate lithofacies are in the lower fourth-order cycle, in contrast to a single tongue in the upper (Plates 3A and 3B). The basal carbonate tongue is the major tongue in the lower cycle and correlates across the strike section (Plate 3B), whereas, between Eagle

Mountain (EM) and the northern Resting Spring Range (NR), the next two tongues grade laterally into a mixed interval. These two thin tongues are somewhat arbitrarily separated by a thin (< 2.5 m) mixed-interval tongue. In turn the mixed interval, overlying the basal carbonate tongue, grades laterally into the clean siliciclastic interval at Winters Pass (WP).

In the dip section (Plate 3A), The lower carbonate tongues pass into the mixed interval east of the Montgomery Hills (MH), whereas the thin upper (third) carbonate tongue extends farther east through the Las Vegas Range (LV). Because the members are defined as lithostratigraphic units rather than as chronostratigraphic units, the extension of the mixed interval into the Las Vegas Range (LV) is assigned to the Pahrump Hills Member (Cf. Plates 3A and 3B). This is due to dominant siliciclastic lithofacies in the interval and despite the apparent isochronism of most of the interval with the lower fourth-order cycle of the Jangle Limestone.

The upper fourth-order cycle is less complicated, consisting of a single thick, clean carbonate interval that extends across all of the dip section (Plate 3A), but merges laterally into a mixed interval south of the middle Resting Spring Range (MR) in the strike section (Plate 3B). Several minor complications are found in the cycle. At the Las Vegas Range (LV) and at Frenchman Mountain (FM), a minor tongue of clean siliciclastics displaces the lower part of the carbonate interval. In the strike section (Plate 3B), the basal part of the carbonate interval extends south of the Nopah Range (N), whereas the upper part grades laterally into the mixed lithofacies between the middle part of the Resting Spring Range (MR) and Chappo Spring (CS). There is also a thin tongue of mixed lithofacies that extends into the clean carbonate interval between Eagle Mountain (EM) and the northern Resting Spring Range (NR). Lastly, there is a 15 m thick interval of subtidal mixed lithofacies at the Montgomery Hills (MH) without laterally equivalent mixed intervals in neighboring ranges 17, 24 and 89 km away (Plates 3A and 3B).

Intertidal carbonate lithofacies in the Jangle Limestone tend to be concentrated at the northern and western parts of the sections and in the upper half of each of the fourth-order cycles. However, the lateral continuity of intertidal lithofacies varies considerably, indicating that large areas of the carbonate bank were probably not receiving intertidal deposits simultaneously. The cross section in Figure 10 shows fifth-order cycle correlations within the upper fourth-order cycle in the Jangle limestone. When lithofacies correlations are further constrained by fifth-order parasequence boundaries, the lateral discontinuity of intertidal facies becomes more pronounced, as can be seen below Parasequence Boundary I, below Parasequence Boundary V, and below the discontinuous Parasequence Boundaries A through H.

**Summary of Interpretation**

This is the most complex of the Grand Cycles wholly contained within the Carrara Formation. The **MNAST**, **IAST**, and **MXAST** are all present and there are several intervals of clean siliciclastics, mixed lithofacies and clean carbonates (Plate 3). Within the **MNAST** and the **IAST** are several tongues of nonmarine shale/mudstone. Because of the progradational stacking that characterizes a **MNAST**, the greatest basinward advance of nonmarine sediments is present at the top of the **MNAST**, not at the base. The lower parasequence set in the Jangle Limestone and part of the Pahrump Hills Shale make up the **IAST**. The **MXAST** is composed of the upper parasequence set and, in the easternmost part of the study area, a part of the Pahrump Hills Shale as well.

**Type 2 Sequence Boundary**

No evidence of exposure or erosion has been found along this boundary and whereas the initial sediments of the Grand Cycle are principally clean siliciclastics, the depositional environment remains peritidal/marine across the boundary. Because of this, the sequence boundary is interpreted as a Type 2.

In most locations, recognition of the boundary is facilitated by the change from clean carbonate or mixed lithofacies into clean siliciclastic lithofacies. At Frenchman Mountain (FM) the positioning of the boundary was decided by the red coloration of the sandstone overlying the boundary and by trilobite occurrences and zonations reported by Palmer and Rowland (1989). Picking of the boundary at the Las Vegas Range (LV) is somewhat more arbitrary, and the boundary could be moved up or down a few meters with little influence on correlations and interpretations. The choice at Titus/Titanothere Canyons (TC) is based on the first influx of siliciclastics, even though the change in lithofacies across the boundary is minor.

No attempt has been made to pick the boundary at the Last Chance Range, where the section is unusually thin. No faulting was recognized for over 50 m above or below where the third and fourth Grand Cycles are divided. Unpublished stratigraphic sections of the Carrara above the Red Pass Limestone, measured by Halley (1974) and by I. Montañez and D. Osleger (personal communication, 1993) are in close agreement with each other and with the approximately 50 m above the Red Pass Limestone measured during the course of the present study. Their picks for the Carrara/Bonanza King contact are also in agreement and appear to be in close agreement with the criteria used in the present study. Neither of the sections measured through the upper Carrara record any faulting, any erosion, or any major exposure or dissolution surfaces. If the correlation of the sandstone between the Last Chance Range (LC) and Titus/Titanothere Canyons (TC) is correct, then the missing section would be placed below the sandstone (Plate 3A). The anomalously thin section at the Last Chance Range (LC) for this Grand Cycle is not explained in this study.

**Minimum Accommodation Systems Tract**

The **MNAST** is contained within the Pahrump Hills Shale, but does not involve the entire member (Plate 3). Nonmarine red beds of shale/mudstone define the progradational nature of the **MNAST**, the position of the transgressive surface (a parasequence set boundary), and the retrogradational stacking that aids in identifying the **IAST**. Five tongues of nonmarine siliciclastics have been delineated on the strike cross section (Plate 3B), and the lower three are within the **MNAST**. Most of the **MNAST** is characterized by alternation of clean siliciclastic intervals and mixed lithofacies intervals. The first two nonmarine tongues are separated by a thin incursion of marine carbonate and siliciclastic lithofacies that mark the base of a parasequence. The third nonmarine tongue is the most widespread; north and west of the Montgomery Hills (MH) equivalent marine siliciclastics predominate over carbonates. This final extension of the third tongue is delineated on Plate 3 as "clean marine siliciclastics" (SIL) in spite of the associated carbonate lithofacies to distinguish it from adjacent mixed lithofacies intervals and to emphasize the greatest basinward extension of nonmarine siliciclastics in this Grand Cycle. The dip cross section (Plate 3A) shows the overall progradational stacking of the lower siliciclastic tongues. The strike cross section (Plate 3B) emphasizes the overall progradational stacking of the three lower nonmarine tongues.

The **MNAST** at Titus/Titanothere Canyons (TC) is predominantly of mixed lithofacies, except for the top 25 m which is clean carbonates underlying the final siliciclastic tongue. The presence of carbonates in the **MNAST** implies that the carbonate bank was never overrun by siliciclastics and that if production was shut off by the decrease in accommodation, it did not remain so for long. The extension of the uppermost siliciclastic tongue to the Last Chance Range (LC) does indicate that, in the study area at least, the bank was overrun by siliciclastics at the end of the **MNAST**, but the thin (<2 m) nature of the interval and the thick intervals of clean carbonates (>50 m) on either side of the siliciclastics again imply that this was relatively short-term.

Between the Montgomery hills (MH) and the Las Vegas Range (LV), the entire **MNAST** appears to onlap the underlying sequence boundary, as is predicted for a **MNAST** (Van Wagoner et al., 1990). The lack of accessible outcrop in this area precludes verification of the relation between **MNAST** and sequence boundary, but if access can be gained, this would be an interesting geometric relationship to confirm. The progradation recorded in this **MNAST** and the **MNAST** of the first Grand Cycle is greater than predicted by standard sequence stratigraphic models (Posamentier and Vail, 1988; Van Wagoner et al., 1990). This may reflect either a lower slope to the shelf or faster siliciclastic sedimentation rates for this area than was used in the models.

**Increasing Accommodation Systems Tract**

The base of the **IAST** is well defined by the transgressive surface at the top of the third nonmarine tongue and by the retrogradational stacking of the fourth and fifth nonmarine tongues. The top of the **IAST** is less clearly defined, but is tentatively placed at the second parasequence set boundary, which lies within the Jangle Limestone. This parasequence set boundary separates two fourth-order, shallowing-upward cycles, each composed of meter-scale, fifth-order, shallowing-upward cycles, which can be recognized over almost all of the Carrara. There is a relatively pronounced deepening across this boundary, in many cases going from intertidal facies to deeper subtidal facies, including bioturbated ribbon rock (see Chapter 4). This surface may represent the maximum flooding surface of the sequence/Grand Cycle. If this interpretation is correct, it represents a significant departure in facies relationships from the standard siliciclastic sequence-stratigraphic model. In the standard model, a position many tens of kilometers offshore from the cratonal shoreline will record subtidal sediments on either side of the maximum flooding surface (Jervey, 1988; Posamentier et al., 1988; Posamentier and Vail, 1988; Van Wagoner et al., 1990). Instead, in the Jangle Limestone, sediments of the carbonate bank and the adjacent part of the lagoon were able to build into the intertidal zone (Plate 3B) below the maximum flooding surface. The dip cross section (Plate 3A) shows that in a distal position from the bank, e.g., the Las Vegas Range (LV), the lagoonal mixed sediments remained subtidal below the maximum flooding surface, as did the clean siliciclastic sediments at Frenchman Mountain (FM). This results in intertidal sediments underlying the maximum flooding surface across the bank and into the adjacent lagoon, but relatively deeper subtidal sediments overlying it. Farther cratonward, the maximum flooding surface has subtidal sediments on either side as in the standard model.

Within the **IAST**, in addition to the two nonmarine tongues at the base, there are three tongues of clean carbonates expanding south and east from the bank, displacing and overriding tongues of mixed lithofacies. The mixed-lithofacies tongues coalesce and laterally grade into clean, marine siliciclastics between the Las Vegas Range (LV) and Frenchman Mountain (FM). The cratonward expansion of the carbonate tongue and the underlying mixed lithofacies may be interpreted to represent continued retrogradational stacking of lithofacies and parasequences. This retrogradational stacking pattern is not shown in the strike cross section because the lowest carbonate tongue extends farther south than subsequent carbonate tongues. A higher rate of siliciclastic influx from the south than from the east during the middle and late portions of the fourth-order cycle could account for this difference of apparent stacking patterns between the two sections.

The nonmarine tongues and the lower mixed interval tongue would lithostratigraphically be named as Pahrump Hills Shale. In the Las Vegas Range (LV) the coalesced mixed interval and the upper carbonate tongue are placed within the Pahrump Hills Shale Member entirely, as is the siliciclastic interval at Frenchman Mountain (FM) (Halley, 1974). However, at Winters Pass (WP) the siliciclastic tongue at the top of the **IAST** is assigned to the Jangle Limestone due to the underlying 14 m of clean carbonates.

**Maximum Accommodation Systems Tract**

The **MXAST** is relatively straight-forward in comparison to the **IAST** and the **MNAST**. Almost all of the dip cross section is made of one clean carbonate interval, except in the Las Vegas Range (LV) and at Frenchman Mountain (FM) where less than 10 m of marine siliciclastics are found at the base. Twenty-six meters of mixed lithofacies are present only at the Montgomery Hills (MH), apparently the result of a local influx of siliciclastics. There is insufficient stratigraphic control to determine if these siliciclastics came from the east or the south, though a southern source is the more likely. The strike cross section (Plate 3B) shows the mixed lithofacies interval overrunning the lower part of the carbonate interval and displacing it northward where a lateral transition between the two lithofacies groups is present between the middle Resting Spring Range (MR) and Chappo Spring (CS). There is a 6-m thick tongue of mixed lithofacies that continues northward into the northern Resting Spring Range (NR) before terminating in the plane of the cross section. This tongue may connect with the isolated mixed interval at the Montgomery Hills (MH). The displacement of the clean carbonate interval is interpreted to reflect an increased rate of siliciclastic sediment influx from the south in the middle to late **MXAST**. All of the **MXAST** is assigned to the Jangle Limestone, except the basal siliciclastics at the Las Vegas Range (LV) and at Frenchman Mountain (FM) which are lithostratigraphically designated as Pahrump Hills Shale.

## FIFTH SEQUENCE/GRAND CYCLE: DESERT RANGE LIMESTONE-PAPOOSE LAKE MEMBER OF THE BONANZA KING FORMATION

### Desert Range Limestone

**Lithology.**—Lithofacies and shallowing-upward cycles in the Desert Range Member are less varied than in previous members. The basal 5.5 to 30 m is a siliciclastic-rich mixed interval which, in turn, is overlain by a clean carbonate interval. The lithostratigraphic pick for the boundary with the overlying Papoose Lake Member of the Bonanza King Formation was chosen based on a change from nodular ribbon rock to oncolitic, bioturbated ribbon rock. Although care was taken to consistently pick this transition, thickness of the Desert Range Member varies considerately (Plates 4A and 4B). In some sections, faulting between the two lithofacies contributes to this variation, however much of it is likely to result from a lithofacies change (Halley, 1974; Palmer and Halley, 1979; this study) and not a significant stratigraphic event such as a sequence or parasequence set boundary. This boundary is an arbitrary and unreliable horizon for use in regional correlations and for distinguishing between the Carrara and Bonanza King Formations (Palmer and Halley, 1979; Stewart, 1970). It should be redefined, perhaps by moving the boundary horizon to the base of the Desert Range, with the reassignment of the Desert Range into the Bonanza King Formation. This would have the added benefit of combining a formation boundary with a sequence boundary and a biostratigraphic boundary (between the *Albertella* and *Glossopleura* Zones (Halley, 1974; Palmer, 1981b; Palmer and Halley, 1979).

Subtidal sandstone and siltstone are the dominant lithofacies in the mixed interval. There are lesser proportions of subtidal shale/mudstone and intertidal shale to sandstone. Carbonate facies present are subtidal mudstone/wackestone, lithoclast packstone/grainstone, fossiliferous packstone/grainstone, oolitic grainstone, well-layered and nodular ribbon rock, and CDAS lithofacies, and intertidal dolosiltite-calcarenite-calcisiltite lithofacies, and calcic fenestral mudstone. The lithofacies are arranged in shallowing-upward cycle-types C1, C2, S1, S2, M1, M3, M4, M6, M7, M9, as well as partial C5 cycles. The clean siliciclastic interval at Frenchman Mountain (FM) is composed of subtidal shale/mudstone arranged in partial S2 cycles. Subtidal nodular ribbon rock and subtidal-to-lowest-intertidal well-layered ribbon rock are most common in the clean carbonate interval. Other subtidal carbonate lithofacies present include oncolitic wackestone/packstone/grainstone, lithoclast packstone/grainstone, fossiliferous packstone/grainstone, oolitic grainstone, and CDAS lithofacies, whereas other intertidal carbonate lithofacies include dolosiltite-calcarenite-calcisiltite lithofacies and microbially laminated dolosiltite. Shallowing-upwards cycles incorporate cycle-types C1 through C5. Intertidal facies are sparse and laterally discontinuous in both intervals.

**Lateral Change.**—Lateral change in the Desert Range Limestone is also simple, with both mixed and carbonate intervals extending essentially across both strike and dip sections (Plate 4A and 4B). The mixed interval grades laterally into the clean siliciclastic interval at Frenchman Mountain (FM) and basal carbonates of the overlying Bonanza King Formation are contemporaneous with the carbonate interval. If section has not been structurally removed in the mixed interval, there is a moderate amount of lateral intergradation along the contact between the mixed and carbonate intervals, as can be seen on both sections (Plates 4A and 4B). There is a second, small tongue of mixed lithofacies on the southern end of the strike section (Plate 4B) that thins to the north, but reaches to the Nopah Range (N). It is more carbonate-rich than the lower mixed interval, but is neither as thick nor as extensive. Very minor lateral variation exists in the carbonate interval.

**A Brief Review of the Papoose Lake Member of the Bonanza King Limestone**

Although Barnes and Palmer (1961) and Barnes and Christiansen (1967) defined the Papoose Lake Member in the Nevada Test Site and Groom Range areas, and this member has been recognized over a wide area (Gans, 1974; Kepper, 1981), no detailed and complete descriptions of the sedimentology have been published. Burchfiel et al. (1982) state that at the Montgomery Hills, Nopah and Resting Spring Ranges member thickness varies from approximately 330 ± 50 m to 460 m. They describe the member as composed of gray and dark gray mottled limestone and dolostone, with two intervals of thick beds of white dolostone, one approximately 130 above the base and the other about 130 m below the top. The middle part of the member has numerous thin beds of white dolostone, generally laminated. Kepper (1981) interprets the member as a shelf lithofacies, with alternation of bioturbated beds and beds with wavy bedding and current ripples. He also states that the base of the overlying Banded Mountain Member is an isochronous, rusty-colored, dolomitic siltstone/sandstone that caps the overall shallowing-upward trend of the Papoose Lake Member.

During the present study, observations of the basal part of the Papoose Lake indicate that it is composed of oncolitic, bioturbated ribbon rock. This is interpreted as a quieter-water lithofacies than the underlying nodular ribbon rock and well-layered ribbon rock lithofacies of the Desert Range Member of the Carrara. In addition, the Papoose Lake may represent deeper subtidal deposition than does the Desert Range.

**Interpretation of the Papoose Lake Member**

If the Papoose Lake represents deeper subtidal deposition than does the Desert Range, the two members may record overall development of a **IAST**. This does not preclude a thin **MNAST** at the base of the Jangle. The interval of thick beds of white dolomite located 130 m above the basal formation contact, as reported by Burchfiel et al. (1982), may represent the uppermost beds of a sequence. In this case, they would combine with the Desert Range to make up a Grand Cycle about 160 to 200 m thick. If these white dolomite beds are an intertidal lithofacies (published descriptions do not provide enough detail to determine this), then they may be analogous to the intertidal beds found in the upper parts of Carrara sequences, e.g., the upper beds of the Red Pass Limestone at Echo Canyon (EC) and Titus/Titanothere Canyons (TC) (Plates 2A and 2B), or the upper beds of the Jangle Limestone at Eagle Mountain (EM), the southern Resting Spring Range (SR) and Titus/Titanothere Canyons (TC) (Plates 3A and 3B). The thickness of the Papoose Lake Member (≥ 330 m) makes it unlikely that the member, with the additional 30 to 70 m of Desert Range Limestone, makes up a single Grand Cycle. It is more reasonable to hypothesize that parts of at least two Grand Cycles make up the Papoose Lake Member.

**Type 1 or Type 2 Sequence Boundary?**

The boundary between the fourth and fifth Grand Cycles is basically similar to the other boundaries in that there is no evidence for exposure and there are similar peritidal/marine lithofacies on either side. However, there is some evidence for as much as 5 to 9.5 m of local relief over a lateral distance of less than approximately 200 m along the boundary at Eagle Mountain (Figure 7). Locally, the sequence boundary appears to be a parasequence boundary, with subtidal siliciclastic lithofacies overlying subtidal carbonate lithofacies. There are no rip-up clasts of the underlying subtidal lithofacies incorporated into the overlying subtidal lithofacies and there are no obvious scoured surfaces. However, when stratigraphic sections D, E, F and G are correlated (Figure 7), using the lower parasequence set boundary as a datum, sections E and F are shorter than the flanking sections, and the nodular ribbon rock topping section D and adjacent to the large thrombolitic complex at section G is found to be missing. No obvious channel or scoured geometries can be recognized on the outcrop, though this may be due, in part, to the two small, Holocene drainage gullies that lie between sections F and G. Some of the apparent relief also may relate to subtle, small-scale faulting lower in the section that sometimes causes loss of stratigraphic thickness. An example of this style of fa[illegible]g is at the top of section H (Figure 7), which is the same measured section as section EM in Plate 3B. Lastly some of the apparent relief along the sequence boundary may have existed prior to the boundary formation, perhaps due to lateral discontinuity of the nodular ribbon rock. Lateral discontinuity of subtidal lithofacies has been demonstrated at Eagle Mountain (see Chapter 4). No other evidence has been found to indicate that erosion occurred along the boundary at other locations. In summary, the evidence for local erosion is equivocal, there is a lack of evidence for widespread erosion at other locations, and other attributes are similar to the previous Type 2 boundaries. Because of these reasons, the sequence boundary is considered to be a Type 2 boundary. Erosion along sequence boundaries has been reported from other Grand Cycles (Aitken, 1978; Mount et al., 1991) and a Type 1 boundary could develop if a decrease in accommodation (fall in relative sea level) was of sufficient amplitude and/or rapidity.

### Systems Tracts

A lack of lateral variation in the Desert Range Limestone and the absence of measured sections in the Papoose Lake Member make it impossible to assign systems tract designations to this Grand Cycle. Stacking patterns are not apparent and there is a paucity of published lithofacies information about the Papoose Lake. A lower mixed lithofacies interval is present along the sequence boundary, and the mixed interval grades laterally into the siliciclastic interval exposed at Frenchman Mountain (FM). These intervals are overlain by a clean carbonate interval of subtidal and intertidal lithofacies that crops out in all sections. All of these intervals, assigned to the Desert Range Limestone, may be part or all of the **MNAST** and/or the **IAST**.

## SEQUENCE STRATIGRAPHIC MODEL OF GRAND CYCLES

### INTRODUCTION

Aitken's (1966, 1978) model of Grand Cycles was originally defined for Cambrian rocks in the Southern Canadian Rocky Mountains and, subsequently, most reported Grand Cycles were deposited along North American passive margins during the long-term eustatic rise associated with the Sauk transgression (Sloss, 1963). Grand Cycles are depositional couplets composed of two half-cycles, one dominantly of carbonate rocks overlying another dominantly of siliciclastic rocks, developed on a scale of tens to hundreds of meters in thickness (Aitken, 1966; Aitken, 1978; Aitken, 1981). Aitken's (1966, 1978, 1981) use of the term "half-cycle" for the two lithologic units of a Grand Cycle arose because he argued that each unit represented half of a depositional cycle. "Half-cycle" is used in this paper in the restricted sense of describing the two major lithologic parts of a Grand Cycle and has no implication regarding cycles of fluctuation in accommodation (relative sea level).

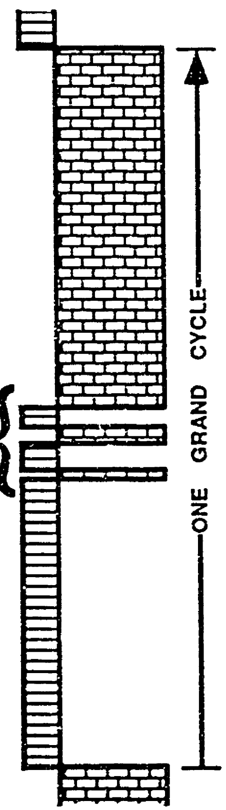
There are no implicit or explicit reasons to restrict Grand Cycle deposition to the Cambrian, and several of the papers listed in Table 8 discuss Grand Cycles from the Ordovician. Grotzinger (1986a, b) applies the concept of Grand Cycles to Paleoproterozoic rocks of the Rocknest Formation. Grand Cycles in the Carrara are approximately $10^6$ years duration or third-order cycles (see discussion in Chapter 4). The model that follows is developed for Cambrian-style, third-order Grand Cycles.

Early papers on Grand Cycles (Aitken, 1966; Aitken, 1978; Palmer and Halley, 1979) favored a mechanism of variable subsidence rates to explain the two different lithologic half-cycles. Subsequent papers (Aitken, 1981; Bond and Kominz, 1984; Bond et al., 1988; Demicco and Spencer, 1990; Demicco et al., 1991; Grotzinger, 1986a; Grotzinger, 1986b; Mount and Rowland, 1981; Palmer, 1981b; Palmer and Nelson, 1981) have recognized that variable rates of eustatic sea level change could also be invoked as a mechanism, with most favoring a eustatic origin for Grand Cycles (Aitken, 1989; Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Chow and James, 1987; Grotzinger, 1986a; Grotzinger, 1986b; Mount et al., 1991). Many papers (see Table 8) recognized that the siliciclastic half-cycle was deposited under conditions of increased rates of accommodation (relative sea level rise due to subsidence and/or eustasy) compared to the carbonate half-cycle.

Most of the previous workers referenced above and in Table 8 have agreed on facies interpretations, facies relationships, recognition of smaller-scale shoaling cycles within a larger shoaling Grand Cycle, and the occurrence of greater rates of accommodation (relative sea level rise) during deposition of the siliciclastic half-cycle relative to the carbonate half-cycle, and this study also agrees with these observations. Some anomalous Grand Cycles have been recognized with supratidal facies in the siliciclastic half-cycle and these have generated disagreement over their sea-level history; e.g., Demicco and Spencer (1990) and Demicco et al. (1991) versus Bond and Kominz (1991). Disagreement between previous workers has also arisen over the interpretation of the eustatic history recorded in Grand Cycles and assignment of sequence stratigraphic terminology to Grand Cycles (cf. Bond and Kominz, 1991; Chow and James, 1987; Demicco and Spencer, 1990; Demicco et al., 1991; Mount and Rowland, 1981). A new sequence stratigraphic model of Grand Cycle development that encompasses both the common Grand Cycle and the anomalous Grand Cycle is presented in this study. First the proposed model will be summarized, a discussion of previous work by other authors follows, and a detailed discussion of the proposed model is presented last.

**Table 8.** A summary of Grand Cycle models and interpretations arranged chronologically. The first column is of an ideal Grand Cycle, based on the literature. As has been shown in this study the thickness of the transitional, or mixed lithofacies interval, takes up a third or more of the thickness of the Grand Cycle. In the last column is the model presented in this paper. Note the large amount of overlap for each systems tract which reflects the variability of Grand Cycles. Also note that a Type 1 sequence boundary may occur in some Grand Cycles, but that none were positively identified in the Carrara Grand Cycles.

# Table 8.

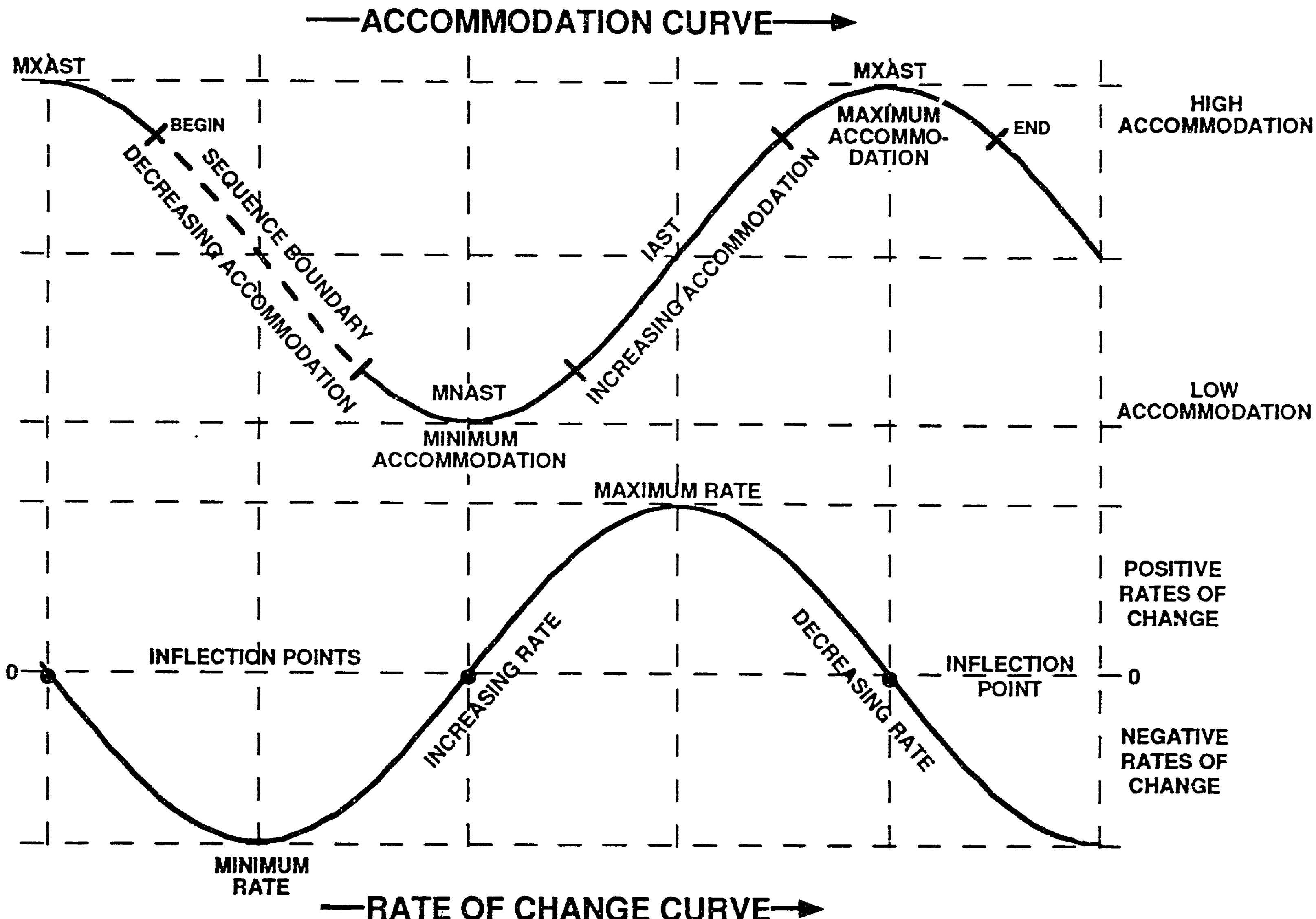
| IDEALIZED GRAND CYCLE | AITKEN, 1966<br>PULSATORY TILTING OF CRATON (EUSTASY AS AN ALTERNATE MECHANISM) | AITKEN, 1978<br>PULSES OF SUBSIDENCE | | PALMER & HALLEY, 1979<br>VARY RATE OF BASIN SUBSIDENCE OR OF SEA LEVEL RISE | MOUNT & ROWLAND, 1981<br>CHANGES IN RATE OF EUSTATIC RISE & OF BASIN SUBSIDENCE | GROTZINGER, 1986a, b<br>RATE OF EUSTATIC SEA LEVEL CHANGE | CHOW & JAMES, 1987<br>EUSTASY |
|---|---|---|---|---|---|---|---|
|  | | Sullivan Grand Cycle | Stephen Grand Cycle | | | | |
| SHARP CONTACT | Stillstand? Possibly followed by little to no deposition | Stagnation of cycle & deposition of peritidal carbonates | Peritidal carbonates | Carbonate deposition ceases due to decrease in area of 'carbonate factory' | Emergence (possible sea level fall w/ erosion) | | (7) Drown platform |
| | | | | | | | (6) Carbonate shoals re-established due to slow increase in sea level rise |
| | | | | | Carbonates keep up w/ very slow rate of relative sea level rise | | (5) Slowest rate of sea level rise. Intertidal deposition &/or exposure |
| | Very shallow to intermittently emergent sea floor during carbonate half-cycle | Decrease rate of transgression | | Decrease rate of subsidence or of sea level rise (water shallows) resulting in peritidal carbonates in upper & western part of carbonate members + rapid basinward spread of siliciclastics | | Decrease rate of sea level rise or increase rate of sea level fall | |
| ONE GRAND CYCLE | | Progradation of carbonates | Subtidal carbonates | | Decrease rate of relative sea level rise and initiate carbonate deposition | | (4) Sea level rise decreases more rapidly & deposition keeps up |
| GRADATIONAL OR TRANSITIONAL CONTACT | Decreased terrigenous sediment supply + decreased water depth due to previous deposition | | | | | | |
| | | High-energy sedimentation | Accelerated rise in relative sea level | | Widespread siliciclastic deposition | | (3) Change upsection from dominantly subtidal to dominantly supratidal |
| | Suddenly initiated shaly half-cycle. A relatively deep & muddy sea floor w/ increased terrigenous sediment supply from uplifted craton | Increase rate of transgression | | Increase rate of subsidence or of sea level rise (water deepens) | Increase rate of relative sea level change | Increase rate of sea level rise or decrease rate of sea level fall | (2) Shallow subtidal & tidal flat deposition |
| | | | | Siliciclastic deposition continues | | | |
| SHARP CONTACT | Flooding surface due to down-dropped shelf | Sudden transgression | A more gradual transgression, but still rapid | | Rapid rise & drowning | Initial net submergence of platform | (1) Rapid increase in sea level rise = transgression |
| | | | | | | | Low ← Rate of sea level rise → High |

1. **Aitken, 1981:** Attributes mechanism to eustatic variation in rate and/or direction of sea level fluctuation. 2. **Palmer, 1981:** Eustatic for some, but not all based on correlatibility.

# Table 8. (End)

| BOND, KOMINZ, & GROTZINGER, 1988<br>EUSTASY | BOND, KOMINZ, STECKLER, & GROTZINGER, 1989<br>EUSTASY | AITKEN, 1989<br>EUSTATIC PULSES OF SEA LEVEL RISE | DEMICCO & SPENCER, 1990 (Abstract)<br>NON-EUSTATIC SEA LEVEL FLUCTUATION | BOND & KOMINZ, 1991<br>EUSTASY | DEMICCO, SPENCER, WATERS, & CLOYD, 1991<br>RELATIVE SEA LEVEL FLUCTUATION | MOUNT, GREEN, HUNT, & DIENGER, 1991<br>EUSTASY<br>MODEL 1 | MODEL 2 | THIS PAPER<br>ACCOMMODATION FLUCTUATION |
|---|---|---|---|---|---|---|---|---|
| | | Terminate by abrupt sea level rise | | | | Type 2 sequence boundary & transgressive surface | Type 2 sequence boundary & transgressive surface | Type 2 sequence boundary |
| Carbonate shoal expands over shales<br>Relatively lower rates of subsidence or eustatic fall | Slower subsidence<br>Increase carbonate production to produce subtidal/intertidal cycles<br>Falling eustatic segment | Carbonate rim begins to expand into lagoon<br>Slow eustatic rise | Not discussed | Accommodation rate decreases, but sedimentation rate < accommodation rate. Transgressive systems tract (p285)<br>Eustatic fall reduces accommodation space | Transgressive systems tract<br>Type 2 sequence boundary<br>Highstand (regressive)<br>Transgressive systems tract (marine deposits)<br>Type 2 sequence boundary | HST<br>Sequence B<br>TST<br>Type 2 sequence boundary & transgressive surface | HST | Keep-up<br>MXAST<br>Catch-up<br>Start-up |
| Relatively higher rates of subsidence<br>Acceleration in rate of rise shuts off carbonate production w/ replacement by shale deposition | Subtidal siliciclastics<br>During rising segment of a eustatic cycle, net subsidence is rapid & shuts off carbonate deposition | Siliciclastic mud swept across lagoon<br>Abrupt sea level rise & marine transgression | Lowstand | Accommodation rate increases, but sedimentation rate > accommodation rate. Highstand or lowstand (p285) | Terrestrial playa-marginal marine tidal flats | HST<br>Sequence A<br>TST<br>Type 2 sequence boundary & transgressive surface | TST<br>Type 2 sequence boundary & transgressive surface | IAST<br>MNAST (Often thin or absent)<br>Type 2 sequence boundary |

**Figure 19.** The upper curve represents an idealized, symmetrical cycle of accommodation fluctuation. The horizontal axis represents time and the cycle progresses from left to right. Starting at the far left, the high point of the curve represents maximum accommodation. Accommodation decreases until the low point of the curve, minimum accommodation, is reached. Accommodation then begins to increase until the high point of the curve is again reached. The positions on the cycle where the various systems tracts are deposited are designated on the curve, as is the position where the sequence/Grand Cycle boundary forms. The derivative of the upper curve is drawn as the lower curve, and this shows the rate at which accommodation changes. See text for further discussion.



ACCOMMODATION CURVE
MXAST
BEGIN
SEQUENCE BOUNDARY
DECREASING ACCOMMODATION
MNAST
MINIMUM ACCOMMODATION
IAST
INCREASING ACCOMMODATION
MXAST
MAXIMUM ACCOMMO-DATION
END
HIGH ACCOMMODATION
LOW ACCOMMODATION
MAXIMUM RATE
POSITIVE RATES OF CHANGE
0
INFLECTION POINTS
INCREASING RATE
DECREASING RATE
INFLECTION POINT
0
NEGATIVE RATES OF CHANGE
MINIMUM RATE
RATE OF CHANGE CURVE


Figure 19.

**Figure 20.** Diagrams showing the two varieties of Grand Cycles. **A)** A complete Grand Cycle with a well developed Minimum Accommodation Systems Tract (**MNAST**) with nonmarine and marine lithofacies, as well as an Increasing Accommodation Systems Tract (**IAST**) and a Maximum Accommodation Systems Tract (**MXAST**). The presence of the **MNAST** is uncommon and complete Grand Cycles have been called anomalous Grand Cycles. **B)** An incomplete Grand Cycle with the **MNAST** thin to nonexistent. This is the common expression of Grand Cycles. See text for elaboration and Table 8 for a summary of published models of Grand Cycles.

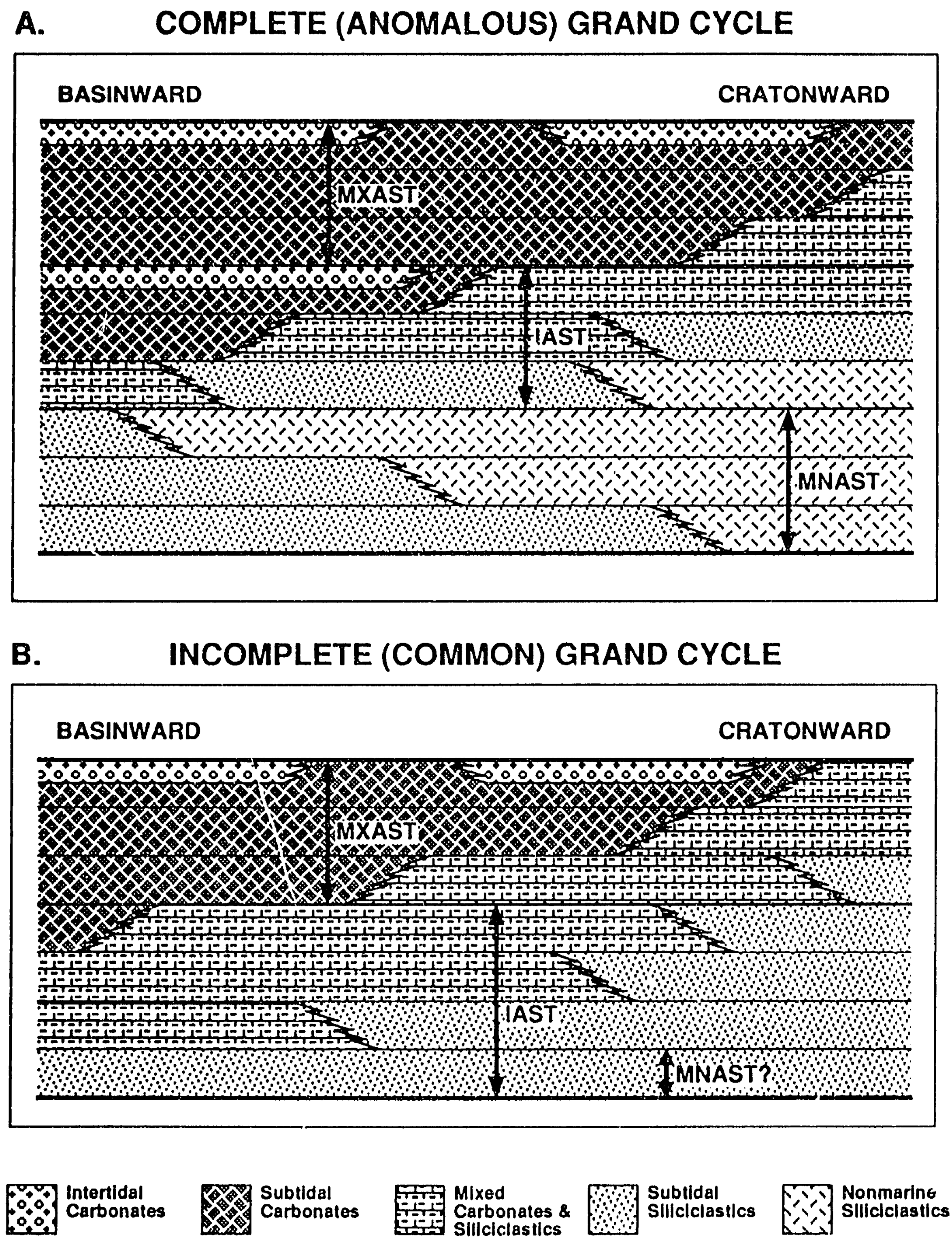

A. COMPLETE (ANOMALOUS) GRAND CYCLE
BASINWARD
CRATONWARD
MXAST
IAST
MNAST
B. INCOMPLETE (COMMON) GRAND CYCLE
BASINWARD
CRATONWARD
MXAST
IAST
MNAST?
Intertidal Carbonates
Subtidal Carbonates
Mixed Carbonates & Siliciclastics
Subtidal Siliciclastics
Nonmarine Siliciclastics

Figure 20.

## SUMMARY OF THE PROPOSED NEW MODEL

The proposed comprehensive model (Figures 19 and 20) that follows differs from most previous attempts to reconcile Grand Cycles and sequence stratigraphic concepts in that it equates high rates of accommodation (relative sea level rise) during siliciclastic deposition with the increasing accommodation systems tract (**IAST**; formerly **TST**), and the subsequent decrease in rate of accommodation (relative sea level rise) with the maximum accommodation systems tract (**MXAST**; formerly **HST**). Further, boundaries of Grand Cycles are considered to be equivalent to sequence boundaries, with the lower part of some siliciclastic half-cycles equivalent to the minimum accommodation systems tract (**MNAST**; formerly **SMST** or **LST**). Lastly, anomalous Grand Cycles, with intertidal and supratidal facies in most or all of the siliciclastic half-cycle (e.g., the Arctomys-Waterfowl Grand Cycle (Aitken, 1981) are interpreted to be unusually thick **MNAST**s.

The sequence stratigraphic model developed here for Grand Cycle deposition equates a Grand Cycle with a sequence, most commonly a third-order cycle with a duration of approximately $10^6$ years, although it is possible for a Grand Cycle to be equivalent to a fourth-order cycle ($10^5$ to $10^6$ years duration). The boundaries of the Grand Cycle are sequence boundaries, normally Type 2, but Type 1 boundaries are possible and may be the cause of minor erosion noted on several Grand Cycle boundaries (Aitken, 1978; Mount et al., 1991; this paper). Siliciclastic sediments were initially spread across the lagoon and possibly over the carbonate bank by the decrease in accommodation (fall in relative sea level) associated with development of the sequence boundary (Figure 19). Carbonate production was either shut off or severely diminished by the decrease in accommodation (fall in relative sea level) and/or the spread of siliciclastics. The **MNAST** may be present, though in most cases, if present it is apparently quite thin and easily overlooked (Figure 19). However, many of the anomalous siliciclastic half-cycles in Grand Cycles, e.g., the Arctomys Formation or the Gog sandstones, with an abundance of intertidal to nonmarine facies, may be interpreted as thick **MNAST** deposits. Commonly, the transgressive surface at the base of the **IAST** either overlies the sequence boundary or is in close proximity to the boundary. In the common case, much or all of the siliciclastic half-cycle was deposited during the time of maximum rates of accommodation, the **IAST**, and recorded retrogradational stacking of meter-scale shoaling cycles in the siliciclastic half-cycle. It is hypothesized that coincident with the cratonward movement of the siliciclastic sediments, as the water column cleared, the carbonate bank was reestablished in its most basinward locations. During the time of maximum rates of accommodation, the carbonate sediments were in a catch-up mode

(Kendall and Schlager, 1981; Schlager, 1981). As the siliciclastics retreated cratonward, the carbonate bank slowly expanded cratonward, its rate of progradation increasing as the rate of accommodation slowed, i.e., as the **IAST** passed into the **MXAST**. The carbonate bank achieved its greatest expansion during the **MXAST**, and may have prograded basinward as well as cratonward. In the late **MXAST**, siliciclastics may have prograded towards the bank sufficiently to begin to encroach upon the area of carbonate deposition. The initiation of the decrease in accommodation (fall in relative sea level) also may have reduced the area of the subtidal carbonate factory, slowing the rate of carbonate sediment production and progradation. Because siliciclastic sediment production would not be slowed by decreasing accommodation (falling relative sea level), the siliciclastics could have prograded faster and this double response to decreasing accommodation may explain the encroachment of siliciclastics over carbonates. Encroachment would have further decreased the area of the carbonate factory.

## PREVIOUS WORK

### Facies Interpretations and Relationships

In general, there is little disagreement among workers regarding the types of facies to be found in Grand Cycles and their interpretation of depositional environments. The carbonate half-cycle, with intertidal and subtidal facies, is commonly interpreted to be of shallower marine origin in comparison with the siliciclastic half-cycle, which generally contains only subtidal facies (Aitken, 1966; Aitken, 1978; Bond et al., 1989; Palmer and Halley, 1979). Early interpretations placed deposition of siliciclastic subtidal facies in deeper water than carbonate subtidal facies (Aitken, 1966; Aitken, 1978) but subsequently some workers determined that siliciclastic and carbonate subtidal facies were both deposited in about the same range of water depths, approximately down to storm wave base (Aitken, 1981; Chow and James, 1987; Mount et al., 1991; this paper).

Some anomalous Grand Cycles have been recognized that have intertidal to nonmarine facies as well as subtidal marine facies in the siliciclastic half-cycle (Aitken, 1966; Aitken, 1978; Aitken, 1981; Aitken, 1989; Bond and Kominz, 1991; Chow and James, 1987; Demicco and Spencer, 1990; Demicco et al., 1991; Mount et al., 1991; Palmer and Halley, 1979; this paper). The Arctomys-Waterfowl Grand Cycle in the Canadian Rockies is perhaps the most extreme example in that the siliciclastic half-cycle, with a preponderance of supratidal to nonmarine facies, tends to represent shallower water deposition than the carbonate half-cycle (Aitken, 1966; Aitken, 1981; Bond and Kominz, 1991; Demicco and Spencer, 1990; Demicco et al., 1991).

The Gog Group of the Canadian Rockies (Aitken, 1968; Aitken, 1978) and the Zabriskie Quartzite of the Death Valley region (Prave, 1992; this paper) are both principally comprised of marine and nonmarine, coarse-grained siliciclastics and can be interpreted to have parasequence stacking patterns that progress upwards from progradational to retrogradational. Aitken (1978) remarks that unpublished Ph. D. work of Palonen (1976) interprets the Gog sandstones as "regressive" and notes that, in combination with the coarse siliciclastic lithology, the Gog presents "... a whole new problem!" (Aitken, 1978; p.539) for Grand Cycle interpretation. Within the upper half of the Gog, the Mural Formation may be considered to be the carbonate half-cycle of one Grand Cycle, and the remaining siliciclastic/carbonate couplet (Mahto Formation-Peyto-Hota Formations) above it may be considered as a second Grand Cycle (Aitken, 1966; Aitken, 1981; Aitken, 1989). This "new problem", presented by the Gog can be reconciled in light of the model presented in this paper; the model recognizes that the sandstones record both the progradational character of the **MNAST** and the retrogradational nature of the **IAST**, whereas the carbonates may consist of the upper part of the **IAST** and all of the **MXAST**. Coarse, nonmarine and marine siliciclastics would not be unexpected in the **MNAST** and may be preserved in more proximal parts of the **IAST**, whereas progradation of the carbonate bank may occur during the late **IAST** and the **MXAST**.

Prave (1992) interprets the Zabriskie as being comprised of parts of two sequences, with a combined sequence boundary/transgressive surface between the progradational lower part (Resting Springs Member) and the retrogradational upper part (Emigrant Pass Member) separating the two sequences. In the Death Valley region, the lower sequence is not a Grand Cycle, whereas the upper sequence is. In his interpretation the basal two members of the Carrara Formation, the Eagle Mountain Shale and the Thimble Limestone, compose the upper part of the **TST (IAST)** and the **HST (MXAST)** in the upper sequence (Grand Cycle). An alternative and simpler reinterpretation that does not violate the field evidence presented in Prave (1992) can be made using the model presented in this study. The basal, progradational member of the Zabriskie is the **MNAST**, with a sequence boundary at the top of the last carbonates in the mixed interval near the top of the Upper Member of the Wood Canyon Formation. The influx of coarse siliciclastics over the carbonates and fine siliciclastics at the top of the Wood Canyon is interpreted to have resulted from the decrease in accommodation (fall in relative sea level) associated with the sequence boundary. The Zabriskie, thinner than the Gog Group and lacking carbonate members, preserved the **MNAST** (progradational stacking) and part of the **IAST** (retrogradational stacking) of a single sequence and Grand Cycle. The basal two members of the Carrara are also interpreted as part of the **IAST** and **MXAST**.

Mount et al. (1991) discussed four Lower Cambrian Grand Cycles that are correlated from the White-Inyo Mountains south to the Death Valley region. Three of their Grand Cycles are between 100 and 200 m thick. However, their Grand Cycle A is approximately 1450 m thick and very likely represents an amalgam of several siliciclastic sequences with a single Grand Cycle forming the uppermost sequence. The siliciclastic half-cycles of these Grand Cycles are generally made up of coarse-grained sediments, interpreted as a mix of marine and nonmarine facies. Mount et al. (1991), in their "Working Model 2", have interpreted these to form **TSTs** (**IASTs**). In the context of the present study, it is possible that the lower parts of some or all of the Grand Cycles are **MNASTs** that have been overlooked.

**Meter-Scale Shallowing-Upward Cycles and Boundaries**

Meter-scale shallowing-upward cycles have been recognized in Grand Cycles starting with Aitken's (1966) seminal paper wherein he noted that he could distinguish between 20 to 50 meter-scale cycles ("rhythms") per Grand Cycle. He described meter-scale cycles in both siliciclastic and carbonate half-cycles though he later simplified the carbonate shoaling cycles (Aitken, 1978). Complete meter-scale shoaling cycles that record deposition from the subtidal into the intertidal and/or the supratidal have been recognized by most workers (see Table 8) in both siliciclastic and carbonate half-cycles. In addition, incomplete meter-scale shoaling cycles composed only of subtidal facies have also been recognized in both siliciclastic and carbonate half-cycles (Grotzinger, 1986a; Grotzinger, 1986b; this paper).

A sharp contact separates the carbonate half-cycle from the overlying siliciclastic half-cycle, whereas a gradational contact separates the carbonate half-cycle from the underlying siliciclastic half-cycle. As a consequence of this depositional asymmetry, the siliciclastics are interpreted as the basal unit of a large-scale, overall shallowing-upward sequence (Grand Cycle), bounded by sharp contacts, but with an internal gradational contact between the two constituent half-cycles. Grand Cycle contacts are normally described as surfaces of flooding, although it has been recognized that erosion and/or subaerial exposure may have occurred along some contacts (Aitken, 1978; Aitken, 1989; Mount et al., 1991; this paper). A few anomalous Grand Cycles, such as the Arctomys-Waterfowl, apparently recorded a more complex depositional history than an overall shoaling (Aitken, 1966; Aitken, 1978; Aitken, 1981; Bond and Kominz, 1991; Demicco and Spencer, 1990; Demicco et al., 1991; Mount et al., 1991). The Arctomys-Waterfowl seems first to have recorded a shoaling (from the Pika Formation to the Arctomys Formation), followed by a deepening (Arctomys to lower Waterfowl Formation), followed again by a shoaling (to upper Waterfowl). Using the proposed model, this part of the Grand Cycle can be reinterpreted as successively encompassing the **MNAST**, the **IAST**, and the **MXAST** of a single sequence. Waters et al. (1989) and Demicco et al. (1991) interpret the uppermost part of the Waterfowl as having recorded a final deepening. If this facies interpretation is correct, then, in light of the new model, this may be due to development of a second parasequence set, deposited in somewhat deeper water, within the **MXAST**.

A somewhat more contentious issue is the isochronous or diachronous nature of Grand Cycle boundaries. Most workers agree that the boundaries are likely to be isochronous or slightly diachronous, but that it is very difficult to resolve this issue with biostratigraphic control because many Grand Cycles are of approximately the same duration as trilobite zones (Chow and James, 1987; Palmer, 1981b; Palmer and Halley, 1979). Mount et al. (1991) argued that the Lower Cambrian Grand Cycle boundaries are strongly diachronous with regard to trilobite zones when correlations are extrapolated between the White-Inyo Mountains and the Death Valley region. However, it is possible that they have miscorrelated carbonate half-cycles at the tops of their A and B Grand Cycles in their Figure 6 (Figure 21 of this study). If it is recognized that carbonate lithofacies may change laterally into siliciclastic lithofacies of either the outer or inner detrital belts (Halley, 1974; Palmer and Halley, 1979), then reasonable alternate correlations can be proposed (Figure 21), which remain within trilobite biostratigraphic zones and bring these Lower Cambrian Grand Cycles into agreement with the younger Carrara Grand Cycles (Palmer, 1981b; Palmer and Halley, 1979; Palmer and Nelson, 1981; this paper), as well as the Lower Cambrian Grand Cycles of the southern Canadian Rockies (Aitken, 1966; Aitken, 1978; Aitken, 1981; Aitken, 1989; Palmer, 1981b). These alternate correlations also remove awkward geometric and lithostratigraphic relationships required if thinner Death Valley carbonate half-cycles of Grand Cycles A and B are older than equivalent thicker White-Inyo region carbonate half-cycles as suggested by the correlations of Mount et al. (1991).

One of the suggested alternate correlations of the data of Mount et al. (1991) requires that the carbonate half-cycle of Grand Cycle $\gamma$ in the Grapevine and Funeral Mountains grade laterally into outer detrital siliciclastics in the White-Inyo region. The proposed position of the outer part of this carbonate bank in the Grapevine/Funeral Mountains region has not been speculated upon before. This predicted correlation could

**Figure 21. A)** Grand Cycle correlations for the Lower Cambrian of Mount et al. (1991), showing a diachronous relationship with trilobite biostratigraphy (*Fallotaspis* Zone, *Nevadella* Zone, and *Bonnia-Olenellus* Zone). **B)** Alternate correlations proposed in this paper based on the new sequence stratigraphic model of Grand Cycles. These correlations honor the trilobite biostratigraphy and are based upon recognition of lateral facies changes within Grand Cycles, and upon the possibility of successive Grand Cycles onlapping older Grand Cycle/sequence boundaries. See text for further discussion. Mount, et al. (1991) did not include a legend relating patterns to lithology. An attempt has been made to replicate their patterns. Interpretation of patterns with respect to lithologies is assumed to match the standards of the field.

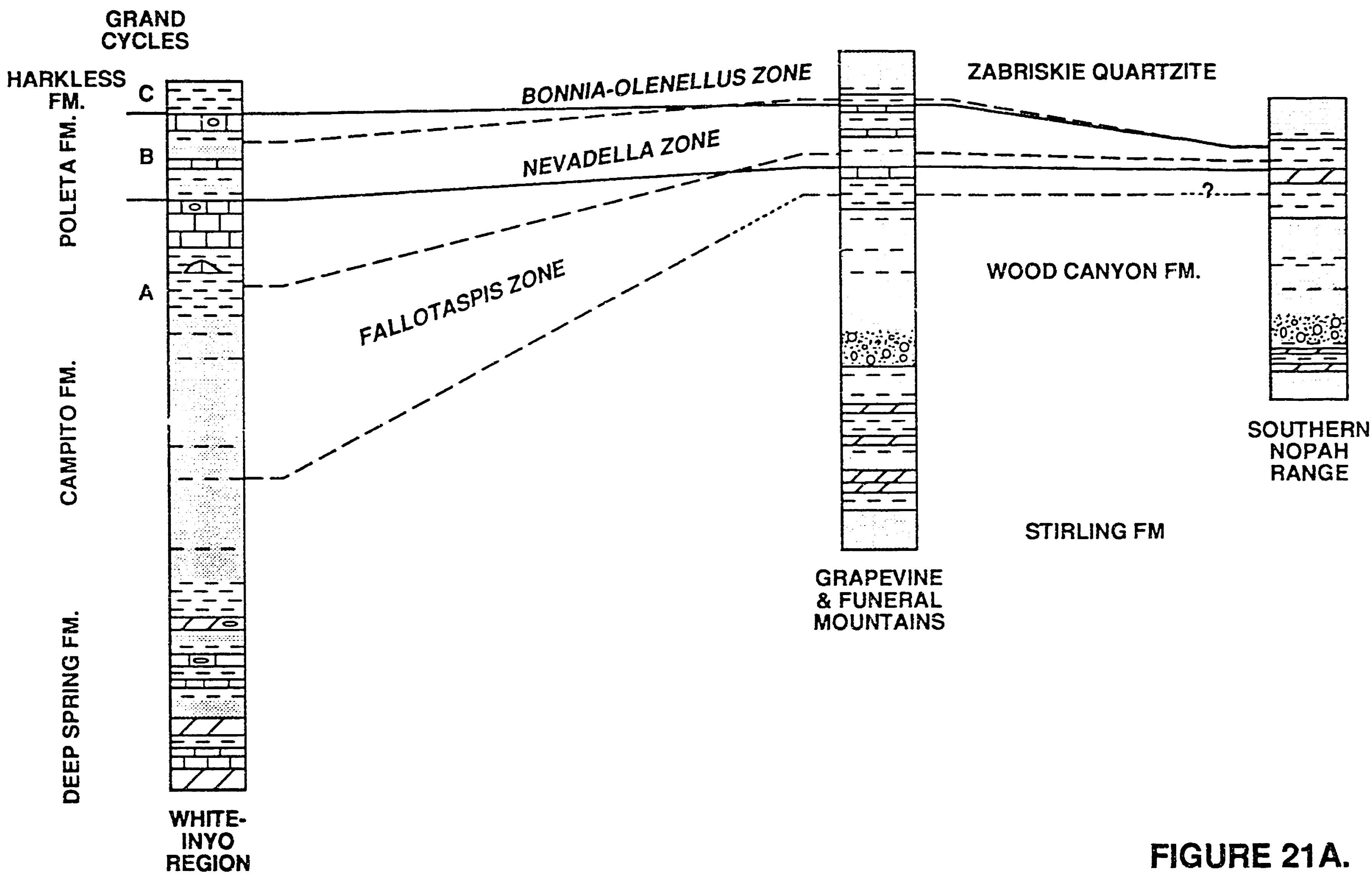
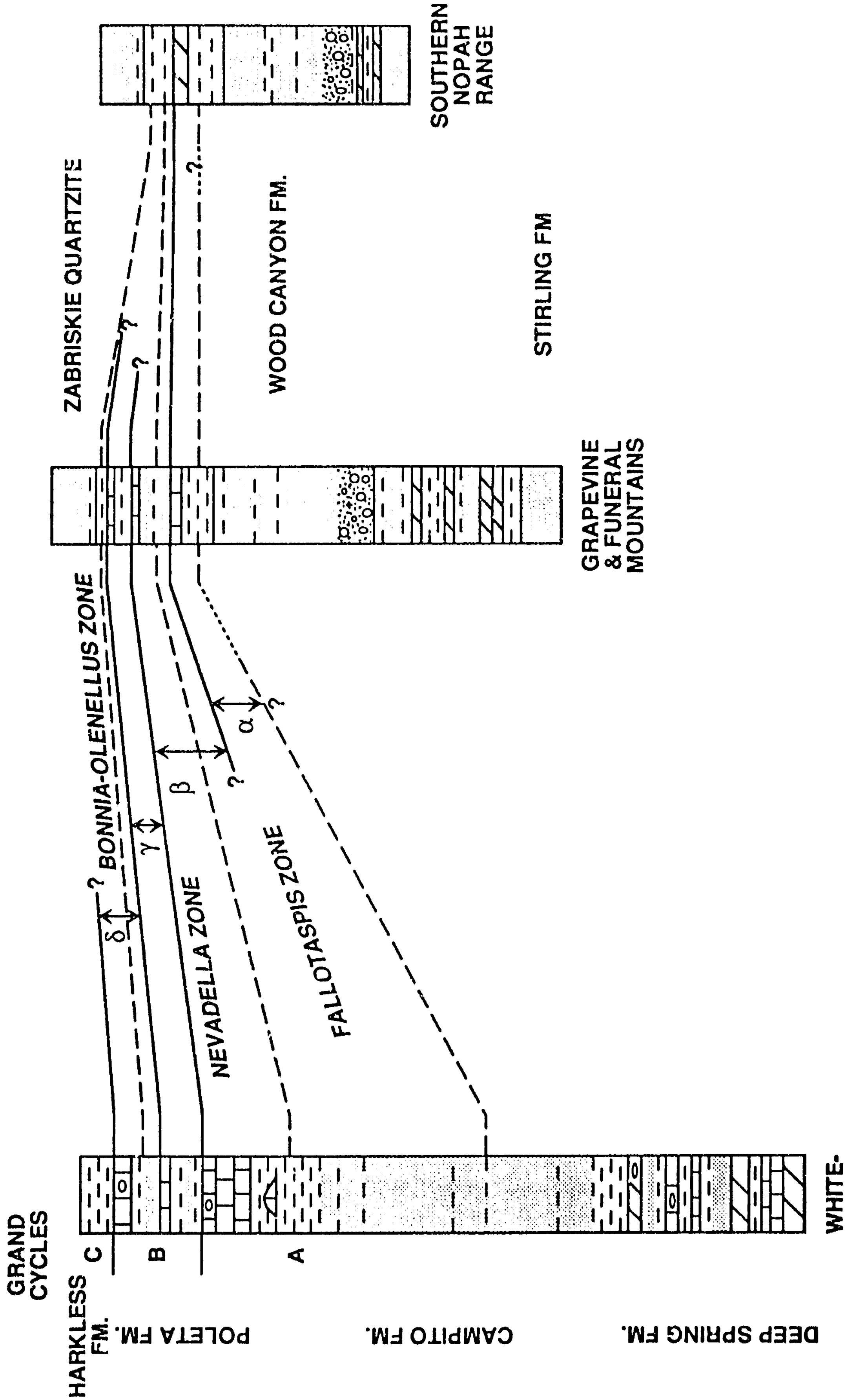

GRAND CYCLES
HARKLESS FM.
POLETA FM.
CAMPITO FM.
DEEP SPRING FM.
C
B
A
BONNIA-OLENELLUS ZONE
NEVADELLA ZONE
FALLOTASPIS ZONE
ZABRISKIE QUARTZITE
WOOD CANYON FM.
STIRLING FM
?
WHITE-INYO REGION
GRAPEVINE & FUNERAL MOUNTAINS
SOUTHERN NOPAH RANGE

FIGURE 21A.



GRAND CYCLES
HARKLESS FM.
POLETA FM.
CAMPITO FM.
DEEP SPRING FM.
C
B
A
WHITE-INYO REGION
GRAPEVINE & FUNERAL MOUNTAINS
SOUTHERN NOPAH RANGE
ZABRISKIE QUARTZITE
WOOD CANYON FM.
STIRLING FM
BONNIA-OLENELLUS ZONE
NEVADELLA ZONE
FALLOTASPIS ZONE
δ
γ
β
α


FIGURE 21B.

be tested by examination of the strata in the White-Inyo region below the top of the *Fallotaspis* Zone to determine if there are outer detrital belt deposits present.

If the suggested alternate correlations are correct, then as shown on Figure 21B, the tops of Grand Cycles β and γ both onlap the top of Grand Cycle α between the Grapevine/Funeral Mountains (possibly Titanothere Canyon, although this is unclear in their paper) and the southern Nopah Range. Using the palinspastic reconstruction of Levy and Christie-Blick (1989), there is approximately 120 km separation in a northwest-southeast direction between Titanothere Canyon in the Grapevine Mountains and the southern Nopah Range, with an east-west separation of about 80 km. Further speculation indicates that Grand Cycle δ, equivalent to the upper half of Grand Cycle B in the White-Inyo region (Mount et al., 1991), may be incorporated into the lower part of the Resting Springs Member of the Zabriskie Quartzite in the Grapevine/Funeral Mountains area where the total thickness of the Zabriskie is approximately 250 m (Prave, 1992). This speculation requires that there be an unrecognized sequence in the lower half of the Resting Springs Member of the Zabriskie in the Grapevine/Funeral Mountains area, and that it be within the *Bonnia-Olenellus* biozone. Hence the top of Grand Cycle δ would also onlap an older boundary before it reached the southern Nopah Range. These speculations may be tested in the future by detailed reexamination of this part of the stratigraphic section with particular emphasis on stacking patterns of parasequences and recognition of sequence boundaries. Such detailed resolution of the stratigraphy of this region could refine our knowledge of the evolution of tectonic subsidence of the passive margin and of the changing position of the hinge line.

The transitional contact between the siliciclastic half-cycle and the overlying carbonate half-cycle is thought to be diachronous by most workers (Aitken, 1978; Aitken, 1981; Chow and James, 1987; Mount et al., 1991; Palmer and Halley, 1979; this paper), given the same qualifying comment regarding the difficulty of dating Grand Cycles with trilobite zonations. Correlations within Grand Cycles in this paper (Plates 1 through 4) strongly support this interpretation.

**Mechanisms and Accommodation History**

Since Aitken's (1966) initial work, new stratigraphic concepts and methodologies have been developed and applied to analysis of Grand Cycles. This has resulted in documentation of additional factors of accommodation fluctuation (relative sea level) and sediment supply that must be considered in an analysis of Grand Cycle origins. The concept of accommodation has received new emphasis (Jervey, 1988; Posamentier et al., 1988; Posamentier and Vail, 1988). R2 analysis (Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989) quantifies the effects of tectonic subsidence, sediment loading, sediment compaction or lithification, depositional water depths, and eustatic sea level fluctuation. Sequence stratigraphy (Jervey, 1988; Mitchum et al., 1977; Posamentier et al., 1988; Posamentier and Vail, 1988; Van Wagoner et al., 1987; Van Wagoner et al., 1988) provides a framework of sedimentologic and stratigraphic response to the interplay of subsidence, sea level, and sediment supply, and encompasses the concept of accommodation. R2 analysis and sequence stratigraphic analysis are complementary in that R2 analysis provides quantitative values for the different components, whereas sequence stratigraphy provides more of a geometric and conceptual framework.

Aitken (1966, 1978) initially called upon pulses of subsidence and uplift at and near the craton edge as the prime mechanism driving formation of Grand Cycles, but subsequently accepted eustatic sea level fluctuations (Aitken, 1981). Differing water depths of the two half-cycles have been ascribed to variations in the rate of subsidence or eustatic sea level rise; fast subsidence or eustatic sea level rise would take place during deposition of the siliciclastic half-cycle versus slower subsidence or eustatic sea level rise taking place during deposition of the carbonate half-cycle (Aitken, 1981; Aitken, 1989; Bond and Kominz, 1984; Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Palmer and Halley, 1979).

Disagreement regarding the accommodation history of the Arctomys-Waterfowl Grand Cycle has been discussed by Demicco and Spencer (1990) and Demicco et al. (1991) on one side and by Bond and Kominz (1991) and Bond et al. (1989) on the other. The papers of Bond et al. (1989, 1991) have presented data from R2 analysis that indicate deposition occurred during a time of high rate of accommodation. The papers of Demicco et al. (1990, 1991) have argued that the intertidal/peritidal facies of the Arctomys indicate deposition during a time of low rate of accommodation and hence during a low stand in sea level. These contrasting views may be reconciled having a high siliciclastic influx during a rise in relative sea level.

**Sequence Stratigraphy and Grand Cycles**

Several attempts (Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Chow and James, 1987; Demicco and Spencer, 1990; Demicco et al., 1991; Mount et al., 1991; Mount and Rowland, 1981) have been made to integrate observations on Grand Cycles with changes in accommodation (relative sea level), resulting in several conflicting models (Table 8). Most of the models have not used sequence stratigraphic terminology, but rather have stated that the siliciclastic half-cycle was deposited during increased rates of accommodation (subsidence or relative sea level rise or eustatic sea level rise) and that the carbonate half-cycle was deposited during decreased rates of accommodation (subsidence or relative sea level rise or eustatic sea level rise). The inference is then made that times of increased rates of accommodation equate with times of highest stands of sea level and that decreased rates of accommodation equate with times of lowest stands of sea level (Bond and Kominz, 1991; Mount et al., 1991). However, Bond and Kominz (1991, p. 274-276) have an excellent discussion of how, given the same accommodation history, differing water depths can develop by variation in rates of sediment supply. Further, they illustrate the important point that the highest position of sea level relative to the craton need not coincide with deepest water depths in an area. The same relationship holds for the lowest position of sea level relative to the craton; it need not coincide with the shallowest water depths in an area.

Bond et al. (1988, 1989) used R2 analysis to decipher the accommodation history of Cambrian Grand Cycles with durations of 2 to 6 m.y. They recognized that the siliciclastic half-cycle recorded an increase in the rate of accommodation and that the carbonate half-cycle recorded a decrease in the rate of accommodation. Changes in accommodation were correlated between several locations in North America and were attributed to probable eustatic fluctuations because they were continent-wide. They attribute the increasing rate of accommodation (rising segment of an R2 curve) to be the cause of a reduction in the rate of carbonate production, which led to widespread deposition of subtidal siliciclastics. During a decrease in accommodation (falling or level segment of an R2 curve), the rate of carbonate production increased which lead to widespread deposition of shallow subtidal to intertidal carbonates. Bond et al. (1988; p. 154) call upon "... a eustatic fall [sequence boundary], or more likely a reduction in the rate of eustatic rise [late **IAST** or **MXAST**], which allows expansion of the carbonate shoal and gradual progradation of carbonate facies over shales". They also state (Bond et al., 1989; p.57): "... cycle [Grand Cycle] tops and the abrupt changes in slopes of the R2 curves do not correspond to sequence boundaries. The sequence boundaries in the carbonate platforms should occur within the flat or falling segments of the R2 curves ..., although they have not yet been identified in outcrop". Both of these statements require a sequence boundary within the carbonate half-cycle, or near its base. Aside from discussing the sequence boundary, they do not apply sequence stratigraphic terminology or systems tract designations. However, their placement of the sequence boundary would imply that:

- a single Grand Cycle is composed of parts of two different sequences;
- the carbonate half-cycle encompasses the sequence boundary, as well as comprising at least parts of both the **MXAST** and the succeeding **MNAST**;

- the siliciclastic half-cycle of a Grand Cycle may comprise part of the **MNAST**, all of the **IAST**, and part of the **MXAST**.

Direct application of sequence stratigraphic concepts and terminology to Grand Cycles has been much more erratic and confused. Chow and James (1987, their Figure 10; see Table 8 of this study) were among the first to plot a curve of "rate of sea level rise" on a Grand Cycle, though they did not apply systems tract terminology. They do indicate that sea level may fall below the platform margin, i.e., form a sequence boundary, during deposition of the upper part of the carbonate half-cycle (step 5 of their Figure 10, and page 418). Their interpretation forces the same sequence stratigraphic interpretations upon a Grand Cycle as stated above for the Bond et al. (1988, 1989) interpretations. Demicco and Spencer (1990) assign the siliciclastic half-cycle of the Waterfowl-Arctomys Grand Cycle to a **LST** (**MNAST**) (Table 8) but do not discuss placement of a sequence boundary, leaving the reader to assume that a sequence boundary may be placed at the base of the siliciclastic Arctomys Formation. Demicco et al. (1991) place one Type 2 sequence boundary at the base of the carbonate half-cycle (Waterfowl Formation) and a second Type 2 sequence boundary within the carbonate half-cycle (Table 8). No **MNASTs** are recognized, rather **TSTs** (**IASTs**) are placed immediately on top of the sequence boundaries, encompassing the lower and upper thirds of the carbonate half-cycle. A **HST** (**MXAST**) is recognized in the middle third of the carbonate half-cycle with the second sequence boundary immediately overlying it. Bond and Kominz (1991) disagree with the interpretations of Demicco and Spencer (1990) and Demicco et al. (1991), declaring that the siliciclastic half-cycle (Arctomys Formation), records an increasing rate of accommodation, and stating that it could be either a **HST** (**MXAST**) or **LST** (**MNAST**) because the sedimentation rate was greater than the accommodation rate. The carbonate half-cycle (Waterfowl Formation) records a decrease in rate of accommodation, but is designated as a **TST** (**IAST**) because the sedimentation rate is less than the accommodation rate. Sequence boundaries are not designated.

Another attempt to merge Grand Cycles with sequence stratigraphy was by Mount et al. (1991) wherein they present two different "working models" (their terminology) and state that their current data do not distinguish between them (Table 8). "Working Model One" (their terminology) assigns two sequences to a Grand Cycle, with Type 2 sequence boundaries at the base of the siliciclastic half-cycle and at the base of the siliciclastic/carbonate transition. Transgressive surfaces are coincident with both sequence boundaries; consequently, basal **MNASTs** are not present. **TSTs** (**IASTs**) are present in the lower part of the siliciclastic half-cycle and in the siliciclastic/carbonate transition, whereas HSTs (MXASTs) are present in the upper part of the siliciclastic half-cycle and the upper part of the carbonate half-cycle. "Working Model Two" assigns one sequence to a Grand Cycle, with a Type 2 sequence boundary at the base of the siliciclastic half-cycle. Again, there is a transgressive surface that is coincident with the sequence boundary and the **MNAST** is absent. The siliciclastic half-cycle is deposited during the **TST (IAST)** and the carbonate half-cycle is deposited during the **HST (MXAST)**. This model forms one variation of the complete sequence stratigraphic model of Grand Cycle deposition presented in this paper.

## PROPOSED NEW MODEL

This model is presented in a sequence stratigraphic framework in that it utilizes sequence, systems tract, and parasequence terminologies; incorporates geometries of depositional units with respect to bounding surfaces (sequence and parasequence boundaries); and relates stratigraphic patterns to the interplay between accommodation and sediment flux from two different sources. The model does not rely upon the eustatic component of accommodation to be the primary control upon sedimentation and stratigraphy. It attempts to discuss systems tracts and Grand Cycles in terms of changes in accommodation with relative sea level position parenthetically appended. It must be noted that in the Carrara there are no Type 1 sequence boundaries with sharp juxtaposition of nonmarine facies over subtidal facies, subaerial exposure of subtidal facies, and/or significant erosion along the boundary. Such Type 1 boundaries are the one feature of a sequence that cannot be formed solely by fluctuation in sediment flux. This lack of Type 1 boundaries precludes elimination of the possibility that variation in siliciclastic sediment flux alone has caused the formation of Carrara Grand Cycles. However, regional studies (Bond et al., 1988; Bond et al., 1989; Palmer, 1981b) indicate that many third-order Cambrian Grand Cycles can be correlated around the North American craton. If these correlations are correct, then whatever mechanism is invoked for Grand Cycle development must apply craton-wide. It is very difficult to envision a mechanism with a frequency of approximately $10^6$ years (see earlier discussion) that would cause simultaneous craton-wide changes in siliciclastic sediment flux. Climatic changes would have to apply to both northern and southern margins of a craton that straddled the Equator and this is unlikely. Thus either a eustatic mechanism or a tectonic mechanism with craton-wide affects is implicated.

Three important points follow:

1) Almost all previous work (see Table 8) has recognized that greater rates of accommodation are recorded in the siliciclastic half-cycle and lesser rates in the carbonate half-cycle. However, many previous studies have equated faster rates

in the siliciclastics with high stands of sea level (equivalent to the **MXAST**) and have equated slower rates in the carbonates with low stands in sea level (equivalent to the **MNAST**). This study, in a departure from most previous papers, equates faster rates of accommodation in the siliciclastics with the **IAST** and slower rates in the carbonates with the **MXAST**.

2 ) A Grand Cycle is a single sequence, and is not made up of parts of two or more separate sequences.

3) The **MNAST** is commonly thin and may be absent, and because of this is relatively obscure and has been overlooked in analyses of Grand Cycles. However, "anomalous" Grand Cycles have well-developed **MNASTs**.

In the proposed model, little or no rock is preserved from the times of:

- decreasing accommodation (relative sea level fall), including the minimum rate of accommodation; and
- minimum accommodation (low stand of relative sea level), with a slowly increasing rate of accommodation.

Almost all of the "rock record" represents times of:

- increasing accommodation (relative sea level rise), including the maximum rate of accommodation; and
- maximum accommodation (high stand of relative sea level), with a slowly decreasing rate of accommodation.

Because this asymmetry of the rock record has not been fully appreciated, the difference of interpretation of the first point has happened. A graph comparing accommodation (relative sea level position) and systems tracts against the rate of accommodation (relative sea level) change, Figure 19, helps to clarify the relations between these concepts.

The sharp sequence boundary between the carbonate half-cycle at the top of a Grand Cycle and the succeeding siliciclastic half-cycle at the base of the next Grand Cycle records the decrease in accommodation (fall in relative sea level) at the end of the **MXAST**. The **MNAST** is deposited at the accommodation minimum (low stand of relative sea level) as the rate of accommodation slowly increases. In most instances the **MNAST** is thin or missing and the transgressive surface marking the top of the **MNAST** is thus stratigraphically close to the sequence boundary or coincident with it. The period of maximum rate of increase in accommodation (relative sea level rise) is during the **IAST**. During the **MXAST** accommodation (relative sea level) is at its maximum. The common presence of Type 2 sequence boundaries coupled with poor development of the **MNAST** may indicate that the Cambrian accommodation (relative sea level) and rate curves were skewed rather than the symmetric curves shown in Figure 19, with short-duration decreases in accommodation (falls in relative sea level) and **MNASTs**, and long-duration increases in accommodation (rises in relative sea level), **IASTs** and **MXASTs** (Also see Jervey, 1988; Posamentier et al., 1988; Posamentier and Vail, 1988).

**Sequence Boundary**

The sequence boundary formed during a time of decreasing rate of accommodation, and included the minimum rate of accommodation (Figure 19). Normally the sequence boundary was a Type 2 boundary, probably due to superposition of higher-order, sinusoidal accommodation fluctuation on the lower-order, long-term eustatic rise (Sauk transgression) that occurred during the Cambrian (Bond et al., 1988; Bond et al., 1989). The lower-order, long-term rise acts to moderate the effects of the higher-order decreases in accommodation. However, there is no reason that a Type 1 sequence boundary could not form if there was a large enough decrease in higher-order accommodation. Erosion has been reported along some contacts between Grand Cycles (Aitken, 1978; Aitken, 1989; Mount et al., 1991; this paper) and this may be indicative of formation of Type 1 sequence boundaries. In these cases only subtle downcutting into the previous sequence/Grand Cycle is present, rather than the large-scale, incised valley type of erosion associated with Type 1 boundaries in siliciclastic sequences. A general lack of evidence for pervasive meteoric diagenesis or for extensive subaerial erosion also indicates that the bank may not have been extensively exposed during development of a sequence boundary. The lack of Type 1 sequence boundaries with extensive downcutting and exposure also may have been affected by the relatively rapid tectonic subsidence during the Cambrian (Sloss, 1988a). Rapid subsidence coeval with a relatively brief and small higher-order decrease in accommodation (eustatic fall?) would also have moderated the effects of the decrease. It may be more illuminating to think of the third-order decrease in accommodation as a "stall" in the increase in accommodation (relative sea level rise).

Several important characteristics of Grand Cycles are associated with the sequence boundary:

- the sharp nature of this contact is a direct result of the decrease in accommodation (fall in relative sea level) causing a cessation or at least a gross reduction in carbonate sedimentation;
- the cratonal strandline moved basinward allowing siliciclastics to spread across the lagoon behind the carbonate bank, overriding some or all of the bank;

- carbonate production became restricted to the outermost portion of the bank or ceased altogether.

Because of the preponderance of Type 2 sequence boundaries and the relatively minor nature of erosion and diagenesis associated with some possible Type 1 boundaries, most **MNASTs** are equivalent to the **SMSTs** of the earlier terminology. This does not imply that Type 1 boundaries and **LSTs** (**MNASTs**) cannot be part of a Grand Cycle.

Recognition of these Type 2 sequence boundaries is not always straight forward because they have not been marked by abrupt juxtaposition of much shallower depositional environments over deeper environments, widespread exposure, erosion, or meteoric diagenesis. Generally, subtidal lagoonal lithofacies are present on either side of the sequence boundary. However, abrupt transitions upward from carbonate-rich strata to carbonate-poor strata commonly mark these boundaries. The clearest examples change from clean carbonate lithofacies up to clean siliciclastic lithofacies across sharp contacts (e.g., from Gold Ace Limestone to Pyramid Shale at the Last Chance Range (LC), Plates 1A and 2A), or from mixed lithofacies intervals to clean siliciclastic lithofacies (e.g., from the Red Pass Limestone to the Pahrump Hills Shale at the middle Resting Spring Range (MR), Plates 2B and 3B). Less clear, but still relatively easy to recognize are changes from clean carbonate lithofacies up to mixed lithofacies intervals (e.g., from Red Pass Limestone to Pahrump Hills Shale at Titus/Titanothere Canyons (TC), Plates 2A and 3A). Examples of difficult-to-recognize sequence boundaries involve mixed lithofacies on each side of the boundary (e.g., from Eagle Mountain Shale to Echo Shale at Eagle Mountain (EM) and the southern Resting Spring Range (SR), Plates 1B and 2B), or involve siliciclastic lithofacies on each side of the boundary (e.g., within the siliciclastics at Frenchman Mountain (FM), Plates 1A, 2A, and 3A). These difficult choices are discussed in the "CARRARA STRATIGRAPHY" section above.

**Minimum Accommodation Systems Tract**

The **MNAST** was deposited during the accommodation minimum (low stand in relative sea level), a time of slowly increasing rate of accommodation (Figure 19). Depending on the interplay between rate of accommodation and rate of sedimentation, siliciclastics may have been deposited in shallow marine to peritidal or peritidal to coastal plain environments. Grain-size of the siliciclastic sediments was not restricted to mud and silt, sandstone also may be found. Examples of probable **MNASTs** incorporate parts of the Middle Member of the Deep Spring Formation (Grand Cycle DS1 in Mount et al., 1991), part of the Arctomys Formation (Bond and Kominz, 1991; Demicco et al., 1991), the Resting Springs Member of the Zabriskie Quartzite (this paper), and part of the Pahrump Hills Shale Member of the Carrara Formation (this paper). In each of these cases, in addition to submarine sediments, subaerial sediments, either supratidal or nonmarine, are also found (Aitken, 1966; Demicco et al., 1991; Prave, 1992). Carbonate sedimentation was generally shut off during this time, principally due to the decrease in accommodation (fall in relative sea level) and the influx of siliciclastics into areas of carbonate production. There may have been a small amount of carbonate production continuing on the outer part of the bank, but it was not sufficient to build the bank laterally (Aitken, 1989).

Generally, the **MNAST** is either not recognized or is not present, apparently the result of a period of nondeposition, bypassing, or only very brief deposition of sediments. Thin intervals of fine-grained, nonmarine siliciclastic sediments immediately overlying carbonate sediments may not be easy to differentiate from succeeding fine-grained, marine siliciclastics of the **IAST**. R2 analysis is not able to recognize surfaces of nondeposition and/or bypassing caused by negative accommodation rates without biostratigraphic or other age control indicating a gap in deposition (Figure 11a in Bond et al., 1989), hence these episodes would be easy to overlook in R2 analysis of Grand Cycles.

**Increasing Accommodation Systems Tract**

The **IAST** incorporates a time of maximum rate of accommodation (Figure 19). Most Grand Cycle workers have recognized that the siliciclastic half-cycle encompasses a time of increased accommodation (Aitken, 1966; Aitken, 1978; Aitken, 1989; Chow and James, 1987; Grotzinger, 1986a; Grotzinger, 1986b; Mount and Rowland, 1981; Palmer and Halley, 1979, in part; Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Mount et al., 1991), but only Mount et al., 1991 explicitly assigned this half-cycle to the **TST** (**IAST**), and then only in their "Working Model Two". Bond et al. (1988, 1989), with the recognition that the siliciclastic half-cycle was deposited during a time of increased rate of accommodation, indirectly indicated that at least part of the siliciclastics would be assigned to the **IAST**. However, their placement of the sequence boundary within the carbonate half-cycle raises the possibility that part of the siliciclastic half-cycle could be within the **MXAST**. Other authors have tended to assume that the high stand in sea level corresponds to the time of greatest rate of accommodation (Aitken, 1966; Aitken, 1978; Chow and James, 1987; Palmer and Halley, 1979, in part; Aitken, 1989; Bond and Kominz, 1991; Bond et al., 1988; Bond et al., 1989; Mount et al., 1991, in part). R2 analysis (Bond and Kominz, 1991; Bond et al., 1989) and independent facies analysis (Mount et al., 1991) indicate that, for some Grand Cycles, carbonates in the transition zone and possibly the lower part of the carbonate half-cycle, also may have been deposited during this time of increasing rate of accommodation. This can also be seen in each of the sequences in the Carrara by the coeval deposition of carbonates with siliciclastics. The lower parts of these carbonate units are commonly more subtidal and hence, tended to be in the start-up and catch-up modes of Schlager (1981) and Kendall and Schlager (1981).

**Maximum Accommodation Systems Tract**

The **MXAST** was deposited during a time of decreasing rate of accommodation prior to the onset of the next sequence boundary (Figure 19). Again, many Grand Cycle workers have noted that deposition of the carbonate half-cycle corresponded to a time of slowing rate of accommodation, but they have generally assumed that this corresponded to the low stand in relative sea level, in part because of the generally shallower depositional environments of the carbonates in comparison with those of the siliciclastics. In contrast, Mount et al. (1991) recognized that most of the carbonate half-cycle formed part of the **MXAST**. The carbonates were able to pass from the catch-up mode to the keep-up mode because of the decreasing rates of accommodation that characterize the **MXAST**. As they moved into the keep-up mode, parasequences commonly shoaled to or near the surface. At any one time the subaerial top of the bank may have been either a series of discontinuous tidal islands (the Carrara Formation) or may have formed a continuous barrier (Aitken, 1978). In at least some cases, e.g., the upper Jangle Limestone Member (see Chapter 4), the top was a series of discontinuous tidal islands. As the carbonate half-cycle moved into the keep-up mode it was able to prograde towards the craton Aitken, 1966; Aitken, 1978; Kendall and Schlager, 1981; Palmer and Halley, 1979; this work) and as Mount et al. (1991) have shown in the Lower Cambrian Grand Cycles of the Inyo Mountain region, the bank was also able to prograde basinward as well. The siliciclastics also were able to resume basinward progradation as the highstand developed and in some cases managed to start to displace carbonate deposition in more cratonward portions of the lagoon. During the latter part of the **MXAST**, in some Grand Cycles (e.g., the Pyramid-Red Pass Grand Cycle in Plate 2A, and the Pahrump Hills-Jangle Grand Cycle in Plate 3B) siliciclastics began to displace carbonates in basinward locations. This may have reflected a decrease in carbonate production brought about by a decrease in area of the subtidal carbonate factory in the lagoon. The decrease in area may have developed due to the beginning of the decrease in accommodation (fall in relative sea level) associated with the late **MXAST** (Figure 19). Although carbonate sediment production decreased, siliciclastic sediment production remained unchanged, and the rate of siliciclastic progradation increased due to the decrease in accommodation.

## COMPARISON BETWEEN HALLEY'S GRAND CYCLE MODEL AND THE NEW GRAND CYCLE MODEL

In many ways this study represents a detailed elaboration of the results reported by Halley (1974) and Palmer and Halley (1979). Both projects recognize the subdivision of the Carrara Formation into five Grand Cycles. Halley (1974) and Palmer and Halley (1979) interpreted the basal Grand Cycle to be completely contained within the Carrara, whereas this study has expanded the basal cycle to include the Zabriskie Quartzite and the upper few meters of the Wood Canyon Formation in the Montgomery Hills/Resting Spring Range/Nopah Range area. Both studies interpret the top Grand Cycle to incorporate the lower part of the Bonanza King Formation. An overview of the regional intertonguing between carbonates and siliciclastics was given by Halley (1974) and Palmer and Halley (1979), but the current study has refined those regional relationships and presented them in much finer detail (Compare Figure 11 of Palmer and Halley (1979) with Plates 1 through 4 of this paper). Palmer and Halley (1979) point out that "The key to the model is the pattern of lithofacies relationships ..." and the refinement in lithofacies relationships in this study has led to a somewhat different model and mechanism than that proposed in the previous study.

Halley (1974) and Palmer and Halley (1979) preferred variable rates of tectonic subsidence as the primary mechanism for determination of stratigraphic geometries, although variable rates of sea level rise and/or siliciclastic sediment supply were noted as other possibilities. Their model starts with a deepening of relative sea level and initiation of shallow subtidal carbonate sedimentation on the outer shelf, followed by gradual cratonward expansion of carbonates over siliciclastics. A decrease in rate of subsidence (or rate of sea level rise) generated simultaneous responses in carbonate and siliciclastic sedimentation. That is, siliciclastics continued to expand basinward while the carbonate bank shoaled into a series of discontinuous peritidal islands that prograded cratonward. The continued progradation of the two sediment systems towards each other decreased the area of the subtidal carbonate factory until it shut off production, thus allowing the siliciclastics to overrun the carbonate bank and initiate a new Grand Cycle.

Mechanisms invoked in this paper include the long-term Cambro-Ordovician sea level rise of the Sauk Transgression (Sloss, 1963) and the long-term, Cambro-Ordovician exponentially decreasing rate of subsidence associated with the cooling passive margin (Bond et al., 1988; Bond et al., 1989; Levy and Christie-Blick, 1991; Stewart, 1970; Stewart, 1991), coupled with shorter-term (third-order?) accommodation fluctuations (Bond and Kominz, 1984; Bond et al., 1988; Bond et al., 1989). The model proposed in the present study incorporates sequence stratigraphic concepts (Jervey, 1988; Mitchum et al., 1977; Posamentier et al., 1988; Posamentier and Vail, 1988; Van Wagoner et al., 1990; Van Wagoner et al., 1988) and applies them to a depositional regime of craton-derived siliciclastics mixing with shelf-derived carbonates, wherein both sediment sources exhibit differing responses to changes in accommodation.

Initiation of a Grand Cycle is marked by a third-order decrease in accommodation (fall in relative sea level) that permitted a basinward shift in siliciclastic sedimentation, and may have caused either a basinward shift in or short-term cessation of carbonate bank sedimentation and production. The decrease in accommodation also resulted in a sharp contact (sequence boundary) between underlying carbonates and overlying siliciclastics. There may not be a substantial thickness of marine sediments deposited during the period of minimum accommodation, **MNAST**, (low stand in relative sea level) and thin deposits may not be differentiatable from marine sediments deposited during the subsequent increase in accommodation, **IAST** (rise in relative sea level). If thick deposits were formed during the **MNAST**, they may include nonmarine sediments, e.g., braid-plain deposits in the Resting Springs Member and paleosols in the Pahrump Hills Shale Member. These nonmarine deposits in the lower half-cycle of some Grand Cycles have been the source of confusion and disagreement for many years (Aitken, 1966; Aitken, 1968; Aitken, 1978; Aitken, 1981; Bond and Kominz, 1991; Demicco and Spencer, 1990; Demicco et al., 1991). If the **MNAST** deposits are thin or nonexistent, then a transgressive surface will either coincide with the sequence boundary or be in close proximity to it. As accommodation began to increase (relative sea level rise), the rate of accommodation increased and marine siliciclastic sediments were preserved in the **IAST**, commonly with a retrogradational stacking of lithofacies and parasequences. Concomitant with this, carbonate sedimentation on the offshore bank either recovered and/or began to shift cratonward, and resulted in carbonate sediments also being incorporated into the **IAST**. The two sediment types were delivered into the lagoon between bank and craton, resulting in mixed lithofacies whenever the areas of distribution overlap. As accommodation began to approach its maximum value (high stand in relative sea level), the rate of accommodation decreased, allowing progradation of both carbonates and siliciclastics in the **MXAST**. Determination of which sediment type would dominate in an area is a function of rate of sediment production, rate of progradation, and of proximity to the area of deposition. Faster rates of production and of progradation, and closer proximity to the depocenter would enhance the potential to be the dominant sediment. In the area of study, variation from dominantly mixed lithofacies t dominantly clean carbonate lithofacies can be seen. Farther to the east and south, siliciclastics were the dominant sediment in the MXAST and Grand Cycles are not recognized, although sequence-stratigraphic analysis would be likely to distinguish sequences and sequence boundaries (e.g., Prave, 1992; Prave et al., 1991). These sequences could be correlated into the Grand Cycle sequences.

Any time there is simultaneous deposition of siliciclastics derived from the craton and carbonates derived from the offshore bank position, a transect parallel to depositional dip extending across the passive margin will show transitions from clean carbonate deposition to mixed deposition to clean siliciclastic deposition. A vertical profile through a sequence will show the "Grand Cycle" style of carbonates over siliciclastics only in the middle region of the transect. If the position of the profile is too far basinward, then the profile is going to only show carbonate deposition with some basal mixed lithofacies, e.g., at Titus/Titanothere Canyons (TC) and at the Last Chance Range (LC) in the Pahrump Hills-Jangle Grand Cycle. If the profile is too far cratonward then only siliciclastics with some or no overlying mixed lithofacies will be preserved, e.g., Frenchman Mountain (FM) during the first three Grand Cycles or the Las Vegas Range (LV) during the second Grand Cycle.

## SUMMARY

The Lower to Middle Cambrian mixed carbonate-siliciclastic Carrara Formation, deposited on the western passive margin of North America, records complex interplay between long-term eustatic sea level rise, long-term passive margin subsidence, shorter-term (third-order?) fluctuation in accommodation, and varying sediment production and delivery rates of both a cratonic source of siliciclastics and an offshore source of carbonates. Fifteen subtidal to intertidal carbonate lithofacies and five subtidal to supratidal siliciclastic lithofacies combine to form the following varieties of shallowing-upward cycles; six carbonate varieties, two siliciclastic varieties, and 15 mixed-lithofacies varieties, all generally between 1 and 5 m thick. Prior lithostratigraphic analysis of the Carrara identified 9 members of the formation and those member designations have been used in this study. Sequence stratigraphic principles have been followed in describing and correlating stratigraphic sections in eastern California and southern Nevada, and five Grand Cycles have been recognized.

Grand Cycles are couplets, ranging in thickness from less than 100 m to over 200 m, of underlying siliciclastic sediments overlain by carbonate sediments. Top and bottom boundaries of Grand Cycles are sharp and relatively isochronous within resolution of trilobite biostratigraphy, whereas the internal boundary between the lower siliciclastic half-cycle and the upper carbonate half-cycle is very gradational and diachronous. Three complete Grand Cycles are totally contained within the Carrara and partial Grand Cycles incorporate the basal and uppermost parts of the formation. The basal Grand Cycle is completed by addition of the Zabriskie Quartzite and the underlying fine-grained siliciclastics above the last carbonates of the Upper Member of the Wood Canyon Formation. The uppermost Grand Cycle is completed by the addition of part or all of the Papoose Lake Member of the overlying Bonanza King Formation.

A new sequence stratigraphic model of Grand Cycle deposition places the sequence boundary at the sharp contact between the upper carbonate half-cycle of the preceding Grand Cycle and the lower siliciclastic half-cycle of the succeeding Grand Cycle. The sequence boundary is a Type 2 sequence boundary in the Carrara Grand Cycles, but there is no restriction against development of a Type 1 boundary. The **MNAST** is dominantly siliciclastic, and may be well developed or thin to nonexistent. The basinward influx of siliciclastics associated with the **MNAST** may have overrun the offshore carbonate bank or may have displaced it farther basinward. There is little or no evidence of erosion, diagenesis, or karst development to indicate that the bank was subaerially exposed for any period of time. Some Grand Cycles, described as anomalous due to the presence of intertidal to nonmarine sediments with progradational stacking of parasequences and facies in the lower half-cycle, have generated much discussion and disagreement over the years. Those anomalous basal intervals are interpreted to be thick **MNASTs** based on the presence of two such units in Grand Cycles associated with the Carrara. Thin or missing **MNASTs** seem to be the normal condition for Grand Cycles and three of the Carrara Grand Cycles record this condition. Thin **MNASTs** would be hard to recognize and differentiate from the similar lithofacies of the overlying **IAST**. The **IAST** was deposited during the period of maximum rate of accommodation associated with increasing accommodation. In many sections measured through Grand Cycles the **IAST** is dominantly siliciclastic with a retrogradational stacking of parasequences and facies. During the retrogradation of siliciclastics, the carbonate bank tended to become re-established and/or prograde cratonward. This coexistence of carbonate and siliciclastic sources results in a transitional internal boundary between lower and upper half-cycles. The complementary reciprocating movement of carbonates and siliciclastics during the **IAST** produced the marked diachroneity of the internal boundary. As accommodation reached its maximum, the rate of accommodation decreased facilitating progradation of both siliciclastics and carbonates during the **MXAST**. The predominance of carbonates in the upper half-cycle of Grand Cycles indicates that proximity to the more basinal parts of the lagoon and higher rates of carbonate progradation tended to allow for deposition of a greater proportion of carbonate sediments. More cratonal positions of the lagoon recorded increased concentration of siliciclastics in the **MXAST**. In this model. there is only one sequence per Grand Cycle.

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PLATES 1 TO 4

**Plates 1 through 4.** These sections are laid out on the palinspastic base map of Levy and Christie-Blick (1989). The cross section lines are on the isopach maps of Figure 18, as are the abbreviations for the locations of the measured stratigraphic columns. "CARB is for clean carbonate lithofacies intervals. "MXT" stands for mixed lithofacies intervals and comes from the <u>**mixt**</u>ure of lithofacies to be found in the mixed interval. "SIL" is for the clean siliciclastic intervals, with "(SAND)" indicating that the interval is dominantly sandstone and siltstone. "NON-MAR" indicates the nonmarine intervals of supratidal or coastal plain shale/mudstone red beds of probable paleosol origin. Other abbreviations are listed below.

<u>DEPOSITIONAL DIP SECTIONS</u>

**1A** = First Grand Cycle/sequence of the Zabriskie Quartzite-Eagle Mountain Shale-Thimble Limestone and second Grand Cycle/sequence of the Echo Shale-Gold Ace Limestone

**2A** = Third Grand Cycle/sequence of the Pyramid Shale-Red Pass Limestone

**3A** = Fourth Grand Cycle/sequence of the Pahrump Hills Shale-Jangle Limestone

**4A** = Fifth Grand Cycle/sequence of the Desert Range-Papoose Lake Member

<u>DEPOSITIONAL STRIKE SECTIONS</u>

**1B** = First Grand Cycle/sequence of the Zabriskie Quartzite-Eagle Mountain Shale-Thimble Limestone and second Grand Cycle/sequence of the Echo Shale-Gold Ace Limestone

**2B** = Third Grand Cycle/sequence of the Pyramid Shale-Red Pass Limestone

**3B** = Fourth Grand Cycle/sequence of the Pahrump Hills Shale-Jangle Limestone

**4B** = Fifth Grand Cycle/sequence of the Desert Range-Papoose Lake Member

Most of the lithofacies boundaries shown are very time transgressive and if parasequence boundaries were shown, then lithofacies lines would truncate against parasequence boundaries and be offset laterally. Parasequence boundaries were left off for clarity in showing gross lithologic changes and how those relate to Grand Cycles/sequences and the various systems tracts. The datum for each of Plates 1 to 3 is the upper Grand Cycle/sequence boundary, chosen as the best available approximation of a time-line. Plate 4 uses the lower sequence boundary for a datum because the upper sequence boundary was not measured. <u>Abbreviations</u>: **DR** = Desert Range Limestone; **E** = Echo Shale; **EM** = Eagle Mountain Shale; **GA** = Gold Ace Limestone; **J** = Jangle Limestone; **P** = Pyramid Shale; **PH** = Pahrump Hills Shale; **RP** = Red Pass Limestone; **T** = Thimble Limestone; **Z** = Zabriskie Quartzite.

## APPENDIX 1: SUMMARY TABLE OF LITHOFACIES DESCRIPTIONS OF THE UPPER JANGLE LIMESTONE AT EAGLE MOUNTAIN

**Appendix 1.**

| LITHO-FACIES | GRAIN TYPES | SEDIMENTARY STRUCTURES | BED & BEDSET THICKNESS | VERTICAL TRENDS | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| **SUBTIDAL** | | | | | |
| THROMBOLITIC BOUNDSTONE | Mesoclots, ≤0.1 to 2 mm, may be ***Renalcis***. | **External geometry** from bulbous heads to squat columns to tabular units. Bulbous heads and columns can be seen within a reefal complex at the top of Parasequence V. | **Size of boundstone units: Individual bulbous & elongate heads and squat columns** w/ heights from 5 cm to 100 cm and widths from 5 cm to 45 cm; **Tabular units** w/ heights from 25 cm to 90 cm, and widths greater than 10 m; **Reefal complex** ≈ 6.3 m in height w/ ≈ outcrop width of 100 to 150 m. | No trends recorded, but within the reef complex, thrombolite geometries of heads and columns can be recognized, with some apparently linked (Figure 6). | **Ribbon rock, oncolitic dolosiltite wackestone**, very fine carbonate **arenite** and orange, unlaminated **dolosiltite** may be found between closely spaced heads |
| OOLITIC GRAINSTONE | **Ooids** ≤ 0.1 to 2 mm; >95% range from ≥0.1 to ≤ 0.75 mm; most are concentric but some have radial fabric. **Fossil fragments** some coated, in minor amounts in ≈ 50% of bedsets. **Lithoclasts** minor, present in ≈ 25% of bedsets; consists of orange dolosiltite, with rare limestone; range in size from ≈ 1x1 mm to 1x12 cm. **Oncoids** rare & ≤1 cm. | **Trough cross-beds** in ≈ 50% of bedsets; 5 to 50 cm in preserved bed height, w/ most 5 to 10 cm. **Horizontal planar laminae** includes laminae that are very gently undulatory with wavelengths of ≈100+ cm and amplitudes ≤ few cm; in ≈ 30% of bedsets. **Current ripples** in ≈ 15% of bedsets. **No physical sed. structures** occur in ≈ 40 % of bedsets, probably due to uniform grain size and composition. **Burrows** are rare but present in ≈ 25% of bedsets. | **Bed thickness** ranges from 1 to 50 cm; ≈ 75% in the range 1 to 15 cm; with two exceptions, rest of beds are ≤ 25 cm. **Bedsets** range from 5 to 400 cm; average ≈ 90 cm. ≈ 35% of bed sets ≥ 100 cm. | Vertical changes were noted in ≈ 25% of bedsets. Upward increases or decreases were of equal probability for **dolsts, fossil fragments, lithoclasts, & grain size**. | **Dolsts** in laminae & possible pressure solution seams in ≈ 45% of bedsets. **Fossiliferous & coated grain grst** interbeds in ≈ 10% of bedsets. One occurrence of interbedded vf to fine **carbonate arenite**. |
| WELL-LAYERED RIBBON ROCK | <u>Lithologies:</u> **Grst & arenite/siltite** except for one **wkst**. <u>Grain Types:</u> **Ooids** in ≈ 55% of bedsets, 0.1 to 0.25 mm; **Fossil fragments** (including trilobites) in ≈ 35% of bedsets; **Lithoclasts** in ≈ 20% of bedsets, ≤ 2 mm; **Unidentified coated grains** in ≈ 10% of bedsets. | **Trough cross-beds** in ≈ 20% of bedsets, preserved bed height not recorded. **Horizontal planar laminae** in ≈ 55% of bedsets. **Current ripples** in ≈ 45% of bedsets. **Wave ripples** in ≈ 35% of bedsets. **No physical sed structures** recognized in ≈ 35% of bedsets. **Burrows** in ≈ 90% of bedsets. | **Bed thickness: Ls** ≈ 10% ≤ 1 cm, ≈ 80% >1 to 4 cm, ≈ 1% >1 to 6+ cm, max. ≈ 12 cm; **Dol** ≈ 75% ≤ 1 cm, ≈ 25% > 1 to 4 cm. **Bedset thickness** ranges from 50 to 340 cm, w/ ave. ≈ 145 cm. ≈ 45% of bedsets ≥ 100 cm. | Upward change in amount of **dolsts**; in ≈ 20% of the bedsets it decreased, & in ≈ 80% no change was recorded. | **Dolsts** in interlams, burrow fills, &/or irregular & discontinuous patches in 100% of bedsets; range from <5% to 75% of a bed. **Fossiliferous wkst** in ≈ 10% of bedsets. **Carbonate arenite** in ≈ 10% of bedsets. |
| NODULAR RIBBON ROCK | <u>Lithologies:</u> ≈ 75% are **pkst, grst, & arenite/siltite**; ≈ 25% are **mdst** or **wkst** or a **peloid grst** (vf-silt) that looks like a mdst in hand sample. <u>Grain Types:</u> **Fossil fragments** (including trilobites) in ≈ 75% of bedsets; **Peloids** in ≥ 30% of bedsets, silt to ≤ 0.1 mm; **Ooids** in ≈ 30% of bedsets, ≤ 0.1 to 1 mm w/ ≈ 50% of ooids 0.1 to 0.25 mm; **Oncoids** in ≈ 25% of bedsets, ≤ 3 cm, w/ ≈ 65% ≤ 1.5 mm; **Lithoclasts** in ≈ 11% of bedsets; **Digitate microbial growths** in ≤ 5% of bedsets. | **Trough cross-beds** in ≈ 5% of bedsets, preserved bed height not recorded. **Horizontal planar laminae** in ≈ 20% of bedsets. **Current ripples** in ≈ 10% of bedsets. **Wave ripples** in ≈ 5% of bedsets. **No physical sed structures** recognized in ≈ 75% of bedsets. **Burrows** in ≈ 90% of bedsets. | **Bed thickness: Ls** ≈ 10% ≤ 1 cm, ≈ 75% >1 to 4 cm, ≈ 15% >1 to 6+ cm, max. ≈ 10 cm; **Dol** ≈ 72% ≤ 1 cm, ≈ 27% > 1 to 4 cm, ≈ 1% >1 to 6 cm. **Bedset thickness** ranges from 20 to 480 cm, w/ ave. ≈ 120 cm. ≈ 45% of bedsets ≥ 100 cm. | Upward change in amount of **dolsts**; in ≈ 50% of the bedsets it decreased, in ≈ 10% of the bedsets it increased, in ≈ 30% no change was recorded, in ≈ 5% it first increased & then decreased, & in ≈ 5% it first decreased & then increased. | **Dolsts** in interlams, burrow fills, &/or blebs in 100% of bedsets; range from ≈5% to 75% in 90% of beds. & up to a max of 75 to 100% in 10% of beds. **Fossiliferous wk/pkst** in ≈ 5% of bedsets. **Oncolitic wk/pkst** in ≈ 5% of bedsets. **Oolitic pk/grst** in ≈ 5% of bedsets. Vf to fine **qtz ss** in < 5% of bedsets. **Carbonate arenite** in < 5% of bedsets. **Siliceous mdst** in < 5% of bedsets. |

**Appendix 1. (Continued)**

| LITHO-FACIES | GRAIN TYPES | SEDIMENTARY STRUCTURES | BED & BEDSET THICKNESS | VERTICAL TRENDS | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| **SUBTIDAL** | | | | | |
| BIOTURBATED RIBBON ROCK | <u>Lithologies;</u> **Mdst** or **peloid grst** (vf-silt) that looks like a mdst in hand sample, and one **md/wkst**. <u>Grain Types:</u> **Peloids** in all bedsets, silt to ≤ 0.1 mm; **Ooids** in ≈ 25% of bedsets, ≤ 0.1 to 0.75 mm; **Oncoids** in ≈ 25% of bedsets, ≤ 2 cm; **Fossil fragments** in ≈ 10% of bedsets; **Lithoclasts** in ≈ 5% of bedsets. | **No physical sed structures recognized** in 100% of bedsets. **Burrows** in 100% of bedsets; filled w/ spar cement or dolsts. | **Bed thickness: Ls** ≈ 70% ≤1 to 4 cm, ≈ 30% >1 to 6+ cm, max. ≈ 10 cm; **Dol** ≈ 20% ≤ 1 cm, ≈ 65% > 1 to 4 cm, ≈ 15% >1 to 6 cm. **Bedset thickness** ranges from 85 to 730 cm, w/ ave. ≈ 290 cm. ≈ 95% of bedsets ≥ 100 cm. | Upward change in amount of **dolsts;** in ≈ 85% of the bedsets it decreased, in ≈ 5% it increased, & in 10% no change was recorded. | **Dolsts** in interlams, burrow fills, &/or blebs in 100% of bedsets; range from <5% to 75% of a bed. **Fossiliferous wk/pkst** in ≈ 5% of bedsets. **Oolitic pk/grst** in ≈ 10% of bedsets. |
| FOSSILIFER-OUS PACKSTONE & GRAINSTONE | **Fossil fragments** (trilobites, echinoids, hyolithoids, brachiopods?) occur in all bedsets. **Ooids** (most ≤ 0.25 to 1 mm, some from 1 to 2 mm) in ≈ 90% of bedsets. **Lithoclasts** (≤ 1.5 x3 cm w/ a few ≤ 1x13 cm) in ≈ 90% of bedsets. **Oncoids** (≤ 0.5 to 1 cm) in ≈ 65% of bedsets. **Coated grains** in ≈ 10% of bedsets. One occurrence of possible **thrombolite fragments** ≈ 5x5 to 10x10 cm. | **Horiz. planar laminae** in ≈ 45% of bedsets. **Internal scour surfaces** in ≈ 20% of bedsets. **Inclined planar laminae** in one bedset. **No physical sedimentary structures** recognized in ≈ 45% of bedsets. **Burrows** in ≈ 55% of bedsets. **Stylolites** in ≈ 35% of bedsets. | **Bed thickness** range from 1 to 7 cm in 35% of bedsets; 2 to 25 cm in ≈ 35% of bedsets; not reported in ≈ 30% of bedsets. **Bedset thickness** ranges from 20 to 280 cm; ave. of ≈ 140 cm; ≈ 65%  100 cm. | Generally **fine & thin** upwards, w/ an increase in amount of **dolsts**. Sometimes the trend extends across several adjacent bedsets. | **Dolsts** in interlaminae, interbeds, & burrows in ≈ 80% of bedsets. **Siliceous mdst** interbeds in ≈ 10% of bedsets. |
| ONCOLITIC PACKSTONE AND GRAINSTONE | **Oncoids** range from < 0.5 cm to ≤ 4 cm; most between 0.5 & 1 cm; shape generally spheroidal, but cylindrical and ellipsoidal shapes also reported (Halley, 1974); discoidal shapes also found by the authors; size range does not vary w/ shape. **Fossil fragments** most common grain-type associated with oncoids. **Ooids** identified in one unit. | **Burrows** in ≈ 20% of bedsets. | **Bed thickness:** bedsets (≈ 45%) ≤ 40 cm are made up of one bed; bedsets ≥ 65 cm are either made up of beds 1 to 10 cm or beds 10 to 30 cm thick. **Bedset thickness** ranges from 10 to 170 cm; ave. ≈ 70 cm; ≈ 65 % between 10 & 75 cm, ≈ 35% between 110 & 170 cm. | In 20% of bedsets there is some variation in amount of **dolsts or cement**, but the changes are not consistent within bedsets. | **Dolsts** interlaminae, **mdst**, & small **stromatolite & thrombolite heads**. |
| CDAS LITHOFACIES (CALCARENITE, CALCISILTITE, DOLARENITE, DOLOSILTITE) | <u>Lithologies;</u> ≈ 55% of the bedsets assigned to this category are partially to mostly covered; Generally, **siltite** is dolomitic & **arenite** (fine to vf sand-sized grains) is calcitic. <u>Grain types;</u> **Unidentified carbonate particles** make up the majority of grains; **Ooids** in ≈ 10% of bedsets; **Qtz silt & vf-f sand** in ≈ 10% of bedsets; **Fossil fragments** in ≈ 5% of bedsets; **Carbonate lithoclasts** in ≈ 5% of bedsets. | **Horizontal planar laminae** in ≈ 60% of bedsets. **Current ripples** in ≈ 35% of bedsets. **Wave ripples** in ≈ 20% of bedsets. **Wavy & lenticular bedding** in ≈ 5% of bedsets. **Trough cross-beds** in ≈ 5% of bedsets. **Wavy parallel laminae** in ≈ 5% of bedsets. **Wavy non-parallel laminae** in ≈ 5% of bedsets. **Burrows** in ≈ 20% of bedsets. **Load structures** in ≈ 5% of bedsets. | **Bed thickness** not recorded in ≈ 65% of bedsets due to poor outcrop; generally in range of 1 to 6 cm w/ one bedset in range of 1 to 10 cm. **Bedset thickness** ranges from 30 to 460 cm; ave. of ≈ 105 cm, w/ ≈ 35% ≥ 100 cm. | None. | Varying amounts of **ls arenite & ls sts & dolsts** are usually present w/in any bedset w/ one lithology dominant. Thin **oolite** beds are associated with arenite in ≈ 10% of bedsets. **Silty, siliceous sh** is associated w/ ls mdst and w/ one of the dolsts bedsets. |

Appendix 1. (End)

| LITHO-FACIES | GRAIN TYPES | SEDIMENTARY STRUCTURES | BED & BEDSET THICKNESS | VERTICAL TRENDS | ASSOCIATED LITHOFACIES |
|---|---|---|---|---|---|
| INTERTIDAL | | | | | |
| CALCAREOUS FENESTRAL MUDSTONE | **Lithoclasts of dolsts & microbial-laminated mdst** in ≈ 10% of bedsets. **Fossil fragments** in < 5% of bedsets. **Oncoids** (≤ 1 cm) in ≤ 5% of bedsets. | **Fenestrae** (≤ 2 mm) filled w/ clear spar cement; in ≥ 95% of bedsets. **Microbial laminae** relatively discontinuous and indistinct; in ≈ 90% of bedsets. **Horiz. planar laminae** (non-microbial) in ≈ 15% of bedsets. **Stylolites** in ≈ 20% of bedsets. **Mudcracks** in < 5% of bedsets. | **Bed thickness** ranges from 2 to 215 cm; ave. of ≈ 30 cm, w/ ≈ 60% ≤ 20 cm thick. **Bedsets** range from 35 to 505 cm, w/ ave. of ≈ 175 cm, w/ ≈ 70% ≥ 100 cm. | Upward increase in amount of **dolsts** in ≈ 25% of bedsets. Upward increase in amount of **microbial laminae** in ≈ 25% of bedsets. | **Orange dolsts** associated w/ ≈ 45% of bedsets. **Dolarenite** in < 5% of bedsets. **Oncolitic wk/pkst** in < 5% of bedsets. |
| ORANGE DOLOSILTITE: UNITS ABOVE PARASEQUENCE BOUNDARY I | **Unidentified carbonate particles** make up the majority of grains. **Qtz silt & vf sand** ≈ 10-20% of total. **Coated grains** in ≈ 15% of bedsets. **Ooids** in ≈ 15% of bedsets. **Glauconitic (?) peloids** in ≈ 5% of bedsets. **Lithoclasts** of dolsts; in ≈ 5% of bedsets. | **Planar microbial laminae** in ≈ 80% of bedsets. **Fenestrae** in ≈ 45% of bedsets. **Horizontal planar non-microbial laminae** in ≈ 30% of bedsets. **Wrinkly microbial laminae** in ≈ 5% of bedsets. **Stromatolitic microbial laminae** in ≈ 5% of bedsets. | No **beds** were measured. **Bedset thickness** ranges from 20 to 175 cm; ave of 65 cm, w/ ≈ 15% of beds ≥ 100 cm. | Upward increase in amount of **laminae** in ≈ 15% of bedsets. Upward decrease in amount of **fenestrae** in ≈ 5% of bedsets. | **Ls arenite & sts** in ≈ 20% of bedsets. **Ooid & coated grain pk/grst** in ≈ 15% of bedsets. **Glauconitic (?) peloid pk/grst** in ≈ 5% of bedsets. |
| ORANGE DOLOSILTITE: UNIT BENEATH PARASEQUENCE BOUNDARY I | **Unidentified carbonate particles** make up the majority of grains. **Qtz silt & vf sand** ≈ 10-20% of total. **Lithoclasts** of dolsts; in ≈ 75% of bedsets. **Ooids** in ≈ 10% of bedsets. **Peloids (?)** in ≈ 10% of bedsets. **Fossil fragments** in ≈ 10% of bedsets. | **Fenestrae** in ≈ 85% of bedsets. **Planar microbial laminae** in ≈ 75% of bedsets. **Wrinkly microbial laminae** in ≈ 25% of bedsets. **Horizontal planar non-microbial laminae** in ≈ 15% of bedsets. **Mudcracks** in ≈ 55% of bedsets. **Tepees** a couple of cm high; in ≈ 15% of bedsets. **Contorted bedding** in ≈ 10% of bedsets. **Burrows** in ≈ 10% of bedsets. **Microfaults** in ≈ 10% of bedsets. | No **beds** were measured. Total **Bedset thicknesses** were not measured as this unit is just below the basal parasequence boundary of the interval studied. Range of bedset thickness from 55 to > 140 cm. | Upward increase in amount of **ls arenite, sts, or mdst** in ≈ 60% of bedsets. | Various **ls** lithologies associated w/ ≈ 75% of bedsets, including **Mdst** in ≈ 40%, **Arenite** in ≈ 25%, **Sts** in ≈ 10%, & Fossiliferous, oolitic, peloidal **wk/pkst** in ≈ 10%. |

## APPENDIX 2: PETROGRAPHIC DESCRIPTION FORMS: PART A. POLISHED SLABS AND HAND SAMPLES

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1, Emigrant Pass, southern Nopah Range. At Wood Canyon/Zabriskie contact (0 m) | **Sample number:**<br>90-1A |

**Dunham classification.** Top 1.5 cm = quartz sandstone. Above surface= muddy sandstone. Below surface = packstone.

**Grain types; sizes; shapes; amounts.** **Top 1.5 cm** = quartz sand; with small trilobite fragments; vf. **Above surface** = Quartz grains; m-f w/ some c & vf; subangular to subround; 25-30%. Siliceous intraformational grains; red, yellow, brown; m-f; 25-30%. Carbonate intraformational grains; m-f; subrounded to subangular; decreasing amounts upward but 15-20% overall. Trilobite fragments; preferred orientation of convex up; decreasing amounts upward but 10% overall. Several black, 'bituminous-looking' grains; <1 mm to 1 x 5 &2 x 3 mm; rounded to subrounded; <2-3%. **Below surface** = Ooids and coated grains, including trilobite fragments; ≤1 mm, most ≈0.5 mm; 40-45%. Carbonate intraformational grains; m-c, subangular to angular;30-35%. Trilobite fragments; no preferred orientation; 5-10%.

**Matrix type; amount.** Above surface = Mud , red, yellow, brown; 10-20 %. Below surface = micrite or siliceous mud, reddish-brown; 10-15%.

**Cement types; amounts.**

**Textures.** Top 1.5 cm = wavy, nonparallel laminae; mm-thickness. Above and below surface = jumbled w/o any particular texture.

**Diagenetic features.** Much red and yellow iron-staining of clasts and grains.

**Comments.** Three-part division to sample: top 1.5 cm is a relatively clean quartz sandstone, middle is a muddy sandstone, separated from the basal packstone by a scoured surface. A siltite clast, 0.5 x 2 cm, subrounded at or near the surface. Surface has 1-2 cm of relief, very irregular and cuts across grains. Possible microkarsting?

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. Within a few cm above Wood Canyon/Zabriskie contact (0 m). | **Sample number:**<br>90-1B |

**Dunham classification.** Above the surface = fossiliferous sandstone. Below the surface = ooid-coated grain-trilobite grainstone.

**Grain types; sizes; shapes; amounts.** Above the surface = Quartz grains,; f-vf; ≈60-70%. Lithoclasts of calcareous and/or siliceous mudstone; ≤1 mm; subangular; ≈15%. Trilobite fragments, ≈15%. Below the surface =
Ooids and coated grains; 0.5-0.75 mm; 60-70%. Echinoderm(?) grains; 0.5-0.75 mm; 10-15%. Trilobite fragments; 10%.

**Matrix type; amount.** Above the surface = mud, <5%. Below the surface = none.

**Cement types; amounts.** Below the surface = clear, spar(?); 5-10%.

**Textures.** Homogeneous.

**Diagenetic features.** Much red, brown and yellow iron staining. Possible pyrite, or other opaque mineral.

**Comments.** Surface has over 1 cm relief in sample, including a hole about a cm deep but less that a cm wide at the top.

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Zabriskie, at ≈11 m. | **Sample number:**<br>90-2 |

**Dunham classification.** Originally a pack/grainstone?

**Grain types; sizes; shapes; amounts.** Calcareous and/or siliceous lithoclasts(?), fossil(?) fragments. Some clasts may be ≤1 x 2 cm.

**Matrix type; amount.** Unsure.

**Cement types; amounts.**

**Textures.** Appears to be conglomeratic now, but this may be, at least partially, the result of alteration.

**Diagenetic features.** Highly altered, with heavy red, brown, and yellow staining, alteration/precipitation of metallic(?), opaque minerals. Dendritic-appearing growths within some of the larger 'clasts'.

**Comments.** High degree of alteration not surprising as location is within 7 km of a once-productive lead mine.

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈147-153 m. | **Sample number:**<br>90-3a to e |

**Dunham classification.** All are fossiliferous wackestones

**Grain types; sizes; shapes; amounts.** Samples a and b may have echinoderm fragments in addition to trilobite fragments; a total of maybe 30-40%. Samples c,d, and e are mostly trilobite fragments, 10-15%.

**Matrix type; amount.** Mud, either siliceous or calcareous originally.

**Cement types; amounts.** Calcite or dolomite crystals up to a mm across in veins in sample a.

**Textures.**

**Diagenetic features.** Samples a, b, and c are stained mostly red with green, concretionary/botryoidal growths. Sample e is mostly yellow-stained.

**Comments.** First carbonate units in the Carrara. Section within 7 km of very productive lead mine.

# PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈167.3 m. | **Sample number:**<br>90-4 |

**Dunham classification.** Quartz sandstone.

**Grain types; sizes; shapes; amounts.** Quartz grains; vf; 80-85%. Feldspar grains, pale yellow to white; vf; 5-7%.

**Matrix type; amount.** Some clay matrix in upper and lower few mm that bound the unit; ≤2-3%.

**Cement types; amounts.** Silica; ≈ 5-10%.

**Textures.** Horizontal planar laminae

**Diagenetic features.** Authigenic micas. Is feldspar also authigenic?

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈168.7 m. | **Sample number:**<br>90-5 |

**Dunham classification.** Silty, trilobite wackestone to mudstone.

**Grain types; sizes; shapes; amounts.** Trilobite fragments, including spines; ≈10+%.

**Matrix type; amount.** Mud, with either silt-sized carbonate material or part of the mud is recrystallized; 90%.

**Cement types; amounts.**

**Textures.** Percent of trilobite fragments decreases upward until the upper part of the sample is a mudstone.

**Diagenetic features.** Some clear spar cement where trilobite pieces have made shelter.

**Comments.** In hand sample, looks much like a siltite, but with microscope it looks much more like mud and recrystallized mud.

# PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈172.2-172.4 m. | **Sample number:**<br>90-6 |

**Dunham classification.** Oncoid packstone with a trilobite-echinoderm mud/wackestone matrix.

**Grain types; sizes; shapes; amounts.** Oncoids; ≤3+ cm; ≈35-40%. Fossil fragments, echinoderm and trilobite; ≤10%. Lithoclasts of mudstone; rounded; 0.25-0.75 mm; ≈5%.

**Matrix type; amount.** Carbonate mud; ≈50%.

**Cement types; amounts.** Clear spar in late, vertical and horizontal fractures.

**Textures.**

**Diagenetic features.** Vertical and horizontal styolitic seams. Tension(?)-fractures, mostly horizontal filled with clear cement, in oncoids and matrix.

**Comments.** Some oncoids have trilobite fragments in cores.

PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈187.8 m. | **Sample number:**<br>90-8 |
|---|---|---|

**Dunham classification.** Fossiliferous quartz sandstone.

**Grain types; sizes; shapes; amounts.** Quartz grains; vf; 80-85%. Trilobite fragments; ≤5%. Echinoderm fragments; <1 mm; subangular to angular; 2-3%.

**Matrix type; amount.** Siliceous mud; ≈5%.

**Cement types; amounts.** Siliceous and calcareous; 5-10%.

**Textures.** Wave rippled.

**Diagenetic features.** Some black stain (or opaque mineral) in fractures and pore space.

**Comments.** Fossil fragments often concentrated in bands ≈5 mm thick with much more mud than the surrounding sandstone.

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈197.9 m. | **Sample number:**<br>90-9 |
|---|---|---|

**Dunham classification.** Fossiliferous-oncolitic wacke/packstone.

**Grain types; sizes; shapes; amounts.** Fossil fragments; 20-25%. Fossil fragments are mostly trilobite, but there are a number of submillimeter fragments that are unidentified. There are also slices through apparent 'multi-chamber' organisms, <1 mm in size, perhaps gastropods, forams or byrozoans. Oncoids; ≤1 cm; spheroid; ≈5-7%. lithoclasts; subrounded to rounded; ≤5 mm; ≈5-7 %.

**Matrix type; amount.** Calcareous mud; 60-70%.

**Cement types; amounts.** Clear spar in horizontal fractures.

**Textures.** Homogeneous.

**Diagenetic features.** Many vertical fractures and dissolution surfaces and some horizontal, cement-filled fractures. A lot of yellow iron(?) staining.

**Comments.** There is an irregular, silicified crust on top of the bed, generally ≤ 3 mm thick, that truncates grains. Cannot tell if late diagenetic origin or if formed shortly after lithification of bed, perhaps analogous to crusts formed on subaerially-exposed Pleistocene/Modern carbonates in the Bahamas.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈207.8 m. | **Sample number:**<br>90-10 |
|---|---|---|

**Dunham classification.** Probably originally a fossiliferous-oncolitic wackestone.

**Grain types; sizes; shapes; amounts.** Very hard to distinguish due to deformation and alteration.

**Matrix type; amount.** Mud?

**Cement types; amounts.** Rock has been sheared such that grains and matrix are deformed, appearing stretched.

**Textures.**

**Diagenetic features.** Iron (yellow, red) staining and replacement. Possibly mostly recrystallized.

**Comments.** Badly altered from both tectonics and fluids. Within the ≈10 m thick carbonate unit from 201-211 m. See also 90-11, 12, 13, 14.

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, at ≈201-211 m. | Sample number: 90-11 |
|---|---|---|

**Dunham classification.** Originally a fossiliferous-oncolitic mudstone?

**Grain types; sizes; shapes; amounts.** Very hard to distinguish due to deformation and alteration.

**Matrix type; amount.** Mud?

**Cement types; amounts.**

**Textures.** Brecciated.

**Diagenetic features.** Probably mostly recrystallized. Iron (yellow, red)stain & alteration. Clear cement along vertical fractures, some of which are still partially open. Dissolution along horizontal seams.

**Comments.** Badly altered from both tectonics and fluids. From the upper surface of the flank of the ≈10 m thick carbonate unit from 201-211 m. See also 90-10, 12, 13, 14.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, lateral to unit at ≈201-211 m. | **Sample number:**<br>90-12 |
|---|---|---|

**Dunham classification.** Originally a carbonate mudstone?

**Grain types; sizes; shapes; amounts.** Can't tell if there were any.

**Matrix type; amount.** Mud?

**Cement types; amounts.** Clear spar cement in partially filled vertical fractures.

**Textures.** Completely recrystallized, with possible reprecipitation of iron-carbonates. There are zoned and botryoidal-looking areas in the sample.

**Diagenetic features.** Recrystallization and iron-staining and replacement.

**Comments.** From a 30 cm-thick carbonate bed lateral to and equivalent(?) to the carbonate unit from 201-211 m. 10-m thick unit is probably mound-shaped from field examination, though this could be due to tectonic structuring (mediocre outcrop). See also 90-10, 11, 13, 14.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:**<br>**Hand spl:** √ | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, lateral to unit at ≈201-211 m. | **Sample number:**<br>90-13 |
| **Dunham classification.** Silty, siliceous shale. | | |
| **Grain types; sizes; shapes; amounts.** Slight amount of silt. | | |
| **Matrix type; amount.** clay. | | |
| **Cement types; amounts.** Slightly reactive to dilute HCl. | | |
| **Textures.** Planar laminated. | | |
| **Diagenetic features.** | | |
| **Comments.** Lateral to carbonate unit. Lithology that onlaps unit. See also 90-10, 11, 12, 14. | | |

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 200.8 m, just below unit at ≈201-211 m. | **Sample number:**<br>90-14 |

**Dunham classification.** Basal 1 cm is a fossiliferous packstone. The rest of the sample is a fossiliferous grainstone.

**Grain types; sizes; shapes; amounts.** **Basal 1 cm:** Fossil fragments, including trilobites, echinoderms, 'unidentifieds', and the small, 'multichambered' gastropod-foram-bryozoan; most < 2 mm; 40-50%. **Upper part:** Same assortment of fossil fragments as basal 1 cm; ≤ 5 mm; 50-60%. Lithoclasts of mudstone; ≤ 5 mm; 5-7%.

**Matrix type; amount.** **Basal 1 cm:** Mud; 50-55+%. **Upper part:** Mud; 5-7% in clumps, either infiltrated in or alteration products.

**Cement types; amounts.** **Basal 1 cm:** Cement ≤5%. **Upper part:** clear spar; 40-45%

**Textures.** Homogeneous.

**Diagenetic features.** The basal 1 cm of packstone has some shelter porosity filled with clear spar cement. The surface between the basal 1 cm and the rest of the sample is ≤3 mm thick, and composed of yellowish-orange carbonate mud (or insolubles?). There is definite dissolution along the surface as grains of the overlying grainstone are truncated by it. Some or all of the mud in the grainstone is likely alteration of cements and/or grains.

**Comments.** See also 90-10, 11, 12, 13.

## PETROGRAPHIC DESCRIPTION FORM

<table>
<tr><td><u>Slab:</u> √<br><u>T. sctn:</u></td><td><u>Location:</u> Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 226.2 m.</td><td><u>Sample number:</u><br>90-15</td></tr>
<tr><td colspan="3"><u>Dunham classification.</u> Fossiliferous packstone or grainstone originally.</td></tr>
<tr><td colspan="3"><u>Grain types; sizes; shapes; amounts.</u> Trilobite (& others?) fragments; 30-35%. Oncoids, now highly altered; spheroids and discoids; ≤1.5 cm; 5-7%.</td></tr>
<tr><td colspan="3"><u>Matrix type; amount.</u> Mud/cement (altered & can't see what it was originally); 60%. May have had both.</td></tr>
<tr><td colspan="3"><u>Cement types; amounts.</u> Mud/cement (altered & can't see what it was originally); 60%. May have had both.</td></tr>
<tr><td colspan="3"><u>Textures.</u> Homogeneous.</td></tr>
<tr><td colspan="3"><u>Diagenetic features.</u> Vertical fractures with clear cements. Much alteration/staining to yellow (iron?). Oncoids are almost unrecognizable from rounded lithoclasts.</td></tr>
<tr><td colspan="3"><u>Comments.</u> Another highly altered sample.</td></tr>
</table>

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 230.9 m. | Sample number: 90-16L & U |
|---|---|---|

**Dunham classification.** Originally a fossiliferous packstone or grainstone.

**Grain types; sizes; shapes; amounts.** Trilobite fragments; 35-40% in the lower piece & 40-45% in the upper. Echinoderm fragments; <1 mm; 5-7% in both.

**Matrix type; amount.** Mud/cement (can't tell now); 50-60%.

**Cement types; amounts.** Mud/cement (can't tell now); 50-60%.

**Textures.** Homogeneous.

**Diagenetic features.** Alteration of the parent rock into what appears to be a lithoclast packstone. Possible alteration of the cement into what appears to be mud. Also, the usual vertical fractures filled with clear cements. Lower piece has more of altered cement/mud than upper. Upper almost more of a grainstone in part, even now.

**Comments.** Two pieces; 'L' is the lower , 'U' is the upper. They are essentially in contact. Originally in field notes, this was described as fossiliferous packstone overlain by a lithoclast packstone, with a hardground/scoured surface between. Now recognized to be very altered, on a cm-scale basis.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:**<br>**Hand spl:** √ | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 232.8 m. | **Sample number:**<br>90-17 |
| **Dunham classification.** Coarsely recrystallized carbonate (dolomite + calcite); crystals ≤ 5 mm. | | |
| **Grain types; sizes; shapes; amounts.** Field notes state also a fossiliferous wacke/packstone associated with this bed. | | |
| **Matrix type; amount.** ? | | |
| **Cement types; amounts.** ? | | |
| **Textures.** Slickensides. < 1 cm layering that splits readily. | | |
| **Diagenetic features.** Extreme recrystallization. | | |
| **Comments.** Similar rocks crop out in the mixed lithology-intervals of the Carrara & I interpret them as fault-related. | | |

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 238.65 m. | **Sample number:**<br>90-18 |
| **Dunham classification.** Originally a trilobite grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Trilobite fragments, many are fragments are broken *in situ* in the sample, i.e. the pieces are next to each other; 35-45%. Echinoderm fragments(?); 1-3%. | | |
| **Matrix type; amount.** What looks to be matrix is interpreted as alteration of the cement. | | |
| **Cement types; amounts.** Clear, spar; 55-65%. | | |
| **Textures.** Trilobites arranged with long axis horizontal. May have some fining upwards, with replacement of fossils by mud/silt. | | |
| **Diagenetic features.** Alteration of clear cement into yellow (iron-stained?), opaque, groundmass that looks like carbonate mud. | | |
| **Comments.** At base of this bed is a slightly calcareous, quartz siltstone. | | |

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 280.2-280.5 m. | **Sample number:**<br>90-19L, M, U |

**Dunham classification.** **Lower:** Fine quartz sandstone. **Middle:** Coarse fossiliferous(?) grainstone originally. **Upper:** Medium fossiliferous grainstone or packstone originally.

**Grain types; sizes; shapes; amounts.** **Lower:** Quartz grains; fine; 80-90%. Yellow feldspar(?) grains; fine to very fine; 10-15%. Green grains, unknown; very fine; ≤5%. **Middle:** Trilobite, and possibly other fossil, fragments; 35-45%. Black opaque mineral, 5-7%. **Upper:** Fossil fragments, including trilobite, 'unidentifieds', echinoderm(?), ≤0.5 mm spheroids that are altered but don't look like ooids; ≈45-50%. Reddish-black opaque mineral (hematite?), 10-15%.

**Matrix type; amount.** **Middle:** Mud/cement (can't tell now); 55-65%. **Upper:** Mud/cement (can't tell now); ≈ 35-45%.

**Cement types; amounts.** **Lower:** Silica; 10%. **Middle:** Mud/cement (can't tell now); 50-60%. **Upper:** Mud/cement (can't tell now), but somewhat siliceous; ≈ 35-45%.

**Textures.** **Lower:** horizontal to low-angle planar laminae. **Middle:** Homogeneous. **Upper:** Homogeneous.

**Diagenetic features.** **Lower:** Possibly yellow and green grains; limonite and ?. **Middle:** Black opaque mineral, lots of yellow-, red-, and pink-stained/altered material. **Upper:** Groundmass (cement/mud) yellow, reddish-black opaque mineral (hematite?).

**Comments.** Each sample taken a bit lateral to and above the previous sample. No contact 'captured' in a sample. In top 1 cm of sample 90-19U, have a laterally discontinuous bed, < 1 cm thick, rippled(?), vf quartz sand interbed, with gradational upper and lower boundaries with the carbonates. A lot of alteration of the two carbonate samples.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 297.0-297.5 m. | **Sample number:**<br>90-20A, B, C |

**Dunham classification.** Fossiliferous-coated grain-ooid grainstone with lithoclasts.

**Grain types; sizes; shapes; amounts.** Fossil fragments, including trilobites, echinoderms, and coated grains of either; ≤2mm, excepting long slender trilobite pieces; 35-50%. ooids; 0.25-0.5 mm; 10-15%. Clasts of vf sand to coarse silt quartz sandstone; ≤ 2 x 4 cm in hand-sample, but larger clasts shown in photos; % of volume not estimated.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; ≈40%.

**Textures.** Field notes record current ripples, and trough cross-beds.

**Diagenetic features.** Some grains altered/stained yellow or red (iron?). Fairly intensive alteration around the clasts w/ lots of stain/alteration to red (hematite?) and yellow (limonite?).

**Comments.** Three samples from 0.5 m bedset. C is at bottom, B includes clasts in upper part of bedset, and A includes the silicified crust of fine, quartz sandstone at the top of the bedset.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 300.4 m. | **Sample number:**<br>90-21 |

**Dunham classification.** **Lower part:** Fine quartz sandstone. **Middle part:** Fossiliferous grainstone with oversized lithoclasts of very fine to fine quartz sandstone. **Upper part:** Fossiliferous quartz sandstone.

**Grain types; sizes; shapes; amounts.** **Lower part:** Quartz grains; f; 90-95%. **Middle part:** Fossil fragments, including trilobites, 'unidentifieds', coated fragments; ≤2 mm, with most <1 mm; 25-30%. Ooids; ≤0.25-0.75 mm; 7-10%. Lithoclast of vf-f quartz sandstone; subrounded; often in contact; ≤1.5 x 4.5 cm; ≈20-25%. **Upper part:** Quartz grains; vf; ≈ 60%. Trilobite fragments; 10-15%.

**Matrix type; amount.** **Upper part:** 15-20% mud + cement, as can't tell apart due to alteration.

**Cement types; amounts.** **Lower part:** Silica; 5-10%. **Middle part:** Clear spar; ≈40%. **Upper part:** 15-20% mud + cement, as can't tell apart due to alteration.

**Textures.** **Lower part:** Horizontal laminae; upper surface with carbonate appears to be scoured, and possibly loaded slightly, with about 1.5 cm of broad, smooth scour, and abrupt and irregular relief on the cut face. **Middle part:** Clasts oriented with long axis horizontal, and concentrated in upper part of bed. **Upper part:** Crude, gently inclined laminae.

**Diagenetic features.** **Middle part:** Some alteration/staining of smaller clasts and along seams. **Upper part:** Red, orange, and yellow staining/alteration of mud matrix and/or cement. Black, opaque mineral ≈3-5%.

**Comments.** Two pieces top the sample, with the lower piece the larger of the two, and it contains the lower and middle parts. The upper piece is smaller and contains only the upper part. See also sample 90-22, which occurs about 40 cm higher in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 300.8 m. | **Sample number:** 90-22 |

**Dunham classification.** Echinoderm grainstone.

**Grain types; sizes; shapes; amounts.** Echinoderm fragments; ≤2 mm, most ≤1 mm; subangular to subround; ≈ 50-55%. Trilobite fragments; 10-15%; Oncoids; ≤1 cm; ≈5%. One nested pair of hyolithoid(?); 7 mm H x 12 mm W; ≤1%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; 25-35%.

**Textures.** Homogeneous.

**Diagenetic features.** Some yellow alteration/stain of grains and cement. Also red, orange, and yellow <2-3 mm thick on top and bottom contacts of bed.

**Comments.** See also sample 90-21, which occurs about 40 cm lower in the same bedset.

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 302.6 m. | **Sample number:**<br>90-23 |
|---|---|---|

**Dunham classification.** **Lower part:** Ooid-coated grain-echinoderm grainstone. **Middle part:** Very complex and highly altered by dissolution; ranges from grainstone to wackestone. **Upper part:** Fossiliferous-oncolitic packstone or grainstone originally; now looks like a packstone.

**Grain types; sizes; shapes; amounts.** **Lower part:** Ooids; 0.25-1 mm; ≈40%. Coated grains, mostly fossil fragments; <1 mm; rounded to subrounded; ≈20%. Echinoderm fragments; ≤1.5 mm; subrounded; ≈15%. Lithoclasts of mudstone; ≤1 x 4 mm; subrounded; ≈5%. **Middle part:** Mostly ooids, 0.5-1 mm; also has clasts of ooid grainstone, ooid packstone, ooid wackestone, mudstone; some fossil fragments; clasts range from ≤5 mm to >4.5 cm. **Upper part:** Echinoderm fragments; subrounded to subangular; ≈20-25%. Trilobite fragments; 5-10%. Oncoids; spheroidal and discoidal; <2 cm; ≈20-25%. Ooids and coated grains; < 1 mm; ≈10-15%.

**Matrix type; amount.** **Middle part:** Carbonate mud. **Upper part:** Carbonate mud/cement, can't distinguish now; ≈35%.

**Cement types; amounts.** **Lower part:** ≈25%. **Middle part:** Some clear spar?. **Upper part:** Carbonate mud/cement, can't distinguish now; ≈35%.

**Textures.** **Lower part:** Homogeneous. **Middle part:** Jumbled. Almost like a disrupted mix of mud, ooids, and clasts. **Upper part:** Homogeneous.

**Diagenetic features.** **Lower part:** Some staining/alteration of grains and cement. **Middle part:** More staining/alteration of grains and cement than below. **Upper part:** Some staining/alteration of grains, matrix, and cement so that can't resolve cement from matrix.

**Comments.** This sample is about 10 cm thick (stratigraphic thickness). The top and bottom surfaces of the sample are dissolution surfaces that also have red and yellow (iron?) alteration/stain along them. Within the sample are at least two more, through-going, dissolution surfaces which truncate grains on both sides of the surfaces. Both of these internal surfaces have 1-2 mm of insolubles/mud along them. The lower of the two has about 1 cm of relief, whereas the upper has less than that and is smoother. Any of the four surfaces could have originally been erosion surfaces as well. There are also internal, semi-horizontal surfaces that truncate grains, often on either side of the surface, but these do not have the same amount of insolubles, nor are they obviously through-going across the sample. Note that the entire bedset this sample comes from is only 20 cm thick. See also sample 90-24, which occurs lower in the same bedset & includes a basal conglomerate.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Carrara, ≈ 302.5 m. | **Sample number:**<br>90-24 |

**Dunham classification.** **Lower part:** Quartz sandstone. **Upper part:** Conglomeratic, fossiliferous-oolitic-lithoclast grainstone.

**Grain types; sizes; shapes; amounts.** **Lower part:** Quartz grains; vf; ≈85%. Trilobite and echinoderm fragments, lithoclasts of mud; all < 1 mm; <5%. **Upper part:** Echinoderm and trilobite fragments, some coated; ≈25-30%. Ooids; <1 mm; <20-25%. Lithoclasts of vf quartz sandstone and siltstone; <1 x 3 cm, with most <2-3 x 5-7 mm; ≈25%.

**Matrix type; amount.** **Lower part:** May be some mud with cement; 5-10%.

**Cement types; amounts.** **Lower part:** May be some mud with cement; 5-10%.. **Upper part:** Clear spar, though some altered/stained; ≈25%.

**Textures.** **Lower part:** Horizontal to low angle planar laminae; may be low-angle, hummocky cross-beds. Some coarsening upwards with an increase in non-quartz grains. **Upper part:** .

**Diagenetic features.** **Lower part:** Some black staining. **Upper part:** .

**Comments.** Irregular, possibly scoured and/or dissolution surface with <1.5 cm of relief. Grains in upper bed do get truncated on surface. See also sample 90-23, which occurs higher in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 304.2 m. | **Sample number:**<br>90-25 |

**Dunham classification.** Ooid grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; ≤1 mm; radial and concentric internal structure; ≈ 70%. Fossil fragments, mostly echinoderm, but also trilobites, and 'unidentifieds'; < 10%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; ≈25%.

**Textures.** Homogeneous in hand sample, although field notes record trough cross-beds.

**Diagenetic features.** Much of cement has been recrystallized, possibly top yellow-stained (iron?) dolomite (no reaction to HCl). In areas with most intense recrystallization, ooids are gone, leaving only echinoderm and other fossil fragments in a matrix of crystals.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 304.8 m. | **Sample number:**<br>90-26 |
|---|---|---|

**Dunham classification.** Now looks like a dolosiltite, but has been altered and probably recrystallized to the point that original grains and texture(?) have been obliterated.

**Grain types; sizes; shapes; amounts.** Yellow-stained (iron?) dolomite rhombs(?); silt-sized; ≈90-95%. Quartz grains; vf; in stringers and thin layers ≤1.5 cm; 5-7%.Echinoderm fragments; < 1 mm; 2-3%.

**Matrix type; amount.** Can no longer tell.

**Cement types; amounts.** Can no longer tell.

**Textures.** Horizontal laminae; micro-ripples of sand, a vertical burrow ≈1.2 cm in diameter.

**Diagenetic features.** Black, opaque grains and spots; <1.5 mm; 3-5%

**Comments.** Grains, cements, and matrix probably very altered by recrystallization, but it is likely that texture and sedimentary structures are moderately well-preserved.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 305.7 m. | **Sample number:**<br>90-27 |

**Dunham classification.** **Lower part:** Oolitic grainstone. **Upper part:** Oolitic-fossiliferous-oncolitic grainstone or packstone originally.

**Grain types; sizes; shapes; amounts.** **Lower part:** Ooids; ≤1 mm; radial and concentric structure; ≈65-70%. Fossil fragments, including echinoderms and trilobites; mostly ≤ 1 mm; ≈5-10%. **Upper part:** Ooids; ≤1 mm; radial and concentric structure; ≈ 45-50%. Fossil fragments, including echinoderm and trilobite; mostly < 1 mm; ≈10-15%. Oncoids; spheroid; ≤ 1 cm; ≈10%. There may be lithoclasts of grainstones, but dissolution makes it difficult to be sure.

**Matrix type; amount.** **Upper part:** Mud/cement, as can't distinguish between due to alteration;≈30-35%.

**Cement types; amounts.** **Lower part:** Clear spar; ≈ 25-30%. **Upper part:** Mud/cement, as can't distinguish between due to alteration;≈30-35%.

**Textures.** **Lower part:** Homogeneous. **Upper part:** Very disrupted due to dissolution. Otherwise, homogeneous.

**Diagenetic features.** **Lower part:** Many ooids, and some cement have been altered. **Upper part:** Alteration of most of the cement/matrix, but less alteration of ooids than in lower part.

**Comments.** A large amount (relative to the sample) of dissolution has occurred in this bed, especially in the upper part. Dissolution has truncated grains above and below , and within the seam. This dissolution surface appears to have also acted as a conduit for fluids that caused alteration, as there is much alteration/staining to red, orange, and yellow within and adjacent to the 2.5 cm thick seam.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 311.9 m. | **Sample number:**<br>90-28 |

**Dunham classification.** Ooid grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; ≤0.25-1 mm; radial and concentric fabric; ≈70%. Fossil fragments, including echinoderms, trilobites, and hyolithoids; mostly ≤ 2mm; ≈10%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; ≈20∞.

**Textures.** Homogeneous.

**Diagenetic features.** Some dissolution and alteration/staining. Also, some ooids may be beginning to interpenetrate one another, though this is hard to confirm in the slab.

**Comments.** Basal 2 cm of sample is a vf-f quartz sandstone, with ripple-lamination. Surface between two lithologies may have been originally scoured, but now has had dissolution along it, as there is < 2 mm of mud/insolubles that has been stained/altered red to yellow and truncates grains from the overlying bed.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 312.4 m. | **Sample number:**<br>90-29 |
|---|---|---|

**Dunham classification.** Oolitic-fossiliferous-oncolitic-lithoclastic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids and coated grains; 0.25-0.75 mm; 35-40%. Fossil fragments, including echinoderms, trilobites, and possibly molluscs; mostly < 1 mm; 10-15%. Oncoids; spheroid and discoid; <1.5 cm, with most < 1 cm; ≈10%. Lithoclasts of vf-f quartz sandstone; ≤ 0.7 x 1.5 cm; elongate and subrounded; ≈5-7%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; ≈ 35%.

**Textures.** Homogeneous.

**Diagenetic features.** Some alteration of cement, and of grains, especially ooids. Some minor dissolution within bed. Alteration and dissolution increase in upper 1 cm and top surface of bed is stained red to black.

**Comments.** Bed sample is from varies from 1 to 10 cm thick. Sample contains entire bed. Basal ≈ 3 cm of sample is a vf-f quartz sandstone with ≈ 15% fossil fragments (echinoderm, trilobite). Some dissolution and alteration/staining along contact, forming ≈ 1 mm of red mud/insolubles.

# PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 313.3 m. | **Sample number:**<br>90-30 |

**Dunham classification.** Oolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; < 0.25 - 1 mm; some with concentric fabric; ≈ 65-70%. Fossil fragments, including echinoderms and trilobites; mostly < 2 mm; ≈ 5-10%.

**Matrix type; amount.**

**Cement types; amounts.** Dark spar(?), although much is altered; ≈30-35%.

**Textures.** Some coarsening upwards from '≈ ≤ 0.25 - 0.5 mm', up to '0.25 - ≤ 1 mm'. Otherwise, relatively homogeneous.

**Diagenetic features.** Alteration of grains to almost destroy all internal fabric, though a few ooids retain some concentric fabric.

**Comments.** Field description was of an arenite overlain by an oolite, but 'arenite' is just a bit finer oolite with a lot more alteration and dark cement and grains where alteration is less. See also sample 90-31, located about 30 cm lower in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 313.0 m. | **Sample number:**<br>90-31 |

**Dunham classification.** Oolitic-fossiliferous-lithoclastic-oncolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; some with concentric fabric, rest altered; ≤ 1 mm; ≈35-40%. Fossil fragments, including echinoderms, trilobites, and possibly mollusc or brachiopod; mostly ≤ 2 mm; ≈ 15-20%. Lithoclasts of vf quartz sandstone, siltstone, calcareous &/or siliceous mudstone; ≤ 1 x 2 cm; subangular to subrounded; ≈ 5-7%. Oncoids; ≤ 1 cm; spheroids; ≈3-5%.

**Matrix type; amount.**

**Cement types; amounts.** Cement is partially altered, but appears to have been clear spar; ≈30-35%.

**Textures.** Homogeneous.

**Diagenetic features.** Alteration of most internal fabric of ooids, and much of cement is altered. Red and yellowing staining/alteration, and minor dissolution .

**Comments.** See also sample 90-30, located about 30 cm higher in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 319.3 m. | **Sample number:**<br>90-32 |

**Dunham classification.** Oolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; 0.25-≤0.5 mm; radial and concentric fabric preserved in some ooids; ≈70-80%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; 20-30%.

**Textures.** Homogeneous.

**Diagenetic features.** Many of ooids are internally altered and recrystallized.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 319.8 m. | **Sample number:**<br>90-33 |

**Dunham classification.** Oolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; 0.25 - ≤ 1 mm; ≈70 - 75%. Fossil fragments, mostly echinoderms; mostly <≤ 1 mm; ≤ 5%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; ≈ 25%.

**Textures.** Homogeneous.

**Diagenetic features.** Some cement, and many of the ooids are altered. Some horizontal and vertical dissolution seams.

**Comments.** See also sample 90-34 located 30 cm above, but within the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 320.1 m. | **Sample number:**<br>90-34 |

**Dunham classification.** Conglomeratic, oolitic-fossiliferous-lithoclastic-oncolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; ≤ 0.5-1 m; many altered internally; 25-35%. Fossil fragments, including echinoderms, trilobites; ≤ 3 mm; 10-15%. Lithoclasts of ooid grainstone, calcareous mudstone/siltite (some may be altered oncoids; 10-15%. oncoids; < 1.5 cm, larger clasts are of grainstone; 10-15%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar, with much altered; 30-35%.

**Textures.** Largest clasts at bottom, but still many large clasts mixed throughout sample. Homogeneous overall.

**Diagenetic features.** Altered ooids, oncoids, cement; with red, orange, yellow stain/alteration (iron?). Dissolution along vertical and horizontal seams

**Comments.** See also sample 90-33 located 30 cm below, but within the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 321.8 m. | **Sample number:**<br>90-35 |

**Dunham classification.** Oolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; 0.5 - 1.0 mm; concentric fabric; ≈ 65-75%. Fossil fragments, almost all coated; 0.5 - 1.0 mm; ≤ 5%.

**Matrix type; amount.**

**Cement types; amounts.** Clear spar; ≈ 20-30%.

**Textures.** Homogeneous.

**Diagenetic features.** Many ooids and cement altered, leading to mottled appearance. Burrowing did not cause mottling in sample.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 329.5 m. | **Sample number:**<br>90-36 |

**Dunham classification.** Oolitic grainstone or packstone originally.

**Grain types; sizes; shapes; amounts.** Ooids; ≤0.5 mm; some concentric fabric preserved; 65-75%. Some quartz grains; vf-f; in some layers < 1 cm, with a mix of ooids and quartz; ≤ 5-7%.

**Matrix type; amount.** Cement/mud can't be distinguished now; 25-30%.

**Cement types; amounts.** Cement/mud can't be distinguished now; 25-30%.

**Textures.** In hand sample, appears to have occasional interlaminae and beds of siltite, but siltite layers are just more heavily altered carbonate. Actually have occasional interbeds of mix of sand and ooids.

**Diagenetic features.** Altered cement/mud matrix to point that can't distinguish the two. Altered ooids, some to point of appearing to be siltite in hand sample. Dissolution, including interpenetrating ooids.

**Comments.** Dolosiltite interlaminae reported in field notes are altered carbonate intervals.

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 326.9 m. | **Sample number:**<br>90-37 |
|---|---|---|

**Dunham classification.** Oolitic grainstone.

**Grain types; sizes; shapes; amounts.** Ooids; 0.1-0.75 mm, most <0.5 mm; radial and concentric fabric; 75-80%. Echinoderm fragments; <1 - 2 mm; ≤3-5%.

**Matrix type; amount.**

**Cement types; amounts.** Dark spar; ≈20-25%.

**Textures.** Slight variation in grain size throughout sample. Most coarser echinoderm fragments and larger ooids are concentrated in interbeds ≤ 1 cm thick.

**Diagenetic features.** A couple of thin dissolution seams < 1 mm thick.

**Comments.** See also sample 90-38, 10 cm lower in same bedset.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 326.8 m. | **Sample number:**<br>90-38 |

**Dunham classification.** Oolitic grainstone with interlaminae of quartz sandstone.

**Grain types; sizes; shapes; amounts.** Ooids; 0.1-0.75 mm, most <0.5 mm; radial and concentric fabric; 55-60%. Echinoderm and trilobite fragments; ≤3-%. Interlaminae and interbeds of quartz grains; f; ≈ 20%.

**Matrix type; amount.**

**Cement types; amounts.** Dark spar; ≈ 20%.

**Textures.**
Interlaminae of quartz sand; < 1 mm to 12 mm, horizontal and possible ripple-lamination. Also have intermixing of ooids and sand within laminae.

**Diagenetic features.** Possibly some ooid-interpenetration; stain/alteration along quartz interlaminae.

**Comments.** See also sample 90-37, 10 cm higher in same bedset.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 323.7 m. | **Sample number:**<br>90-40 |
|---|---|---|

**Dunham classification.** **Upper part:** Oolitic grainstone. **Lower part:** Oolitic-fossiliferous grainstone.

**Grain types; sizes; shapes; amounts.** **Upper part:** Ooids; 0.25-0.5 mm; some with concentric fabric, but most are altered; ≈ 65-70%. Fossil fragments, including echinoderms and trilobites; ≤ 3 mm; ≈ 5-7%. **Lower part:** Ooids; < 1 mm; radial and concentric fabric; 50-55%. Fossil fragments, mostly echinoderms, but also trilobites; ≤ 8 mm, most < 1-2 mm; 10-15%. Possibly some lithoclasts of oolitic grainstone, but difficult to tell for sure because of the wide-spread dissolution and alteration.

**Matrix type; amount.**

**Cement types; amounts.** **Upper part:** Spar cement, but some altered; ≈ 25-30%. **Lower part:** Spar cement, some altered; ≈35-40%.

**Textures.** **Upper part:** Homogeneous. **Lower part:** Crude lamination defined by oriented fossil fragments.

**Diagenetic features.** **Upper part:** Most ooids and some cement altered and stained orange (iron?). **Lower part:** Many ooids, some cement, and rims of many fossil fragments altered. Altered mud/insoluble residue along dissolution discontinuous seams.

**Comments.** Surface between the upper and lower parts is irregular, with less than 1 cm of relief; altered mud/insoluble residue along surface; grains on both sides truncated by surface. Originally there may have been erosion along the surface, as there is quite a difference between the two parts of the sample.
**Upper part:** **Lower part:**

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 334.25 m. | **Sample number:**<br>90-41 |

**Dunham classification.** Quartz grain-and-fossiliferous wackestone, and may have been a wacke/packstone originally if grains have been completely altered.

**Grain types; sizes; shapes; amounts.** Quartz grains; vf and silt-sized; may be silica-replacement; ≈ 25%. Fossil fragments, mostly echinoderms; < 1 mm; subround; ≈5%.

**Matrix type; amount.** Calcareous mud; ≈70%.

**Cement types; amounts.**

**Textures.** Relatively homogeneous with some slightly more silty interlaminae, though they may be alteration.

**Diagenetic features.** Some alteration/staining of mud. There is a slight possibility that all of this rock is an alteration product of a prior carbonate lithology, especially given the alteration of the lower part of 90-42.

**Comments.** See also sample 90-42 located 10 cm below in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 334.15 m. | **Sample number:**<br>90-42 |

**Dunham classification.** **Upper part:** Quartz grain-and-fossiliferous wackestone. **Lower Part:** May have originally been a fossiliferous-oncolitic wacke/packstone, but is very altered now.

**Grain types; sizes; shapes; amounts.** **Upper part:** Quartz grains; vf and silt-sized; may be silica-replacement; ≈ 25%. Fossil fragments, mostly echinoderms; < 1 mm; subround; ≈5-7%. **Lower Part:** Quartz grains; vf and silt-sized; may be silica-replacement; ≈ 25%. Fossil fragments, mostly echinoderms; ≤ 3 mm; ≈ 15-20%(?). Oncoids, almost completely altered; ≤ 1 cm; ≈ 15%.

**Matrix type; amount.** **Upper part:** Calcareous mud; ≈70%. **Lower Part:** Calcareous mud; ≈40-50%. In both cases, mud may have been altered.

**Cement types; amounts.**

**Textures.** **Upper part:** Homogeneous. **Lower Part:** Fines upward, with most of oncoids and fossil fragments in lower half. Also have a couple of clumps of mud/alteration product that could be original mud displaced by loading or could be dissolution/alteration caused.

**Diagenetic features.** **Upper part:** Some alteration/staining of mud. There is a possibility that all of this rock is an alteration product of a prior carbonate lithology, especially given the alteration of the lower part. **Lower Part:** Same comments as for the upper part, plus there are black, opaque flecks and spots.

**Comments.** Surface between two parts is irregular with ≤ 1 cm relief, and may be a possible dissolution seam. Similar to slightly silty interlaminae of 90-41, but about 1 cm thick. See also sample 90-41 located 10 cm above in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Red Pass Member of Carrara, ≈ 337.7 m. | **Sample number:**<br>90-43 |
| **Dunham classification.** Quartz grain-and-fossiliferous wackestone. | | |
| **Grain types; sizes; shapes; amounts.** Quartz grains; vf and silt-sized; may be silica-replacement; ≈ 25%. Fossil fragments, mostly echinoderms; < 1 mm; subround; ≈5-7%. | | |
| **Matrix type; amount.** Calcareous mud, may have been altered; ≈70%. | | |
| **Cement types; amounts.** | | |
| **Textures.** Relatively homogeneous, with some crude bedding, < 1-2 cm. There is either the remnant of a pack/grainstone bed in the bottom 1 cm or there is a clast, ≈ 1 x 3 cm of pack/grainstone. Alteration makes it difficult to determine which. | | |
| **Diagenetic features.** Some alteration/staining of mud. There is a possibility that all of this rock is an alteration product of a prior carbonate lithology, especially given the alteration of the lower part of 90-42. There are black, opaque flecks and spots as well. | | |
| **Comments.** Very like 90-41 & 90-42. | | |

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 355.8 m. | **Sample number:**<br>90-44 |
|---|---|---|

**Dunham classification.** A very recrystallized rock. Perhaps originally an ooid-echinoderm fragment grainstone.

**Grain types; sizes; shapes; amounts.** Can only make out sparry-looking irregular grains that may have been echinoderm fragments originally (since they seem to be very resistant to alteration in the Carrara); ≤ 1-2 mm; ≈ 25%.

**Matrix type; amount.** ?

**Cement types; amounts.** ?

**Textures.** Can see crude lamination in sample, as well as squat 'posts' of less altered material sticking up into almost totally altered material. Field notes record impression of digitate stromatolites, but sample doesn't look anything like stromatolites under the binocular microscope. May be dissolution/stylolite surface; or less likely, a micro-karsted surface.

**Diagenetic features.** Rest of rock (≈ 75%) is recrystallized into yellowish-orange, 'spots', ≈ silt-size.

**Comments.** See also samples 90-45 20 cm below, and 90-46 40 cm below. All three samples from same bedset.

## PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 355.6 m. | **Sample number:**<br>90-45 |

**Dunham classification.** Mudstone just from the hand sample; (≈ 7 x 7 x 3 cm) or a microbial boundstone given the field observations of the geometries of the laminae and beds.

**Grain types; sizes; shapes; amounts.** None.

**Matrix type; amount.** Mud, much of it recrystallized to vf sand- to silt-sized particles.

**Cement types; amounts.**

**Textures.** In hand sample, mm to ≤ 1 cm laminae and beds that curve gently can be recognized. Field observations record small (2-3 cm wide), high-domed geometries, with convex down-laminae between.

**Diagenetic features.** Much of mud is altered to yellowish silt-sized particles, probably of dolomite.

**Comments.** Given the field observations of the domal geometries, an interpretation of microbial boundstone is preferred, either thick-laminar and/or stromatolitic. See also samples 90-44 20 cm above, and 90-46 20 cm below. All three samples from same bedset.

PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 355.4 m. | **Sample number:**<br>90-46 |
|---|---|---|

**Dunham classification.** Thin-laminated microbial boundstone.

**Grain types; sizes; shapes; amounts.** Mostly calcareous mud/silt, although there are some of the thicker laminae that have some silt- to vf sand-sized quartz grains.

**Matrix type; amount.**

**Cement types; amounts.**

**Textures.** Sub-mm laminae, planar to gently curved, parallel to sub-parallel laminae.

**Diagenetic features.** Much of original carbonate material looks to be recrystallized to more of a yellowish (iron-stained or impurities?) dolomite. Some laminae more altered than others.

**Comments.** See also samples 90-45 20 cm above, and 90-44 40 cm above. All three samples from same bedset.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 366.7 m. | **Sample number:**<br>90-48 |

**Dunham classification.** Siltstone.

**Grain types; sizes; shapes; amounts.** Quartz silt grains.

**Matrix type; amount.** Some, but quantity unsure. Sample reacts with HCL, but whether its calcareous mud matrix or calcareous cement is unclear.

**Cement types; amounts.** Some, but quantity unsure. Sample reacts with HCL, but whether its calcareous mud matrix or calcareous cement is unclear.

**Textures.** Curved, non-parallel laminae, possibly ripple-cross laminated.

**Diagenetic features.** Stained pinkish-orange. Also has black, opaque alteration/stain spots.

**Comments.** Field notes recorded as a dolosiltite with quartz grains. Given the reaction with HCl, interpretation is altered to siltstone with calcareous matrix/cement.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 376.8 m. | **Sample number:**<br>90-49 |

**Dunham classification. Upper part:** Siliceous, silty mudstone, although it may be an almost completely altered carbonate originally. **Lower part:** Wackestone with unidentified grains, possibly peloids. Orange silty interlaminae and beds are interpreted as alteration products.

**Grain types; sizes; shapes; amounts. Upper part:** Quartz, vf silt-sized material. Irregular carbonate grains, or at least areas; ≤0.5 mm; 1-2%. **Lower part:** Unidentified grains, possibly peloids and echinoderm fragments; mostly< 0.5 mm; mostly rounded to subrounded (peloids?), with some subrounded to subangular (echinoderm fragments?); ≈ 20-30%.

**Matrix type; amount. Upper part:** ? **Lower part:** Carbonate mud(?); 65-70%.

**Cement types; amounts. Upper part:** ? **Lower part:** Clear spar in small (≤0.5 mm) void space; may be fenestrae; very irregular; ≈ 5%.

**Textures. Upper part:** Faint, irregular lamination, otherwise relatively homogeneous. **Lower part:** Broken into somewhat irregular layers and interlaminae of gray wackestone and orange silty material, both between ≈ 0.5 and 1.5 cm. Within wackestone, texture is homogeneous. Amount of grains varies from mudstone to wackestone. Within orange layers, there are irregular sub-mm laminae, some of which follow (bend within) layers from horizontal to vertical.

**Diagenetic features. Upper part:** Pinkish-orange, with black spots. **Lower part:** Orange layers have gradational contacts with the wackestone, are made up of small, silt-sized and smaller grains (possibly of dolomite), and in places have vertical or near-vertical connections to other layers. Alteration also follows some fractures across wackestone. these orange layers are interpreted to result from total (or near total) alteration of the original carbonate lithology. The original lithology may have been wackestone or may have been a different lithology, perhaps a more porous siltite. Within the orange layers are black, opaque spots.

**Comments. Upper part:** There is a slight reaction to HCl from the main part of the sample. The irregular areas of carbonate do not look like echinoderm grains, but rather have a somewhat mottled appearance, and look somewhat like cement. May be a late calcite replacement, or more likely represents remnants of original lithology. **Lower part:** The interlayering of orange material and the gray wackestone in this layer increases the possibility that the upper part represents a near total replacement of an original lithology.

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 377.4 m. | Sample number:<br>90-50 |
|---|---|---|

**Dunham classification.** Stromatolitic boundstone; within the stromatolitic layers and laminae, the composition is fenestral mudstone.

**Grain types; sizes; shapes; amounts.**

**Matrix type; amount.** Calcareous mud; ≈ 95%.

**Cement types; amounts.** Clear spar in irregular voids; < 1 mm; fenestrae(?); ≈5-7 %.

**Textures.** Roughly equant heads ≤4-5 cm across can be seen in the sample. Within the crude layers and laminae of the heads, the texture is homogeneous.

**Diagenetic features.** There is alteration and lessor dissolution along head boundaries (unrelated to caliche, though some caliche appears to have, at least partially, followed head boundaries). In addition to alteration, there appears to have also been precipitation of cement within long void spaces.

**Comments.** Sample is about 15 x 13 cm. There is a moderate amount of recent dissolution and formation of caliche along vertical cracks that has been ignored for the purpose of this description. See also sample 90-51 located 70 cm above in the same bedset.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 378.1 m. | **Sample number:**<br>90-51 |

**Dunham classification.** Dense mudstone with interlaminae of silt-sized, orange, alteration product.

**Grain types; sizes; shapes; amounts.** Mud.

**Matrix type; amount.** Mud.

**Cement types; amounts.** Mud.

**Textures.** Mudstone is layered from 1 mm to 22 cm, whereas the silt-sized, orange, alteration product is laminated from ≤ 1 to 8 mm. Laminae are often irregular and discontinuous.

**Diagenetic features.** Orange alteration product (iron carbonate or limonite or hematite?) occurs as laminae with gradational boundaries with mudstone, and as isolated 'grains'. Some of the laminae are stylolitic in appearance. As in sample 90-49, the alteration may have been of mudstone like the rest of the sample, or may have been a different lithology altogether.

**Comments.** Field relations indicate that this may be a microbial, thick-laminated boundstone, but hand sample (≈ 6 x 14 cm) does not have evidence of this interpretation. See also sample 90-50 located 70 cm below in the same bedset.

PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 398.37 m. | **Sample number:**<br>90-52 |
| **Dunham classification.** Not sure. Rock is highly altered. See 'Comments'. | | |
| **Grain types; sizes; shapes; amounts.** | | |
| **Matrix type; amount.** | | |
| **Cement types; amounts.** | | |
| **Textures.** | | |
| **Diagenetic features.** Some red and yellow alteration, as well as black opaque mineral (various iron minerals?). | | |
| **Comments.** Sample appears to have been originally laminated on a mm-scale, but has been recrystallized (≈ 0.5 mm average) and laminae has been split apart by precipitation of calcite and quartz along seams parallel to laminate, and of greater thicknesses (≈2-8 mm) than original laminae. No attempt made to decipher original lithology. | | |

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 402.7 m. | **Sample number:**<br>90-53 |

**Dunham classification.** Dolomitic mudstone.

**Grain types; sizes; shapes; amounts.** A small amount of silt-sized grains; possibly including some quartz; ≈ ≤ 5-10%.

**Matrix type; amount.**

**Cement types; amounts.** Reacts with HCL and is probably a calcitic and/or dolomitic cement.

**Textures.** Finally laminated on a mm to sub-mm scale. Lower part of sample is disrupted, perhaps from loading or perhaps from some desiccation. Upper part is not disrupted, although there is some gentle convex-down curvature to the laminae. There is a sharp contact between disrupted lower, and laminated upper parts.

**Diagenetic features.** Some black, opaque mineral 'spots'. If this is altered carbonate sediment, there are no remnant areas of carbonate as can be seen in sample 90-49. The lack of remnant areas indicates that this sample has not been extensively altered.

**Comments.** See also sample 90-54 located 10 cm above in next bed.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 398.37 m. | **Sample number:**<br>90-54 |
|---|---|---|

**Dunham classification.** A gradational change upwards from a look of alteration/mixing to a brecciated appearance. The whole sample may be possibly completely altered. JPG says the 'brecciated' part is the initiation and growth of "classic meso-clots".

**Grain types; sizes; shapes; amounts.** None discernable, aside from meso-clots.

**Matrix type; amount.** Calcareous mud?

**Cement types; amounts.** ?

**Textures.** There is a generally sharp, probably erosive, contact with laminated, dolomitic mudstone like sample 90-53. The contact is gradational in one part that appears to be affected by secondary alteration that is interpreted to have effected the main part of the sample. The main portion of the sample grades up from mixed red, dolomitic mudstone/siltite mixed with an green calcareous dolomite (slightly reactive with HCl), into a green and pinkish-orange, 'brecciated' rock. In the 'brecciated' area, the contacts between green 'pieces' and pinkish-orange 'pieces' are sharp. JPG states that in the uppermost part of the brecciated-looking part of the sample, the green areas are classic meso-clots and the rest of the brecciated area looks like mesoclots trying to get started.

**Diagenetic features.** Red and pinkish-orange areas look to be altered carbonate mud.

**Comments.** See also sample 90-53 located 10 cm below in previous bed.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 390.8 m. | **Sample number:**<br>90-55 |
|---|---|---|

**Dunham classification.** F-VF arenite/grainstone.

**Grain types; sizes; shapes; amounts.** Most grains unrecognizable, ≈ 5-7% ooids + unidentified fossil fragments.

**Matrix type; amount.** None.

**Cement types; amounts.** Clear spar, ≈ 10%.

**Textures.** Wave ripples and small hummocky cross-bedding.

**Diagenetic features.** Much of sample is probably recrystallized, although still calcite. Original grains may have been ooids and/or peloids. Some brown crystals replacing grains that are obviously diagenetic.

**Comments.** Total thickness of unit is ≈ 12 cm. Background sediments are red siliceous mudstone interpreted as paleosols. Also see samples 90-56 and 90-57 which are within 2 meters below this sample.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 389.3 m. | **Sample number:**<br>90-56 |

**Dunham classification.** Arenite or packstone/grainstone.

**Grain types; sizes; shapes; amounts.** All grains VF and unidentifiable. Cannot tell if matrix or cement. Grains probably peloids originally.

**Matrix type; amount.** See above.

**Cement types; amounts.** See above.

**Textures.** Wave ripples.

**Diagenetic features.** Possibly recrystallized, though still calcitic. Some brown crystals replacing grains that are obviously diagenetic.

**Comments.** Total thickness of unit is ≈ 5 cm. Background sediments are red siliceous mudstone interpreted as paleosols. Also see samples 90-55 (≈ 1.5 m above) and 90-57 (≈ 20 cm below).

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 389.1 m. | **Sample number:**<br>90-57 |
|---|---|---|

**Dunham classification.** Ooid-peloid-fossiliferous packstone with fenestrae.

**Grain types; sizes; shapes; amounts.** Difficult to estimate percentages of grain types. ≈ 70-85% grains total. Ooids ≤ 1 mm, smaller ooids difficult to differentiate from peloids. Peloids ≤ 0.5 mm. Fossil fragments may be trilobites. A few rounded lithoclasts of mudstone ≤ 1x3 mm.

**Matrix type; amount.** ≈ 10-20% calcitic mud.

**Cement types; amounts.** ≈ 5-10% spar cement.

**Textures.** Relatively homogeneous.

**Diagenetic features.** Very irregular fenestrae filled with spar cement, ≤1-2 mm.

**Comments.** Total thickness of unit is ≈ 8 cm. Background sediments are red siliceous mudstone interpreted as paleosols. Also see samples 90-55 (≈ 1.7 m above) and 90-56 (≈ 20 cm above).

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 406.8 m | **Sample number:**<br>90-59 |

**Dunham classification.** Lithoclast packstone.

**Grain types; sizes; shapes; amounts.** Lithoclasts of muddy, VF quartz sandstone and siltstone; most ≤ 0.5 x 0.5 cm, some ≤ o.5 x 1.5 cm; subround to round, many subequant; ≈ 75%.

**Matrix type; amount.** Mix of carbonate mud, quartz silt and VF sand, fossil fragments; ≈ 20-25%.

**Cement types; amounts.** Clear spar in irregular "voids"; ≈ 5%. Some may be cemented shelter porosity, some may be fenestrae.

**Textures.** Some crude fining upwards of clasts.

**Diagenetic features.** Some sutured contacts between lithoclasts.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Pahrump Hills Shale Member of Carrara, ≈ 408.45-409.55 m. | **Sample number:**<br>90-60 |

**Dunham classification.** Arenite/grainstone.

**Grain types; sizes; shapes; amounts.** Carbonate grains, unidentified, VF sand-sized; ≈ 80-85%. Some VF sand-sized quartz grains; ≈5-7%. Unidentified fossil fragments; ≤1-3%.

**Matrix type; amount.** None.

**Cement types; amounts.** Calcite cement; ≈10%.

**Textures.** Horizontal and low-angle-inclined planar lamination.

**Diagenetic features.** Seams with higher percentage of quartz grains and with iron-stained carbonate grains. May be dissolution seams.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 414.4-414.9 m. | **Sample number:**<br>90-61 |

**Dunham classification.** Grainstone.

**Grain types; sizes; shapes; amounts.** Ooids/peloids, probable ooids although can't see internal structure; ≤0.125 mm; round; ≈ 75%.

**Matrix type; amount.** None.

**Cement types; amounts.** Clear spar; ≈ 25%.

**Textures.** Trough cross-bedding, ≤ 4 cm in sample, ≤ 10 cm in outcrop.

**Diagenetic features.** Many grains altered with yellowish (iron?) color.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 416.2-421.4 m. | **Sample number:**<br>90-62 |
|---|---|---|

**Dunham classification.** Two lithologies (ribbon rock): Gray, limestone ooid/peloid grainstone (≈ 80%) and orange dolosiltite (≈ 20%).

**Grain types; sizes; shapes; amounts.** Ls: ooid/peloids; < 0.1 mm; round; ≈ 80%. Sts: Dolosiltite; 100%.

**Matrix type; amount.** None.

**Cement types; amounts.** Ls: dark gray calcite; ≈ 20%.

**Textures.** Ls: some burrows 1-2 mm diameter, filled with calcite cement partially altered to orange dolomite.

**Diagenetic features.** Alteration of calcite cement to dolomite. Some or all of the dolosiltite may be alteration, although it is not possible to say whether original lithology was siltite or grainstone.

**Comments.** Ls in beds 1-4 cm thick. Dolosiltite in interbeds 4-12 mm thick.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 421.4-421.7 m. | **Sample number:**<br>90-63 |

**Dunham classification.** Grainstone.

**Grain types; sizes; shapes; amounts.** Peloid/ooids; ≤0.125-0.25 mm; round; ≈ 80%. Can't see internal structure. Fossil fragments; ≤ 1-2%.

**Matrix type; amount.** None.

**Cement types; amounts.** Calcite; ≈ 205.

**Textures.** Homogeneous.

**D'agenetic features.** Most grains partially to totally altered to orange/yellow dolomite.

**Comments.** Vertical tension gashes filled with calcite.

PETROGRAPHIC DESCRIPTION FORM

<table>
<tr><td><u>Slab:</u> √<br><u>T. sctn:</u></td><td><u>Location:</u> Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 421.7-423.2 m.</td><td><u>Sample number:</u><br>90-64</td></tr>
<tr><td colspan="3"><u>Dunham classification.</u> Grainstone (overall outcrop appearance is of ribbon rock).</td></tr>
<tr><td colspan="3"><u>Grain types; sizes; shapes; amounts.</u> Peloids; ≤ 0.125-0.25 mm; round to ellipsoidal; ≈ 80%. Ellipsoidal grains appear to have been deformed.</td></tr>
<tr><td colspan="3"><u>Matrix type; amount.</u> None.</td></tr>
<tr><td colspan="3"><u>Cement types; amounts.</u> Dark gray calcite; ≈ 20%.</td></tr>
<tr><td colspan="3"><u>Textures.</u> Homogeneous with regard to physical sedimentary structures.</td></tr>
<tr><td colspan="3"><u>Diagenetic features.</u> Much alteration to orange dolomite in a relatively random fashion, with altered areas ≤ 1 cm across.</td></tr>
<tr><td colspan="3"><u>Comments.</u> With hand lens, sample looks to be a dark gray mudstone. Peloids only visible with binocular scope in areas that are slightly leached and are lighter in color. See also sample 90-68.</td></tr>
</table>

# PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 424.7 m. | **Sample number:**<br>90-65 |

**Dunham classification.** Two lithologies (ribbon rock): Gray limestone VF arenite (≈ 75%) and orange dolosiltite (≈ 25%).

**Grain types; sizes; shapes; amounts.** Ls: unidentified VF sand-sized carbonate grains; ≈ 90%(?). Dolosiltite; 100%.

**Matrix type; amount.** None.

**Cement types; amounts.** Ls: calcite; ≈ 10%>

**Textures.** Limestone and dolosiltite both crudely bedded; Ls ≈ 1.5-2.5 cm; Dol ≈ <0.5-2 cm. Small (≤ 1.5 mm diameter) burrows filled with dark spar cement.

**Diagenetic features.** Dolosiltite may be entirely diagenetic.

**Comments.** Some features in dolosiltite that look like mudcracks extending into limestone. However, the features can be found extending up into limestone as well as down into limestone. Probably diagenetic in origin.

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 425.8 m. | **Sample number:**<br>90-66 |
|---|---|---|

**Dunham classification.** Two lithologies (ribbon rock): Gray limestone grainstone (≈ 80-85%) and orange dolosiltite (≈ 15-20%).

**Grain types; sizes; shapes; amounts.** Limestone: unidentified grains; ≤ 0.125 mm; ≈ 80-85%. Also unidentified fossil fragments; 1-3%. Dolosiltite; 100%.

**Matrix type; amount.** None.

**Cement types; amounts.** Ls: calcitic; ≈ 15-20%.

**Textures.** Crudely bedded; ls ≈ 1-3 cm and dol ≤ 0.5 cm.

**Diagenetic features.** Dolosiltite laminae/beds are irregular and wispy in places. All of the dolosiltite may be diagenetic.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 426.3-426.4 m. | **Sample number:**<br>90-67 |

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|---|
| **Dunham classification.** Ooid-lithoclast-fossiliferous grainstone. |
| **Grain types; sizes; shapes; amounts.** Ooid & coated grains; ≤ 1 mm; round & subround; ≈ 40%. Lithoclasts of muddy VF arenite/sandstone and siltstone; ≤ 3 mm; ≈ 30%. Fossil fragments, unidentified; ≈ 10%. |
| **Matrix type; amount.** None. |
| **Cement types; amounts.** Dark gray calcite; ≈ 20%. |
| **Textures.** Homogeneous. |
| **Diagenetic features.** Some orange dolomite crystals. |
| **Comments.** |

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 426.4-426.8 m. | **Sample number:**<br>90-68 |
|---|---|---|

**Dunham classification.** Peloid grainstone (in outcrop the unit is a dark gray nodular ribbon rock with a low percentage of orange dolosiltite).

**Grain types; sizes; shapes; amounts.** Peloids; ≤ 1.5 mm; rounded to ellipsoidal; ≈ 80-85%.

**Matrix type; amount.** None.

**Cement types; amounts.** dark gray calcite; ≈ 15-205.

**Textures.** Generally homogeneous, with an irregular surface in the lower quarter of the sample. Below the surface, the grain size is smaller, but the grains are very difficult to distinguish.

**Diagenetic features.** Orange dolomite replacing grains and filling burrows. Is not dolosiltite in burrows.

**Comments.** With hand lens, sample looks to be a dark gray mudstone. Peloids only visible with binocular scope in areas that are slightly leached and are lighter in color. See also sample 90-64.

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 430.1-431.6 m. | **Sample number:**<br>90-69 |
|---|---|---|

**Dunham classification.** Ribbon rock with two limestone lithologies (≈85%) and dolosiltite (≈15%); limestone either a VF arenite or a peloidal grainstone.

**Grain types; sizes; shapes; amounts.** Arenite; VF sand-sized, unidentified grains with ≈ 5-7% fossil fragments. Peloid grainstone: peloids mostly ≈ 0.125 mm, with <3-5% fossil fragments.

**Matrix type; amount.** None.

**Cement types; amounts.** Arenite ≤ 10%. Grainstone ≤15-20%.

**Textures.** Arenite & dolosiltite ≈ horizontal planar laminated. Grainstone with ≤ 4 cm planar cross-beds. Dolosiltite bedded < 1 cm. Arenite bedded ≈ 2.5-5 cm. Grainstone bedded ≈ 1-5 cm. Some burrows ≤ 1-2 mm diameter.

**Diagenetic features.** Dolomite replacing some grains and in burrows. Dolosiltite looks to be less likely to be totally diagenetic.

**Comments.** Peloids difficult to see with a hand lens.

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 433.7 m. | **Sample number:**<br>90-70 |

**Dunham classification.** Ooid grainstone.

**Grain types; sizes; shapes; amounts.** Ooids with radial fabric; ≈ 0.25-0.5 mm; ≈ 80-85%.

**Matrix type; amount.** None.

**Cement types; amounts.** Calcite cement; ≈ 15-20%.

**Textures.** Homogeneous.

**Diagenetic features.** Some alteration of upper and lower parts of sample, possibly weathering.

**Comments.** See also samples 90-71 and 90-72.

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 434.7 m. | Sample number:<br>90-71 |
|---|---|---|

**Dunham classification.** Ooid grainstone.

**Grain types; sizes; shapes; amounts.** Ooids with radial fabric; ≈ 0.125-0.25 mm; ≈ 75%. Lithoclasts; 2 of arenite/siltite (≈ 0.5-1 cm), one of ooid grainstone (x 1 x 5cm); subangular to subround; ≈ 5%. Fossil fragments, unidentified; 2-4%.

**Matrix type; amount.** None.

**Cement types; amounts.** Calcitic; ≈ 20%.

**Textures.** Homogeneous.

**Diagenetic features.** Several areas with pink dolosilt that have clear calcitic cement around the altered areas. Thin seams of altered dolosilt. Also have several irregularly shaped areas with dark rinds and pink and orange and white carbonate crystals growing in void space. Likely to be a hydrothermal alteration fabric.

**Comments.** See also samples 90-70 and 90-72.

PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 434.5 m. | **Sample number:**<br>90-72 |
|---|---|---|

**Dunham classification.** Ooid-lithoclast grainstone.

**Grain types; sizes; shapes; amounts.** Ooids with radial fabric; ≤0.25 mm; ≈ 70%. Lithoclasts of arenite/siltite and ooid grainstone; up to 2 x 4 cm; angular to subround; ≈ 10-15%. Fossil fragments, including trilobite fragments; ≈3-5%.

**Matrix type; amount.** None.

**Cement types; amounts.** Calcitic; ≈ 10-15%.

**Textures.** Homogeneous as there is no pattern to the distribution of clasts.

**Diagenetic features.** Some dissolution seams/stylolites and occasional dolomite crystals.

**Comments.** See also sample 90-70 and 90-71.

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 436.5 m. | **Sample number:**<br>90-73 |

**Dunham classification.** Fossiliferous wackestone/packstone.

**Grain types; sizes; shapes; amounts.** Fossil fragments, including trilobites; platey, oriented horizontally; ≈ 20-25%. One mudclast, 2-4 mm thick, over 5 cm long (may be deposited mud bed that has been truncated).

**Matrix type; amount.** Calcareous mud; ≈ 70-75%.

**Cement types; amounts.** Calcitic, in occasional shelter porosity under fossil fragments, ≤ 55.

**Textures.** Horizontal planar bedded, ≤ 0.5 cm.

**Diagenetic features.** Some dolomite replacing mud. A few irregular dissolution seams.

**Comments.**

# PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 438.2-438.3 m. | **Sample number:**<br>90-75 |

**Dunham classification.** Three distinct layers; a shale in the bottom 2 cm, a lithoclast packstone in the middle 4 cm, and a lithoclast-fossiliferous packstone in the top 5 cm.

**Grain types; sizes; shapes; amounts.** Shale, somewhat calcareous. Lithoclast packstone: lithoclasts of shale, siliceous mudstone, sandstone/siltstone; ≤ 0.5 x 2.5 cm; ≈ 80%. Lithoclast-fossiliferous packstone: lithoclasts of same composition; ≤ 1 x 5 mm; ≈ 50-60%. Fossil fragments include trilobites and echinoderms; ≈ 15-20%.

**Matrix type; amount.** Lithoclast packstone. matrix of calcite mud, ≈15-20%. Lithoclast-fossiliferous packstone: calcitic mud; 20-30%.

**Cement types; amounts.** Shale: somewhat reactive with HCl. Packstones: ≤5% calcitic cement.

**Textures.** Shale laminated and bedded ≤ 5 mm, with burrows and mudcracks; burrows and mudcracks filled with arenite/sandstone and small lithoclasts. Lithoclast packstone has a disrupted 2-3 mm thick mud layer/drape across sample; most clasts horizontal, with some inclined. Lithoclast-fossiliferous packstone: homogeneous.

**Diagenetic features.** Packstones are naturally stained pink and yellowish-brown (iron-staining?).

**Comments.** Contacts between three units are sharp.

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 444.15-444.65 m. | Sample number: 90-77 |
|---|---|---|
| Dunham classification. Dolosiltite. | | |
| Grain types; sizes; shapes; amounts. Dolosiltite; 100%. | | |
| Matrix type; amount. N/A | | |
| Cement types; amounts. N/A | | |
| Textures. Laminations, some disrupted; ≤ 2 mm thick. Fenestrae, irregular and laminoid; filled with clear calcitic cement; ≤ 2 mm. | | |
| Diagenetic features. orange dolosiltite is probably a replacement mineralogy, not a primary dolomite. Some black spots that may be pyritic. | | |
| Comments. | | |

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 447.25-447.75 m. | **Sample number:**<br>90-78 |
| **Dunham classification.** Lithoclast-fossiliferous packstone/grainstone | | |
| **Grain types; sizes; shapes; amounts.** Lithoclasts of calcitic mudstone, siltstone/siltite; ≤ 2 x 10 mm; platey; ≈ 40-50%. Fossil fragments, including echinoderm and trilobite fragments; ≈ 25-30%. | | |
| **Matrix type; amount.** Calcitic mud; ≈ 5-10%. | | |
| **Cement types; amounts.** Calcitic cement; ≈ 15-20%. | | |
| **Textures.** Most lithoclasts oriented horizontally. | | |
| **Diagenetic features.** Most lithoclasts dolomitized, stained yellow to pink. | | |
| **Comments.** | | |

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 451.5 m. | Sample number:<br>90-79 |
|---|---|---|

**Dunham classification.** Peloid-fossil-lithoclast grainstone.

**Grain types; sizes; shapes; amounts.** Peloids; ≤ 0,125-0.25 mm; ≈ 40-50%. Fossil fragments, including echinoderms and trilobites; ≈ 15-20%. Lithoclasts of mudstone; ≤ 1 x 8 mm; platy; ≈10-15%.

**Matrix type; amount.** Perhaps some calcitic mud, though it may be cement; ≤ 5%.

**Cement types; amounts.** Calcitic cement; ≈ 15-20%.

**Textures.** Most lithoclasts oriented approximately horizontally.

**Diagenetic features.** Many lithoclasts dolomitized; some individual dolomite rhombs; subvertical dissolution seam with cement and dark minerals.

**Comments.** See also samples 90-80 and 90-81

PETROGRAPHIC DESCRIPTION FORM

| Slab:<br>T. sctn:<br>Unslabbed:<br>√ | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 451.7 m. | Sample number:<br>90-80 |
|---|---|---|

**Dunham classification.** Dolarenite/dolosiltite interlaminated with dolomitic mudstone.

**Grain types; sizes; shapes; amounts.** Dolarenite/dolosiltite composed of VF sand-sized and silt-sized grains, unidentified.

**Matrix type; amount.** Carbonate mud.

**Cement types; amounts.** Calcitic.

**Textures.** Wavy horizontal lamination and small (≤ 5 mm) ripples.

**Diagenetic features.**

**Comments.** See also samples 90-79 and 90-81.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 451 7 m. | **Sample number:**<br>90-81 |

| |
|---|
| **Dunham classification.** Peloid grainstone (85-90%) with interlaminations of dolosiltite (10-15%) (ribbon rock). |
| **Grain types; sizes; shapes; amounts.** Grainstone: Peloids; ≤ 0.125-1 mm, quite variable between beds; beds and laminae moderately to well sorted; ≈ 75-80%. Fossil fragments, unidentified; ≈ 5%. Dolosiltite: 100%. |
| **Matrix type; amount.** None. |
| **Cement types; amounts.** Grainstone: calcitic; ≈ 15-20%. |
| **Textures.** Grainstone: essentially none except for one 12 mm bed of ripples. Dolosiltite: in wispy, irregular interlaminae≤ 5 mm thick. |
| **Diagenetic features.** All dolosiltite may be diagenetic replacement, though can't tell original lithology. |
| **Comments.** See also samples 90-79 and 90-80. |

## PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 453.7-454.0 m. | Sample number: 90-82 |
|---|---|---|

**Dunham classification.** Orange dolosiltite.

**Grain types; sizes; shapes; amounts.** Dolosilt.

**Matrix type; amount.** N/A.

**Cement types; amounts.** N/A.

**Textures.** Homogeneous, except for irregular fenestrae that are mostly filled with dolomitic replacement crystals. Some partially filled with calcitic white-clear cement.

**Diagenetic features.** Red and black replacement minerals in small spots.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 455.3 m. | **Sample number:**<br>90-83 |
| **Dunham classification.** Limestone arenite (limestone pa.' of ribbon rock). | | |
| **Grain types; sizes; shapes; amounts.** unidentified VF sand-sized grains; ≈80%. | | |
| **Matrix type; amount.** | | |
| **Cement types; amounts.** Calcitic cement; ≈ 20%. | | |
| **Textures.** Homogeneous. | | |
| **Diagenetic features.** Scattered orange dolosilt crystals. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 456.7 m. | **Sample number:**<br>90-84 |

**Dunham classification.** Ooid/peloid grainstone.

**Grain types; sizes; shapes; amounts.** Ooids/peloids (can't see internal structure due to dolomite replacement, probably ooids originally); ≈ 0.25-0.5 mm; ≈ 70-75%. Fossil fragments, unidentified; ≤ 5%.

**Matrix type; amount.**

**Cement types; amounts.** Calcitic; ≈ 20-25%.

**Textures.** Homogeneous.

**Diagenetic features.** Almost all ooids/peloids replaced by orange dolosilt.

**Comments.**

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 459.3 m. | **Sample number:** 90-85 |
|---|---|---|

**Dunham classification.** Two lithologies (ribbon rock): dark gray carbonate mudstone and orange dolosiltite.

**Grain types; sizes; shapes; amounts.** Mudstone; no grains apparent. Dolosiltite; only VF dolomite rhombs.

**Matrix type; amount.**

**Cement types; amounts.**

**Textures.** Mudstone in crude beds 1-3 cm thick. Dolosiltite in crude, irregular interlaminations ≤ 7 mm.

**Diagenetic features.** Dolosiltite is an alteration/replacement mineralogy, but can't tell original lithology.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 471.7 m. | **Sample number:**<br>90-86 |

**Dunham classification.** Ooid-fossiliferous grainstone.

**Grain types; sizes; shapes; amounts.** Ooids, at least some with radial fabric; ≤ 0.25 mm; ≈ 55-65%. Fossil fragments, including trilobite and possible echinoderm; ≈ 15-20%.

**Matrix type; amount.**

**Cement types; amounts.** Calcitic cement; ≈ 20%.

**Textures.** Homogeneous.

**Diagenetic features.** Some alteration to dolomite.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 477.6 m. | **Sample number:**<br>90-87 |

**Dunham classification.** Ooid grainstone.

**Grain types; sizes; shapes; amounts.** Ooids, with radial fabric; ≤ 0.125 mm, in lower bed ooids are ≤ 0.25 mm; ≈ 75-80%. Fossil fragments, mostly trilobites; ≤ 5%, mostly in lower bed.

**Matrix type; amount.**

**Cement types; amounts.** Calcitic; ≈ 20%.

**Textures.** Homogeneous, except that most trilobite fragments in lower bed are oriented horizontally.

**Diagenetic features.** Some orange dolosiltite replacement.

**Comments.**

# PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 480.7 m. | **Sample number:**<br>90-88 |

**Dunham classification.** Dolosiltite.

**Grain types; sizes; shapes; amounts.** Mostly dolosiltite, though there are some VF-F sand-sized grains as well.

**Matrix type; amount.**

**Cement types; amounts.**

**Textures.** Laminated ≤ 1-5 mm, with some laminae disrupted and broken into angular lithoclasts. Some fenestrae.

**Diagenetic features.** Fenestrae are partially to completely filled by yellow dolomite crystals.

**Comments.** See also sample 90-90.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 481.1 m. | **Sample number:**<br>90-90 |
| **Dunham classification.** Dolosiltite. | | |
| **Grain types; sizes; shapes; amounts.** Dolosilt; 100%. | | |
| **Matrix type; amount.** | | |
| **Cement types; amounts.** | | |
| **Textures.** Bedded/laminated ≤ 5 mm, with some bedding disrupted. Some fenestrae. | | |
| **Diagenetic features.** Fenestrae filled with red dolomite. | | |
| **Comments.** See also sample 90-88. | | |

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Jangle Limestone Member of Carrara, ≈ 491.7 m. | **Sample number:**<br>90-91 |

**Dunham classification.** Quartz VF sandstone.

**Grain types; sizes; shapes; amounts.** VF quartz grains; ≈65-70%; trilobite fragments; ≤ 5%.

**Matrix type; amount.** None.

**Cement types; amounts.** Mostly silica cement, with some calcitic cement; ≈ 25%.

**Textures.** Horizontal planar lamination.

**Diagenetic features.** ≈ 10-15% of grains are stained yellow, may be dolomitic.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 503.5 m. | Sample number:<br>90-92 |
|---|---|---|
| Dunham classification. Fossiliferous wackestone. | | |
| Grain types; sizes; shapes; amounts. Fossil fragments, including trilobites; ≈ 20-25%. | | |
| Matrix type; amount. Calcitic mud; ≈75-80%. | | |
| Cement types; amounts. | | |
| Textures. Crude bedding ≤ 1-3 cm thick with irregular interlaminae a few mm thick of dolosilt. | | |
| Diagenetic features. | | |
| Comments. | | |

PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 512.1 m. | Sample number:<br>90-93 |
|---|---|---|

**Dunham classification.** Two lithologies (well-layered ribbon rock): calcisiltite (≈50-55%) and dolosiltite (≈45-50%).

**Grain types; sizes; shapes; amounts.** Silt-sized gray calcite and orange dolomite; ≥ 97%. Trilobite fragments in one lamina ≤ 1 mm thick; ≤ 1-3%.

**Matrix type; amount.**

**Cement types; amounts.**

**Textures.** Laminated and bedded ≤ 1 cm.

**Diagenetic features.** Much of dolosiltite may be alteration of calcisiltite. Often gradational and wispy contacts between two lithologies when looked at under the binocular scope.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 522.6 m. | **Sample number:**<br>90-94 |

**Dunham classification.** Lithoclast-fossil grainstone.

**Grain types; sizes; shapes; amounts.** Lithoclasts of carbonate mudstone; ≤0.7 x 3.5 cm; angular to subround; ≈40%. Fossil fragments, including trilobites; ≈ 30-35%.

**Matrix type; amount.**

**Cement types; amounts.** Calcitic cement; ≈30-35%.

**Textures.** Two beds, the lower is more of a fossil-lithoclast grainstone. Clasts aligned generally horizontal.

**Diagenetic features.** Cement in lower bed is lightered colored than cement in upper bed and appears to be a diagenetic effect. Many of lithoclasts are altered to red and yellow dolomitic (?) mineral.

**Comments.**
See also sample 90-97.

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 519.1-519.25 m. | **Sample number:**<br>90-96 |

**Dunham classification.** Lithoclast grainstone.

**Grain types; sizes; shapes; amounts.** Lithoclasts of carbonate mudstone; ≤1 x 3 cm; angular to subround, blocky; ≈ 80-855. Trilobite fragments; ≤1-3%.

**Matrix type; amount.**

**Cement types; amounts.** Clear calcite spar.

**Textures.** Shelter-porosity filled with calcite cement.

**Diagenetic features.** Many lithoclasts with mildly sutured boundaries in contact with other lithoclasts. Often concentrations of yellow-orange dolomite around edges of lithoclasts. Also have diagonal fracture filled with both white calcite and yellow, orange red dolomite and other minerals.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 521.7 m. | **Sample number:**<br>90-97 |
|---|---|---|

**Dunham classification.** Mostly an intimate intermixing of dolosiltite (≈60-70%) and calcisiltite (≈30-40%) with occasional carbonate mudstone interclasts (part of a ribbon rock unit).

**Grain types; sizes; shapes; amounts.** Almost entirely carbonate siltite. Carbonate mudstone lithoclasts; ≤ 1 x 1 mm; ≤ 1-3%.

**Matrix type; amount.**

**Cement types; amounts.**

**Textures.** There is a wispy, submillimeter intermixing of dolosilt and calcisilt that does not appear depositional. Also there is often a concentration of dolosilt at the upper and lower ends of lithoclasts. Most if not all dolosilt is probably an alteration/replacement mineralogy, possibly related to dissolution.

**Diagenetic features.** See "textures".

**Comments.** The basal 5-10 mm are submillimeter-laminated, but not wispy, calcisiltite and dolosiltite scoured into by a lithoclast-trilobite fragment packstone/grainstone that may have been the precursor to the main part of the sample. See also sample 90-94.

# PETROGRAPHIC DESCRIPTION FORM

| Slab: √<br>T. sctn: | Location: Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 542.5 m. | Sample number:<br>90-98 |
|---|---|---|

**Dunham classification.** Dolosiltite.

**Grain types; sizes; shapes; amounts.** Dolosilt; ≥90%. Small, 1-3 mm, elongate patches of calcisilt; ≤ 5-10%. Trilobite fragments; ≤ 2-5%.

**Matrix type; amount.**

**Cement types; amounts.**

**Textures.** Trilobite fragments and elongate areas of calcisilt are all aligned horizontally.

**Diagenetic features.** It is likely that the dolosilt is a replacement mineral.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 549.9-550.0 m. | **Sample number:**<br>90-99 |

**Dunham classification.** Lower 2/3 of sample: calcareous dolomite mudstone with ≤ 3 mm interlaminae of fossiliferous wackestone/packstone. Upper 1/3 of sample: lithoclast-fossiliferous packstone.

**Grain types; sizes; shapes; amounts.** Mudstone: fossil fragments, including trilobites; < 1 mm; ≤ 5%. Packstone: Lithoclasts of carbonate mudstone; most ≤ 5 x 10 mm, one clast may be 7 x 30 mm and bent; most subround; ≈ 50%. Fossil fragments, including trilobites; ≈ 15%.

**Matrix type; amount.** Packstone: carbonate mud; ≈ 35%.

**Cement types; amounts.**

**Textures.** Mudstone: bedded ≈1-2.5 cm, with interlaminae of fossiliferous wackestone/packstone ≤ 3 mm; wackestone/packstone + mudstone is essentially a fining-upward bed; burrows in mudstone filled with wackestone/packstone and/or packstone. Packstone: Homogeneous in sample.

**Diagenetic features.**

**Comments.** Sample badly effected by Holocene caliche and jointing.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 556.9-557.2 m. | **Sample number:**<br>90-101 |
| **Dunham classification.** Lithoclast-ooid/peloid-fossiliferous packstone/grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Lithoclasts, probably originally of carbonate mudstone, now mostly altered; ≤ 2 mm; rounded to subrounded. Ooid/peloids, altered so internal structure is not clear; ≤ 1 mm. Lithoclasts + ooids/peloids are ≈ 60-70%. Fossil fragments; ≈ 10-15%. | | |
| **Matrix type; amount.** See cement. | | |
| **Cement types; amounts.** Cement/matrix slightly reactive to HCl, probably dolomitic; ≈ 25-30%. | | |
| **Textures.** Relatively homogeneous. | | |
| **Diagenetic features.** Much of matrix/cement is altered, and many lithoclasts are now composites of dolomite rhombs. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:** √<br>**T. sctn:** | **Location:** Section 90-1. Emigrant Pass, southern Nopah Range. In Desert Range Limestone Member of Carrara, ≈ 559.2-559.8 m. | **Sample number:**<br>90-102 |
| **Dunham classification.** Calcareous mudstone.. | | |
| **Grain types; sizes; shapes; amounts.** None. | | |
| **Matrix type; amount.** 100% mud. | | |
| **Cement types; amounts.** | | |
| **Textures.** Homogeneous. | | |
| **Diagenetic features.** Some dolomitization at top and bottom of sample altering original lithology to dolosiltite. | | |
| **Comments.** | | |

# APPENDIX 2: PETROGRAPHIC DESCRIPTION FORMS:
# PART B. THIN SECTIONS

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-2, Emigrant Pass area, southern Nopah Range; ≈ 348.0 m. | **Sample number:** 90-128 |
| **Dunham classification.** Peloia(?)-echinoderm grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Peloids, appear to be sheared or stretched at an oblique-to-horizontal angle; ≈ 40-45%. Echinoderm fragments, often with a micrite rim; ≈ 15-20%. Reddish mudstone clasts: ≤ 1 x 3 mm; ≤2-4%. | | |
| **Matrix type; amount.** None. | | |
| **Cement types; amounts.** Spar; ≈ 25-30%. | | |
| **Textures.** Peloids are sheared or stretched. | | |
| **Diagenetic features.** Reddish-brown patches associated with dolomite rhombs; ≈ 20%. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-4, Red Wing Mine, middle Resting Spring Range; ≈ 215.2 m. | **Sample number:**<br>90-139 |
| **Dunham classification.** Echinoderm grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Echinoderm fragments; ≈≤ 0.5-1.0 mm; ≈ 75-80%. Quartz silt; ≤ 1-2%. | | |
| **Matrix type; amount.** None. | | |
| **Cement types; amounts.** Coarsely equant, probably recrystallized; ≈ 20-25%. | | |
| **Textures.** Homogeneous. | | |
| **Diagenetic features.** Echinoderm fragments have crystals impinging on their borders; reddish-brown to opaque mineral in patches, along seams, and between grain-to-grain contacts. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-4, Montgomery Hills; ≈ 394.2 m. | **Sample number:**<br>90-144 |
| **Dunham classification.** Microbially laminated dolosiltite. | | |
| **Grain types; sizes; shapes; amounts.** Carbonate silt, unidentified; ≈ 30-35%. Quartz silt; ≈ 20-25%. | | |
| **Matrix type; amount.** Carbonate mud; ≈ 45-50%. | | |
| **Cement types; amounts.** ? | | |
| **Textures.** Horizontal lamination. Also there is a secondary alignment oblique to horizontal that is noticeable in the fabric of the mud and in the alignment of the chlorite/muscovite crystals. | | |
| **Diagenetic features.** Chlorite/muscovite crystals; ≈ 5-7%. Possibly some quartz is authigenic. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-4, Red Wing Mine, central Resting Spring Range; ≈ 427.7 m. | **Sample number:**<br>90-145 |

**Dunham classification.** Calcareous fenestral mudstone.

**Grain types; sizes; shapes; amounts.** Quartz silt; ≤1-2%.

**Matrix type; amount.** Mud; 80-85%.

**Cement types; amounts.** Blocky cement in fenestrae; ≈ 15-20%

**Textures.** Fenestrae, filled with blocky cement.

**Diagenetic features.** Muscovite, probably diagenetic; ≤ 1-2%. Reddish-brown alteration mineral, in patches and along seams; ≤ 1-3%.

**Comments.** Sample 90-146 has isopachous, equant, and blocky cement in fenestrae, and is only 2.6 m away.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-4, Red Wing Mine, central Resting Spring Range; ≈ 430.3 m. | **Sample number:**<br>90-146 |

**Dunham classification.** Calcareous fenestral mudstone.

**Grain types; sizes; shapes; amounts.** Quartz silt; ≈ 3-5%.

**Matrix type; amount.** Calcareous mud; ≈ 65-70%.

**Cement types; amounts.** In fenestrae, isopachous cement followed by equant cement followed by blocky cement; ≈ 25-30%.

**Textures.** Fenestrae.

**Diagenetic features.** Muscovite; <1-2%. Also reddish-brown alteration mineral in patches and along seams.

**Comments.** Sample 90-145 has only blocky cement in fenestrae, and is only 2.6 m away.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-5, Eagle Mountain; ≈ 360.05 m. | **Sample number:**<br>90-159 |

**Dunham classification.** Peloid-fossil-lithoclast grainstone (parts of two beds).

**Grain types; sizes; shapes; amounts.** Peloids; ≤ 0.25-1.0 mm; ≈ 25-30%. Fossil fragments, mostly echinoderm; ≈ 20-25%. Lithoclasts, carbonate mudstone and siltite; ≤ 1 x 2 mm; subround to round; ≈ 20%.

**Matrix type; amount.** None.

**Cement types; amounts.** Isopachous and equant; ≈ 25-30%.

**Textures.** Each bed appears to be homogeneous.

**Diagenetic features.** Dissolution. Micritization.

**Comments.** Thin section intersects the contact between two grainstone beds; the lower is coarser-grained and has more cement, the upper is finer-grained with less cement. The contact between the two beds has undergone dissolution. Percentages for components is an average between the two beds.

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** From section 90-5, Eagle Mountain, ≈ 28.2 m. | **Sample number:**<br>91-1A |
|---|---|---|
| **Dunham classification.** Mudstone with quartz grains (nodular ribbon rock). | | |
| **Grain types; sizes; shapes; amounts.** Quartz grains; VF sand to silt; ≈ 20-25% (average of entire slide). | | |
| **Matrix type; amount.** Carbonate mud; ≈ 70-75%. | | |
| **Cement types; amounts.** Blocky cement in irregular "voids"; ≤ 2-4 mm across; ≈3-5%. | | |
| **Textures.** Homogeneous except for irregular, subhorizontal dissolution seams ≤ 5 mm thick with increased concentrations of quartz grains. Seams are not well developed. | | |
| **Diagenetic features.** Dissolution seams. Some reddish-brown replacement material. | | |
| **Comments.** See also sample 91-1B. | | |

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From section 90-5, Eagle Mountain, ≈ 28.2 m. | **Sample number:**<br>91-1B |

**Dunham classification.** Mudstone with quartz grains (nodular ribbon rock).

**Grain types; sizes; shapes; amounts.** Echinoderm fragments; ≤ 3-5%. Quartz grains; VF sand and silt; ≈ 10%.

**Matrix type; amount.** Carbonate mud; ≈ 80-85%.

**Cement types; amounts.** Equant and blocky cement in burrows and irregular "voids" that may be burrows; ≤ 1-2 mm; ≈3-5%.

**Textures.** Also have burrows ≤ 2-4 mm that are filled with coarser (≤ silt sized) carbonate material that may be recrystallized mud or fine carbonate silt; ≈ 5% of slide.

**Diagenetic features.** Sparse reddish-brown material in fractures and seams, as well as scattered in mud.

**Comments.** See also sample 91-1A.

# PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-6, Montgomery Hills; ≈ 325.8 m. | **Sample number:**<br>91-5 |
| **Dunham classification.** Fossil-lithoclast grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Fossil fragments, mostly echinoderm fragments with syntaxial overgrowths; ≤ 2 x 2 mm; ≈ 50-60% including overgrowths. Carbonate mudstone and siltite; ≤ 2 x 2 mm; ≈ 20-25%. | | |
| **Matrix type; amount.** None. | | |
| **Cement types; amounts.** Equant, blocky, and isopachous; syntaxial not separated out from fossil fragments; ≈ 15-20%. | | |
| **Textures.** Homogeneous. | | |
| **Diagenetic features.** Reddish-brown patches and dolomitic rhombs and replacement crystals; ≈ 10-15%. Patches and dolomite seen replacing echinoderm fragments, lithoclasts, and cement. Some clusters of crystals with a little reddish-brown material. | | |
| **Comments.** | | |

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-5a, upper Jangle Limestone Member, Eagle Mountain; ≈ 30.6 m. | **Sample number:**<br>91-6 |

**Dunham classification.** In hand sample is classified as a"fenestral mudstone" but in thin section is a peloid packstone/grainstone with some fenestrae.

**Grain types; sizes; shapes; amounts.** Peloids; ≤ 0.25-0.5 mm; ≈ 50-60%. Quartz silt; ≈ 10%. Trilobite fragments; ≈ 3-5%.

**Matrix type; amount.** Micrite, may be recrystallized cement; ≈ 15%.

**Cement types; amounts.** Cement, including blocky cement in fenestrae; ≈ 15%.

**Textures.** Fenestrae; filled mostly with blocky cement; ≈5-7%.

**Diagenetic features.** Muscovite; ≤1-3%. Reddish-brown mineral and reddish brown dolomite rhomb; ≈ 3-5%.

**Comments.** Lowermost intertidal to uppermost subtidal at northernmost end of fenestral mudstone interval in the Eagle Mountain cross section.

## PETROGRAPHIC DESCRIPTION FORM

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| **Slab:**<br>**T. sctn:** √ | **Location:** From section 90-5D, upper Jangle Limestone Member, Eagle Mountain, ≈ 19.2 m. | **Sample number:**<br>91-7 |

**Dunham classification.** Thrombolitic boundstone.

**Grain types; sizes; shapes; amounts.** Peloids, some within fossil fragments; ≤ 0.2 mm, with most ≤ 0.1 mm; ≈ 10-15%. Quartz grains; mostly silt, but some VF sand; ≈ 5-7%. Trilobite and other fossil fragments; ≈ 5-7%.

**Matrix type; amount.** Carbonate mud; 50-60%.

**Cement types; amounts.** Mostly equant and blocky, but some isopachous within trilobite spines; ≈ 20-25%.

**Textures.** Very irregular with void-space filled with cement and/or peloid-fossil wackestone to packstone/grainstone.

**Diagenetic features.** Microstylolite with relief ≤ 3 mm and thickness ≤ 0.2 mm; concentration of quartz grains and some reddish-brown iron-carbonate.

**Comments.** Slide varies from cemented void-space to mudstone to peloid packstone/grainstone. Some parts look somewhat micro-clotted with cement between pockets of micrite but no distinctive microfabric is recognized to allow an interpretation of *Renalcis* vs. *Epiphyton* vs. *Girvanella*.

## PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-5e upper Jangle Limestone Member, Eagle Mountain; ≈ 36.0 m. | **Sample number:**<br>91-8 |
| **Dunham classification.** Peloid-lithoclast packstone/grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Peloids; ≤ 0.25-0.5 mm; ≈ 45-50%. Lithoclasts of carbonate mud with quartz silt; 2 x 4 mm; ≈ 25-30%. | | |
| **Matrix type; amount.** Carbonate mud with quartz silt in discontinuous intervals; ≈ 10%. | | |
| **Cement types; amounts.** Equant and blocky; ≈ 20%. | | |
| **Textures.** Some bedding and lamination, approximately horizontal. | | |
| **Diagenetic features.** Some reddish-brown replacement mineral. Also muscovite/chlorite in scattered small crystals. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 90-5f, upper Jangle Limestone Member, Eagle Mountain; ≈ 43.4 m. | **Sample number:**<br>91·10 |
| **Dunham classification.** Lithoclast-fossil-ooid packstone. | | |
| **Grain types; sizes; shapes; amounts.** Lithoclasts of carbonate mudstone with quartz VF sand and silt; ≤ 2 x 4 mm; round and subround; ≈ 50-60%. Fossil fragments including trilobites; ≈ 10%. Ooids and coated grains; ≤ 1 mm; X 7-10%. | | |
| **Matrix type; amount.** Carbonate mud with some quartz VF sand and silt; ≈ 20%. | | |
| **Cement types; amounts.** Equant, isopachous, and blocky cement, between grains, within fossils, and filling shelter porosity; ≈ 5-7%. | | |
| **Textures.** Relatively homogeneous. | | |
| **Diagenetic features.** Alteration to dolomite and reddish-brown mineral. | | |
| **Comments.** | | |

## PETROGRAPHIC DESCRIPTION FORM

| Slab: <br> T. sctn: √ | Location: From Section 90-5f, upper Jangle Limestone Member, Eagle Mountain; ≈ 43.5-46.3 m. | Sample number: <br> 91-12 |
|---|---|---|

**Dunham classification.** Lithoclast grainstone.

**Grain types; sizes; shapes; amounts.** Lithoclasts of carbonate mudstone with quartz VF sand and silt, trilobite fragments, ooids; ≈ 80-90%. Some trilobite fragments, ooids, quartz VF sand and silt grains; total ≤ 5%.

**Matrix type; amount.** Possibly some carbonate mudstone though may be more lithoclasts.

**Cement types; amounts.** Mostly blocky with some earlier equant; ≈ 5-7.

**Textures.** Relatively homogeneous.

**Diagenetic features.** Some dolomite/reddish-brown patches replacing other components.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-1, Baxter Mine, northern Resting Spring Range; ≈ 230.3 m. | **Sample number:** 91-17 |
| **Dunham classification.** Fenestral mudstone. | | |
| **Grain types; sizes; shapes; amounts.** Quartz silt; ≤ 1-2%. | | |
| **Matrix type; amount.** Calcareous mud; ≈ 80-85%. | | |
| **Cement types; amounts.** Equant-to-isopachous followed by blocky in fenestrae; ≈ 10-15%. | | |
| **Textures.** Fenestrae. | | |
| **Diagenetic features.** Stylolites with reddish-brown alteration/replacement mineral along them; some reddish-brown patches. | | |
| **Comments.** Some of the mud has a clotted texture (structure grumeleuse) and may also include some peloid packstone/grainstone. | | |

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** From section 91-1, Baxter Mine, northern Resting Spring Range, ≈ 231.3 m. | **Sample number:**<br>91-19R |
|---|---|---|

**Dunham classification.** Originally a peloid packstone/grainstone (nodular ribbon rock)? Now very much recrystallized.

**Grain types; sizes; shapes; amounts.** Peloids?; ≤ 0.1-0.2 mm; ≈ 40-60%?

**Matrix type; amount.** ?

**Cement types; amounts.** Mostly small crystals between "peloids", but some large blocky crystals; ≈ 40-06%.

**Textures.** Some clusters of reddish-brown to clear dolomite rhombs; ≈5-10%.

**Diagenetic features.** Dolomite (see above). Some opaque mineral; ≈ 1-2%.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| Slab:<br>T. sctn: √ | Location: From section 90-5F, in the thrombolite complex at the top of the section; upper Jangle Limestone Member, Eagle Mountain. | Sample number:<br>91-21A |
|---|---|---|

**Dunham classification.** Thrombolite boundstone.

**Grain types; sizes; shapes; amounts.** Quartz silt; ≈ 5%.

**Matrix type; amount.** Carbonate mud, with homogeneous and clotted texture; ≈60-65%.

**Cement types; amounts.** Equant and blocky (≤ 4 mm), with some bladed; ≈ 30-35%.

**Textures.** Irregular distribution of cement-filled voids and mud.

**Diagenetic features.** Reddish-brown iron-carbonate rhombs, mostly in lower part of slide; ≈ 5-7%.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From section 90-5F, in the thrombolite complex at the top of the section; upper Jangle Limestone Member, Eagle Mountain. | **Sample number:**<br>91-22 |

**Dunham classification.** Thrombolitic boundstone.

**Grain types; sizes; shapes; amounts.** Quartz silt; ≈ 5-7%.

**Matrix type; amount.** Carbonate mud, some clotted; ≈ 80%.

**Cement types; amounts.** Equant, blocky, and some bladed; ≈ 10-15%. There may be more fine crystals of cement that can't be readily distinguished from the mud.

**Textures.** Some variation in percentage of quartz grains and cement across slide.

**Diagenetic features.** Micro-dissolution seams. Some reddish-brown iron-carbonate.

**Comments.** One void-space ≈ 1 x 2 mm looks to be ≈ half-full of carbonate VF silt with bladed (almost isopachous) and blocky cement in the upper half.

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 5.75-7.55 m. | **Sample number:**<br>91-23 |
| **Dunham classification.** Originally a peloid/ooid packstone/grainstone? | | |
| **Grain types; sizes; shapes; amounts.** ? | | |
| **Matrix type; amount.** ? | | |
| **Cement types; amounts.** ? | | |
| **Textures.** Subhorizontal bands of varying amounts of reddish-brown recrystallization. | | |
| **Diagenetic features.** The entire sample appears to be recrystallized leaving only "ghosts" of the original grains. Some recrystallization into small, micritic clear crystals, but other clear crystals are larger. Also a ≈ 35-50% reddish-brown iron-carbonate, possibly dolomite. | | |
| **Comments.** | | |

PETROGRAPHIC DESCRIPTION FORM

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|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 11.75-12.55 m. | **Sample number:**<br>91-24 |

**Dunham classification.** Oncoid/lithoclast grainstone.

**Grain types; sizes; shapes; amounts.** Either oncoids without lamination or are very well-rounded lithoclasts; ≤ 2 mm to 6 x 8 mm; ≈ 75%.

**Matrix type; amount.** None.

**Cement types; amounts.** Equant, isopachous, and blocky cement; ≈ 25%.

**Textures.** Homogeneous.

**Diagenetic features.** Some reddish-brown rhombs of iron-carbonate, possibly dolomite.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2, upper Jangle Limestone Member, Dublin Hills; ≈ 13.55 m. | **Sample number:**<br>91-25 |

**Dunham classification.** Fossil-litnoclast grainstone.

**Grain types; sizes; shapes; amounts.** Unidentified fossil fragments; ≈ ≤ 0.5 mm; ≈ 50-55%. Lithoclasts of siltite/siltstone with a high proportion of quartz silt grains; ≈ ≤ 5 x 10 mm; ≈ 20%. Scattered quartz silt and carbonate mud in lower part of slide; ≈ 5-7%.

**Matrix type; amount.** See above.

**Cement types; amounts.** Blocky cement; ≈ 25%.

**Textures.** Some subhorizontal alignment of fossils and lithoclasts.

**Diagenetic features.** Much recrystallization of cement and fossil fragments to micrite.

**Comments.**

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 22.4 m. | **Sample number:**<br>91-28 |
|---|---|---|

**Dunham classification.** Ooid & quartz silt "packstone".

**Grain types; sizes; shapes; amounts.** Quartz silt forms ≈ 25% of the slide as a single bed and is ≈ 45% of the ooid-silt packstone. Ooids, with radial & concentric fabric; ≤ 0.5 mm; ≈ 45%.

**Matrix type; amount.** Carbonate mud or cement; ≈ 5-10%.

**Cement types; amounts.** See above.

**Textures.** Horizontal bedding and lamination with variation in the ratio of ooids to silt.

**Diagenetic features.** Most of ooids are at least partially micritized.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 36.0 m. | **Sample number:**<br>91-30 |
|---|---|---|

**Dunham classification.** Dolosiltite.

**Grain types; sizes; shapes; amounts.** Unidentified carbonate silt; ≈ 30-35%. Quartz silt; ≈ 25-30%.

**Matrix type; amount.** Carbonate mud; ≈ 35-40%.

**Cement types; amounts.** Blocky; in fenestrae.

**Textures.** /bedded with amounts of carbonate silt and quartz silt varying.

**Diagenetic features.** Chlorite/muscovite crystals; ≤ 1-3%. Some dolomite rhombs and reddish-brown mineral.

**Comments.**

PETROGRAPHIC DESCRIPTION FORM

| Slab:<br>T. sctn: √ | Location: From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 34.75 m. | Sample number:<br>91-31A |
|---|---|---|

**Dunham classification.** Oolitic-oncolitic-fossiliferous grainstone.

**Grain types; sizes; shapes; amounts.** Ooids, with radial and concentric fabric; ≤ 0.75 mm; ≈ 35-40%. Oncoids, with trilobite fragments, quartz VF sand and silt grains, and ooids incorporated; 2 mm diameter to 5 x 10 mm; spherical to discoidal and well laminated; ≈ 20-25%. Fossil fragments, including trilobites; ≈ 15-20%.

**Matrix type; amount.** None.

**Cement types; amounts.** Equant, isopachous, and blocky; ≈20-25%.

**Textures.** Homogeneous.

**Diagenetic features.** Muscovite/chlorite within oncoids. Much of thin section with some recrystallization/micritization. Reddish-brown iron-carbonate replacement of grains and cement.

**Comments.** See also sample 91-31B.

PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 34.75 m. | **Sample number:**<br>91-31B |
| **Dunham classification.** Oolitic-oncolitic-fossiliferous grainstone. | | |
| **Grain types; sizes; shapes; amounts.** Ooids, with radial and concentric fabric; ≤ 1 mm; ≈ 45-50%. Oncoids, with trilobite fragments, quartz VF sand and silt grains, and ooids incorporated; ≤ 2 mm diameter to 6 x 8 mm; spherical to subspherical and well laminated; ≈ 20%. Fossil fragments, including trilobites; ≈ 5-10%. Quartz VF sand to silt grains; ≈ 5-7%. | | |
| **Matrix type; amount.** None. | | |
| **Cement types; amounts.** Equant, isopachous, and blocky; ≈ 20%. | | |
| **Textures.** Homogeneous except for two ≈ horizontal dissolution seams that cut across grains and cement and have remnant grains within them. | | |
| **Diagenetic features.** Two dissolution seams ≈ 2-5 mm thick extend across the slide; Carbonate micrite (≈ 30-35%), quartz VF sand and silt grains (≈ 25%), dark reddish-brown iron-carbonate (≈ 25%) and remnant ooids , oncoids, and fossil fragments (≈ 15-20%) are within the seams. | | |
| **Comments.** Estimated percentages do not include dissolution seams. See also sample 91-31A. | | |

PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** From Section 91-2 upper Jangle Limestone Member, Dublin Hills; ≈ 35.0 m. | **Sample number:**<br>91-32 |
|---|---|---|

**Dunham classification.** Oncolitic-oolitic-fossiliferous packstone.

**Grain types; sizes; shapes; amounts.** Oncoids, well-laminated with quartz VF sand to silt, fossil fragments, and ooids within; some of the smaller, less laminated & more irregular-shaped may be lithoclasts; 4 x 8 to 11 x 16 mm; ≈ spherical; ≈ 40-45%. Ooids with radial and concentric fabric; ≤ 0.75 mm; ≈ 30-35%. Fossil fragments, including trilobites; ≈ 5-7%.

**Matrix type; amount.** Carbonate mud with quartz VF sand to silt; ≈ 10-15%.

**Cement types; amounts.** Shelter porosity filled with isopachous and blocky cement ≈3-5%..

**Textures.** Relatively homogeneous.

**Diagenetic features.** Some recrystallization/micritization. Muscovite/chlorite ≈ 1-3%. Reddish-brown iron carbonate replacing some components, including part of one horizontal edge of the slide that may include part of a dissolution seam.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| | | |
|---|---|---|
| **Slab:**<br>**T. sctn:** √ | **Location:** Between sections 90-5C and 90-5D, upper Jangle Limestone Member, Eagle Mountain, in nodular ribbon rock lateral to large fenestral mudstone unit. | **Sample number:**<br>91-34 |

**Dunham classification.** Mostly peloid packstone/grainstone (≈ 85-90% of slide), with some carbonate mudstone (≈ 10-15% of slide) that may have been a peloid packstone originally (nodular ribbon rock).

**Grain types; sizes; shapes; amounts.** Peloids; ≤ 0.2 mm; ≈ 60-65%. Trilobite fragments; ≤ 2-4%. Quartz grains; ≤1-3% in peloid packstone/grainstone and in mudstone.

**Matrix type; amount.** Carbonate mud in the mudstone part: ≈ 10-15%.

**Cement types; amounts.** Mostly fine-grained between peloids; ≈ 10-15%. Also some equant and blocky under trilobite fragments in shelter porosity; ≈1-3%.

**Textures.** Relatively homogeneous, with stylolites between most of peloid packstone/grainstone and mudstone, although there is some peloid packstone/grainstone gradationally in contact with mudstone. It is possible that the mudstone is just highly micritized/recrystallized packstone/grainstone.

**Diagenetic features.** Stylolitic dissolution seams with ≈ 1.5 cm relief, and ≤ 2 mm thick; composed of ≈ 45% carbonate mud, ≈ 35% quartz VF sand and silt grains, and ≈ 25% reddish-brown replacement iron-carbonate. Overall, seams/stylolites are ≈ 3-5% of slide.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** Between sections 90-5C and 90-5D, upper Jangle Limestone Member, Eagle Mountain, in nodular ribbon rock lateral to large fenestral mudstone unit. | **Sample number:**<br>91-35 |
|---|---|---|

**Dunham classification.** Peloid-quartz packstone/grainstone (≈ 80% of slide) with irregular seams (≈ 20% of slide) filled with quartz grains, reddish-brown iron-carbonate, and carbonate mud (nodular ribbon rock).

**Grain types; sizes; shapes; amounts.** Peloids; ≤ 0.1 mm; ≈ 60-70% in packstone/grainstone. Quartz grains; silt-sized; ≈15% in packstone/grainstone. Trilobite fragments; ≈ 3-5% in packstone/grainstone.

**Matrix type; amount.**

**Cement types; amounts.** Small crystals between peloids may be recrystallized matrix in part; ≈15% in packstone/grainstone.

**Textures.** Homogeneous except for seams which are mostly subhorizontal, but with some vertical.

**Diagenetic features.** Seams are likely to be dissolution features; composed of ≈ 35% reddish-brown iron-carbonate (dolomite?), ≈ 35% carbonate mud, ≈ 30% quartz silt, and muscovite/chlorite; ≈ 2-3%.

**Comments.**

## PETROGRAPHIC DESCRIPTION FORM

| Slab: T. sctn: √ | Location: Between sections 90-5C and 90-5D, upper Jangle Limestone Member, Eagle Mountain, in nodular ribbon rock lateral to large fenestral mudstone unit. | Sample number: 91-36 |
|---|---|---|

**Dunham classification.** Peloid-quartz packstone/grainstone (≈ 75% of slide) with irregular seams of quartz, iron-carbonate, and carbonate mud (≈ 25% of slide) (nodular ribbon rock).

**Grain types; sizes; shapes; amounts.** Packstone/grainstone: Peloids; ≤ 0.1 mm; ≈ 65%. Quartz silt; ≈ 15-20%. Trilobite fragments; ≈ 1-3%.

**Matrix type; amount.** See below.

**Cement types; amounts.** Fine-grained in packstone/grainstone, some or all may be recrystallized carbonate mud matrix; ≈ 15-20%.

**Textures.** Homogeneous except for seams which are irregular and subhorizontal to subvertical.

**Diagenetic features.** Seams are likely to be dissolution/alteration features; composed of ≈ 30-35% reddish-brown iron-carbonate (dolomite?), ≈ 30-35% quartz silt, and ≈ 30-35% carbonate mud. Muscovite/chlorite in seams and packstone/grainstone; ≤ 1-3%.

**Comments.**

# PETROGRAPHIC DESCRIPTION FORM

| **Slab:**<br>**T. sctn:** √ | **Location:** From section 90-5H, upper Jangle Limestone Member, Eagle Mountain, in nodular ribbon rock lateral to large fenestral mudstone unit; ≈ 33.35-33.85 m. | **Sample number:**<br>91-37 |
|---|---|---|

**Dunham classification.** Peloid-quartz packstone/grainstone (≈ 80-85% of slide) and irregular seams of quartz silt, reddish-brown iron carbonate, and carbonate mud (≈ 15-20% of slide) (nodular ribbon rock).

**Grain types; sizes; shapes; amounts.** Packstone/grainstone: Peloids; ≤ 0.2 mm; ≈ 65-70%. Quartz silt; ≈ 10-15%.

**Matrix type; amount.** See below.

**Cement types; amounts.** Packstone/grainstone: small equant crystals between peloids; ≈ 20-25%.

**Textures.** Homogeneous except for subhorizontal and subvertical seams.

**Diagenetic features.** Seams are likely to be dissolution features; composed of reddish-brown iron-carbonate with some dolomite rhombs ≤ 0.5 mm (total ≈ 65-75%), quartz silt (≈ 10-15%) and carbonate mud (≈10-15%). Muscovite/chlorite in packstone/grainstone and seams; ≤ 1-3%.

**Comments.**

# APPENDIX 3: STRATIGRAPHIC SECTIONS:
## PART A. LOCATIONS

## SECTION LOCATIONS

Locations are given with reference to the 1:100,000-scale metric topographic map series (30 x 60 minute quadrangles) of the U. S. Geological Survey unless stated otherwise. Sections were commonly measured across widths from a few hundreds of meters to a kilometer in order to describe the best exposed stratigraphic intervals. Contacts were walked out to ensure continuity. However, because of the wide area covered, section locations are only given to the relevant township, range, and topographic section.

**SECTION 89-2: WINTERS PASS (WP)** Section measured north of the road through Winters Pass, Mesquite Mountains, San Bernardino, California in T19N, R12E, Section 33 (Mesquite Lake Quadrangle, California-Nevada. 1985).

**SECTION 89-3: FRENCHMAN MOUNTAIN (FM)** Section measured just south of Lake Mead Boulevard, Las Vegas on the west flank of Frenchman Mountain, Clark County, Nevada in T20S, R62E, Sections 23 and 24 (Frenchman Mountain 7.5 Minute Quad., Nevada. 1970).

**SECTION 90-1: SOUTHERN NOPAH RANGE (N)** Section measured north of Old Spanish Trail Highway in Emigrant Pass, Nopah Range, Inyo County, California, in T21N, R8E, Section 23 (North of Tecopa Pass 7.5 Minute Quad., California. Provisional Edition 1983).

**SECTION 90-2: SOUTHERN NOPAH RANGE (NOT USED IN CROSS SECTIONS)** Section measured north of Old Spanish Trail Highway in Emigrant Pass, Nopah Range, Inyo County, California, in T21N, R8E, Section 14 (North of Tecopa Pass 7.5 Minute Quad., California. Provisional Edition 1983).

**SECTION 90-3: CHAPPO SPRING, SOUTHERN RESTING SPRING RANGE (CS)** Section measured just north of Chappo Spring in the southern part of the Resting Spring Range, Inyo County, California in T21N, R7E, Section 2 (Resting Spring 7.5 Minute Quad., California. Provisional Edition 1983).

**SECTION 90-4: REDWING MINE, MIDDLE RESTING SPRING RANGE (MR)** Section measured north of Red Wing Mine, middle Resting Spring Range, Inyo County, California in T23N, R7E, Section 32, just north of the line separating T23N from T22N (Death Valley Junction Quad., California-Nevada. 1986).

**SECTION 90-5: EAGLE MOUNTAIN (EM)** Section measured east of Highway 127, on the southwest flank of Eagle Mountain, Inyo County, California in T24N, R6E, Section 20 (Death Valley Junction Quad., California-Nevada. 1986).

**SECTION 90-6: MONTGOMERY HILLS (MH)** Section measured north of the paved road that connects with Bell Vista Rd. in Pahrump, Nye County, Nevada, in the Montgomery Hills (also known as the Pahrump Hills), in T19S, R52E, in the southwest quarter of Section 17 (Death Valley Junction Quad., California-Nevada. 1986).

**SECTION 91-1: BAXTER MINE, NORTHERN RESTING SPRING RANGE (NR)** Section measured west of the Baxter Mine in the northern Resting Spring Range, Inyo County, California in T23N, R7E, southwest quarter of Section 9 and northwest quarter of Section 16 (Death Valley Junction Quad., California-Nevada. 1986).

**SECTION 92-1: ECHO CANYON, SOUTHERN FUNERAL MOUNTAINS (EC)** Section measured on both sides of the gravel road in Echo Canyon, southern Funeral Mountains, Inyo County, California in T27N, R2E, Section 15 (Death Valley Junction Quad., California-Nevada. 1986).

**SECTION 92-2: SOUTHERN RESTING SPRING RANGE (SR)** Section measured just southeast of Chappo Spring in the southern part of the Resting Spring Range, Inyo County, California in T21N, R7E, Section 13 (Resting Spring 7.5 Minute Quad., California. Provisional Edition 1983).

**SECTION 92-3: LAS VEGAS RANGE (LV)** Section measured immediately upslope from Quail Spring, Las Vegas Range, Clark County, Nevada in T17S, R61E. No topographic sections are delineated and the approximate latitude and longitude are 36° 27' and 115° 08' (Las Vegas Quad., Nevada-California. 1986)

**SECTION 92-4: TITUS AND TITANOTHERE CANYONS, GRAPEVINE MOUNTAINS (TC)** Section measured south of Red Pass, the divide between Titus Canyon and Titanothere Canyon, and the one-way dirt road through Titus Canyon, Grapevine Mountains, Inyo County, California in T13S, R46E. No topographic sections are delineated and the approximate latitude and longitude are 36° 49' and 117° 01' 30" (Saline Valley Quad., California-Nevada. 1985).

**SECTION 92-5: LAST CHANCE RANGE (LC)** Section measured in the Eureka Valley side of the Last Chance Range, Inyo County, California northeast of the big sand dune in T9S, R40E, Section 33 and approximate latitude and longitude are 37° 07' 30" and 117° 37' 30" (Last Chance Range Quad., California-Nevada. 1985).

**Grain types:**
- ooids
- peloids
- undifferentiated ooids & peloids
- oncoids
- general fossils
- trilobites
- hyolithoids
- lithoclasts

↑ = vertical trend changing in upward direction

**Carbonate sedimentary structures and textures:**
- A planar microbial laminae
- A wavy microbial laminae
- R well-layered ribbon rock texture
- NR nodular ribbon rock tecture
- BR bioturbated ribbon rock texture
- stromatolitic boundstone
- T thrombolitic boundstone
- D digitate miocrobial boundstone

**Sedimentary structures:**
- H homogenous beds (no structures)
- current ripples
- climbing current ripples
- flaser ripples
- wave ripples
- W climbing wave ripples
- combined flow rippples
- planar cross beds
- trough cross beds
- hummocky cross beds
- horizontal planar laminae
- wavy parallel laminae
- wavy nonparallel laminae
- W wrinkly laminae
- G gutter casts

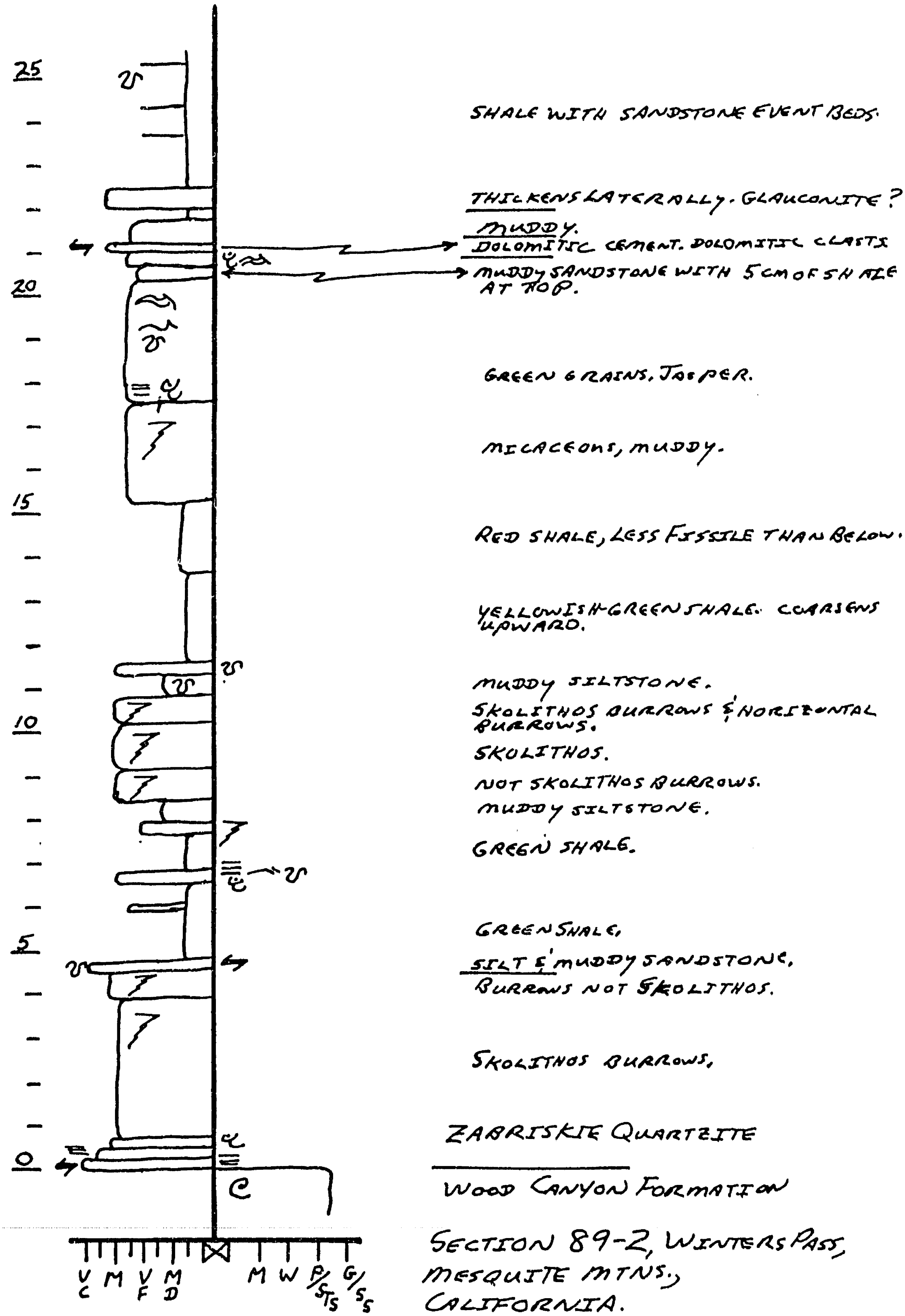
**Sedimentary structures:**
- scoured surfaces
- hardgrounds
- load structures
- contorted beds
- burrows
- burrowed-to-bioturbated
- bioturbated
- S soil-churned
- # mudcracks
- tepees
- fenestrae
- microfaulting
- pyrite

**Abbreviations:**

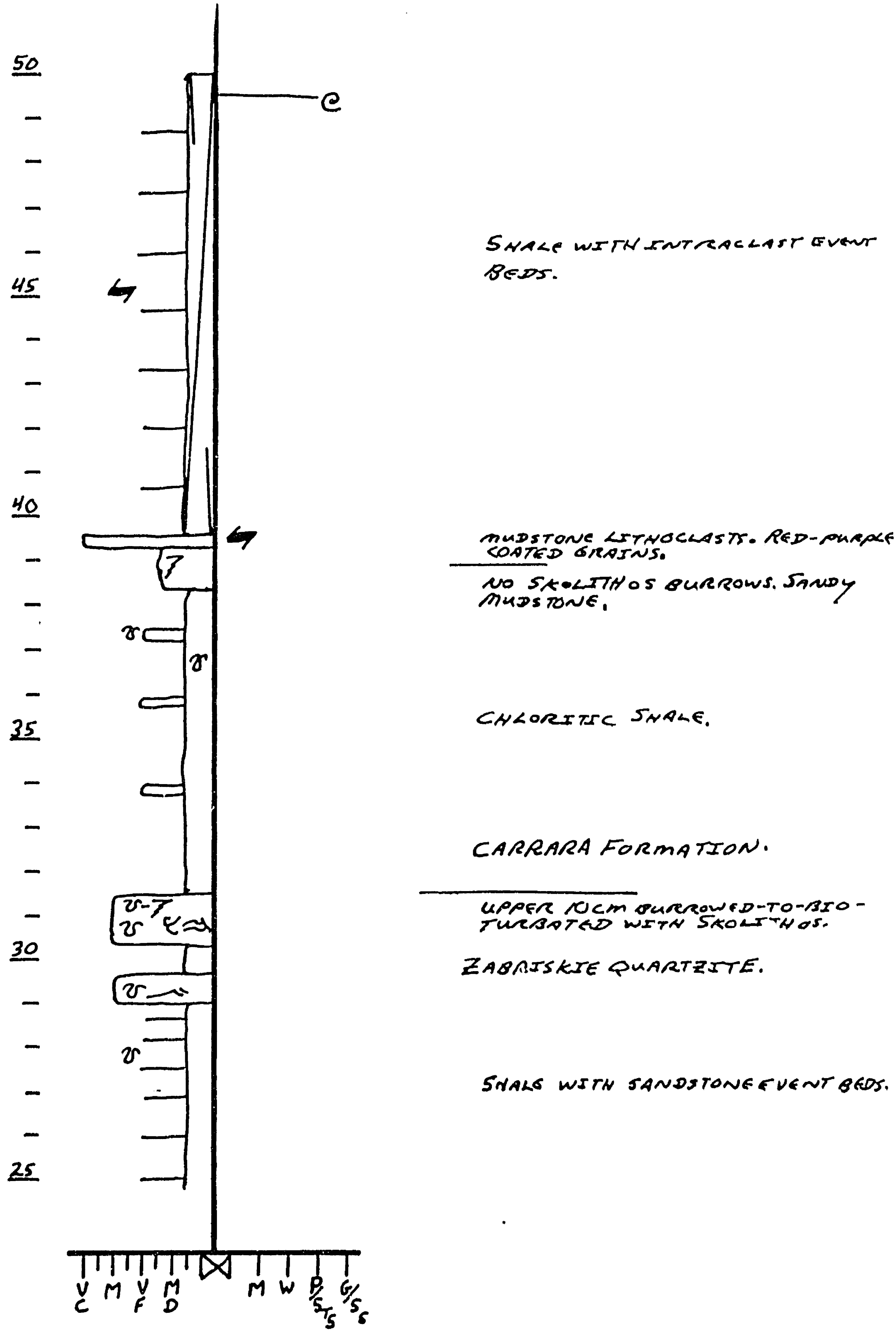
| | | | | |
|---|---|---|---|---|
| bndst = boundstone | mdst = mudstone | wkst = wackestone | pkst = packstone | grst = grainstone |
| w/ = with | % = per cent | sh = shale | sts = siltsite or siltstone | |
| ss = sandstone | aren = arenite | ls = limestone | dol = dolostone or dol- or dolo- or dolomitic | |
| VF = very fine | F = fine | C = coarse | VC = very coarse | M = medium |
| m = meter | cm = centimeter | mm = millimeter | qtz = quartz | crsn = coar⁻ən |
| incr = increase | decr = decrease | ps = parasequence | talc = altered sediments | |
| | | | skol = *Slolithos* burrows | |

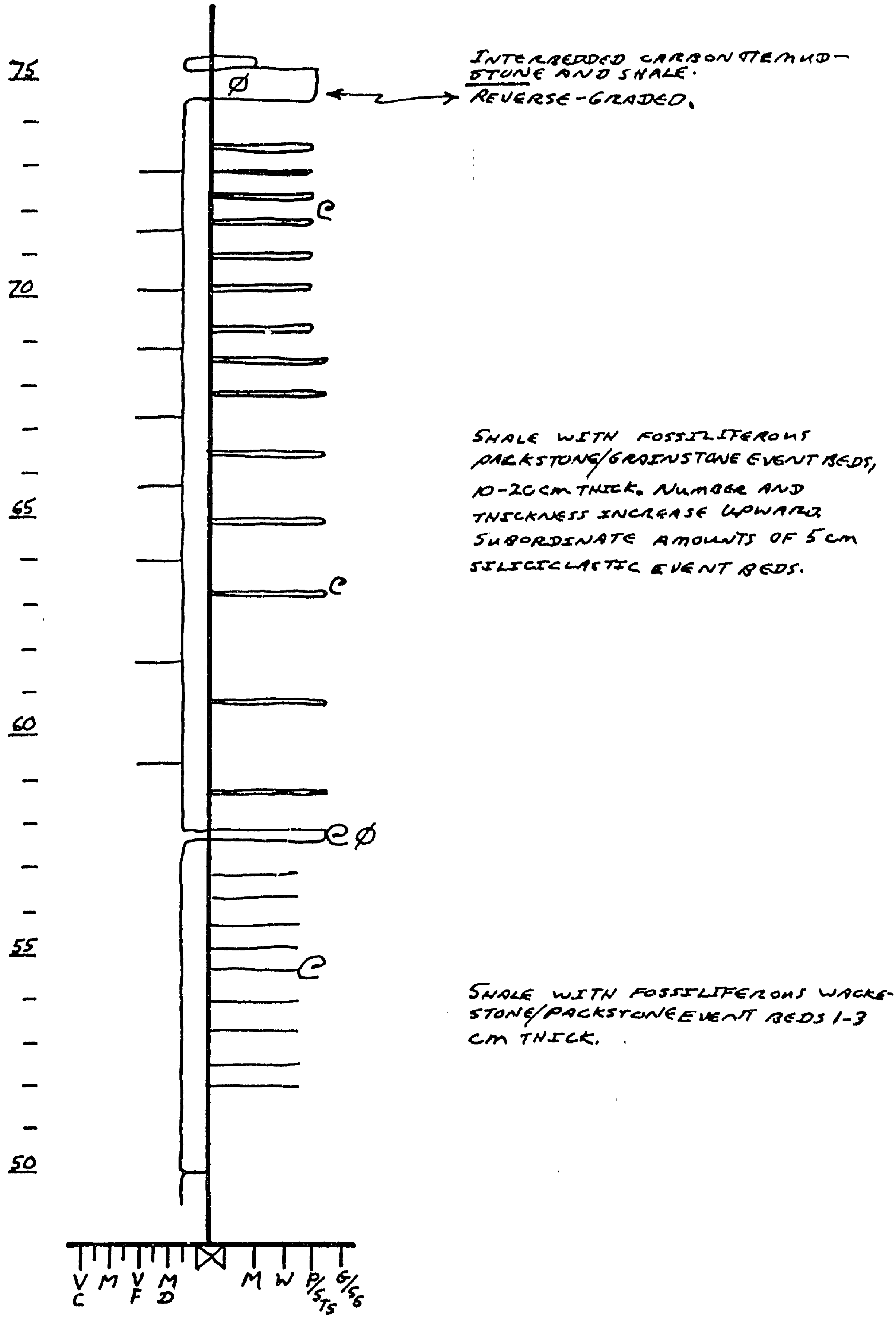
u1, u2, u3 etc. = informal units in shallowing-upwards cycles.
CDAS = calcarenite, calcisiltite, dolarenite, and dolosiltite

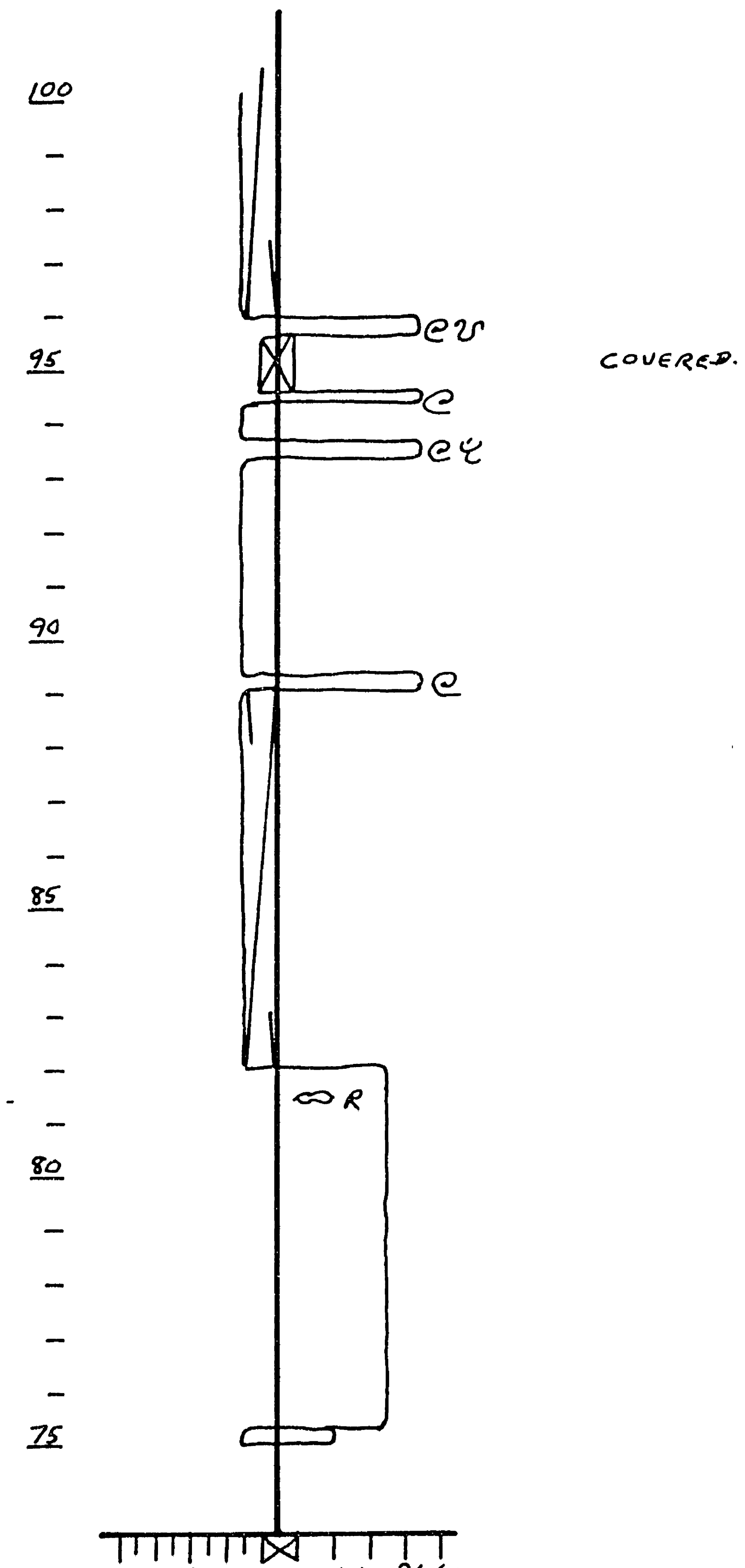
# LEGEND

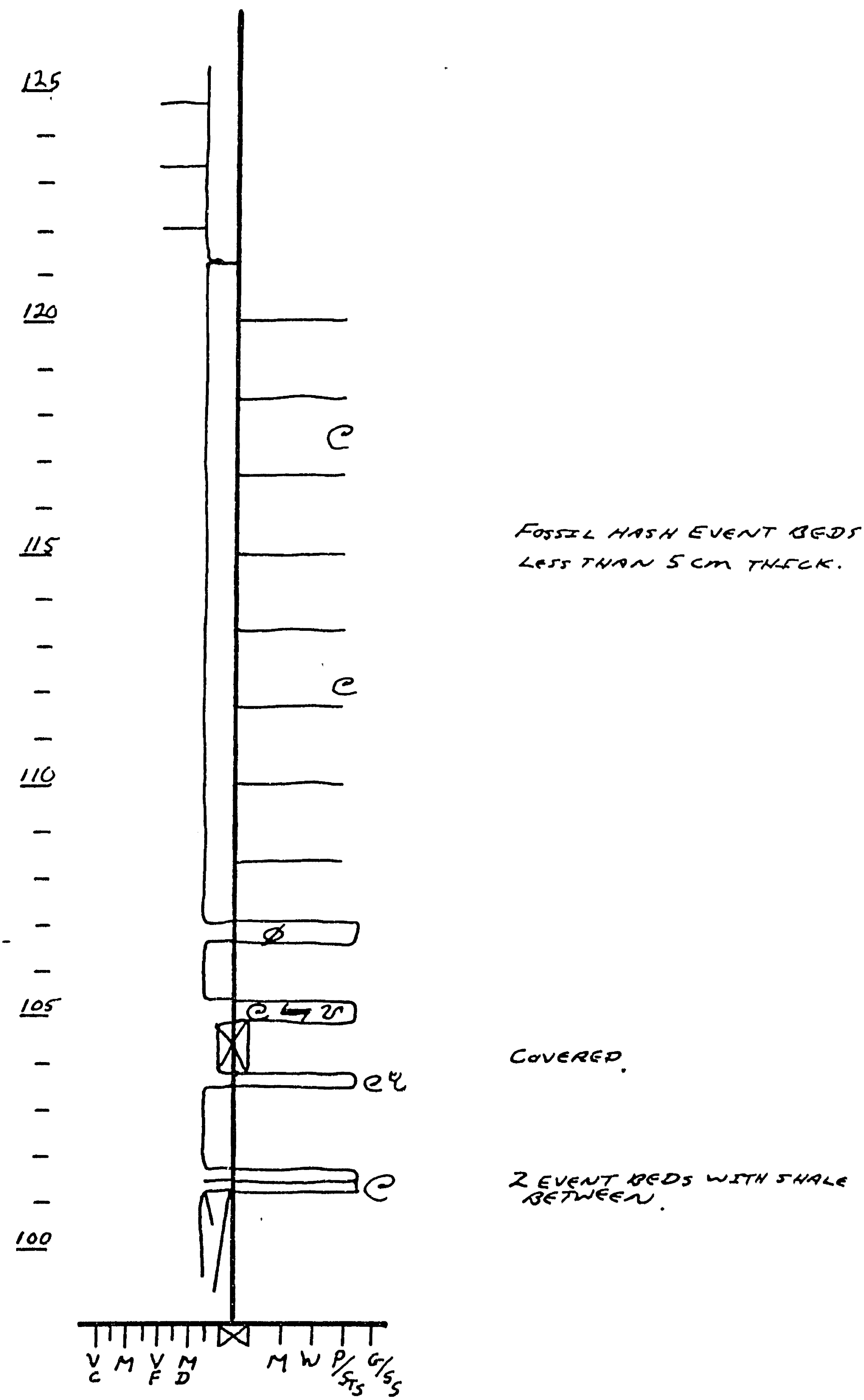


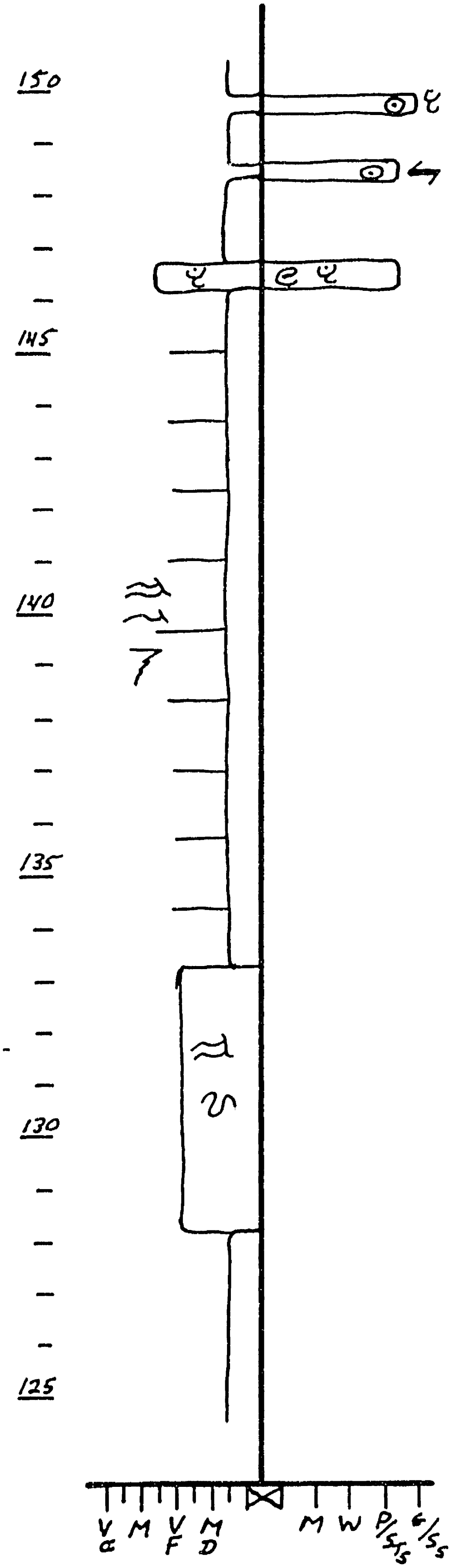

SECTION 89-2, WINTERS PASS, MESQUITE MTNS., CALIFORNIA.


50
45
40
35
30
25
SHALE WITH INTRACLAST EVENT BEDS.
MUDSTONE LITHOCLASTS. RED-PURPLE COATED GRAINS.
NO SKOLITHOS BURROWS. SANDY MUDSTONE.
CHLORITIC SHALE.
CARRARA FORMATION.
UPPER 10CM BURROWED-TO-BIO-TURBATED WITH SKOLITHOS.
ZABRISKIE QUARTZITE.
SHALE WITH SANDSTONE EVENT BEDS.
VC M VF MD M W P/S G/S


75
70
65
60
55
50
INTERBEDDED CARBONATE MUD-STONE AND SHALE.
REVERSE-GRADED.
SHALE WITH FOSSILIFEROUS PACKSTONE/GRAINSTONE EVENT BEDS, 10-20CM THICK. NUMBER AND THICKNESS INCREASE UPWARD. SUBORDINATE AMOUNTS OF 5CM SILICICLASTIC EVENT BEDS.
SHALE WITH FOSSILIFEROUS WACKE-STONE/PACKSTONE EVENT BEDS 1-3 CM THICK.
VC M VF MD M W P/S G/S

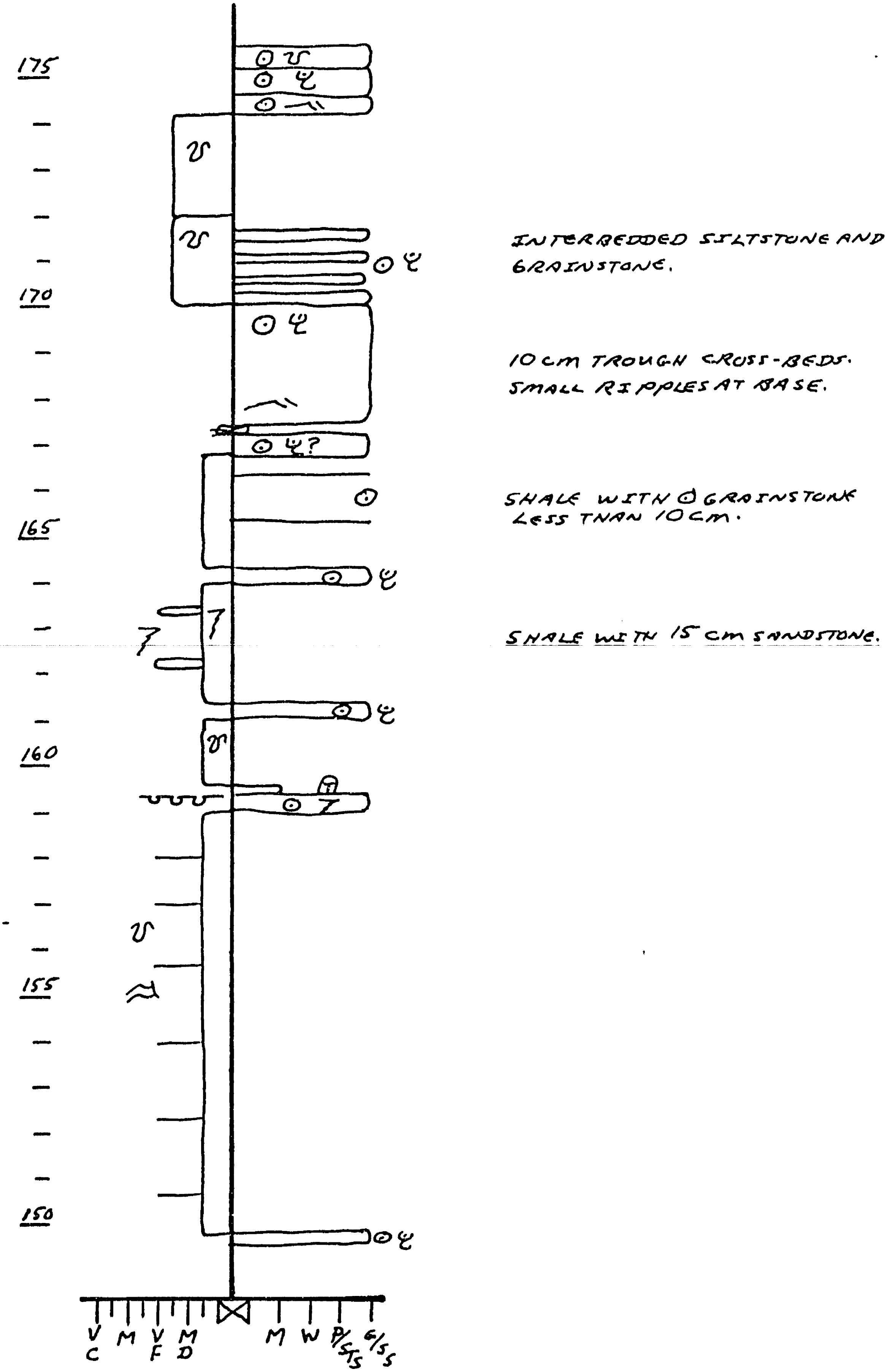

100
95
90
85
80
75
COVERED.
R
V C
M
V F
M D
M
W
P/S TS
G/SS

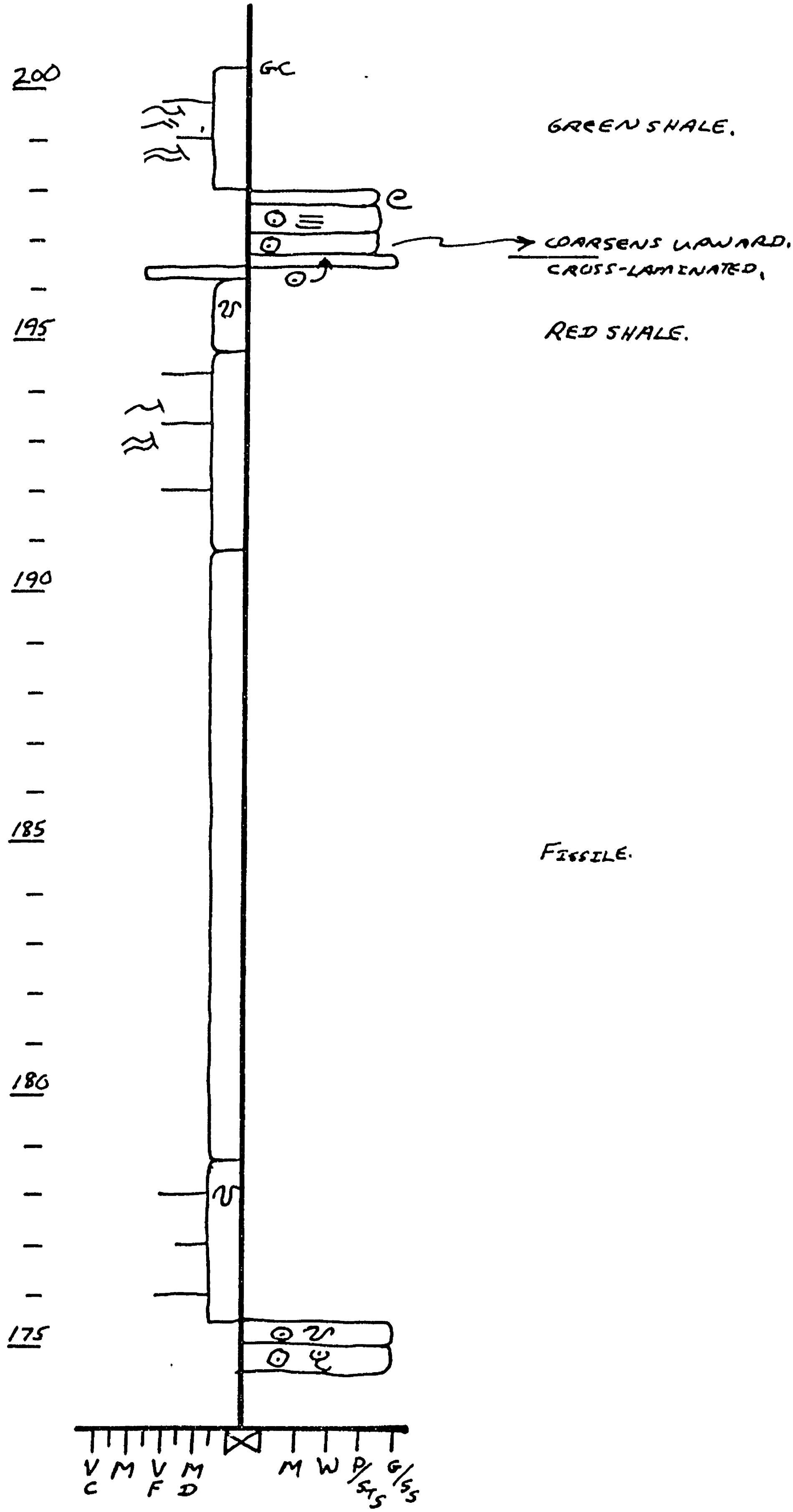

125
120
115
110
105
100
V C
M
V F
M D
M
W
P/SS
G/SS
FOSSIL HASH EVENT BEDS LESS THAN 5 cm THICK.
COVERED.
2 EVENT BEDS WITH SHALE BETWEEN.

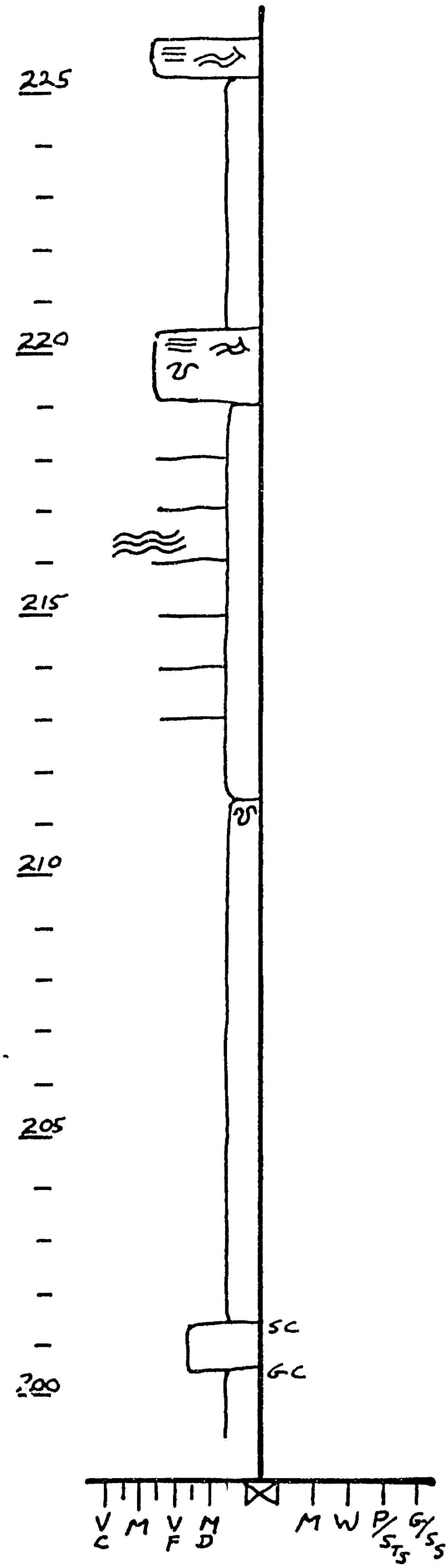



SHALE WITH SANDSTONE EVENT BEDS.

APPROXIMATELY 50% SANDSTONE AND 50% SHALE, INTERBEDDED.


175
170
165
160
155
150
V C
M
V F
M D
M
W
P/STS
G/SS
INTERBEDDED SILTSTONE AND GRAINSTONE.
10 CM TROUGH CROSS-BEDS. SMALL RIPPLES AT BASE.
SHALE WITH ⊙ GRAINSTONE LESS THAN 10 CM.
SHALE WITH 15 CM SANDSTONE.


200
195
190
185
180
175
GC
GREEN SHALE.
COARSENS UPWARD.
CROSS-LAMINATED.
RED SHALE.
FISSILE.
V C
M
V F
M D
M
W
P/SLS
G/SS




RED SHALE.

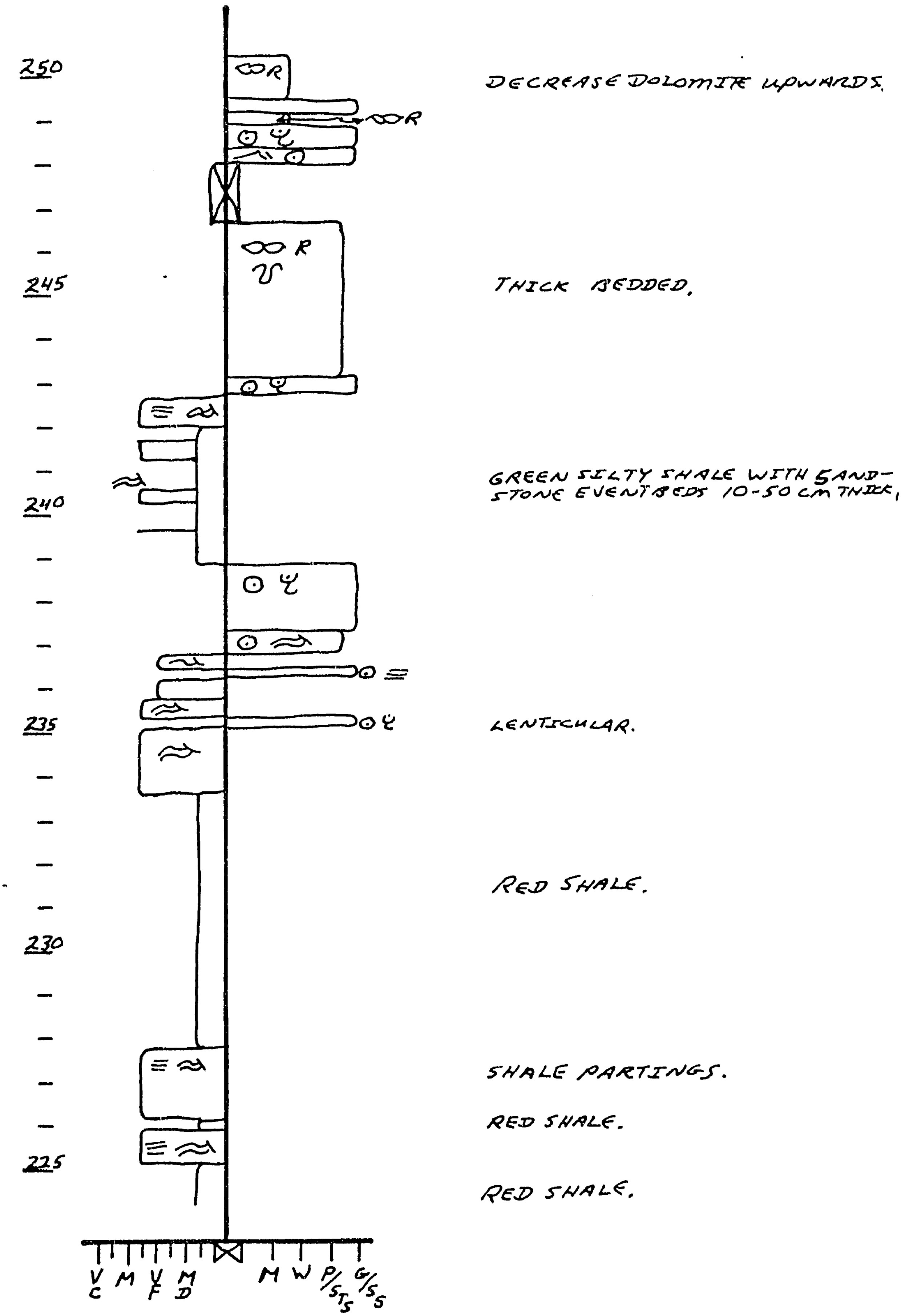
LOCALLY BURROWED. THIN SHALE PARTINGS

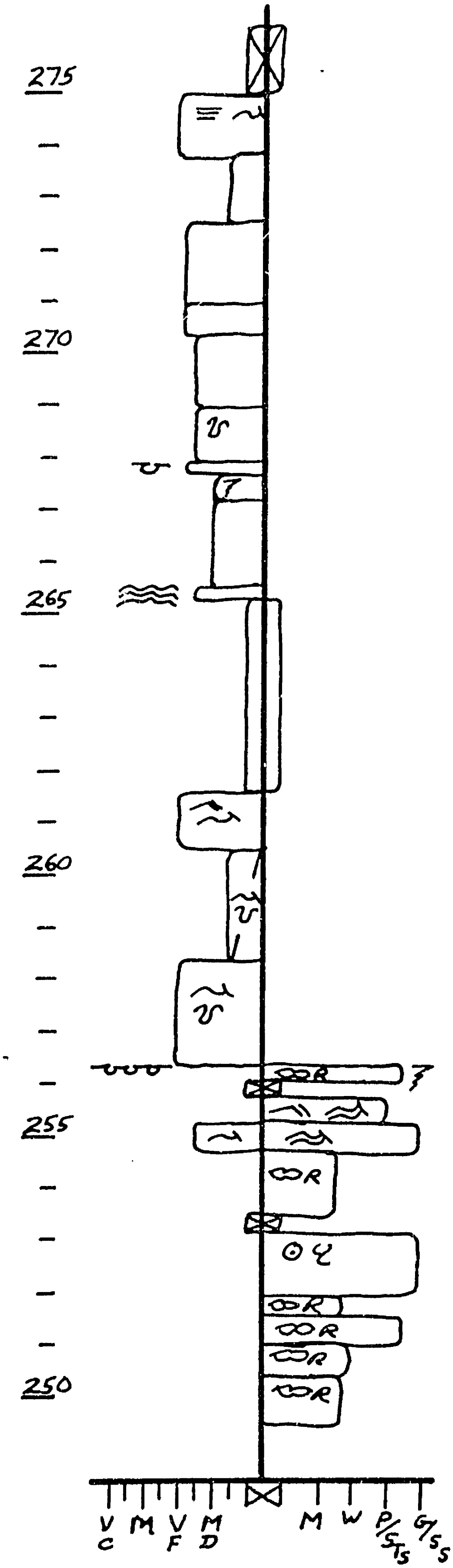
NOT RED SHALE.

CHRONDRITES(?) BURROWS AT TOP.

RED SHALE.

THICKLY LAMINATED SHALE & FINE SANDSTONE.


250
DECREASE DOLOMITE UPWARDS.
245
THICK BEDDED.
GREEN SILTY SHALE WITH 5 SAND-STONE EVENT BEDS 10-50 CM THICK,
240
235
LENTICULAR.
RED SHALE.
230
SHALE PARTINGS.
RED SHALE.
225
RED SHALE.
V C
M
V F
M D
M
W
P/ST S
G/S S




COVERED.

INTERBEDDED FINE SANDSTONE, SHALE AND VERY FINE SANDSTONE.

RED SHALE.

VARIGATED, INTERBEDDED TAN, LIMY SILTSTONE, FINELY LAMINATED RED SHALE, & VERY FINE SANDSTONE.

LAMINATED VERY FINE SANDSTONE & SILTSTONE.

GREEN SILTSTONE.

RED, LAMINATED SILTSTONE.

LAMINATED SANDSTONE & SILTSTONE.

SAME AS 266 m.

LAMINATED RED SHALE & VERY FINE SANDSTONE.

VERY FINE SANDSTONE & GREEN SHALE.

COVERED.

SANDSTONE AND GREEN SHALE.

INTERLAMINATIONS OF SHALE.

SKOLITHOS BURROWS.

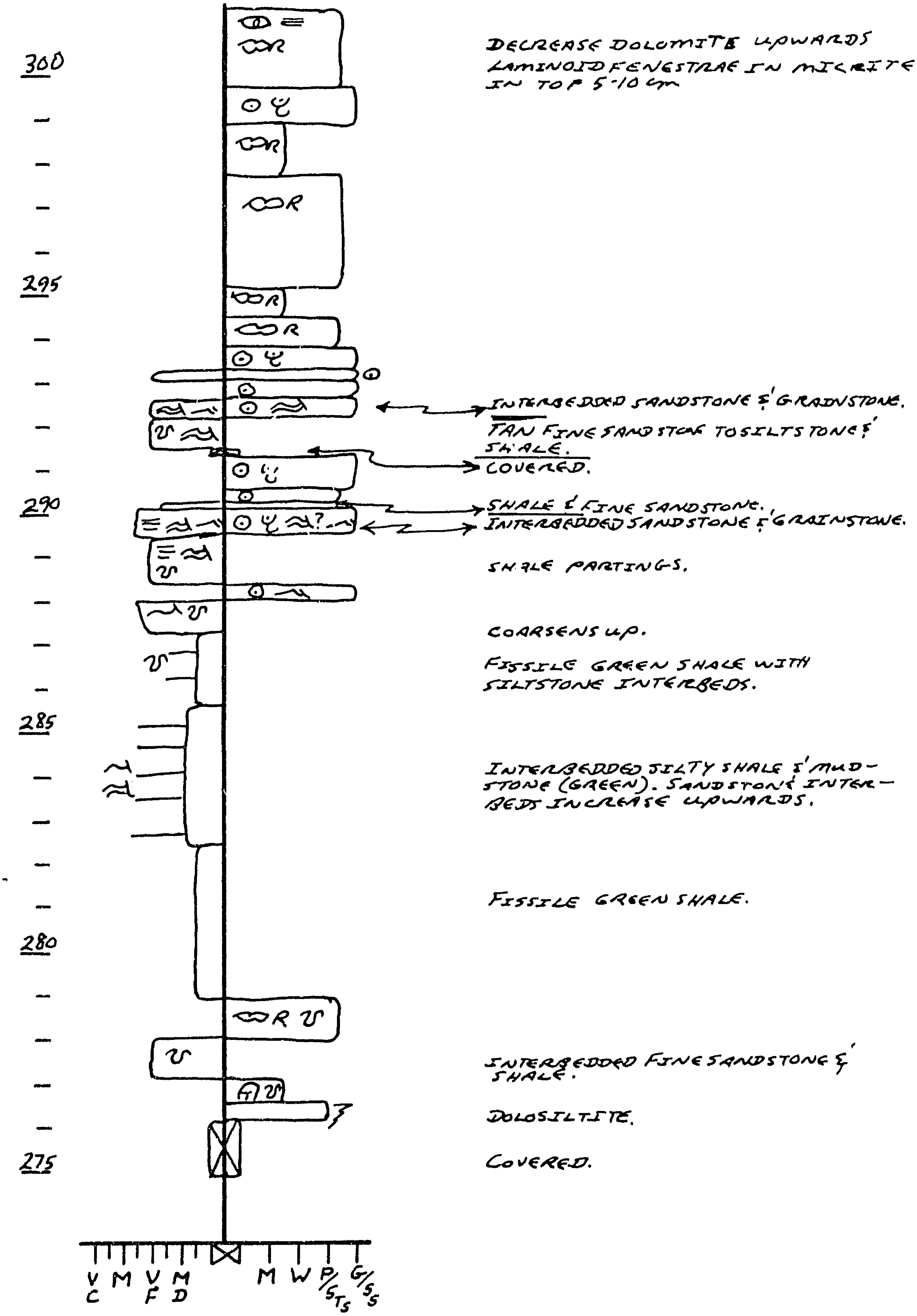
DOLOSILTITE.

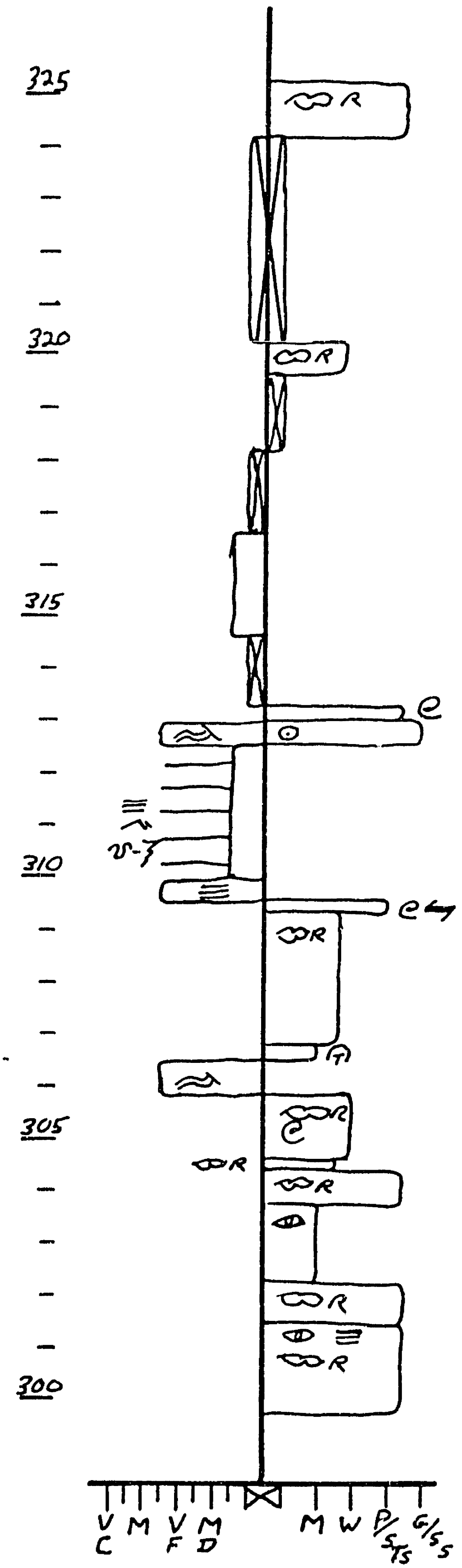
INTERBEDDED SILICEOUS SILTSTONE AND DOLARENITE.

COVERED.

DECREASE DOLOMITE UPWARDS.

DECREASE DOLOMITE UPWARDS.


300
295
290
285
280
275
DECREASE DOLOMITE UPWARDS
LAMINOID FENESTRAE IN MICRITE IN TOP 5-10 cm
INTERBEDDED SANDSTONE & GRAINSTONE.
TAN FINE SANDSTONE TO SILTSTONE & SHALE.
COVERED.
SHALE & FINE SANDSTONE.
INTERBEDDED SANDSTONE & GRAINSTONE.
SHALE PARTINGS.
COARSENS UP.
FISSILE GREEN SHALE WITH SILTSTONE INTERBEDS.
INTERBEDDED SILTY SHALE & MUDSTONE (GREEN). SANDSTONE INTERBEDS INCREASE UPWARDS.
FISSILE GREEN SHALE.
INTERBEDDED FINE SANDSTONE & SHALE.
DOLOSILTITE.
COVERED.
VC M VF MD M W P/STS G/SS




DECREASE DOLOMITE UPWARDS.

COVERED.

COVERED. PROBABLY RIBBON ROCK.

COVERED. PROBABLY GREEN SHALE.

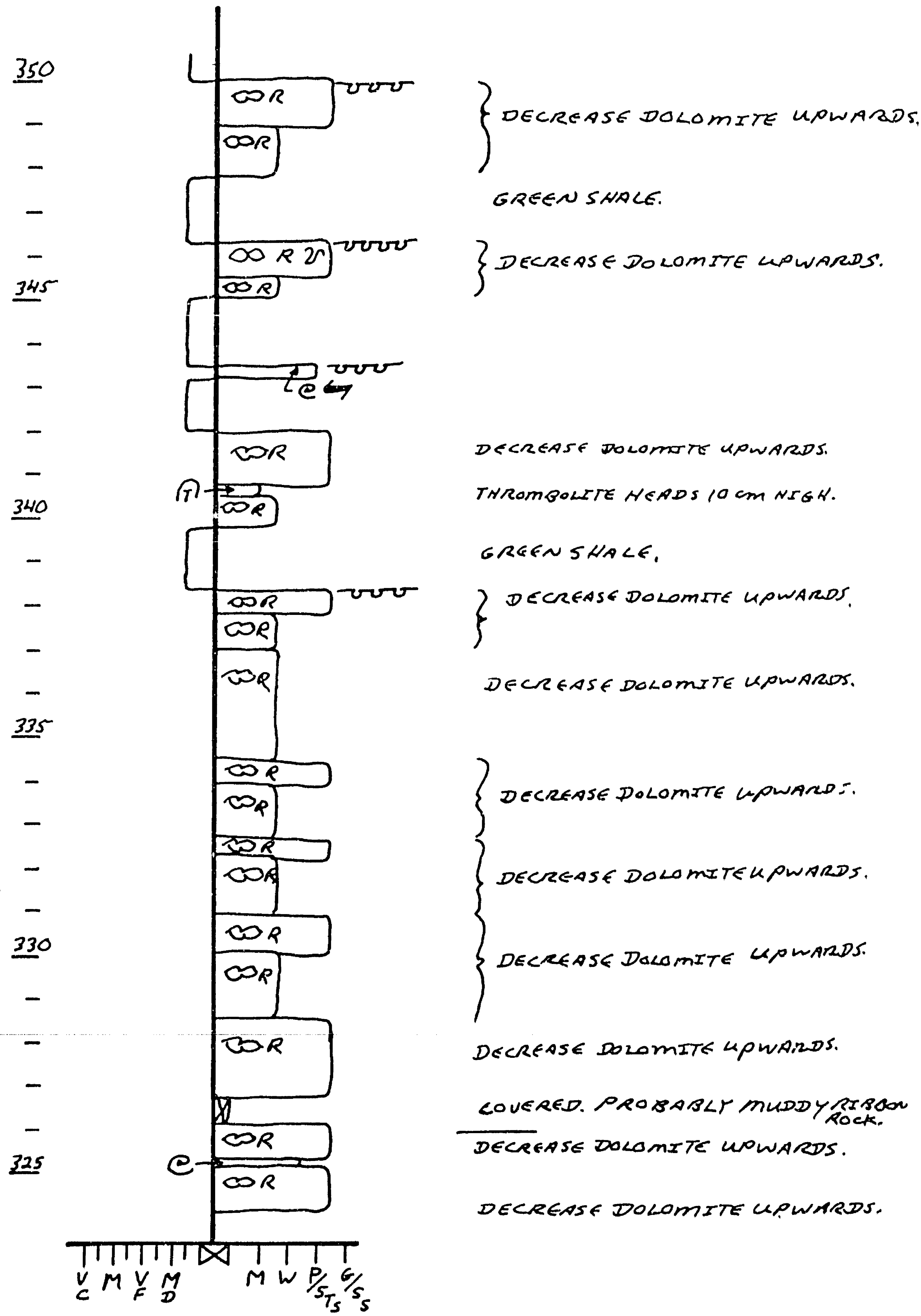
GREEN SHALE.

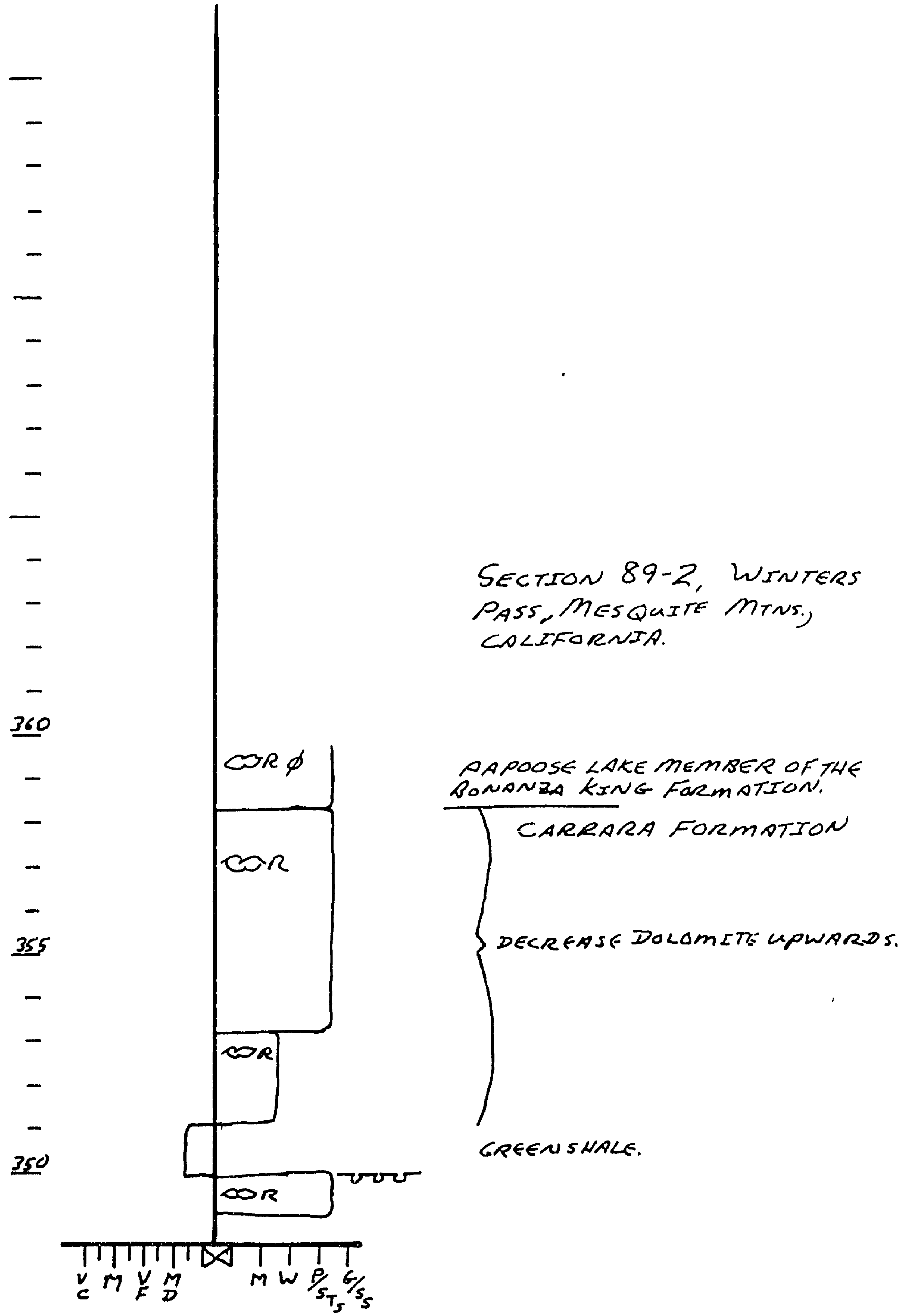
COVERED. PROBABLY GREEN SHALE.

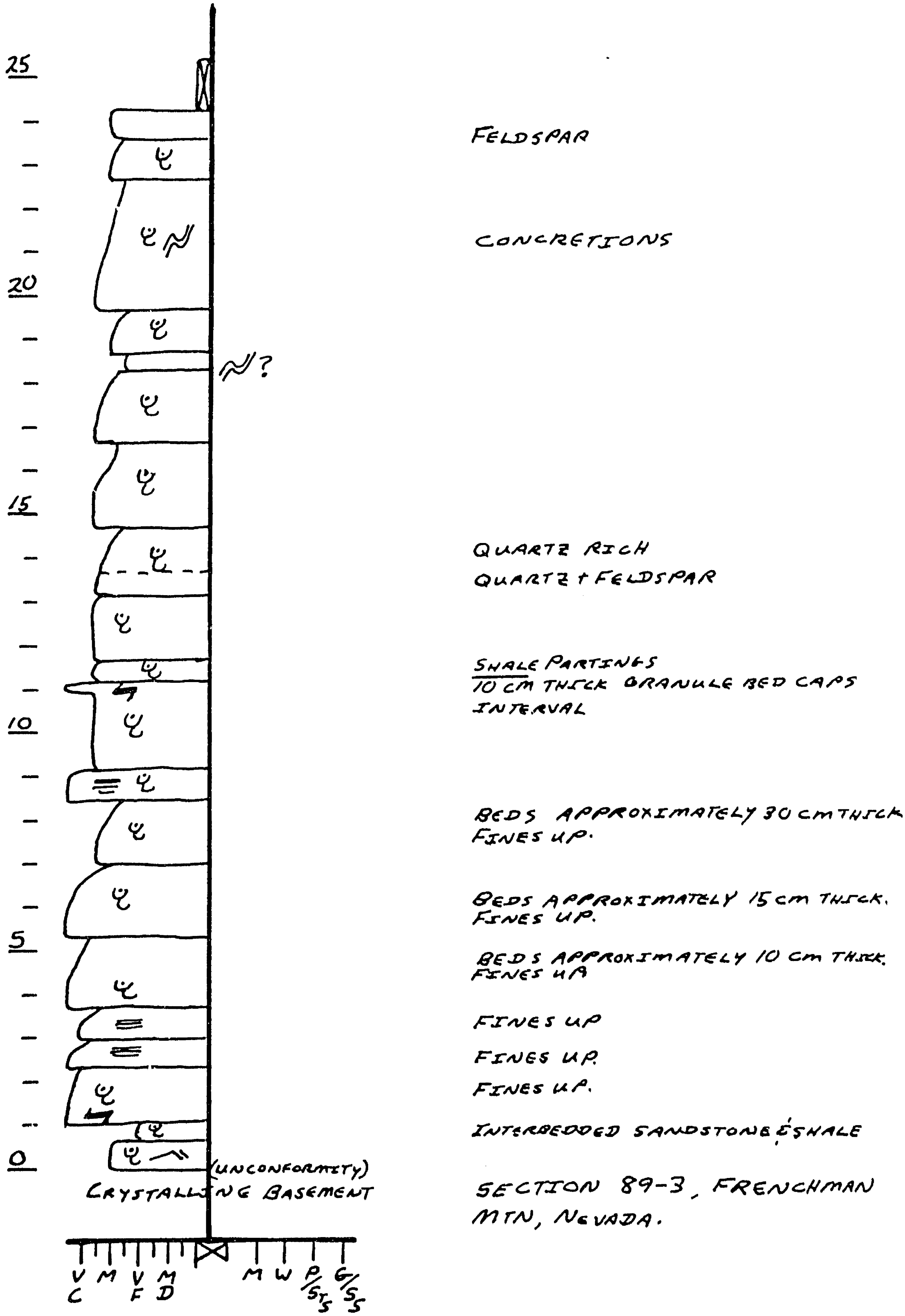
INTERBEDDED SANDSTONE & GRAINSTONE.

DECREASE DOLOMITE UPWARDS.
FOSSILIFEROUS WACKSTONE.

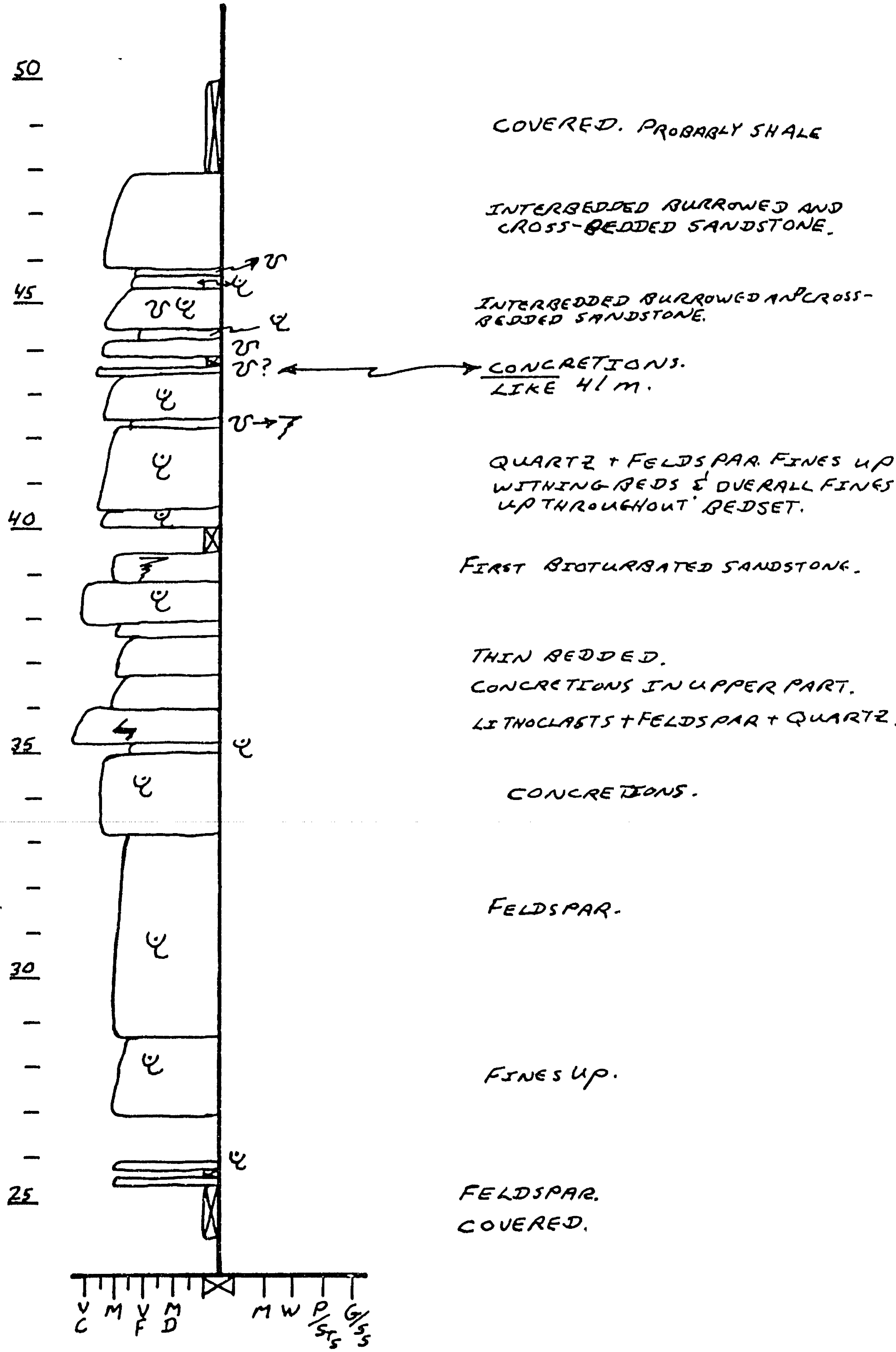
FISSILE, DOLOMITIC MUDSTONE.

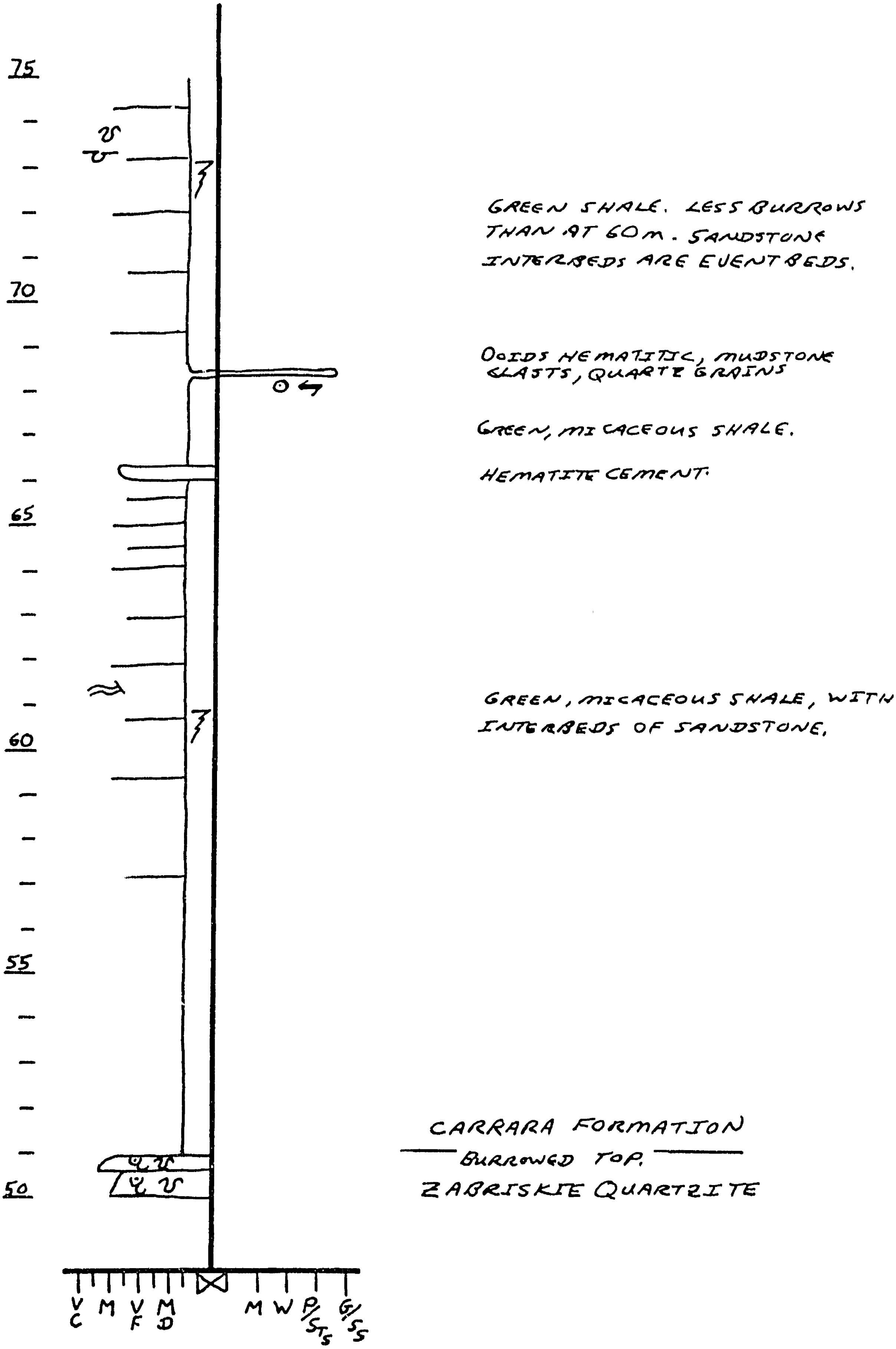

350
DECREASE DOLOMITE UPWARDS.
GREEN SHALE.
DECREASE DOLOMITE UPWARDS.
345
DECREASE DOLOMITE UPWARDS.
THROMBOLITE HEADS 10 cm HIGH.
340
GREEN SHALE.
DECREASE DOLOMITE UPWARDS.
DECREASE DOLOMITE UPWARDS.
335
DECREASE DOLOMITE UPWARDS.
DECREASE DOLOMITE UPWARDS.
330
DECREASE DOLOMITE UPWARDS.
DECREASE DOLOMITE UPWARDS.
COVERED. PROBABLY MUDDY RIBBON ROCK.
DECREASE DOLOMITE UPWARDS.
325
DECREASE DOLOMITE UPWARDS.
VC M VF MD M W P/S TS G/S S

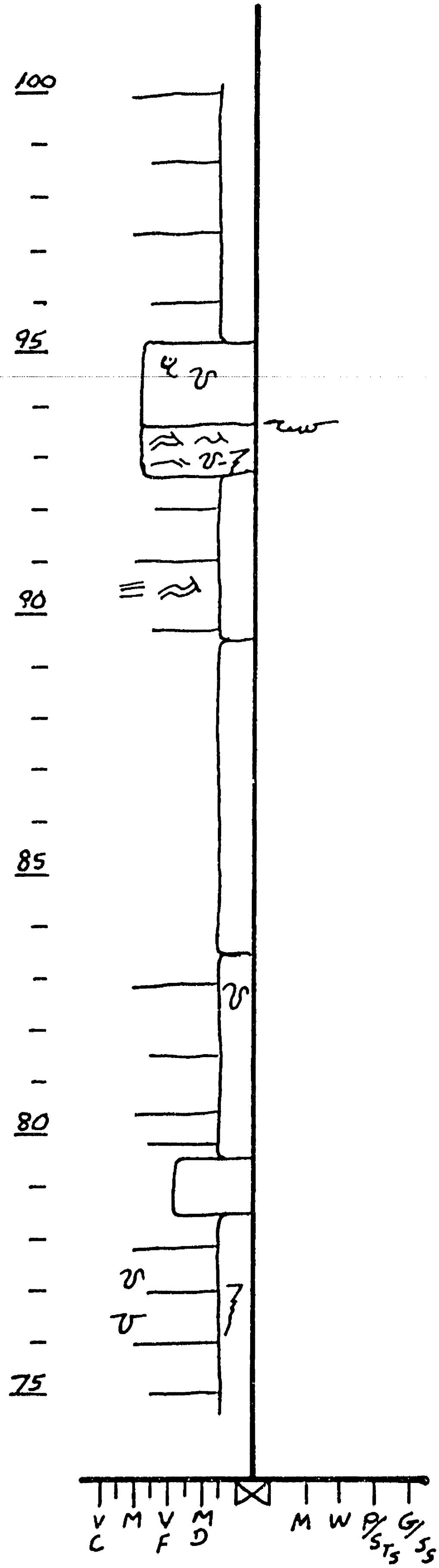

SECTION 89-2, WINTERS PASS, MESQUITE MTNS., CALIFORNIA.
360
355
350
PAPOOSE LAKE MEMBER OF THE BONANZA KING FORMATION.
CARRARA FORMATION
DECREASE DOLOMITE UPWARDS.
GREEN SHALE.
V C
M
V F
M D
M
W
P/S
G/S



25
20
15
10
5
0
FELDSPAR
CONCRETIONS
QUARTZ RICH
QUARTZ + FELDSPAR
SHALE PARTINGS
10 CM THICK GRANULE BED CAPS
INTERVAL
BEDS APPROXIMATELY 30 CM THICK
FINES UP.
BEDS APPROXIMATELY 15 CM THICK.
FINES UP.
BEDS APPROXIMATELY 10 CM THICK.
FINES UP
FINES UP
FINES UP.
FINES UP.
INTERBEDDED SANDSTONE & SHALE
(UNCONFORMITY)
CRYSTALLINE BASEMENT
SECTION 89-3, FRENCHMAN MTN, NEVADA.
V C
M
V F
M D
M
W
P/S
G/S


50
45
40
35
30
25
COVERED. PROBABLY SHALE
INTERBEDDED BURROWED AND CROSS-BEDDED SANDSTONE.
INTERBEDDED BURROWED AND CROSS-BEDDED SANDSTONE.
CONCRETIONS. LIKE 41 m.
QUARTZ + FELDSPAR. FINES UP WITHIN BEDS & OVERALL FINES UP THROUGHOUT BEDSET.
FIRST BIOTURBATED SANDSTONE.
THIN BEDDED.
CONCRETIONS IN UPPER PART.
LITHOCLASTS + FELDSPAR + QUARTZ.
CONCRETIONS.
FELDSPAR.
FINES UP.
FELDSPAR.
COVERED.
VC M VF MD M W P/STS G/SS


75
70
65
60
55
50
GREEN SHALE. LESS BURROWS THAN AT 60 m. SANDSTONE INTERBEDS ARE EVENT BEDS.
OOIDS HEMATITIC, MUDSTONE CLASTS, QUARTZ GRAINS
GREEN, MICACEOUS SHALE.
HEMATITE CEMENT.
GREEN, MICACEOUS SHALE, WITH INTERBEDS OF SANDSTONE.
CARRARA FORMATION
BURROWED TOP.
ZABRISKIE QUARTZITE
V C
M
V F
M D
M
W
P/S
G/S

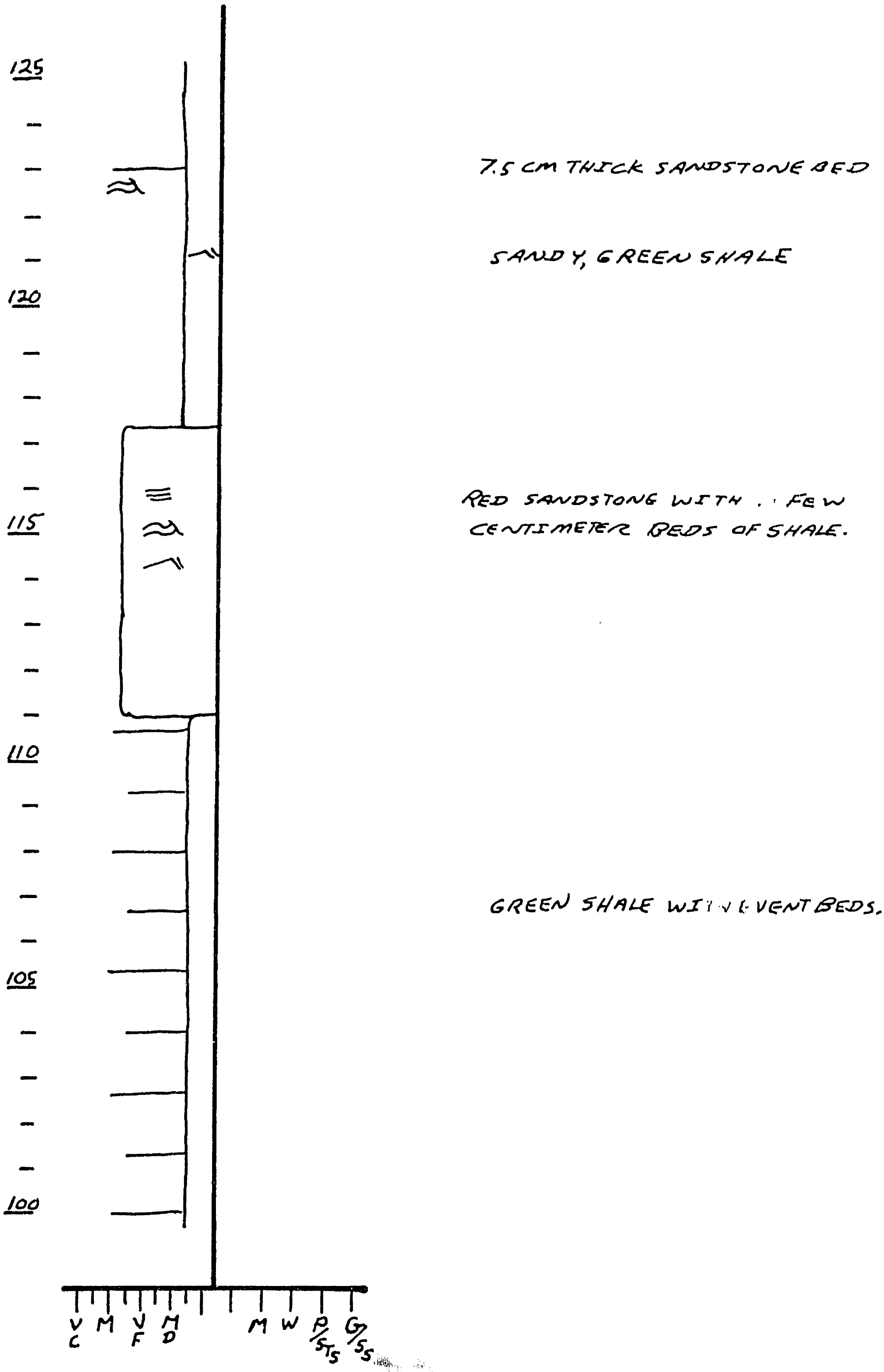


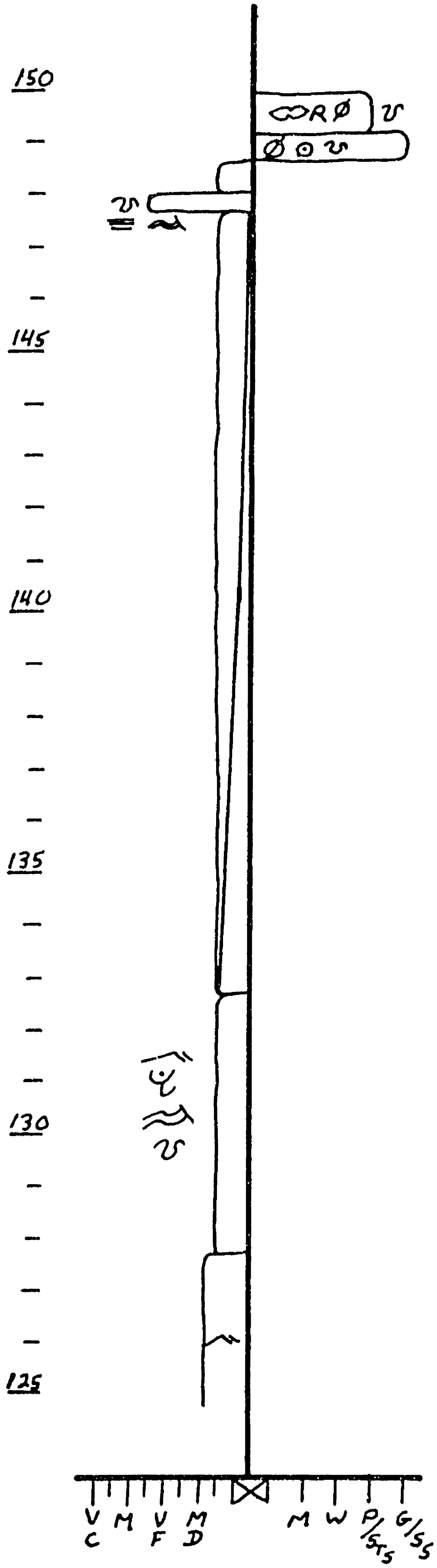

GREEN SHALE.

ALTERNATING INTERVALS OF PHYSICAL AND BIOLOGICAL SEDIMENTARY STRUCTURES

GREEN SHALES WITH GLAUCONITE. AMOUNT OF BURROWS INCREASE UPSECTION.

GREEN SHALE. SEE 70m.


125
120
115
110
105
100
7.5 CM THICK SANDSTONE BED
SANDY, GREEN SHALE
RED SANDSTONE WITH . FEW
CENTIMETER BEDS OF SHALE.
GREEN SHALE WI EVENT BEDS.
V C
M
V F
M D
M
W
P/STS
G/SS

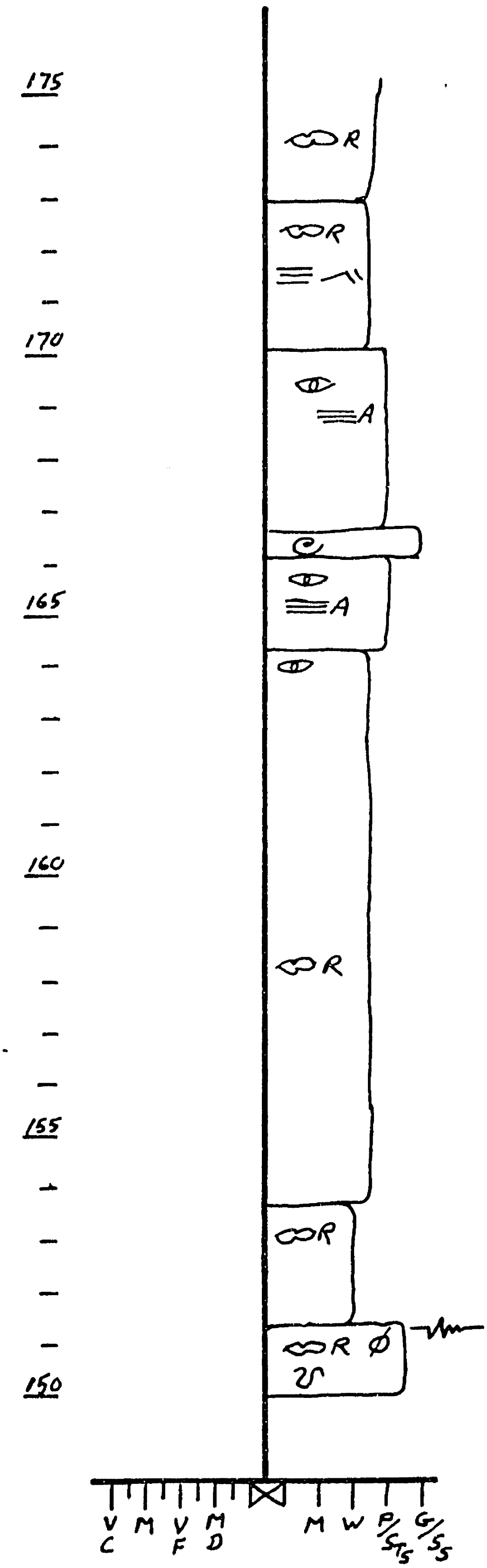



DECREASE DOLOMITE UPSECTION.

GREEN SHALE, PARTIALLY COVERED.

GRAY SHALES. BURROWS LOCAL, NOT UBIQUITOUS.

SANDY GREEN SHALE.



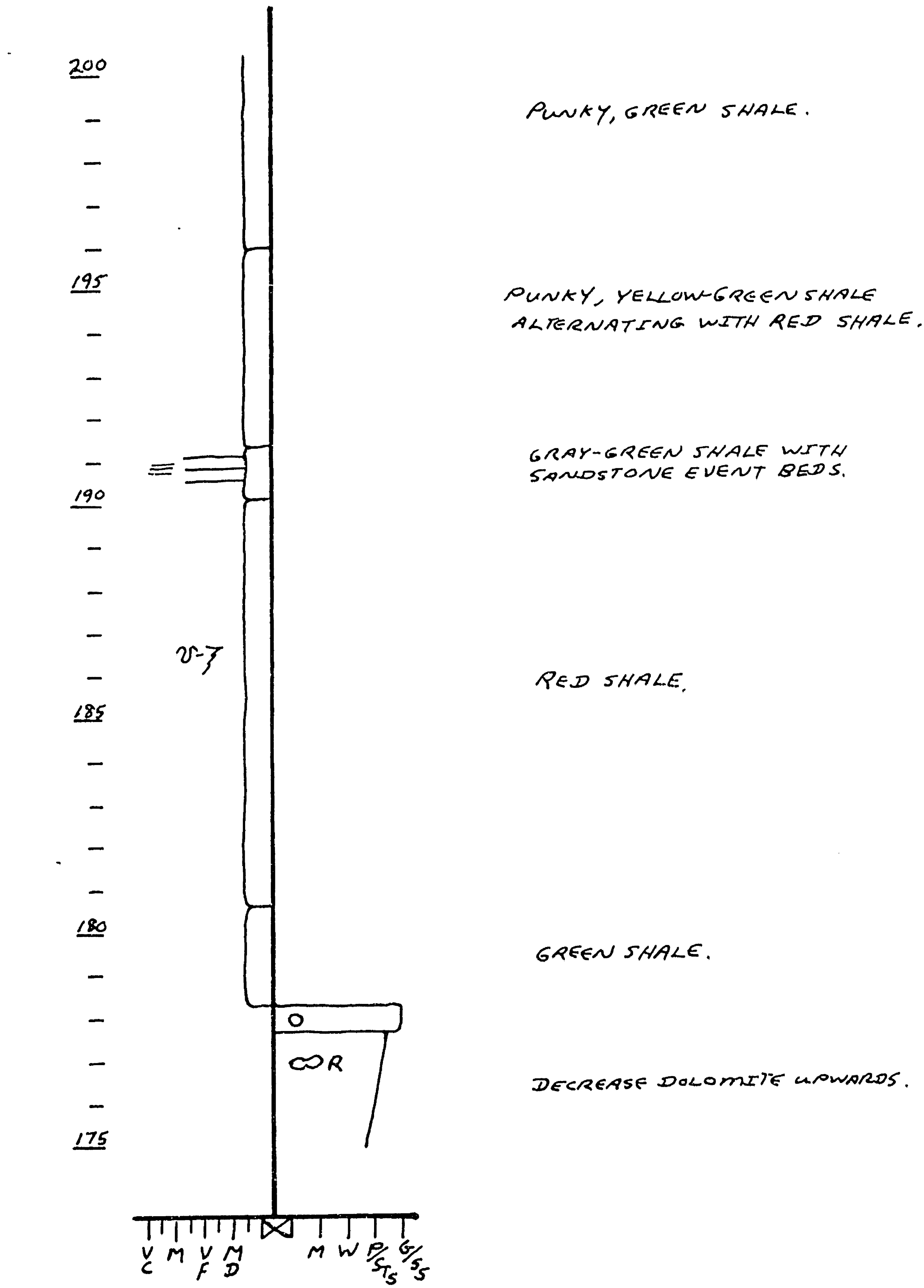

DECREASE DOLOMITE UPWARDS

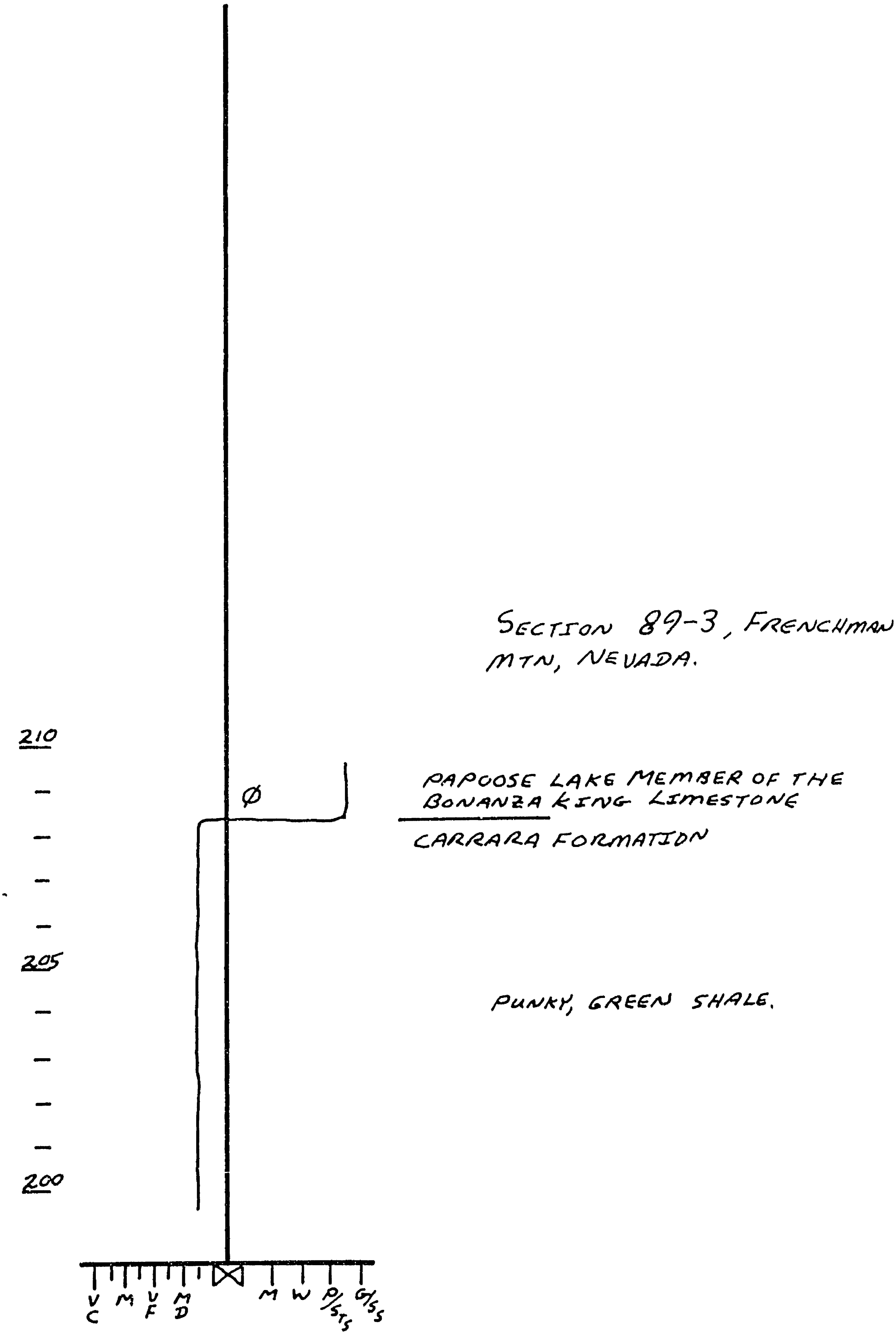
MIX OF DOLOSILTITE (≡, ⌒) AND MUDDY RIBBON ROCK

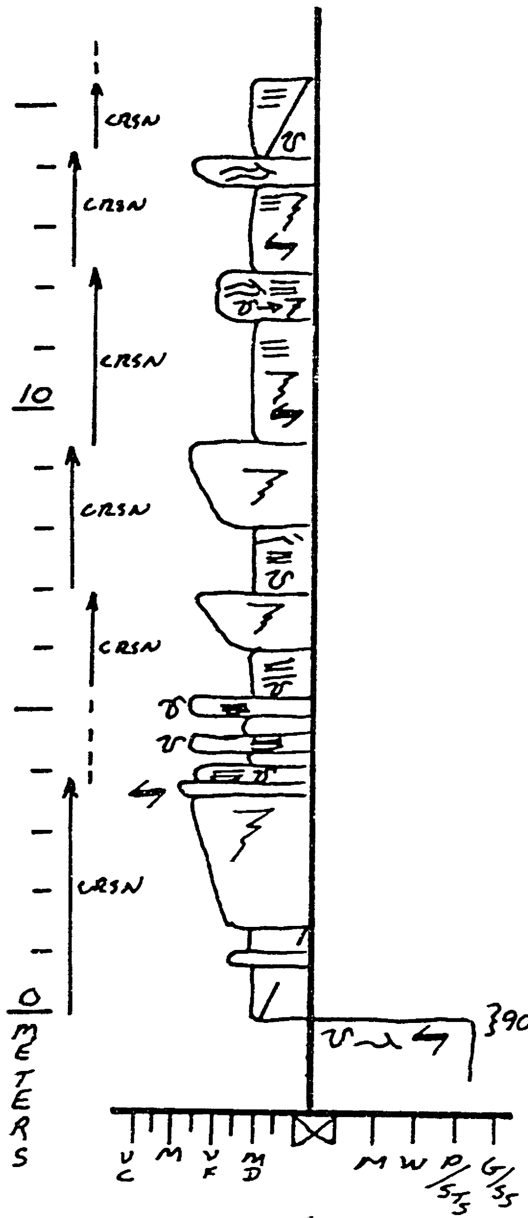
DECREASE DOLOMITE UPWARDS

INCREASE MUD UPWARDS.

DECREASE DOLOMITE UPWARDS.


200
195
190
185
180
175
PUNKY, GREEN SHALE.
PUNKY, YELLOW-GREEN SHALE ALTERNATING WITH RED SHALE.
GRAY-GREEN SHALE WITH SANDSTONE EVENT BEDS.
V-7
RED SHALE.
GREEN SHALE.
DECREASE DOLOMITE UPWARDS.
V C
M
V F
M D
M
W
P/STS
G/SS


SECTION 89-3, FRENCHMAN MTN, NEVADA.
210
205
200
Ø
PAPOOSE LAKE MEMBER OF THE BONANZA KING LIMESTONE
CARRARA FORMATION
PUNKY, GREEN SHALE.
VC
M
VF
MD
M
W
P/STS
G/SS




LIKE 7m

LIKE 10 m.

90-2 } SOME ≤ 5cm LAYERS OF INTRAFORMATIONAL CLAST CONGLOMERATE.

MUDDY SS. SOME VERTICAL BURROWS, BUT MOSTLY HORIZONTAL.

MUDDY SS.

} SS LENSOIDAL OVER 10's OF METERS. MAY HAVE ⥲.

MUDDY SS. BURROWS NOT SKOLITHOS

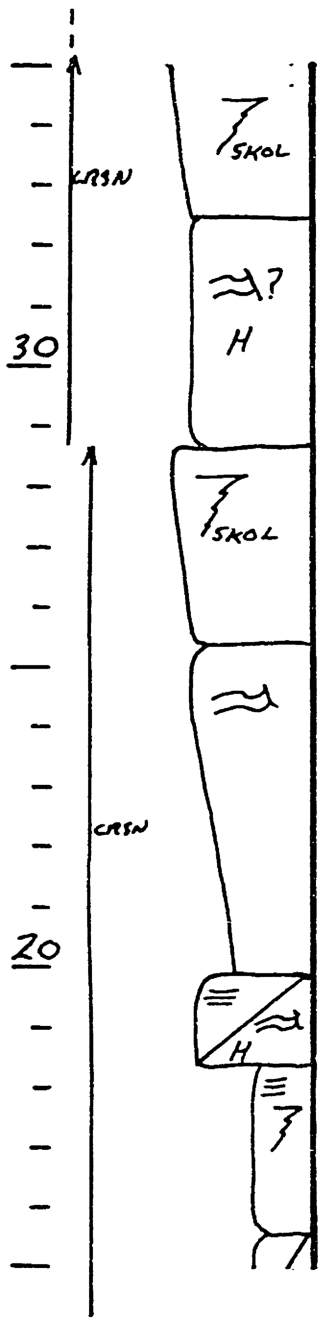
ZABRISKIE QUARTZITE

}90-1

OLIVE GRAY TO BROWN DOLOMITE WITH CHERT. SLIGHTLY SCOURED TOP CONTACT WITH A FEW CM RELIEF.

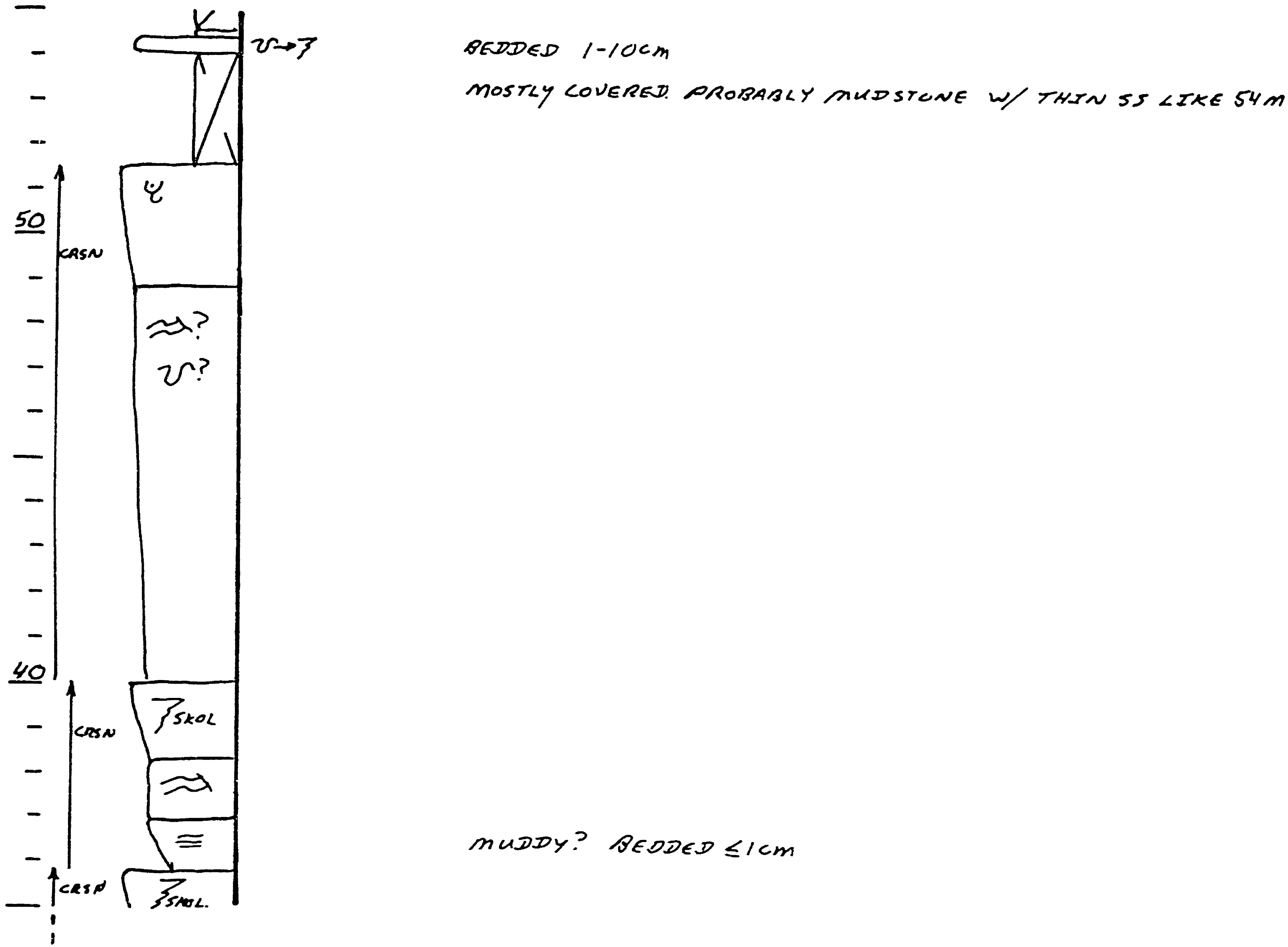
WOOD CANYON FORMATION

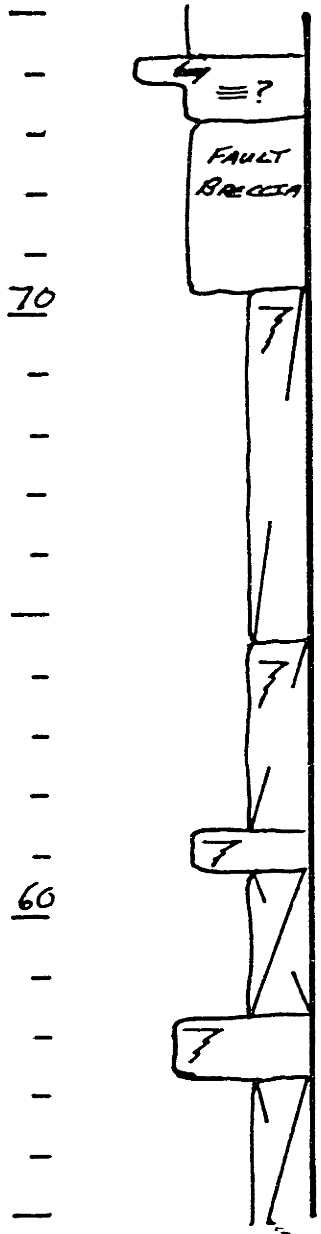
SECTION 90-1, NOPAH RNG., NORTH OF EMIGRANT PASS




BEDDES 3-10cm.

LIKE 10m.


50
40
CRSN
CRSN
CRSP
SKOL
SKOL.
BEDDED 1-10cm
MOSTLY COVERED. PROBABLY MUDSTONE W/ THIN SS LIKE 54M
MUDDY? BEDDED ≤1cm




CLASTS ARE CHERT PEBBLES IN A 10-20 cm CONGLOMERATE BED
BEDDED 10-20 cm

PURPLE, SILTY. SIMILAR TO 64m EXCEPT FOR COLOR.

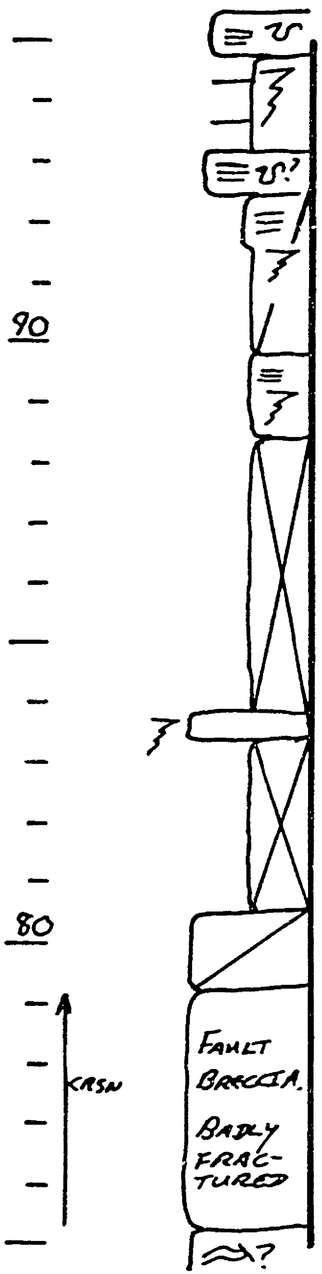
GREEN. SILTY.

LIKE 58m

LIKE 53m.

MOSTLY HORIZONTAL BURROWS W/SOME SKOLITHOS.

LIKE 53m.




LIKE 93 m.

OCCASIONAL BIOTURBATED SS LENSES, ≤10 cm THICK.

POSSIBLY BROAD & LOW AMPLITUDE HUMMOCKY CROSS-BEDS.

PURPLE, SILTY & SANDY.

GREEN, SILTY.

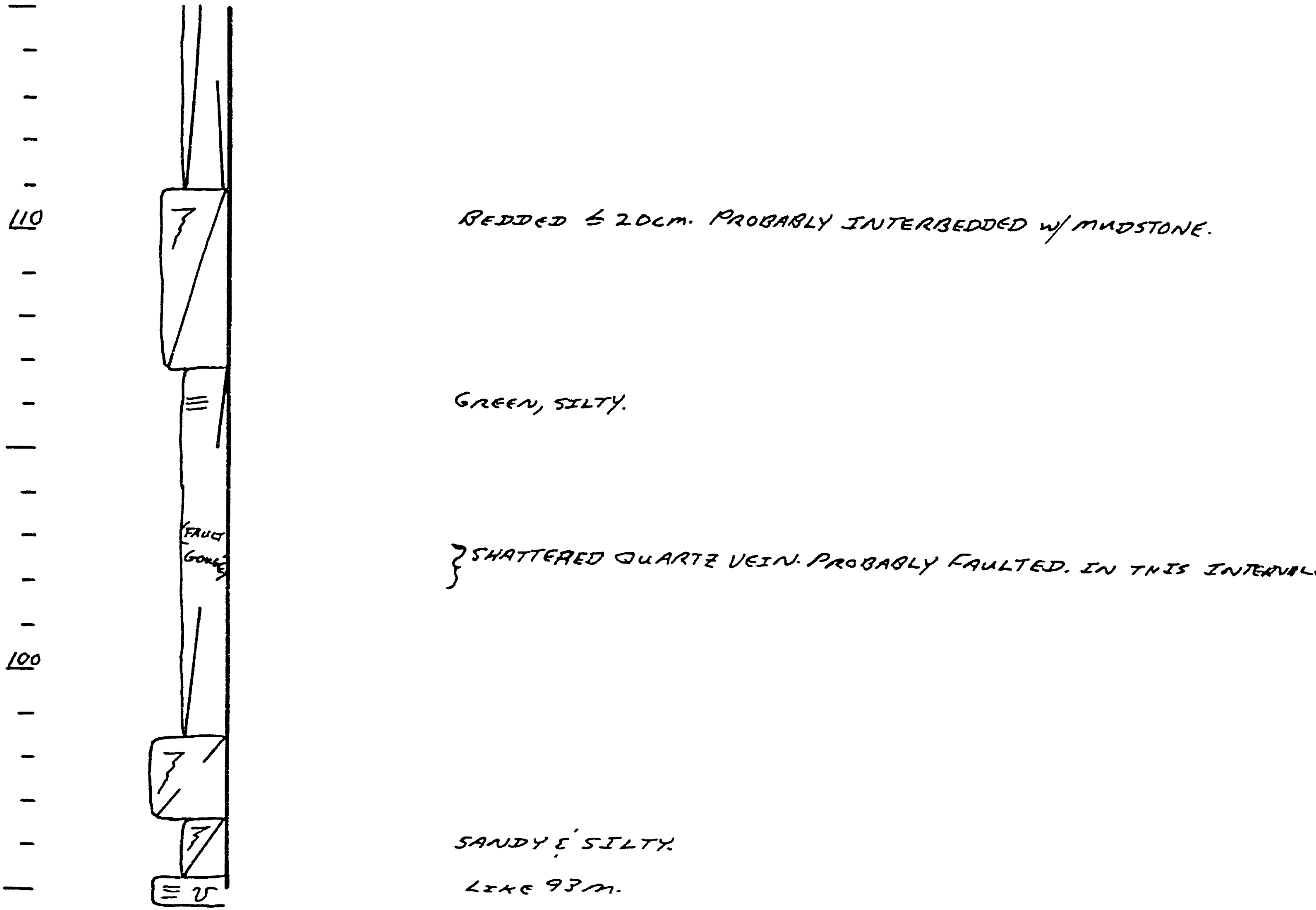
COVERED. PROBABLY SILTY MUDSTONE

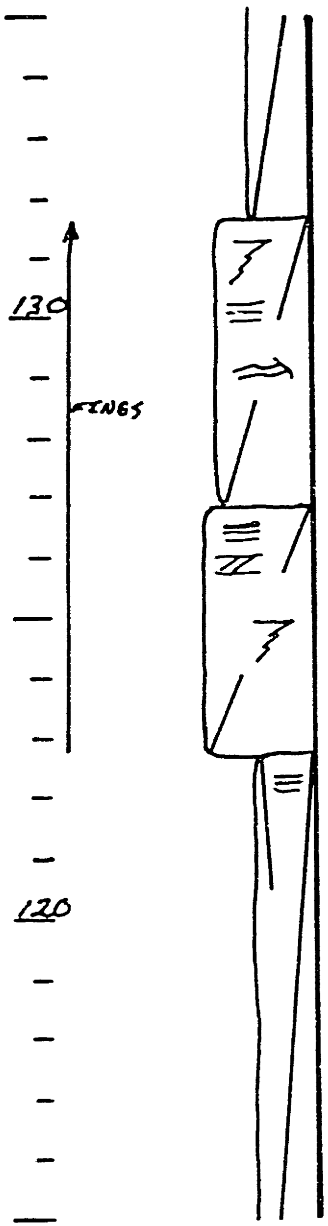
MUDDY SS

COVERED. PROBABLY MUDSTONE

PROBABLY BRECCIATED

NOTE: 70-80 m IS A FAULT ZONE.


110
100
FAULT GOUGE
BEDDED ≤ 20cm. PROBABLY INTERBEDDED w/ MUDSTONE.
GREEN, SILTY.
SHATTERED QUARTZ VEIN. PROBABLY FAULTED. IN THIS INTERVAL.
SANDY & SILTY.
LIKE 93m.



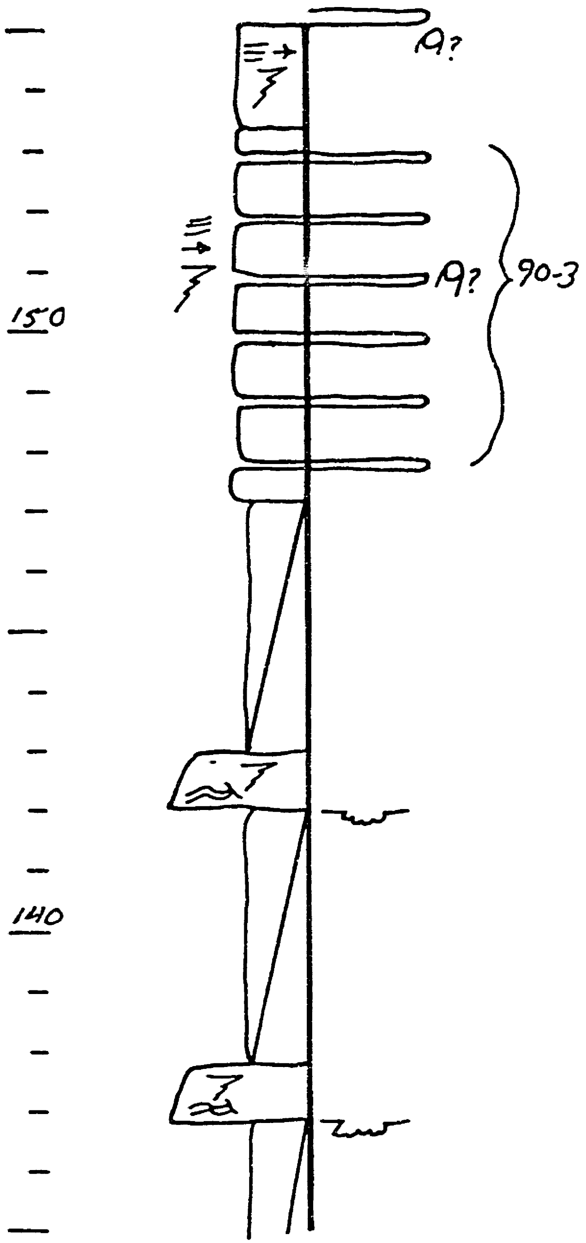

CARRARA FORMATION

SEEMS TO FINE & THIN UP. SS BEDDED $<$20 CM. ONLY BOTTOM BEDS ARE M-F GRAINED HUMMOCKY CROSS-BEDS. HORIZONTAL PLANAR LAMINATED, & BIOTURBATED INTERVALS ARE F-VF. INTERVAL MOSTLY COVERED. MAY BE MOSTLY MUDSTONE.

ZABRISKIE QUARTZITE

SANDSTONE BEDDED $\leq$ 20cm PROBABLY INTERBBEDJEDW/ SILTY MUDST. PLANAR CROSS-BEDDED INTERVALS M-F. HORIZONTAL PLANAR LAMINATED BEDS F. BIOTURBATED BEDS VF & CONCENTRATED IN UPPER PART OF INTERVAL. INTERVAL IS PROBABLY FOLDED & MAY BE FAULTED.

GREEN, SILTY MUDSTONE W/OCCASIONAL DARKER GREEN, BIOTURBATED, SANDY MUDSTONE. $\leq$5-10CM THICK & PROBABLY LENSOIDAL. MUDSTONE LIKE 105M

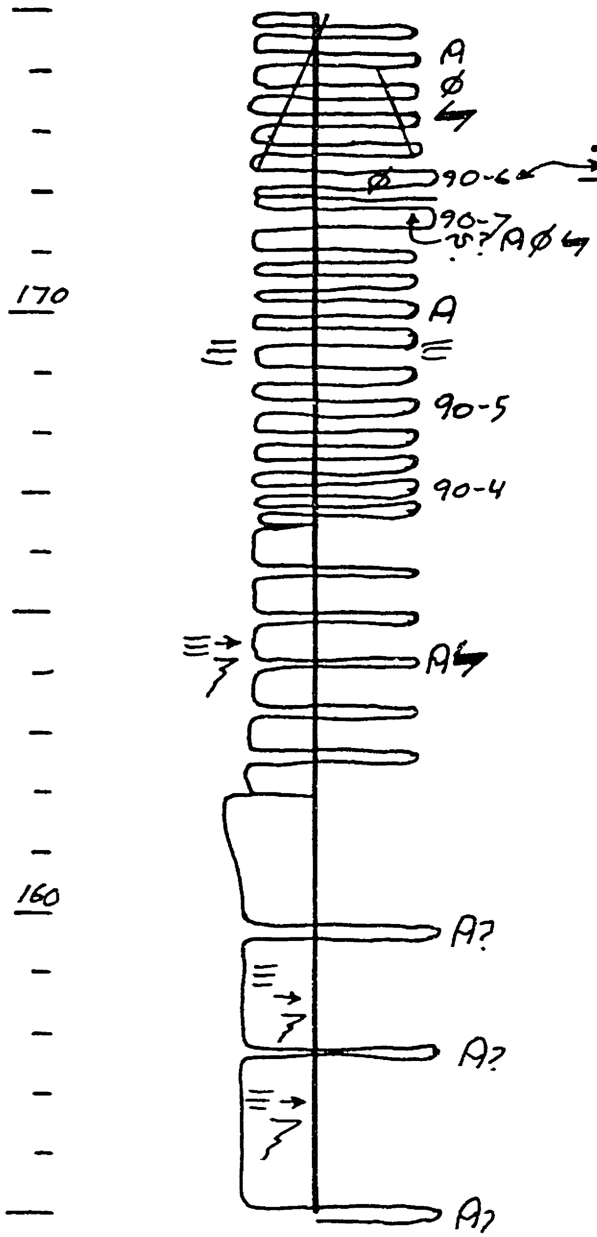



CARBONATE BEDS: FOSSILIFEROUS (POSSIBLY TRILOBITES) WACKESTONE/PACKSTONE. DOLOMITE. MAY BE DISCONTINUOUS BEDS. REDDISH-BROWN COLORATION.

SILICICLASTIC BEDS: GREEN, SILTY MUDSTONE & TAN, MUDDY, BIOTURBATED SS LIKE 145 m. Ss BEDDED < 10 cm.

147–171.5: BEDDING SHOWN SCHEMATICALLY.

131.5–147 m: SILTY, GREEN. OCCASIONAL BIOTURBATED MUDDY SS ≤1-2 cm THICK. ALSO HAVE 2 FINING-UPWARD M. TO F-VF SS LENSES ≤1 m THICK. SLIGHTLY SCOURED BASES, ≈50 m WIDE. HUMMOCKY CROSS-BEDS IN LOWER PARTS, BIOTURBATED IN UPPER PARTS.



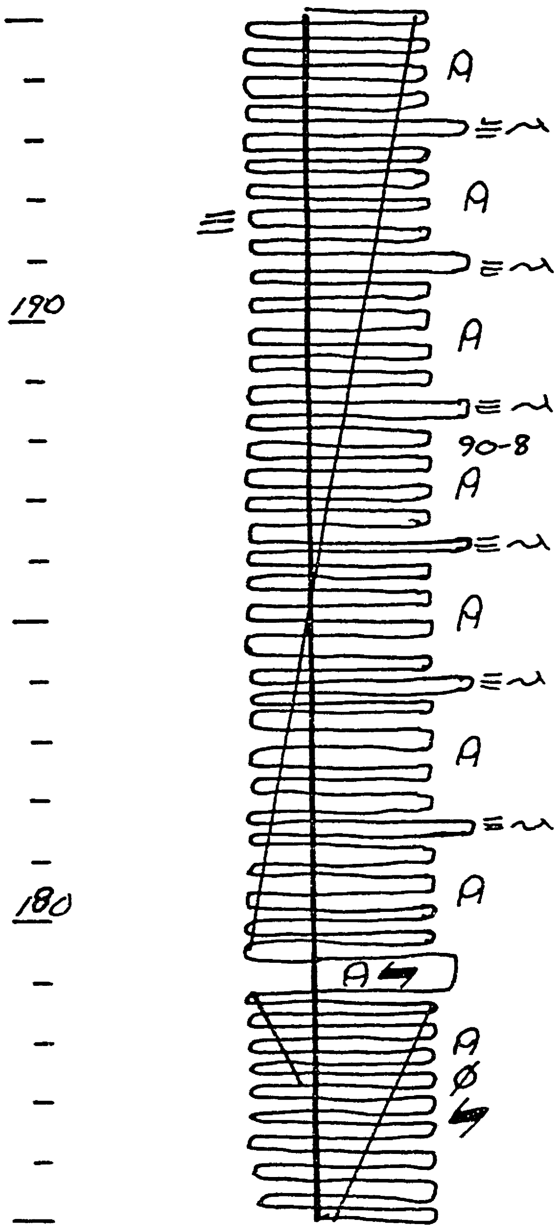

172.5–179: BEDDING SHOWN SCHEMATICALLY. ESSENTIALLY COVERED. OCCASIONAL DISCONTINUOUS SKELETAL WACKESTONE/PACKSTONE BEDS, ≤ 10 CM THICK, WITH CLASTS. OCCASIONAL ONCOLITIC WACKESTONE/PACKSTONE BEDS, ONCOIDS ≤ 2 CM.

ONCOIDS ≈ 2 CM (1ST ONCOLITIC BED) LIKE 170 M.

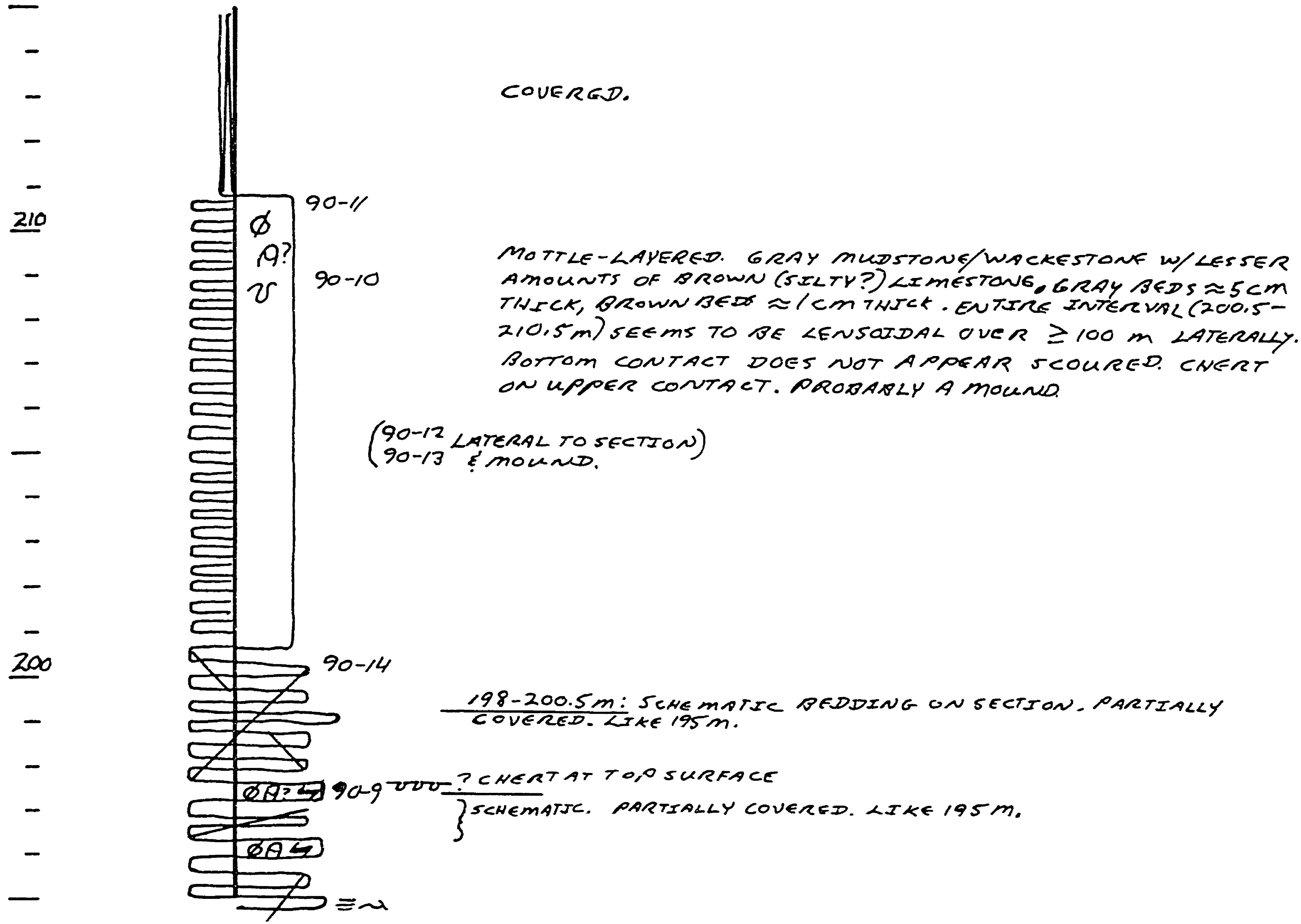
166.5–171.5 m: MORE CARBONATE BEDS THAN SILICICLASTIC BEDS. CARBONATE BEDS W/ FOSSIL FRAGMENTS & F–VF SAND SIZED QUARTZ GRAINS.

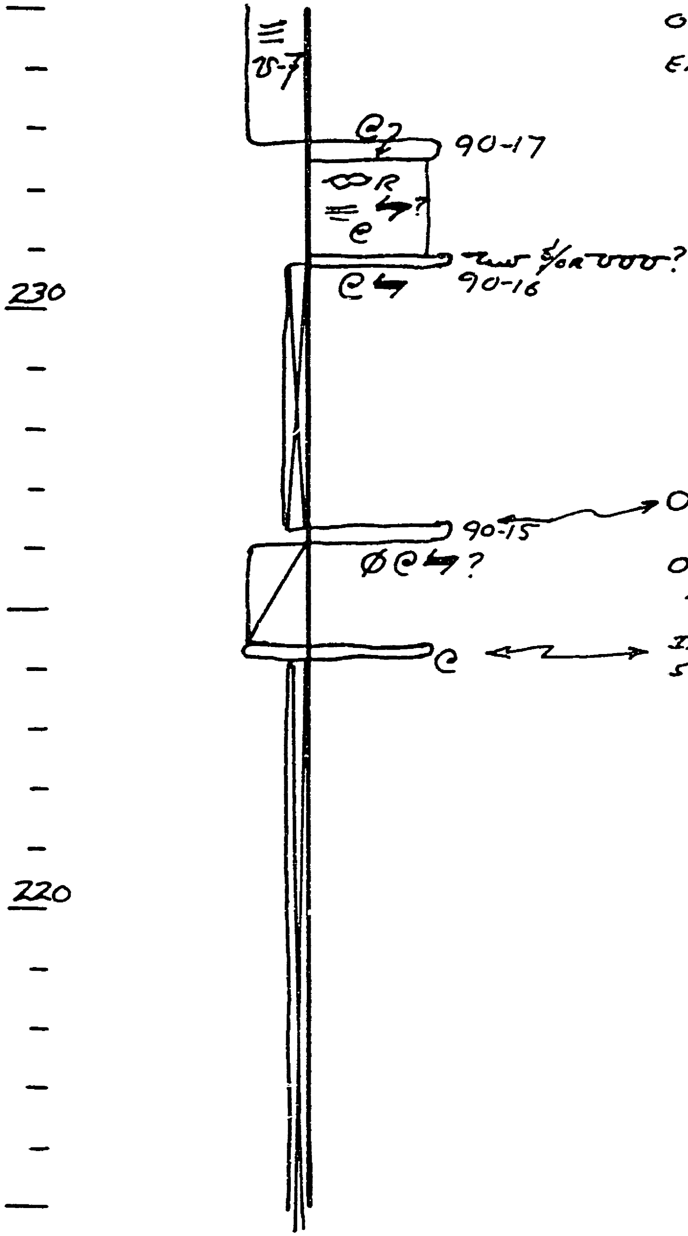
162–166.5 m: GREEN, SILTY MUDSTONE W/ UPWARD INCREASE IN NUMBERS OF THIN CARBONATE BEDS

157–162 m: GREEN SILTY MUDSTONE W/ INTERBEDS OF BIOTURBATED, MUDDY SS ≤ 2 CM THICK, & A FEW CARBONATE BEDS AS IN INTERVAL AT 150 M. THIS INTERVAL HAS MORE MUDDY SS BEDS THAN 150 M AS WELL AS A FEW HORIZONTAL, PLANAR LAMINATED VF-SILT SS/STS BEDS ≤ 3 CM THICK NEAR TOP.




179.5→196.5m: BEDDING SHOWN SCHEMATICALLY.
GREEN, SILTY MUDSTONE W/ CARBONATE INTERBEDS, MOSTLY TRILOBITE WACKESTONE/PACKSTONE, BEDDED ≤10 CM W/ MOST 1-5 CM THICK. SOME PACKSTONE/GRAINSTONE BEDS WITH HORIZONTAL PLANAR LAMINATION & POSSIBLE WAVE RIPPLES.


210
200
90-11
90-10
COVERED.
MOTTLE-LAYERED. GRAY MUDSTONE/WACKESTONE W/ LESSER AMOUNTS OF BROWN (SILTY?) LIMESTONE. GRAY BEDS ≈ 5CM THICK, BROWN BEDS ≈ 1CM THICK. ENTIRE INTERVAL (200.5–210.5m) SEEMS TO BE LENSOIDAL OVER ≥ 100 m LATERALLY. BOTTOM CONTACT DOES NOT APPEAR SCOURED. CHERT ON UPPER CONTACT. PROBABLY A MOUND.
(90-12 LATERAL TO SECTION)
(90-13 & MOUND.)
90-14
198-200.5m: SCHEMATIC BEDDING ON SECTION. PARTIALLY COVERED. LIKE 195m.
90-9
? CHERT AT TOP SURFACE
SCHEMATIC. PARTIALLY COVERED. LIKE 195m.




ORANGE, SILTY, CALCAREOUS (DOLOMITIC?) SILICA-MUDSTONE. 3 INTERVALS, EACH APPROXIMATELY 8 CM THICK, BURROWED-TO-BIOTURBATED.

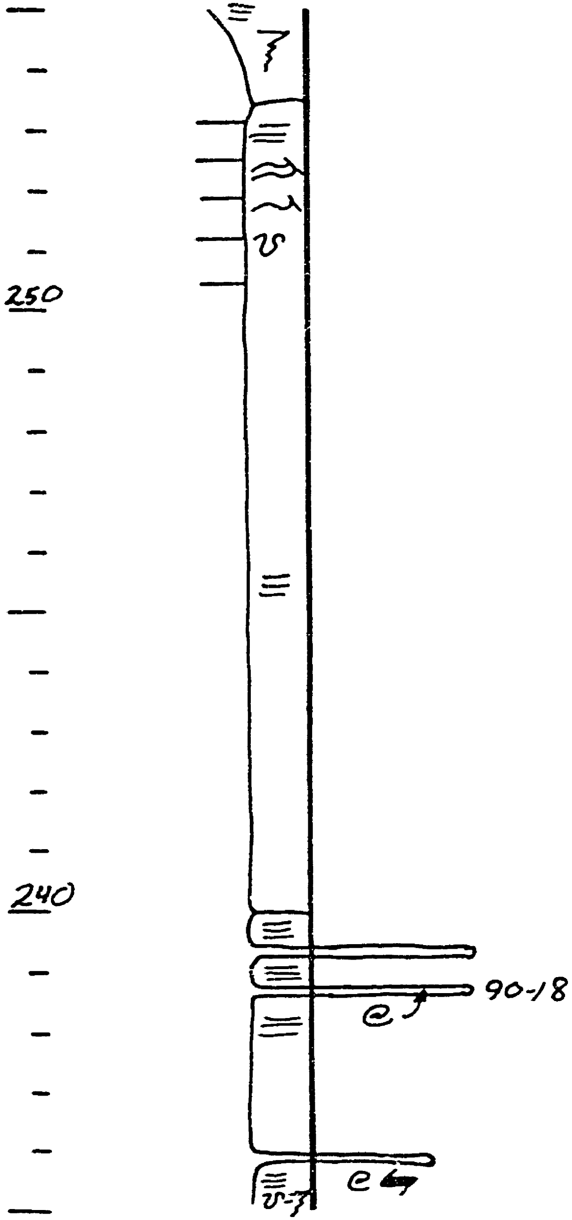
COVERED.

ONCOIDS IN TOP 3/3 OF A 20 CM THICK PACKSTONE. ONCOID ≤ 2 CM.

ORANGE, SILTY MUDSTONE, BEDDED ≤ 5 MM. CALCAREOUS, POSSIBLY DOLOMITIC

INTERBEDDED CARBONATE & SILICEOUS MUDSTONE, WITH SEVERAL BEDS (≤ 2 CM) OF FOSSILIFEROUS WACKESTONE/PACKSTONE.

COVERED.

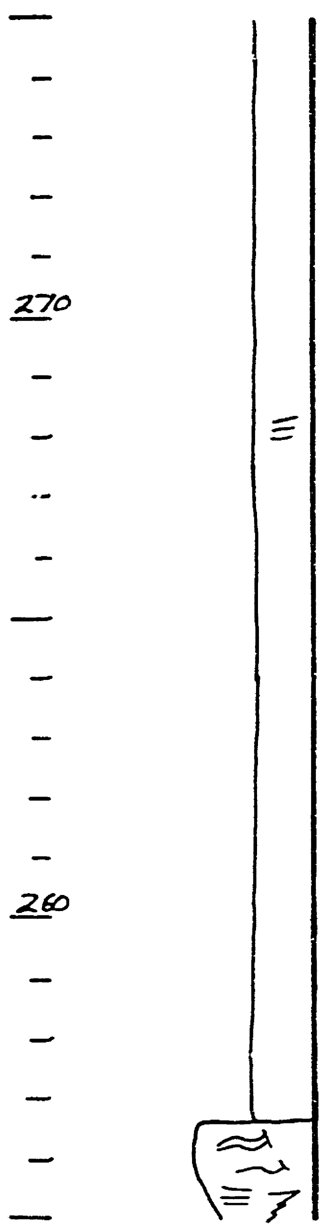



GREEN, NON-CALCAREOUS, SILTY MUDSTONE. BEDDED ≤ 2 CM. IN UPPER 25% OF INTERVAL, THERE ARE OCCASIONAL 2-10 CM THICK BEDS OF VF-F SS WITH HUMMOCKY CROSS-BEDS, WAVE RIPPLES, & SOME HORIZONTAL BURROWS. SS BEDS SHOWN SCHEMATICALLY.

2 PACKSTONE/GRAINSTONE W/ MUDSTONE LIKE 237 M ON EITHER SIDE.

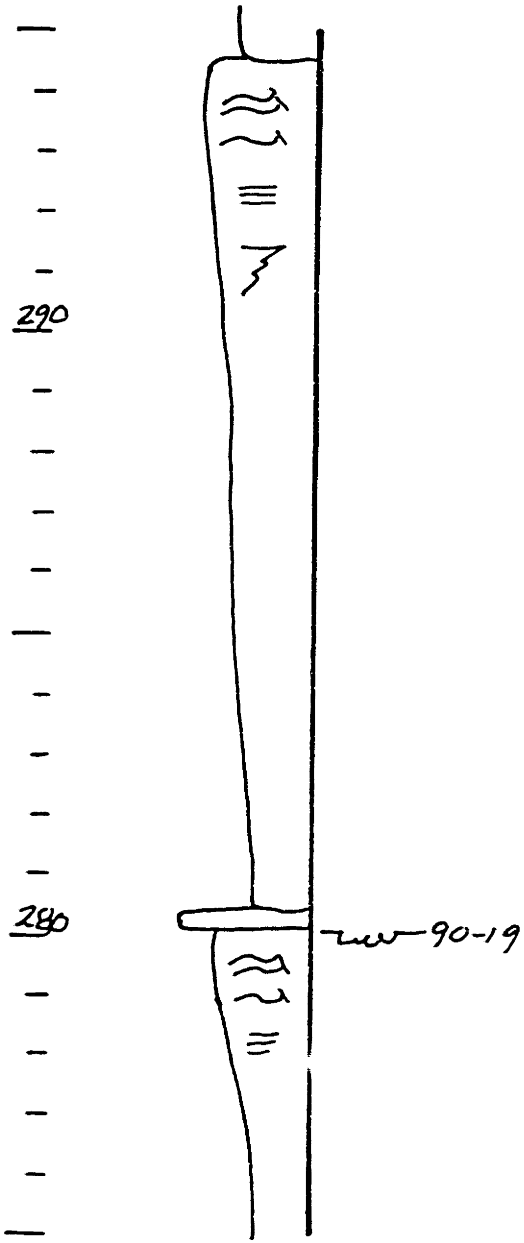
ORANGE, SILTY, CALCAREOUS (DOLOMITIC?), SILICA-MUDSTONE BEDDED ≤ 2 CM.

10 CM THICK WACKESTONE/PACKSTONE



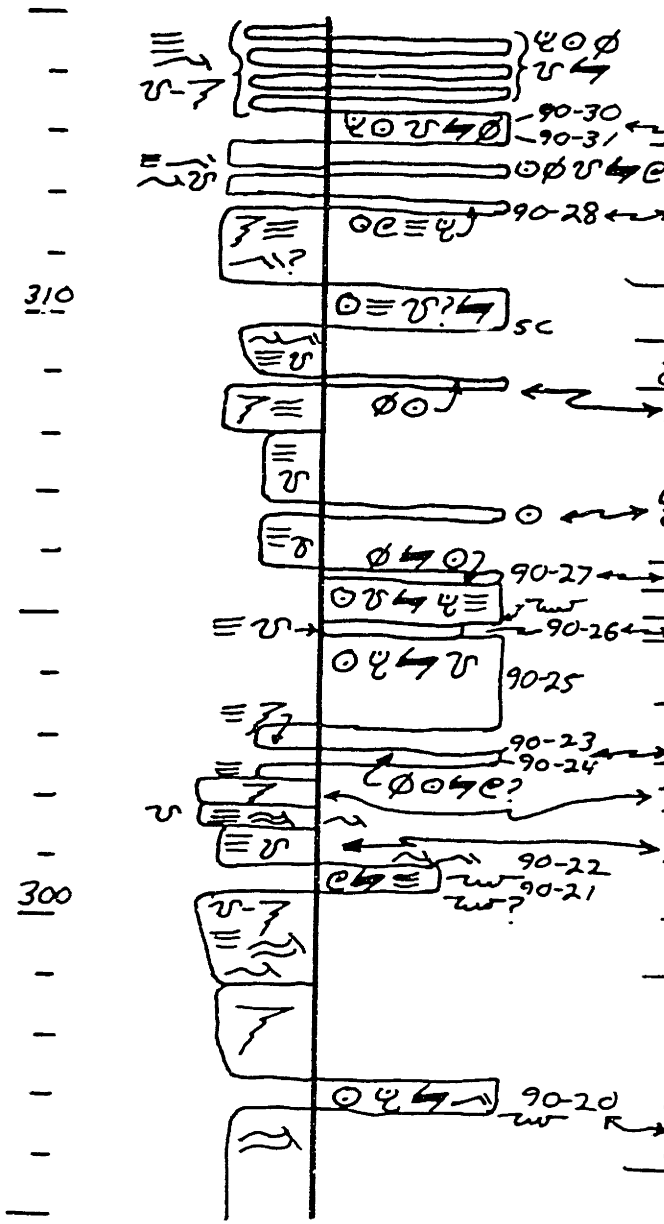

SLIGHT COARSENING & THICKENING UP. MOSTLY GREEN TO PURPLE, SILTY MUDSTONE W/ HORIZONTAL PLANAR LAMINATIONS. VF-F SS WITH HUMMOCKY CROSS-BEDS & WAVE RIPPLES, BEDDED ≤ 20 CM.

50:50 MIX OF SS & MUDSTONE. MUDSTONE HAS HORIZONTAL PLANAR LAMINATIONS. SS HAS HUMMOCKY CROSS-BEDS, WAVE RIPPLES. SS BEDDED ≤ 30-40 CM AT TOP <u>VS.</u> 5-15 CM AT BASE. LOWER 1M HAS 20-30 CM BEDS OF BIOTURBATED MUDDY SS.




SS/MUDSTONE RATIO INCREASES UPWARDS F-VF SS, HUMMOCKY CROSS-BEDS & WAVE RIPPLES ONLY IN UPPER PART. BIOTURBATED MUDSTONE & MUDDY SS.

GREEN SILTY MUDSTONE CHANGING UPWARDS TO BIOTURBATED MUDSTONE. BEDDED ≤ 1CM.




313.5-315m: BEDDING SHOWN SCHEMATICALLY. INTERBEDDED GRAINSTONE (LIKE 313.0m) & SILTSTONE TO VF SS. CARBONATE BEDDED ≤10cm. STS & SS BEDDED 1-4cm. RECESSIVE WEATHERING.

TOP IS OOLITIC GRST. MIDDLE IS CALCARENITE. BOTTOM 5 cm IS LITHOCLASTS, ONCOIDS

VF SS W/ GRST BED IN MIDDLE

GRAINSTONE/CALCARENITE W/ A 3cm BED OF BROWN, VF SS IN CENTER.

GREEN-TAN VF-F SS, BIOTURBATED. SOME POSSIBLE WAVE RIPPLES W/ CURRENT RIPPLES

⊙ ≤ 1mm. MOSTLY IN BOTTOM 10-20cm. SOME ORANGE, SILTY, DOLOMITIC, INTERLAMINATIONS W/ ≡.

SILTY MUDSTONE (≡ ʊ) W/ OCCASIONAL VF SS, BEDDED ≤ 1.5cm, (≡ ~)

Ø ≤ 1-2cm. MAY HAVE SOME QUARTZ GRAINS

GREEN, SILTY MUDSTONE, BEDDED ≤ 5mm.

OOLITIC GRST W/ A 1cm THICK BROWN, SILTY DOLOSILT INTERBED IN CENTER.

GREEN, SILTY MUDSTONE, BEDDED ≤ 5mm.

Ø ≤ 1-2 cm. ⊙ ½ -1mm. ≤ 1x7cm. VARIABLE THICKNESS LIKE 304m.

ORANGE DOLOSILTITE. 10-30cm THICK.

⊙ ≤ ½ mm. 5-15cm. ORANGE-BROWN, SILTY LITHOCLASTS & ʊ-FILL & INTERLAMINATIONS

TAN, SILTY CALCAREOUS, SILICA-MUDSTONE

ONCOLITIC GRAINSTONE ATOP ⊙ GRAINST. , @ IN Ø GRST. BASAL 3 cm IS A CONGLOMERATE.

GREEN MDST, ≤ 5mm BEDS

MUDDY SS. LIKE 300m

LIKE 298m

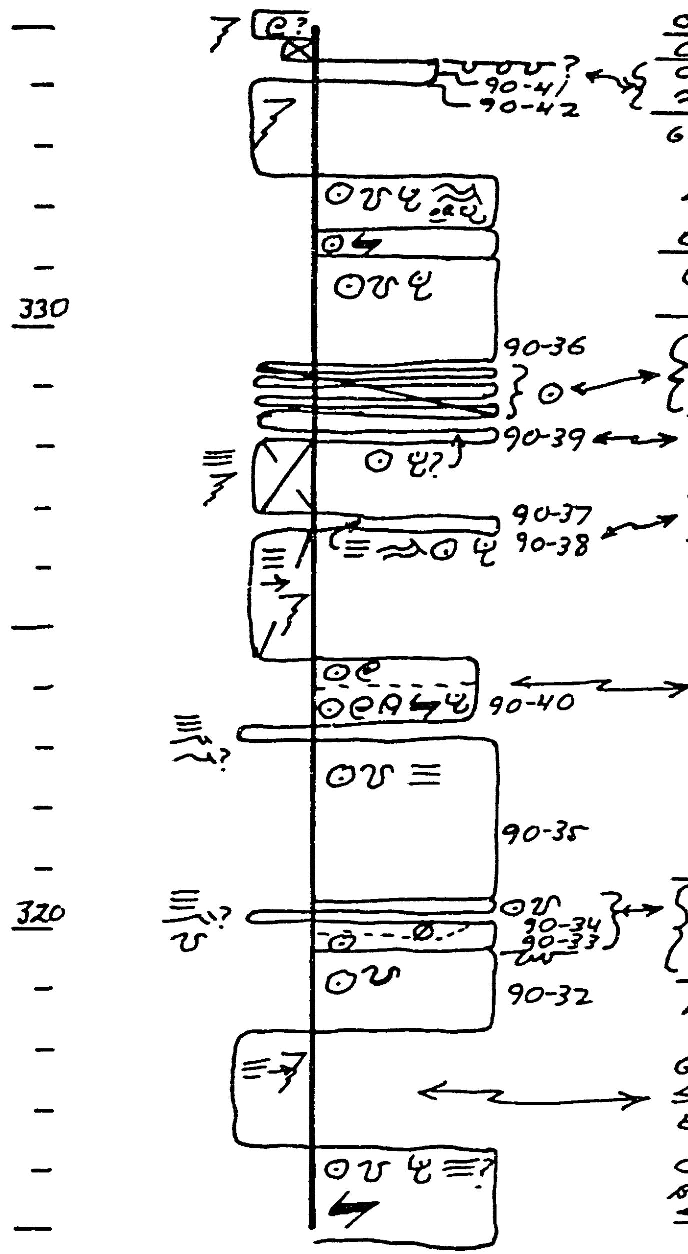
@ WKST/PKST W/ VF SS & SILICEOUS MDST INTERBEDS. ≡, ~, IN SS. ≡ IN MDST

VF-F COARSENS UP TO F SS. UPPER 20-30 cm BURROWED-TO-BIOTURBATED

VF COARSENS UP TO VF-F, BIOTURBATED SS. BURROWS NOT OFTEN VERTICAL.

GRST. OF BROWN, SILTY DOLOMITE, 0.5-1.5 X 5-15 cm, SOME CURVED, SOME HORIZONTAL PLANAR LAMINATED. BROWN DOLOSILTITE INTERLAMINATIONS.

VF SS




OLIVE GREEN, SILTY, CALCAREOUS, SILICA-MUDSTONE

COVERED

OLIVE-GREEN FOSSILIFEROUS WKST/PKST W/F-VF QTZ SAND, A FEW Ø ≈1CM. SMOOTH UPPER SURFACE W/ BURROWS PENETRATING DOWN INTO UNIT

GREEN, SILTY MUDSTONE

LIKE 330.0 M. ≈ OR ¥ ON TOP.

CLASTS ANGULAR TO ROUND, IN AN OOLITIC GRST.

OOLITIC (≤½ mm) GRST. W/ DOLOSILTITE INTERLAMINATIONS. GRST BEDDED 10-30CM. DOLOSILTITE BEDDED ≤15 CM, MOST 1-3CM.

328.5-329.5 m: BEDS SCHEMATICALLY SHOWN. INTERBEDDED OOID GRST & BIOTURBATED, SILICEOUS MUDSTONE. BOTH BEDDED 2-10 CM

OOLITIC GRST W/ DOLARENITE INTERLAMINATIONS

MIXED SILICICLASTICS AND CARBONATE IN LOWER ½ W/ ≡ ≈ & ¥. UPPER ½ IS CLEAN OOLITIC (<½ mm) GRST

GREEN SILTY MUDSTONE W/OCCASIONAL VF SS BEDS ≤1-2CM THICK.

OOIDS (½ mm) DOMINANT IN TOP ½. FOSSIL FRAGMENTS DOMINANT IN LOWER ½. ¥ 5-10 CM HIGH. DOLOSILTITE BEDS ≤ 2 CM IN LOWER ½

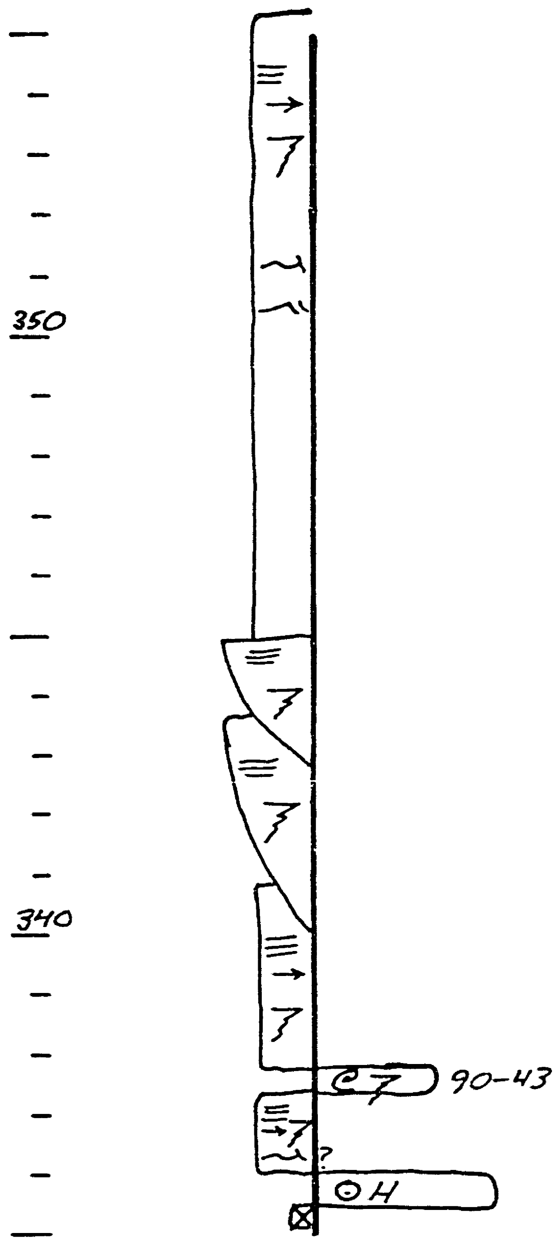
GREENISH-GRAY. BURROW-MOTTLING. ⊙ ½ mm. LIMESTONE BEDDED 10-20 cm. DISCONTINUOUS DOLOSILTITE INTERLAMINATIONS 1-2 CM THICK, W/ ≡. BURROWS BOTH HORIZONTAL & VERTICAL.

OOIDS 3/4-1 mm. ONCOLITE BED IS DISCONTINUOUS. UPPER OOLITE IS BURROW-MOTTLED. THIN SILICEOUS MUDSTONE BED. BOTTOM CONTACT HAS 10 CM OF RELIEF—SCOURED OR KARST?

REDDISH. NOT MOTTLED. ⊙ APPROXIMATELY ½ mm.

GREEN, SILTY MUDSTONE W/OCCASSIONAL VF SS (≡) BEDDED ≤2cm. MUDSTONE BEDDED ≤5 mm. NON-CALCAREOUS EXCEPT FOR BASAL 20 CM, WHICH IS ORANGE.

OOLITIC (<1mm) GRST, BEDDED ABOUT 10 cm. ORANGE-BROWN DOLOSILTITE IN NUMEROUS INTERLAMINATIONS ≤1-2 cm, & IN BURROW-FILLS. ↳ OF DOLOSILTITE.




GREEN, WEATHERED TO PURPLE-GRAY-SILTY SHALE TO SILTY MUDSTONE. THE LOWER 4-5 m ARE MOSTLY LIGHT GREEN, SILTY SHALE (≡, 1-2 mm). THE UPPER 12 m ARE MOSTLY BIOTURBATED, SILTY MUDSTONE BEDDED 1-2 cm, W/ INTERVALS OF SILTY SHALE (≡). GENERALLY MORE MUDSTONE ABOVE THE CHANNEL COMPLEX & MORE SHALE BELOW. SOME WAVE & CURRENT RIPPLES IN SEDIMENTS ABOVE THE CHANNEL COMPLEX, BUT NONE FOUND IN COMPLEX OR BELOW.

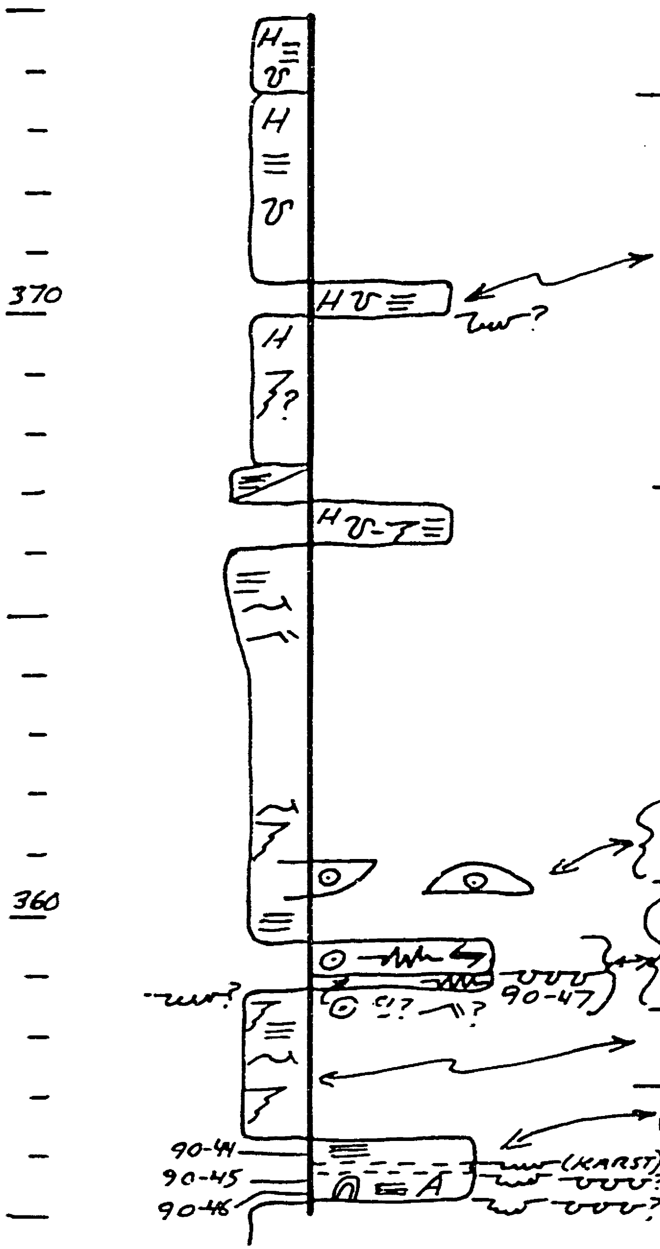
FROM 341-344 m: A CHANNEL COMPLEX OF AT LEAST 2 CHANNELS FILLED W/ ORANGE-BROWN, MUDDY VF SS. MOSTLY BIOTURBATED, WITH SOME ≡ BEDS ≤ 2 cm THICK. APPROXIMATELY 50 m WIDE.

OLIVE-GREEN WKST/PKST LIKE 334.2 m, BUT WITH BETTER-DEVELOPED LAYERING WITH SILTY CARBONATE MUDSTONE.

GREEN, SILTY MUDSTONE, BEDDED ≤ 1 cm. SOME INTERBEDDED VF SS (~?).

OOLITIC (< ½ mm) GRST, BEDDED 10 cm. VERY CLEAN W/ ONLY A FEW < 5 m THICK LENSES OF ORANGE DOLOSILTITE.

COVERED.




GREEN, BLOCKY MUDSTONE LIKE 369 m, EXCEPT COLOR. SOME DOLO-SILTITE INTERLAMINATIONS IN BASAL 25 cm.

RED, BLOCKY TO PLANAR LAMINATED MUDSTONE LIKE 369 m, BUT WITH MORE ≡, & CAN DISTINGUISH INDIVIDUAL BURROWS

ORANGE DOLOSILTITE LIKE 366.5 m.

RED, BLOCKY MUDSTONE, NOT VERY SILTY. MOTTLED BIOTURBATED TEXTURE. 1ST GOOD RED MUDSTONE.

PINK STS & VF SS. SIMILAR TO BOTTOM OF UNIT BENEATH.

ORANGE DOLOSILTITE, W/ QUARTZ GRAINS. THICKENS UP FROM 1 cm BEDS TO 15 cm BEDS. LOWER PART IS BURROWED-TO-BIOTURBATED W/ ≡. UPPER PART IS MORE HOMOGENEOUS-LOOKING IN BEDS

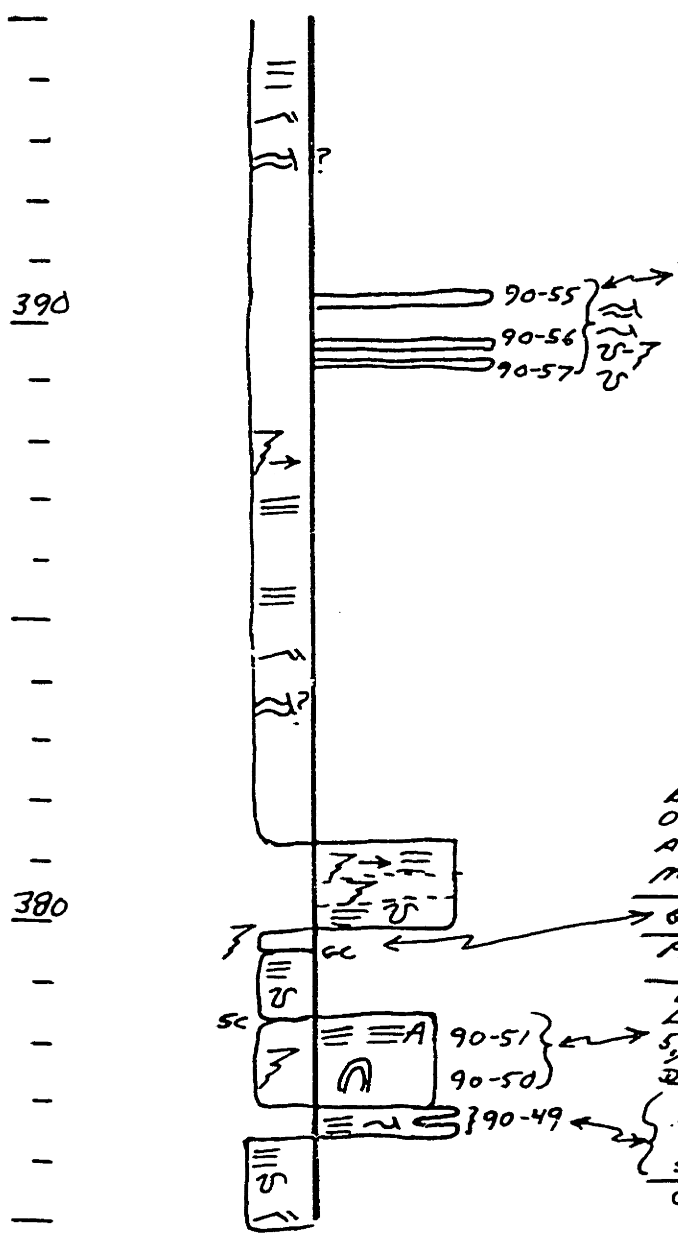
GRADATIONAL CHANGE UPWARDS FROM GREEN, SILTY MUDSTONE (≡) TO GREEN, MUDDY SILTSTON & VF SS (≡). ALL BEDDED ≤ 2 cm

HAVE 2 LATERALLY DISCONTINUOUS ⊙ GRST BEDS AT APPROXIMATELY THE SAME STRATIGRAPHIC LEVEL, ONE CHANNEL-SHAPED & THE OTHER MOUND-SHAPED.

LATERALLY CONTINUOUS OOID GRST, W/ BROWN SILTY INTERLAMINATIONS & LITHOCLASTS (≤ 3 cm). A SMOOTH SURFACE W/ APPROXIMATELY 1 cm RELIEF TRUNCATES OOIDS BELOW. UPPER GRST W/ OOIDS APPROXIMATELY 1 mm DIAMETER. LOWER GRST W/ OOIDS OF 0.5 mm DIAMETER.

MOSTLY GREEN, SILTY MUDSTONE (≡), W/ OCCASIONAL VF SS INTERBEDS, ≤ 3 cm (≡). TOP 5 cm IS BIOTURBATED MUDDY SS. TOP CONTACT MAY BE SCOURED.

ORANGE CARBONATE: BOTTOM IS FINELY LAMINATED ≡ A & BROAD, (20 cm WIDE) STROMATOLITES. GRADES UP TO COARSE ≡ A & SMALL (2-3 cm), BUT HIGHER-DOMED STROMATOLITES. MIDDLE IS A COARSE PKST/GRST W/ QUARTZ SILT, THAT THINS & PINCHES OUT LATERALLY. TOP IS CARBONATE SILTITE/ARENITE W/ ≡ & DISCONTINUOUS SCALLOPED 1-3 mm INTERLAMINATIONS.




RED MUDSTONE, APPROXIMATELY ½ BLOCKY & BIOTURBATED/CHURNED, W/ THE OTHER ½ ≡ WITH BURROWS. A FEW INTERBEDS ≤ 5 CM THICK OF F-VF SS W/ ≡, ⌒, & POSSIBLE ≈.

THREE CALCARENITE BEDS, 5-12 CM THICK, WITH SOME QUARTZ GRAINS. LATERALLY DISCONTINUOUS.

BROWN-ORANGE DOLOSILTITE W/ SOME QUARTZ SILT. MIDDLE OF INTERVAL IS BIOTURBATED. UPPER & LOWER PARTS ARE MORE BURROWED-TO-BIOTURBATED W/ SOME ≡. ALSO MORE SILICEOUS THAN MIDDLE

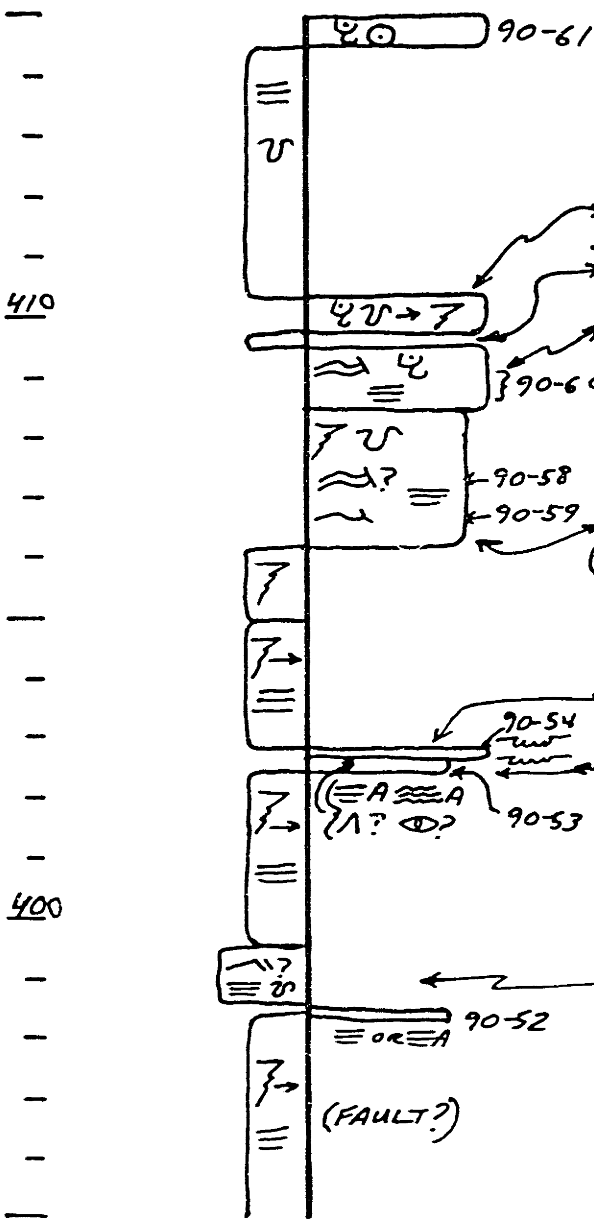
GREEN, SILTY, BIOTURBATED MUDSTONE, LIKE 378 M.

PINK-TAN MDST & SILTY MDST

CARBONATE UNIT IS LATERALLY DISCONTINUOUS & LATERALLY EQUIVALENT TO GREEN, SILTY, BIOTURBATED SILICEOUS MUDSTONE. LOWER 50-80 CM IS GRAY, SMALL HIGH-DOMED STROMATOLITES; UPPER ½ IS WACKESTONE W/ PLANAR ALGAL LAMINATIONS, QUARTZ SILT & DOLOSILTITE INTERLAMINATIONS. (MOUND-SHAPED?)

A COMPLEX UNIT W/ 3 PARTS UPPER & LOWER: ORANGE DOLOSILTITE LIKE 366.5 M, MOSTLY ≡, SOME ~ AT TOP OF LOWER BED. THE MIDDLE IS GRAY WACKESTONE INTERBEDDED W/ ORANGE DOLOSILTITE, BOTH BEDDED 1-2 CM

ORANGISH-GREEN OR TAN, MUDDY STS. BEDDED 5-10 MM.




OOLITIC (≤¼ mm) GRAINSTONE. HERRINGBONE ≤ 10cm. SOME ORANGE DOLOSILTITE INTERLAMINATIONS ≤ 1cm.

GREEN, MUDDY SILTSTONE, ≤ 1 cm, MOST < 5 mm.

GREENISH INTERBEDDED CALCARENITE (GREEN) & DOLARENITE (BROWN). UPPER ½ ʊ-ʒ. LOWER ½ (15 cm HIGH).

GREEN MUDSTONE LIKE 411 m

GRAY CALCARENITE. ≈ & ≤ 10 cm. 10-15% ORANGE DOLOSILTITE. ALL BEDDED < 1 → 8 cm THICK.

BEDDED CALCARENITE, DOLARENITE, CALCISILTITE & DOLOSILTITE, 2-15 cm, ALL PROBABLY W/ QUARTZ SILT. INTERVAL IS DIVIDED INTO 4 UNITS: UPPER IS 90 cm THICK & LWR 3 ARE 30 cm, 50 cm & 60 cm THICK. LOWER 3 UNITS HAVE VERTICAL SUCCESSION OF STRUCTURES!

TOP ① ʒ 2-15 cm
② ~ & ≈ 5-20 cm, SOME ʊ
BTM ③ ʊ-ʒ W/ ≡ ~ 5-25 cm

FOR EACH OF LWR 3 UNITS. UPPER 90 cm THICK UNIT IS A MIX OF ② & ③.

GREEN TO BROWN SILTY MUDSTONE. TOP 5 cm DISTINCTLY BURROWED, POSSIBLY W/ A CARBONATE MATRIX.

RED MUDSTONE LIKE 390 m

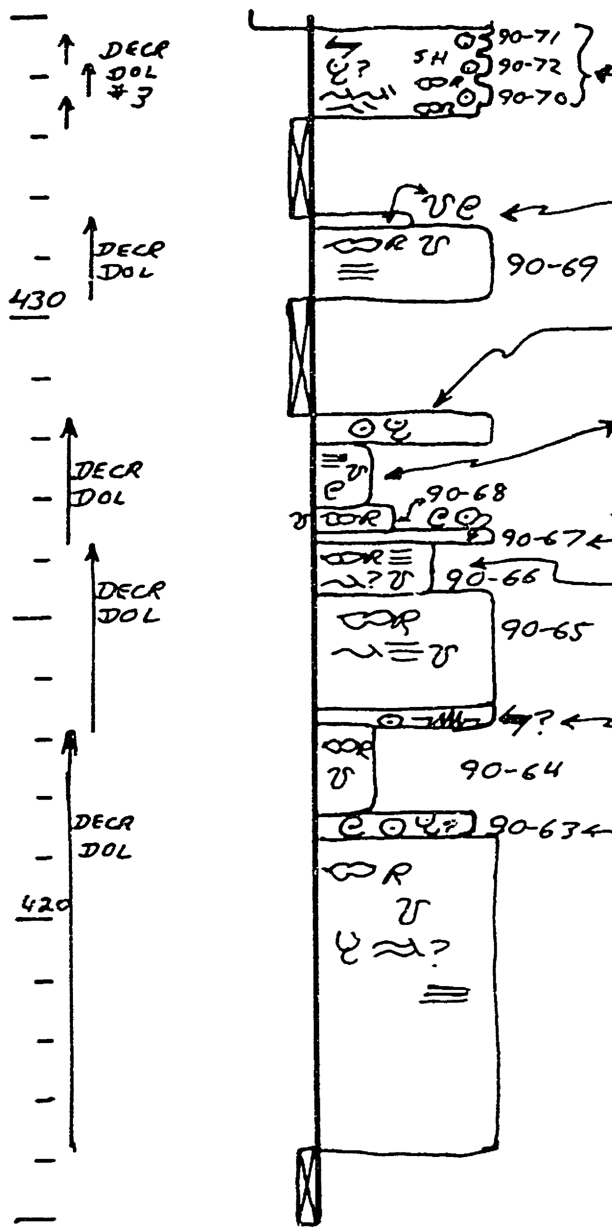
GLAUCONITE? BRIGHT GREEN SPHERES ≤ 5 mm IN WHITE, NON-CALCAREOUS MUD MATRIX. VARIES 3-13 cm THICK. SCOURED UPPER & LOWER CONTACTS W/ 10 cm RELIEF ON UPPER CONTACT.

ORANGE DOLOSILTITE. LOOKS LIKE INTERTIDAL-SUPRATIDAL. BOTTOM CONTACT LOOKS CONFORMABLE W/ RED MUDSTONE.

RED MUDSTONE LIKE 390 m.

PINK, MUDDY VF SS (~ ≡ ʊ) & SANDY, SILTY MUDSTONE (ʊ-ʒ) INTERBEDDED. BOTH BEDDED ≤ 2 cm. MAY BE DISCONTINUOUS.

5 cm THICK OLIVE-GREEN LIMESTONE W/ SOME QUARTZ VEIN MATERIAL. PROBABLY AFFECTED BY FAULTING.




TWO MAIN LITHOLOGIES: (1) LIGHT GREEN OOLITIC (≤1/4 mm) GRST, SOME BURROWS, W/ & W/OUT DOLOSILTITE. FEW LITHOCLASTS. ? 5-20 cm. (2) BROWN-TAN CALCISILTITE TO CALCARENITE W/ QUARTZ GRAINS, , ALL IN WELL-LAYERED RIBBON ROCK, 20-30 cm THICK. BESIDES 2 MAIN LITHOLOGIES, THERE IS SILICEOUS MUDSTONE LIKE 436 m BELOW TOP 2 THIN GRST BEDS. TOP 2 GRST BEDS MERGE LATERALLY. OVER LATERAL DISTANCES OF 10'S OF m, NUMBER & THICKNESS OF BEDS VARIES.

COVERED. SEE 429 m

GRAY WKST W/ BURROW-FILL OF DOLOSILTITE.

RECESSIVE WEATHERING CALCARENITE & DOLOSILTITE, 50/50 MIX. HEAVILY BURROWED. BEDDED APPROXIMATELY 1-2 cm.

COVERED.

GRAY-GREEN OOLITIC (1/4-1/2 mm) GRST.

GRAY WACKESTONE, BEDDED 1-8 cm (≡ ) & SOME <1 cm BEDS OF FOSSILIFEROUS PKST. ORANGE-BROWN DOLOSILTITE (≡) ≤1-3 cm, ABOUT 25-35% OF ROCK.

GRAY MUDSTONE/WACKESTONE, W/ ORANGE-BROWN DOLOSILTITE IN BURROWS, <5-10% OF UNIT. SIMILAR TO 423 m

GRAY FOSSILIFEROUS-OOLITIC GRAINSTONE, W/ POSSIBLE LITHOCLASTS.

GRAY WACKESTONE/PACKSTONE, BEDDED 1-3 cm (≡ ?). INTERBEDDED ORANGE-BROWN DOLOSILTITE, BEDDED ≤1 cm ( ≡). 20-25% DOLSTS.

GRAY CALCARENITE, BEDDED ≤3 cm ( ≡ ), W/ FINE QUARTZ SAND. INTERBEDDED W/ PINK-BROWN DOLOSILTITE, BEDDED ≤3 cm ( , ≡). MORE BURROWED AT BOTTOM. ABOUT 40% DOLOSITIVE OVERALL.

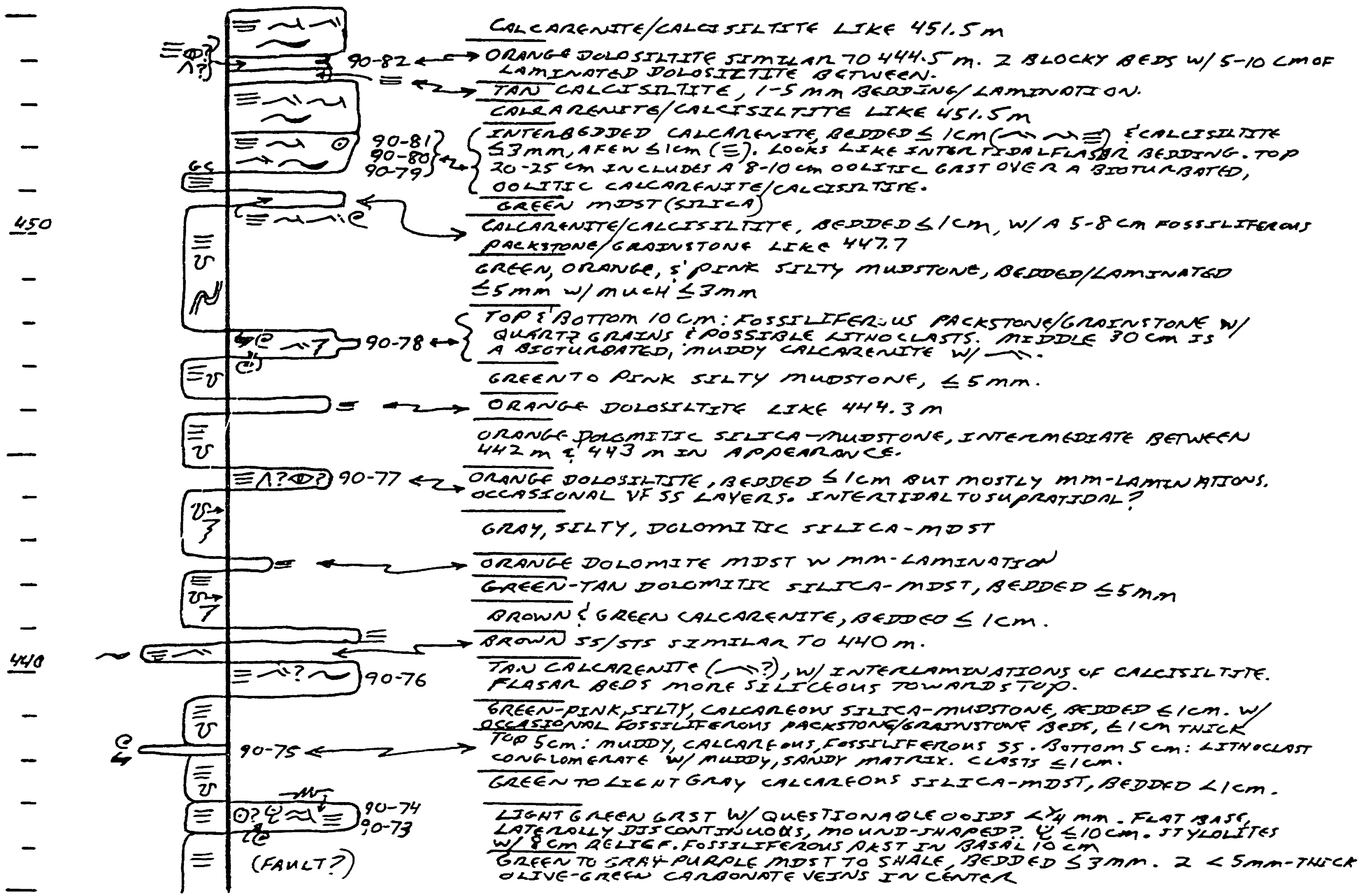
GREEN-GRAY, OOLITIC (1/2 mm) GRST, WITH DOLOSILTITE INTERLAMINATIONS NEAR TOP

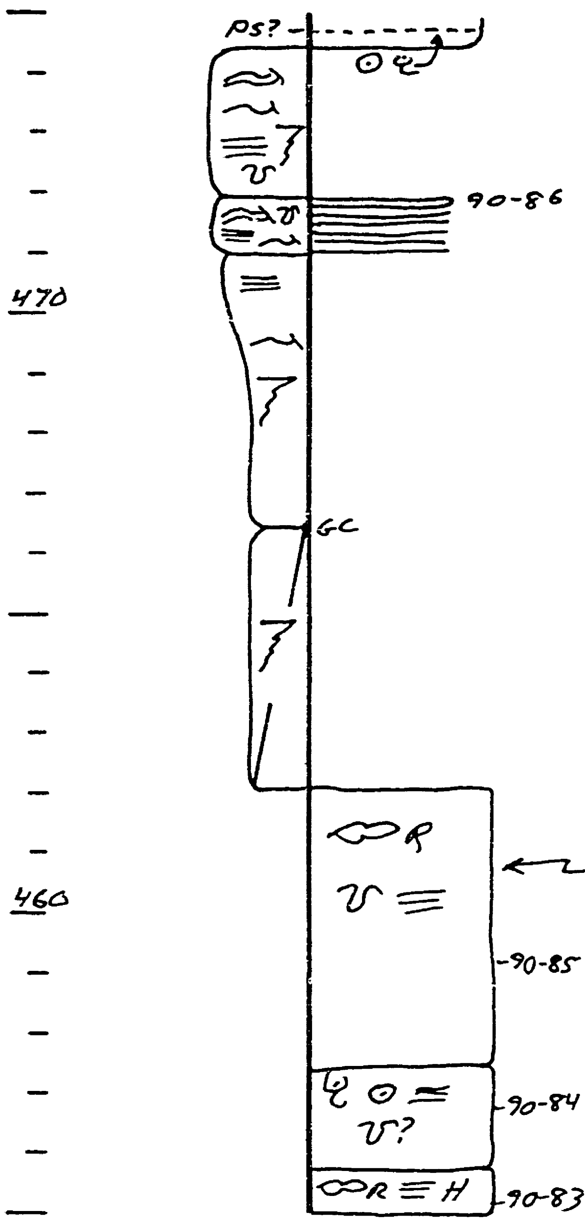
GRAY CALCAREOUS MUDSTONE. BURROW-FILL OF ORANGE-BROWN DOLOSILTITE.

GRAY FOSSILIFEROUS PACKSTONE/GRAINSTONE W/ SOME DOLOMITIZED OOIDS.

GRAY LIMESTONE, BEDDED 2-8 cm ( , , ?, ≡) & ORANGE DOLOSILTITE, BEDDED ≤1-2 cm ( , ≡). APPROXIMATELY 20% DOLOSILTITE.

COVERED.


450
440
90-82
90-81
90-80
90-79
90-78
90-77
90-76
90-75
90-74
90-73
(FAULT?)
CALCARENITE/CALCISILTITE LIKE 451.5m
ORANGE DOLOSILTITE SIMILAR TO 444.5m. 2 BLOCKY BEDS W/ 5-10 CM OF LAMINATED DOLOSILTITE BETWEEN.
TAN CALCISILTITE, 1-5mm BEDDING/LAMINATION.
CALCARENITE/CALCISILTITE LIKE 451.5m
INTERBEDDED CALCARENITE, BEDDED ≤ 1cm & CALCISILTITE ≤3mm, A FEW ≤1cm. LOOKS LIKE INTERTIDAL FLASER BEDDING. TOP 20-25 cm INCLUDES A 8-10 cm OOLITIC GRST OVER A BIOTURBATED, OOLITIC CALCARENITE/CALCISILTITE.
GREEN MDST (SILICA)
CALCARENITE/CALCISILTITE, BEDDED ≤1cm, W/ A 5-8 cm FOSSILIFEROUS PACKSTONE/GRAINSTONE LIKE 447.7
GREEN, ORANGE, & PINK SILTY MUDSTONE, BEDDED/LAMINATED ≤5mm w/ much ≤3mm
TOP & BOTTOM 10 cm: FOSSILIFEROUS PACKSTONE/GRAINSTONE W/ QUARTZ GRAINS & POSSIBLE LITHOCLASTS. MIDDLE 30 cm IS A BIOTURBATED, MUDDY CALCARENITE W/
GREEN TO PINK SILTY MUDSTONE, ≤5mm.
ORANGE DOLOSILTITE LIKE 444.3m
ORANGE DOLOMITIC SILICA-MUDSTONE, INTERMEDIATE BETWEEN 442m & 443m IN APPEARANCE.
ORANGE DOLOSILTITE, BEDDED ≤1cm BUT MOSTLY MM-LAMINATIONS. OCCASIONAL VF SS LAYERS. INTERTIDAL TO SUPRATIDAL?
GRAY, SILTY, DOLOMITIC SILICA-MDST
ORANGE DOLOMITE MDST W MM-LAMINATION
GREEN-TAN DOLOMITIC SILICA-MDST, BEDDED ≤5mm
BROWN & GREEN CALCARENITE, BEDDED ≤1cm.
BROWN SS/STS SIMILAR TO 440m.
TAN CALCARENITE (?), W/ INTERLAMINATIONS OF CALCISILTITE. FLASER BEDS MORE SILICEOUS TOWARDS TOP.
GREEN-PINK, SILTY, CALCAREOUS SILICA-MUDSTONE, BEDDED ≤1cm. W/ OCCASIONAL FOSSILIFEROUS PACKSTONE/GRAINSTONE BEDS, ≤1cm THICK
TOP 5cm: MUDDY, CALCAREOUS, FOSSILIFEROUS SS. BOTTOM 5cm: LITHOCLAST CONGLOMERATE W/ MUDDY, SANDY MATRIX. CLASTS ≤1cm.
GREEN TO LIGHT GRAY CALCAREOUS SILICA-MDST, BEDDED <1cm.
LIGHT GREEN GRST W/ QUESTIONABLE OOIDS <1/4 mm. FLAT BASE, LATERALLY DISCONTINUOUS, MOUND-SHAPED? ≤10cm. STYLOLITES W/ 8cm RELIEF. FOSSILIFEROUS PKST IN BASAL 10cm
GREEN TO GRAY-PURPLE MDST TO SHALE, BEDDED ≤3mm. 2 <5mm-THICK OLIVE-GREEN CARBONATE VEINS IN CENTER




(SEE NEXT PAGE)

AT ABOUT 10-15cm FROM BOTTOM OF INTERVAL, MAY HAVE A PARASEQUENCE BOUNDARY (PS): IRREGULAR SURFACE W/ CLEAN OOID GRST BELOW AND MORE OF A RIBBON-ROCK TEXTURED OOID GRAINSTONE ABOVE.

VF SS, MOSTLY ≤10-15cm. A FEW BIOTURBATED MUDDY SS BEDS < 3cm THICK. A FEW CARBONATE INTERLAMINATIONS IN HUMMOCKY CROSS-BEDS.

VF SS (≡ ~) W/ 6 OR MORE PACKSTONE/GRAINSTONE BEDS, ≤ 1-15 cm THICK (~ ?). 15 cm PKST/GRST BED AT TOP.

VF SS & MUDDY STS. COARSENS & THICKENS UPWARD. ≡ ONLY IN TOP 1½ m. STS BEDDED FROM ≤1-2cm AT BOTTOM TO ≤5cm TOWARDS TOP. SLIGHT DECREASE IN BURROWING UPWARDS.

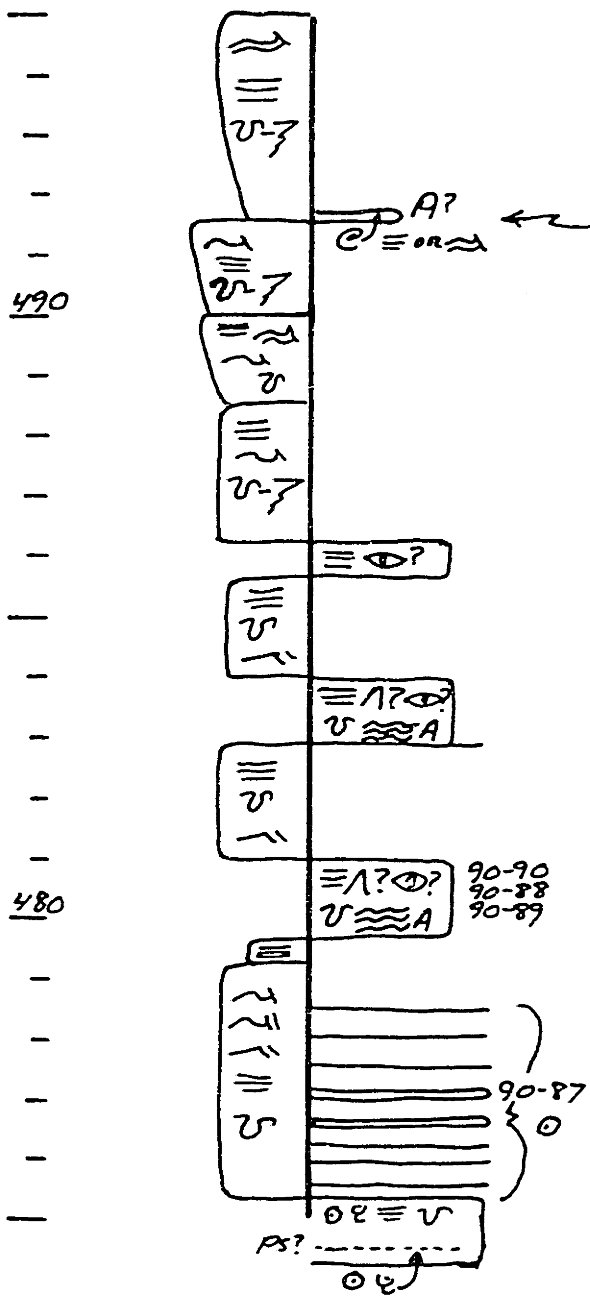
GRAY, SILTY MUDSTONE. PODS OF CALCARENITE/DOLARENITE IN LOWER HALF, SIMILAR TO 451.5m RECESSIVE WEATHERING. NO CARBONATE PODS SEEN IN UPPER ½.

GRAY CALCARENITE/GRST OR COARSLEY RECRYSTALLIZED MDST. INTERBEDDED W/ ABOUT 10% BROWN DOLOSILTITE, ≡ & BURROW-FILL

NOTE: 447.25-455.1 m: MOST, IF NOT ALL PACKSTONE/GRAINSTONE & THICKER ARENITE BEDS ARE PROBABLY LATERALLY DISCONTINUOUS OVER 10's OF METERS. THE ORANGE DOLOSILTITE AT 453.7-454 m MAY ALSO BE DISCONTINUOUS

BROWNISH OOLITIC (¼ mm) GRST, & ≤10cm. W/ DISCONTINUOUS BROWN DOLOSILTITE (≡). SOME OOIDS DOLOMITIZED. 50-75% DOLOSILTITE.

GRAY CALCARENITE/GRST (H) & BROWN DOLOSILTITE, ABOUT 50-60% DOLOSILTITE.




UPPER ½: MIXED VF QUARTZ SS AND CALCARENITE/DOLARENITE IN HUMMOCKY CROSS-BEDS
LOWER ½: LESS CARBONATE LAMINATIONS & MORE BURROWED-TO-BIOTURBATED, MUDDY SANDSTONE.

15 CM LIMY, DOLOMITIC WACKESTONE/PACKSTONE (@, POSSIBLY A). ARENITIC

TAN, CALCAREOUS, VF COARSENS UP TO F SS, W/ A FEW INTERLAMINATIONS OF DOLARENITE & DOLOSILTITE.

VF SS, BEDDED ≤ 30 CM, MOST ≤ 10 CM. SOME THICKENING & COARSENING UP. LESS BURROWS THAN 488 M.

MOSTLY VF SS, BEDDED ≤ 1-2 CM, W/ ABOUT 5% DOLOSILTITE INTERLAMINATIONS. MOST BURROWS IN SCATTERED INTERVALS, ESPECIALLY IN LOWER ⅓.

ORANGE SILTY DOLOMITE LIKE 480 M

GRAY-BROWN, VF SS, ETC LIKE 482 M. SS BEDDED ≤ 20-25 CM

ORANGE LIMY DOLOSILTITE LIKE 480 M

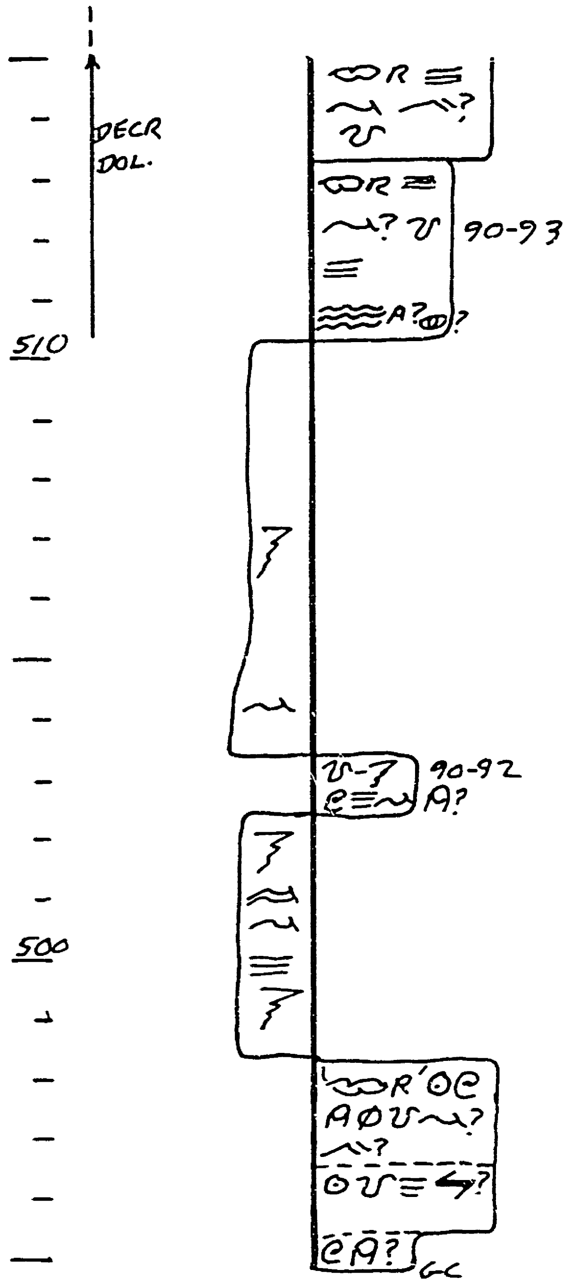
GRAY-BROWN VF SS & MUDDY SS TO SANDY MUDSTONE. 5 MM TO 1 CM BEDDED, WITH A FEW SS BEDS 10-15 CM & ≡.

ORANGE, LIMY DOLOSILTITE, ≤ 5 MM. BROKEN LAMINAE (MUD FLAKES). NOT BLOCKY-WEATHERING

GRAY-BROWN, LAMINATED MDST

VF SS & SOME SILTY MDST. W/ CALCARENITE & OOLITIC (≤ ¼ MM) GRST INTERLAMINATIONS & INTERBEDS, ≤ 8 CM, OFTEN ABOUT 1 CM. THICKER CARBONATE BEDS ARE GRST.

GRAY OOLITIC (¼ - ½ MM) PACKSTONE/GRAINSTONE, ≤ 15 CM. W/ ORANGE-BROWN DOLOSILTITE, ≤ 5 CM (≡ Ʋ). OOLITIC PKST/GRST ALSO BURROWED, OFTEN W/ DOLOSILTITE FILL. (SEE PREVIOUS PAGE FOR CONTINUATION)



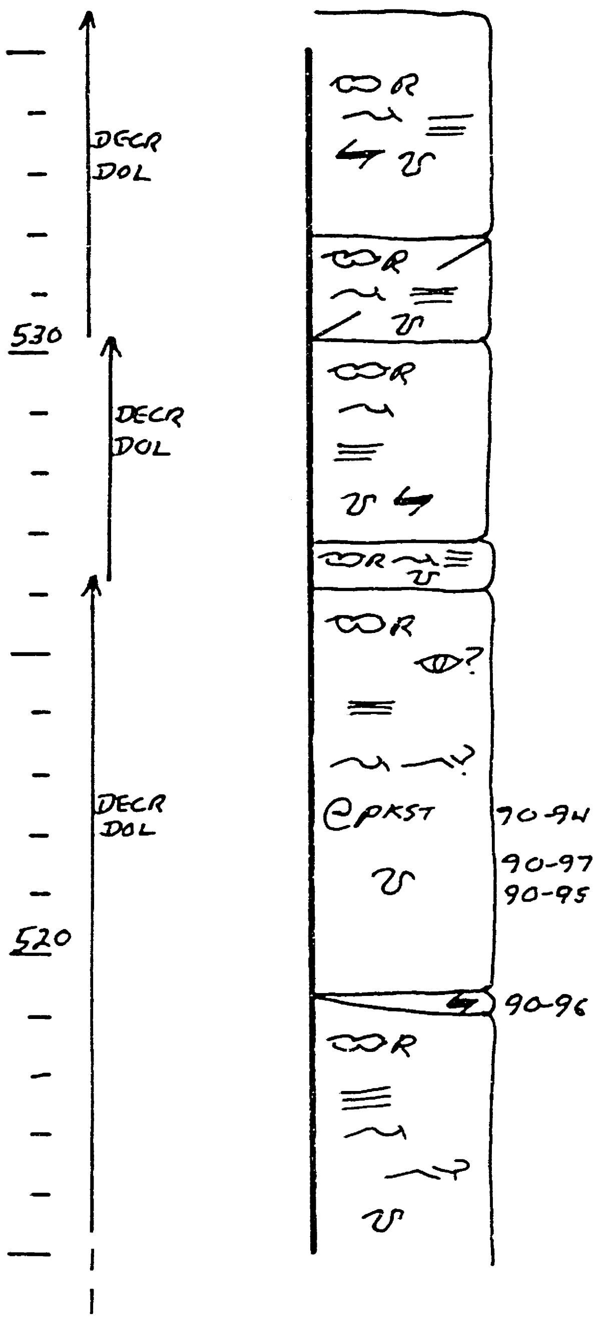

TAN, LIMY DOLOSILTSTONE, BEDDED ≤1cm (≡ ≋A? ⦶?), WITH 10-20% GRAY CALCARENITE, BEDDED ≤ 2cm (≡? ?). OCCASIONAL BURROWS IN BOTH LITHOLOGIES

BROWN-GRAY, SILTY MUDSTONE & MUDDY VF SS, BEDDED ≤1-2cm, MOSTLY ≤1cm. FINES & THINS UP. TOP CONTACT COVERED. SIMILAR TO 500 m

GREEN & BROWN, ARENITIC, FOSSILIFEROUS WACKESTONE & SILTY MUDSTONE, MIXED BY BURROWING. BEDDED ≤10cm; W/ MUCH ≤ 5cm THICK

MOSTLY GRAY-BROWN SILTY MUDSTONE (≡), W/ VF SS (≈ ~ ≡ ?). ALL BEDDED ≤12cm, MOST ≤ 1-2 cm. ABOUT 60% MUDSTONE.

UPPER ½: GRST W/ ⊙ ≈½ mm, Ø ≤1cm, BURROWS, INTERBEDDED DOLOSILTITE. TOP 20 cm IS A ⊙-C GRST. NEXT 40 cm IS A BURROWED-TO-BIOTURBATED DOLOSILTITE/DOLARENITE BED W/ ~ OR ~. BOTTOM 15 cm IS ORANGE DOLOSILTITE (≡).
MIDDLE: OOLITIC (¼-½ mm) GRST, W/ ORANGE DOLOSILTITE-FILLED BURROWS, & A FEW 1-3 cm THICK DISCONTINUOUS DOLOSILTITE INTERLAMINATIONS OR LONG LITHOCLASTS (≡).
BOTTOM: GRAY, FOSSILIFEROUS WACKESTONE/PACKSTONE IN 5-10 cm THICK BEDS.




LIKE 528 M. LIMESTONE, ABOUT 75%, BEDDED ≤ 3 CM
DOLOSILTITE, BEDDED ≤ 2 CM
ONE OR MORE CLAST CONGLOMERATE BEDS, 8 CM THICK.

GREEN ARENITE-MUDSTONE, DOLOSILTITE & RED SILICEOUS MDST. LIKE 526.5 M. ALL BEDDED ≤ 1 CM. RECESSIVE WEATHERED.

GRAY ARENITE-MUDSTONE (SEE NOTE RE: 447.25-445.1 M), BEDDED ≤ 3-5 CM (~ ≡ ʊ), ABOUT 75% OF INTERVAL. ORANGE DOLOSILTITE BEDDED ≤ 1 CM (≡ ʊ)
MORE THAN 4 BEDS OF INTRAFORMATIONAL CLAST (LS & DOL) CONGLOMERATE BEDS, 3-5 CM THICK. MORE BURROWED THAN 526.5 M.

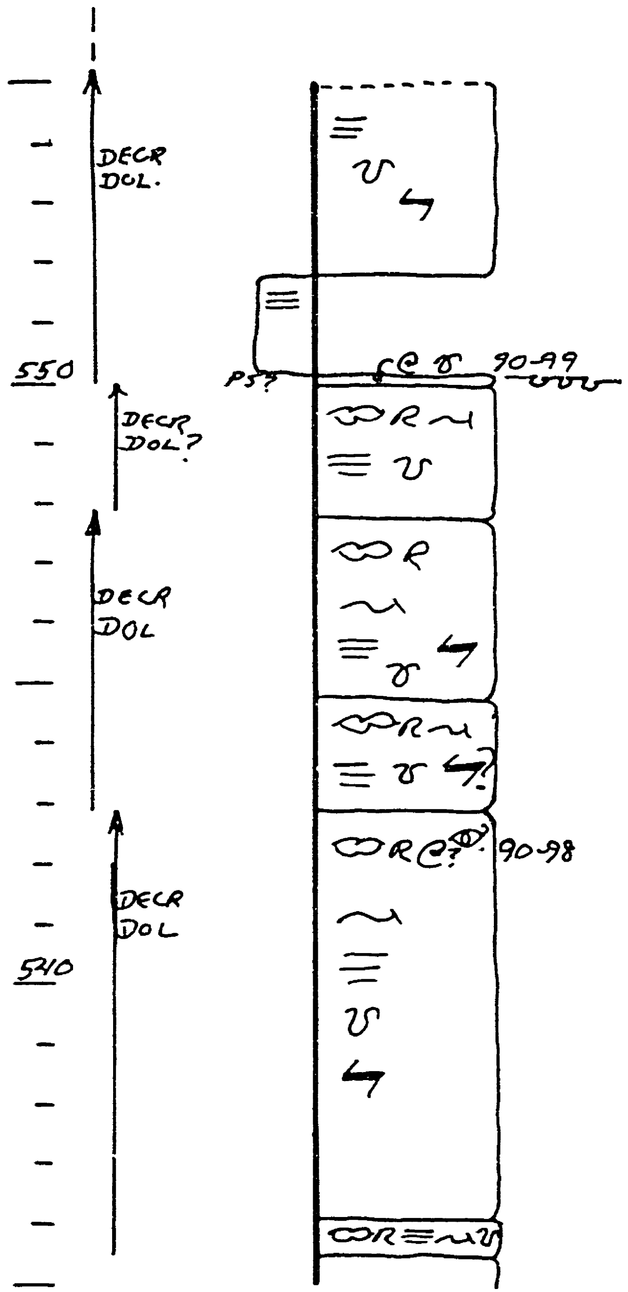
GREEN ARENITE-MUDSTONE (SEE NOTE RE: 447.25-455.1 M) BEDDED ≤ 2 CM (~ ≡), W/ DOLOSILTITE & RED SILICEOUS MUDSTONE, BEDDED ≤ 2 CM (≡), ABOUT 50% LIMESTONE. RECESSIVE WEATHERING.

GRAY ARENITE-MUDSTONE (SEE NOTE REGARDING 447.25-455.1 M), BEDDED 3-4 CM, ABOUT 75% OF INTERVAL.
DOLOSILTITE, BEDDED ≤ 1 CM, ABOUT 25% OF INTERVAL

10 CM-THICK FOSSILIFEROUS PACKSTONE AT APPROXIMATELY 522 M.

LENTICULAR LITHOCLAST-RICH LIMESTONE, ≤ 15 CM HIGH BY A FEW 10'S OF METERS WIDE.

GRAY ARENITE-MUDSTONE, BEDDED ≤ 3 CM (~ ≡ ʊ ~?), ABOUT 60% OF TOTAL INTERVAL. ORANGE-BROWN DOLOSILTITE, BEDDED ≤ 1 CM (≡ ʊ), W/ MORE BURROW IN DOLOSILTITE THAN IN LIMESTONE.




(TO 557m): LIKE 528 m, BUT MORE BURROWED. LIMESTONE, ≤5 cm, ABOUT 85-90%. DOLOSILTITE ≤1cm. CLAST CONGLOMERATE BEDS PRESENT, BUT NOT COUNTED. AT 555.0 TO 555.1 m: A 10 CM THICK, OLIVE-GREEN OOLITIC-FOSSILIFEROUS PACKSTONE/GRAINSTONE. (SEE NEXT PAGE)

GREEN, SILTY SHALE, BEDDED ≤1cm, WEATHERS REDDISH-BROWN.

12 CM THICK, GREEN CALCARENITE, BEDDED ≤1-2 cm. W/ ≤3 mm FOSSILIFEROUS PACKSTONE. VERTICAL BURROWS TRUNCATED AT TOP OF BED.

LIKE 528m & 547m. NO CLAST CONGLOMERATES SEEN.

LIKE 528m. LIMESTONE, ≤3cm, ABOUT 80% DOLOSILTITE, ≤1 cm, ABOUT 20%

MORE THAN 3 CLAST CONGLOMERATE BEDS, ≤3 CM THICK.

LIKE 528m. LIMESTONE, ≤2 cm, 60%. DOLOSILTITE, ≤1cm, 40%. LESS BURROWING THAN 528m. MORE THAN ONE CLAST CONGLOMERATE BED, 1CM THICK

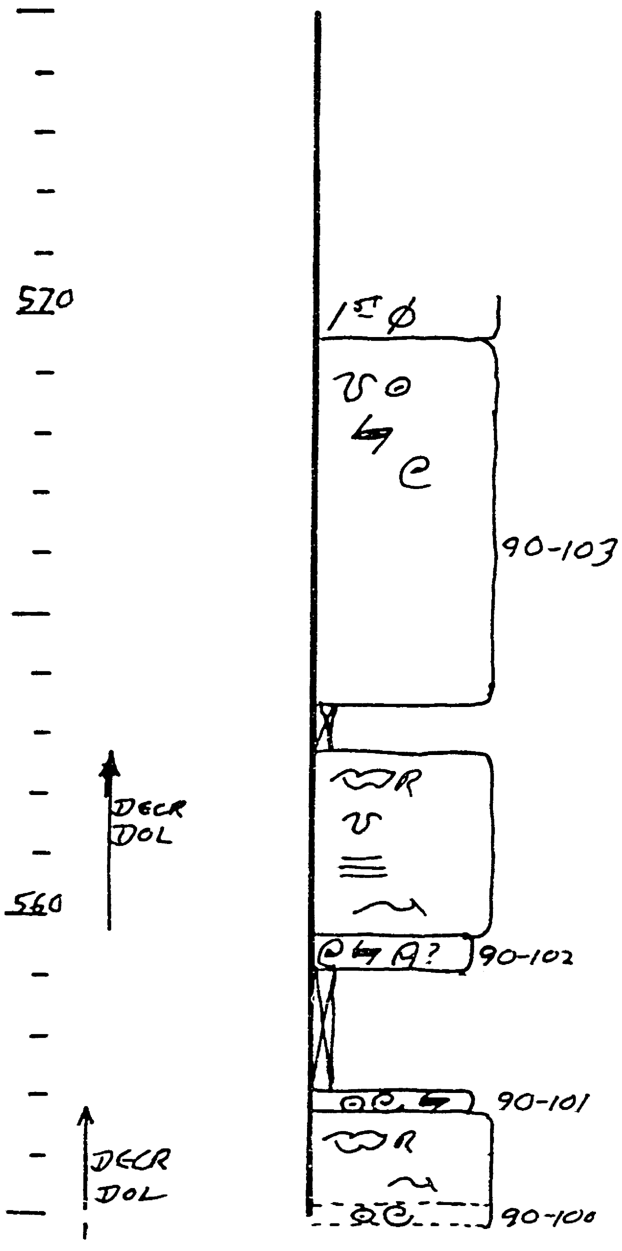
LIKE 528m. LIMESTONE, ≤3cm, ABOUT 75%
DOLOSILTITE, ≤2cm

NEAR TOP HAVE 15 cm DOLOSILTITE BED W/ EITHER FENESTRAE OR FLAT, HORIZONTAL FOSSIL FRAGMENT.

MORE THAN 7 CLAST CONGLOMERATE BEDS, ≤3 CM THICK, W/ ONE BED 8 CM THICK. CLASTS BOTH LIMESTONE & DOLOSILTITE.

LIKE 526.5m. RECESSIVE WEATHERING.

SECTION 90-1, NOPAH RANGE, JUST NORTH OF EMIGRANT PASS, CALIFORNIA




DARK GRAY WACKESTONE/PACKSTONE, BEDDED 2-10 cm. SOME PACKSTONE/GRAINSTONE

BURROWS FILLED W/ BROWN, LIMY DOLOSILTITE. DOLOSILTITE DECREASES UP TO ALMOST 0% AT 570 m

PAPOOSE LAKE MEMBER OF THE BONANZA KING FORMATION

CARRARA FORMATION

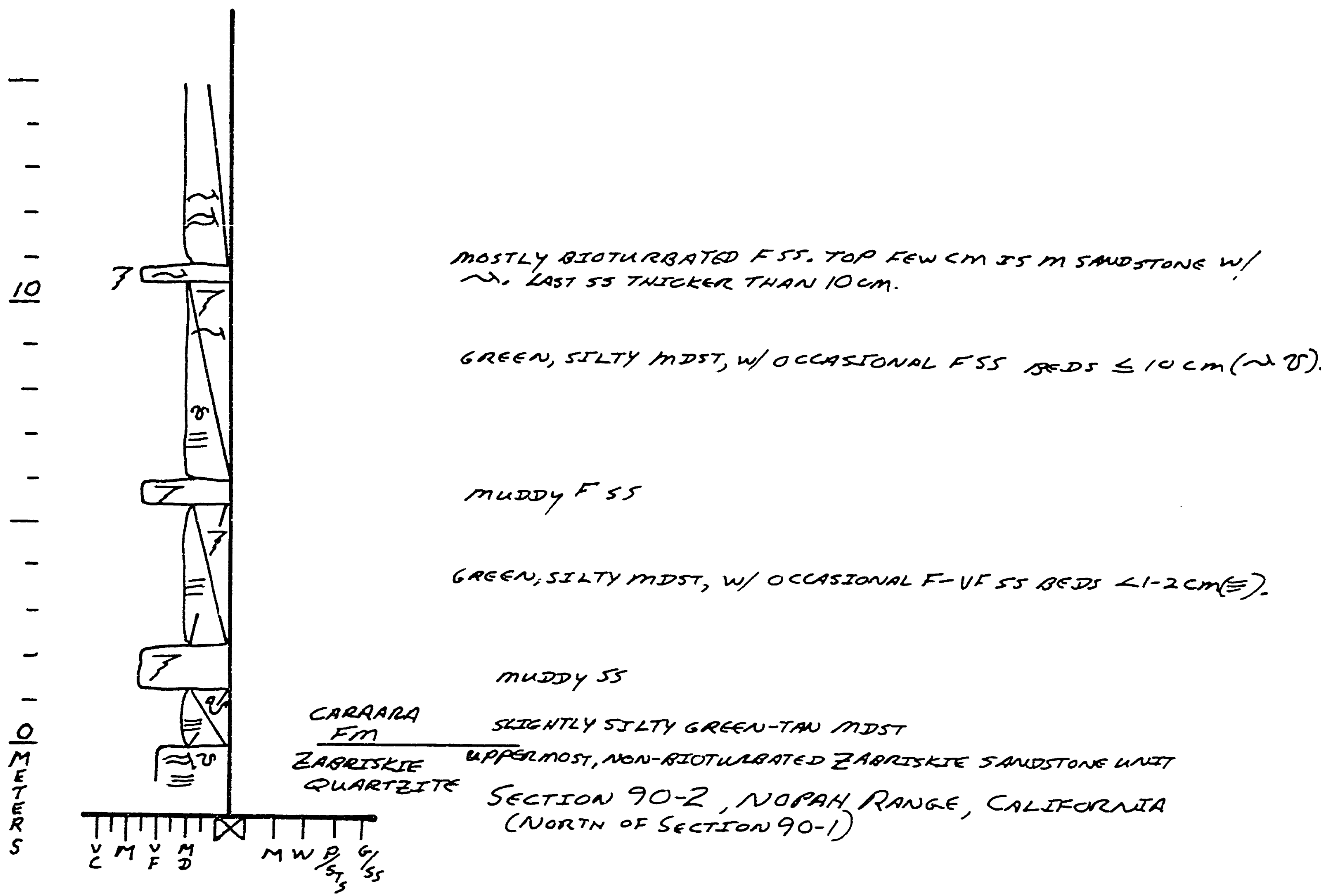
LIKE 528 m: LIMESTONE, 1-3 cm // DOLOSILTITE, 1-2 cm // ABOUT 90% LIMESTONE IN UPPER ½, ABOUT 60% LS IN LOWER ½. GRADUAL CHANGE FROM LOWER TO UPPER HALVES

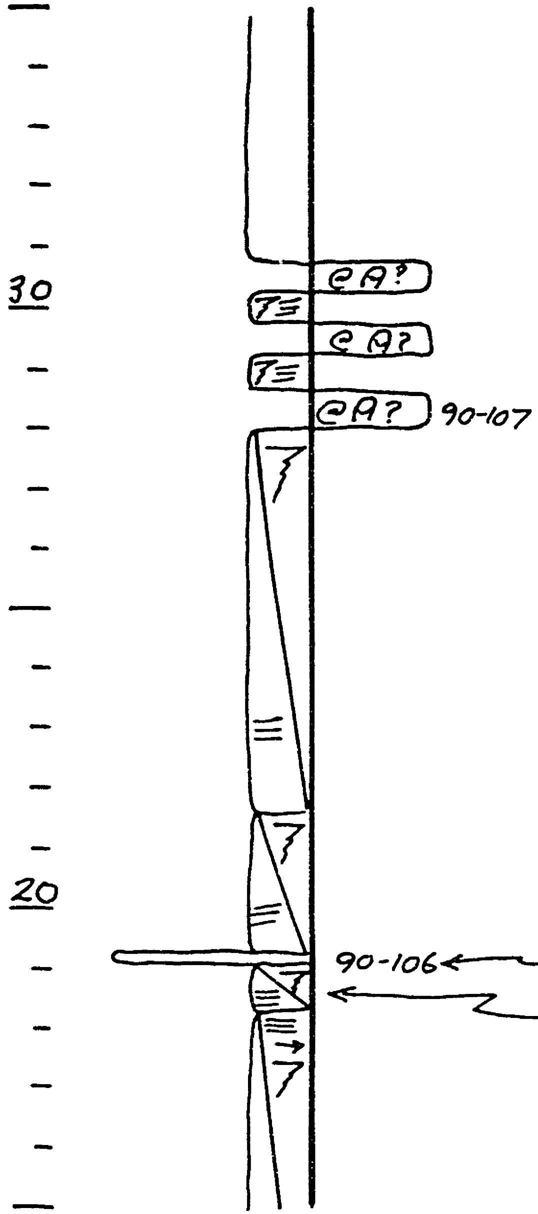
GREEN CALCARENITE-MUDSTONE & FOSSILIFEROUS-LITHOCLAST WACKESTONE/PACKSTONE, BOTH BEDDED 3-10 cm.

COVERED. MORE GREEN LIMESTONE?

OLIVE-GREEN PACKSTONE/GRAINSTONE.

SEE PREVIOUS PAGE.


MOSTLY BIOTURBATED F SS. TOP FEW CM IS M SANDSTONE W/ ~. LAST SS THICKER THAN 10 CM.
GREEN, SILTY MDST, W/ OCCASIONAL F SS BEDS ≤ 10 CM (~ ϑ).
MUDDY F SS
GREEN, SILTY MDST, W/ OCCASIONAL F-VF SS BEDS <1-2 CM (≡).
MUDDY SS
CARRARA FM
SLIGHTLY SILTY GREEN-TAN MDST
ZABRISKIE QUARTZITE
UPPERMOST, NON-BIOTURBATED ZABRISKIE SANDSTONE UNIT
SECTION 90-2, NOPAH RANGE, CALIFORNIA
(NORTH OF SECTION 90-1)
10
0
METERS
VC M VF MD
M W P/STS G/SS




GREEN, SILTY MDST, LIKE 18.5 m & LIKE 30m. ONLY A FEW LIMESTONE & SS INTERBEDS LIKE 30m.

GREEN, SILTY MDST W/ FREQUENT INTERBEDS OF BROWN, FOSSILIFEROUS WACKESTONE/PACKSTONE & SOME VF SS INTERBEDS LIKE 27.0m.
28–31m: BEDS SHOWN SCHEMATICALLY

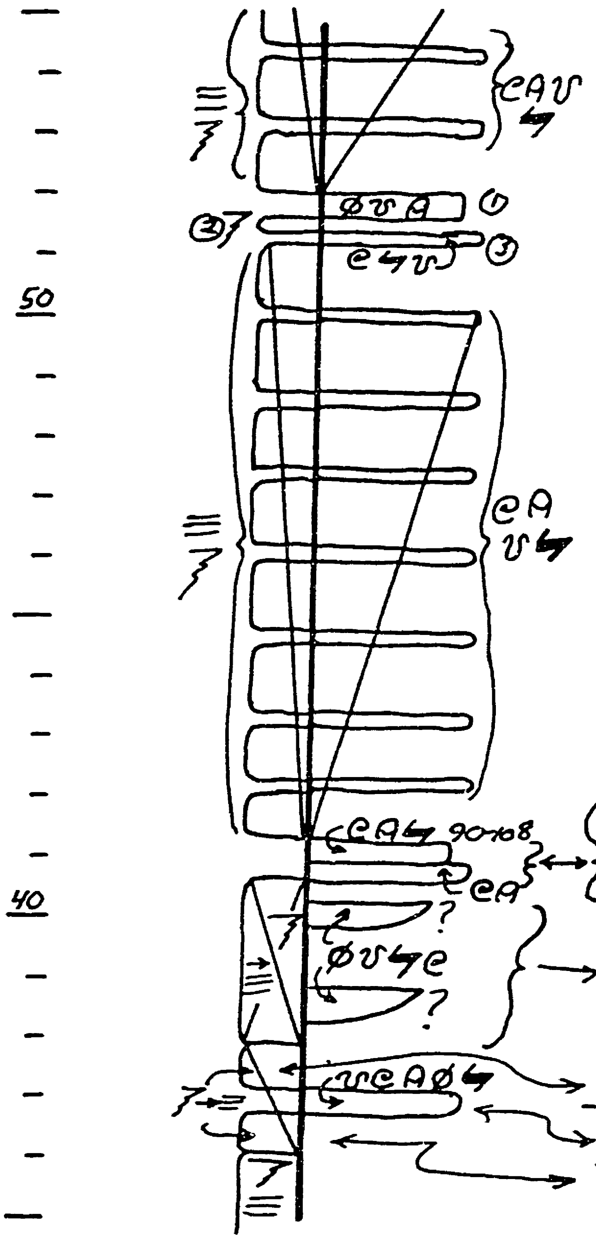
GREEN MDST W/ INCREASING NUMBERS OF VF SS BEDS, ≤ 5m (≡ ʊ) AS GO UPWARDS IN INTERVAL.

GREEN & TAN SILTY MDST LIKE 18.5m

5cm THICK NON-CALCAREOUS BED OF 1-2mm DIAMETER GREEN CLASTS/BALLS/PELOIDS.

GREEN & TAN MDST

(SEE PREVIOUS PAGE)




52-58 m: BEDS SHOWN SCHEMATICALLY. LIKE 50m

(1) OLIVE-GREEN ONCOLITIC (1-4 cm) LIMESTONE W/ A FOSSILIFEROUS PACKSTONE MATRIX. LOTS OF BURROWS FILLED W/ RED DOLOSILTITE. SOME INTERBEDS OF BURROWED DOLOSILTITE, ≤ 1 cm THICK.

(2) RECESSIVE MDST, MAY BE CARBONATE INSTEAD OF SILICEOUS

(3) FOSSILIFEROUS PACKSTONE/GRAINSTONE W/ LIMESTONE & DOLOSILTITE LITHOCLASTS, SOME BURROWS.

41.5→51m: BEDS SHOWN SCHEMATICALLY. MAIN LITHOLOGY IS GREEN, SILTY, SILICEOUS MDST, SOME W/ VERY LITTLE SILT. EVERY ½-1m HAVE AN INTERBED OF OLIVE-GREEN FOSSILIFEROUS PACKSTONE/GRAINSTONE, BEDDED 3-10 cm, & PROBABLY DISCONTINUOUS LATERALLY. LITHOCLASTS OF BOTH RED DOLOSILTITE & OLIVE-GREEN LIMESTONE LIKE 41.3m, MOSTLY IN 10 cm-THICK BEDS. ALSO A FEW FOSSILIFEROUS CALCARENITE BEDS ≤ 3 cm THICK.

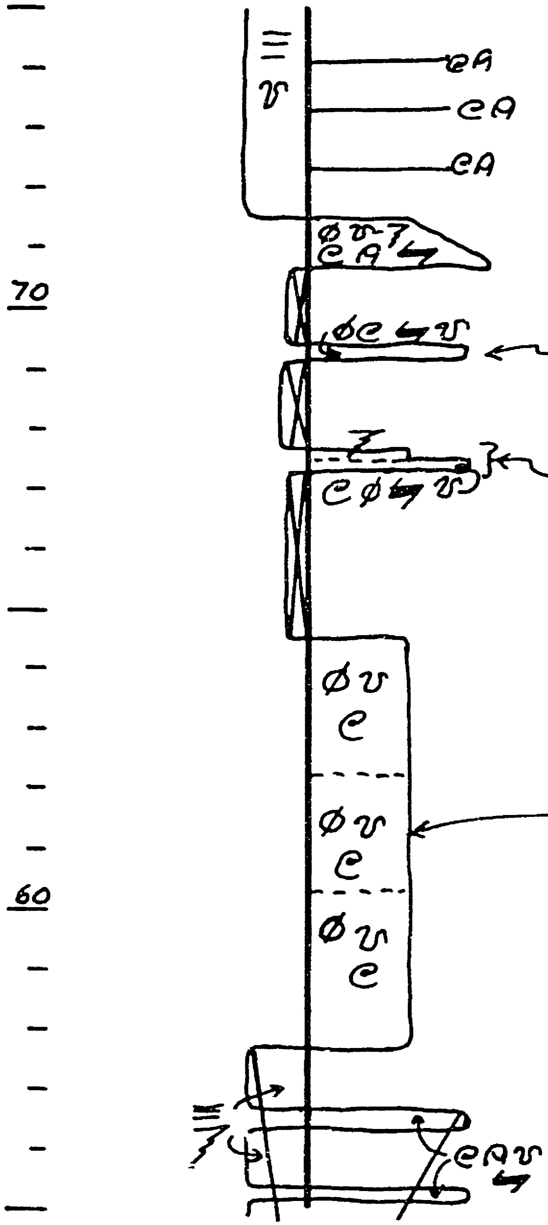
OLIVE-GREEN FOSSILIFEROUS WACKESTONE/PACKSTONE, BEDDED 1-5 cm, W/ TOTAL THICKNESS OF 15 cm IS OVERLAIN BY AN OLIVE-GREEN, FLAT-CLAST CONGLOMERATE. CLASTS ≤ 1×5 cm OF OLIVE-GREEN LIMESTONE, ARRANGED HORIZONTALLY. MATRIX IS CALCAREOUS WACKESTONE/PACKSTONE. SOME RED DOLOSILTITE CLASTS ALSO.

MOSTLY GREEN TO LIGHT GRAY SILTY MDST (SILICEOUS). 2 POSSIBLE CHANNEL-FILLS, 30-40 cm THICK & ABOUT 3-5 m WIDE. BOTH FILLED W/ GREEN, LIMESTONE FOSSILIFEROUS-ONCOLITIC (1-4 cm)-LITHOCLAST WACKESTONE/PACKSTONE

LIKE 36.5m

OLIVE-GREEN FOSSILIFEROUS PACKSTONE/GRAINSTONE W/ ONCOIDS ≤ 1½ cm, LITHOCLASTS OF LIMY REDSTS (DOLOMITIC?) CLASTS & BURROW-FILL.

PINK, MORE SILTY MDST THAN 35m. THICKER (≤ 1-2 cm) & BLOCKIER. SOME INTERBEDDED OLIVE-GREEN, LIMY, SILTY SILICEOUS MDST.




TAN TO PINK, LIMY, SILICEOUS MDST, BEDDED ABOUT 1cm. OCCASIONAL GREEN FOSSILIFEROUS PACKSTON BEDS < 1cm THICK W/ ℮ A

GREEN, PINK, & TAN CALCISILTITE & DOLOSILTITE. BASAL 10cm IS AN OLIVE GREEN, FOSSILIFEROUS GRST WITHOUT ONCOIDS. ABOVE GRST THERE IS AN UPWARD INCREASE IN NUMBER & SIZE OF ONCOIDS (FROM ≤1cm TO ≤2cm). AMOUNT OF BURROWING ALSO INCREASES UPWARD. RECESSIVE WEATHERING.

COVERED. PROBABLY LIKE 73m.

OLIVE-GREEN LIMESTONE LIKE 67.4m, BUT LITHOCLASTS ≤ 1x2cm.

COVER. PROBABLY LIKE 65m.

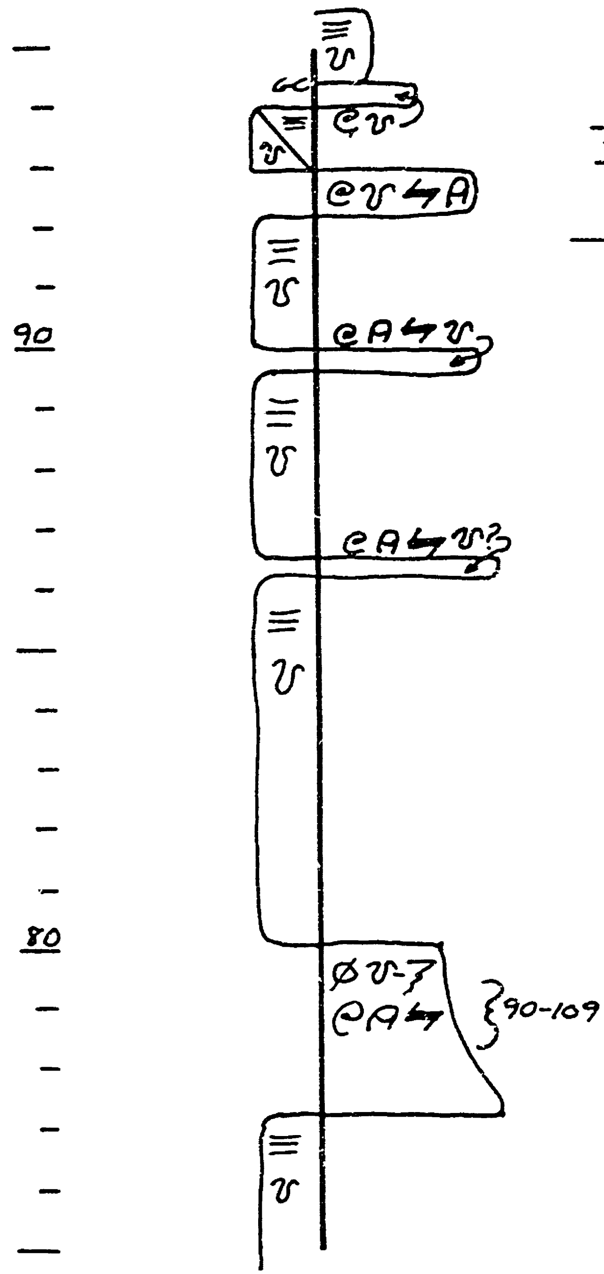
TOP 15cm: BIOTURBATED & MIXED PACKSTONE & SILTY CARBONATES & SILICEOUS MDST. RED & GREEN

LOWER 20cm: OLIVE-GREEN LIMESTONE PACKSTONE/GRAINSTONE. ONCOIDS < 1cm. LITHOCLASTS TABULAR, ≤ 1x10cm & OF SAME LITHOLOGY. SOME REDDISH DOLOSILTITE IN BURROW-FILL.

COVERED. PROBABLY GREEN MUDSTONE, SILICEOUS & ≡

BURROW-MOTTLED, GRAY ONCOLITIC (≤1cm) & FOSSILIFEROUS WACKESTONE. ≤ 10% DOLOSILTITE (ORANGE) IN BURROW-FILLS. MIDDLE PART OF INTERVAL IS RECESSIVE WEATHERING

LIKE 50m.




CALCISILTITE, DOLOSILTITE & POSSIBLY QUARTZ SILTSTONE, RED, TAN, GRAY, ALL BEDDED 1-2cm

OLIVE-GREEN MUDSTONE/WACKESTONE, W/ INTERBEDS OF RED DOLOSILTITE, ALSO BURROW-FILL. ABOUT 15-20% DOLOSILTITE OVERALL

TAN TO PINK MUDSTONE LIKE 75m

OLIVE-GREEN CALCAREOUS PACKSTONE/GRAINSTONE. LITHOCLASTS ≤ 1x5cm. MORE BURROWED THAN 2 LIMESTONES IMMEDIATELY BELOW, BUT NOT AS MUCH AS 80m

TAN TO PINK SILICEOUS MUDSTONE LIKE 75m

OLIVE-GREEN LIMESTONE LIKE 86.5m

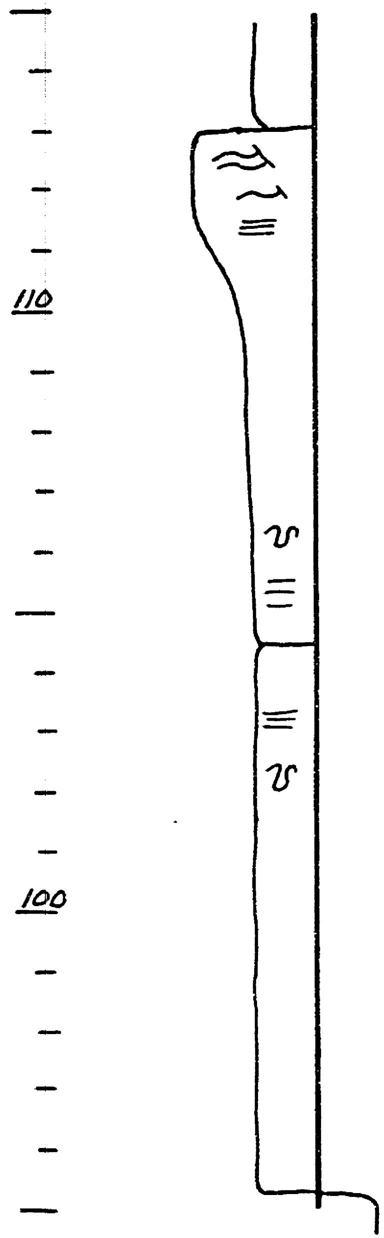
TAN TO PINK SILICEOUS MUDSTONE LIKE 75m

OLIVE GREEN CALCAREOUS GRST W/ LIMESTONE LITHOCLASTS ≤ 1x5cm.

TAN TO PINK, LIMY SILICEOUS MUDSTONE LIKE 75m

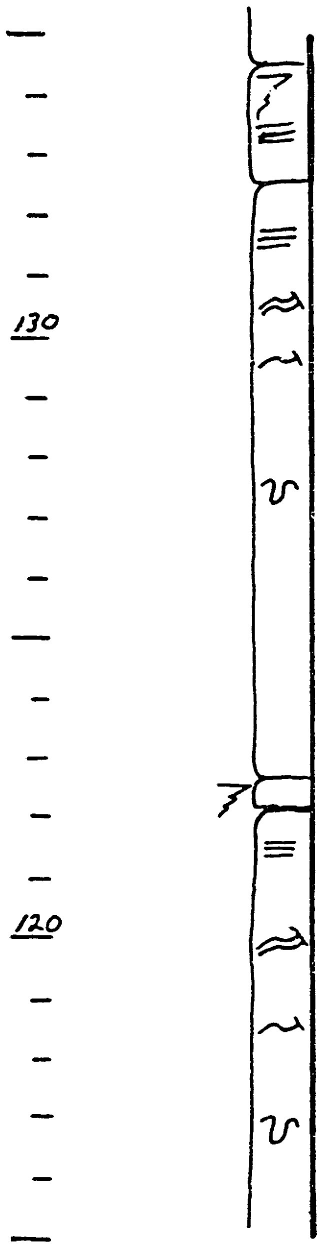
CALCISILTITE-DOLOSILTITE LIKE 71m. BOTTOM 30cm IS A GRAINSTONE.

TAN TO PINK LIMY, SILICEOUS MUDSTONE, BEDDED ABOUT 1cm. OCCASIONAL FOSSILIFEROUS, CALCAREOUS PACKSTONE, BEDDED ≤ 1cm




LIGHT GREEN TO GREEN SILTY MUDSTONE, COARSENS UP TO F & VF SS BEDS. SOME CALCAREOUS-CEMENT. NOT MUCH BURROWING IN MUDSTONE. SS BEDDED ≤ 10CM. MUDSTONE BEDDED ≤ 1-2CM.

LIGHT GRAY TO TAN SILTY MUDSTONE. OCCASSIONAL MIXED CALCISILTITE/ARENITE & DOLOSILTITE/ARENITE, ≤ 1 CM.

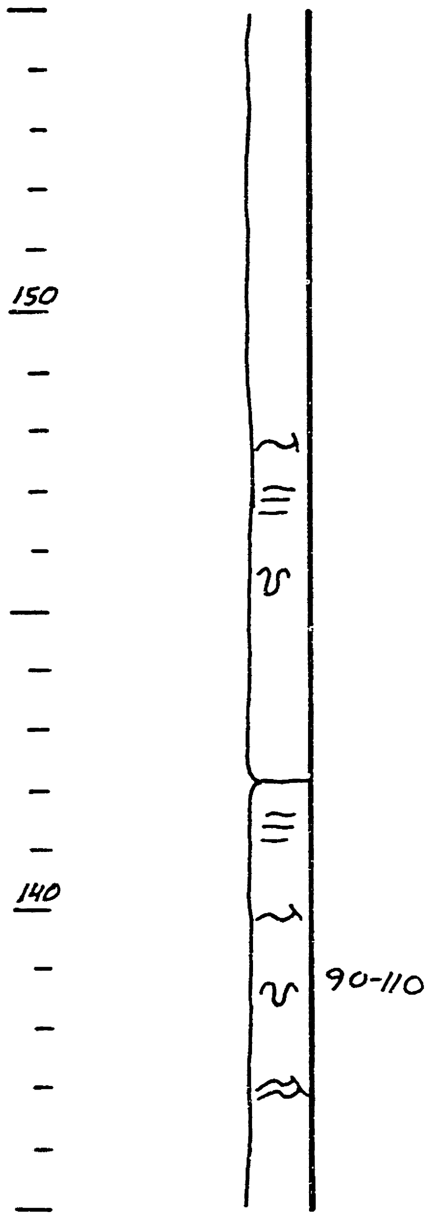



GREEN, SANDY MDST. SEVERAL INTERBEDS, 1-3 CM THICK, OF VF SS W/ ≡ ~

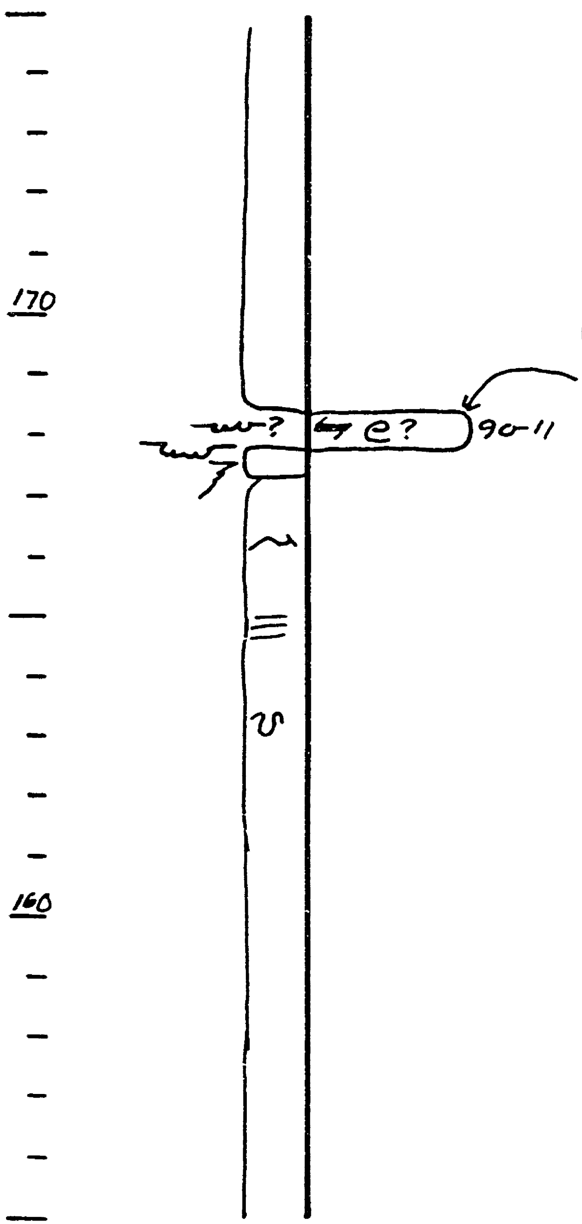
GREEN, SOMEWHAT SILTY MUDSTONE, LIKE 120 M

GREEN, SANDY MDST. NO SKOLITHOS BURROWS

GREEN, SOMEWHAT SILTY MUDSTONE. PROBABLY A BIT LESS SILTY THAN IMMEDIATELY BELOW. VERY SIMILAR TO 104.5-1130M. ONLY VF SS & NOT AS MUCH.



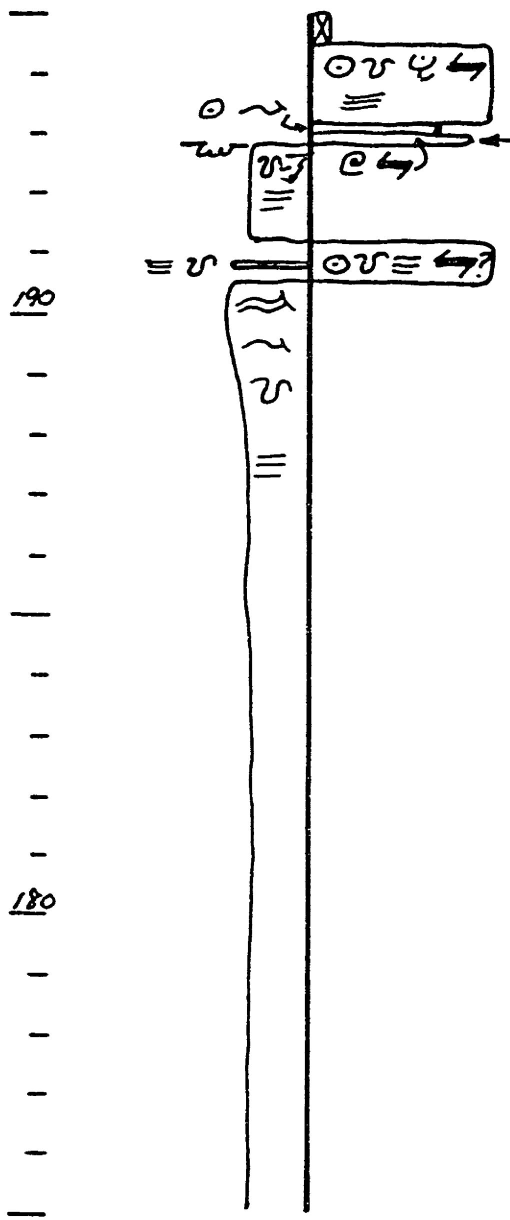

GREEN, SILTY MDST LIKE 120 m.




50-70 CM OF PACKSTONE/GRAINSTONE IN 2 UNITS. BOTH DARK BROWN & HARD TO IDENTIFY GRAINS. LITHOCLASTS OF MUDSTONE IMMEDIATELY BELOW. PROBABLE SCOURED SURFACE BETWEEN 2 PKST/GRST UNITS. LITHOCLASTS APPEAR TO HAVE BEEN PLASTICALLY DEFORMED DURING SCOUR & DEPOSITION

GREEN TO GRAY, SANDY MUDSTONE. OVER 20 CM RELIEF ON UPPER SCOURED SURFACE

GREEN TO PURPLISH-GRAY TO GREEN FROM BOTTOM TO TOP; MUDSTONE THROUGHOUT, BEDDED ABOUT 5 MM. ALMOST NO SS UNTIL TOP 5 M. VERY FEW BURROWS. MUCH FINER-GRAINED THAN 134.6 TO 142.1 M




COVERED.

GREEN OOLITIC (½ mm) GRST. ψ ≤ 10cm. INTERLAMINATIONS OF ORANGE-BROWN DOLOSILTITE, ≤ 5cm, MOST ≤ 1cm (≡). ALSO DOLOSILTITE LITHOCLASTS & BURROWFILL. ABOUT 15% DOLOSTS OVERALL.

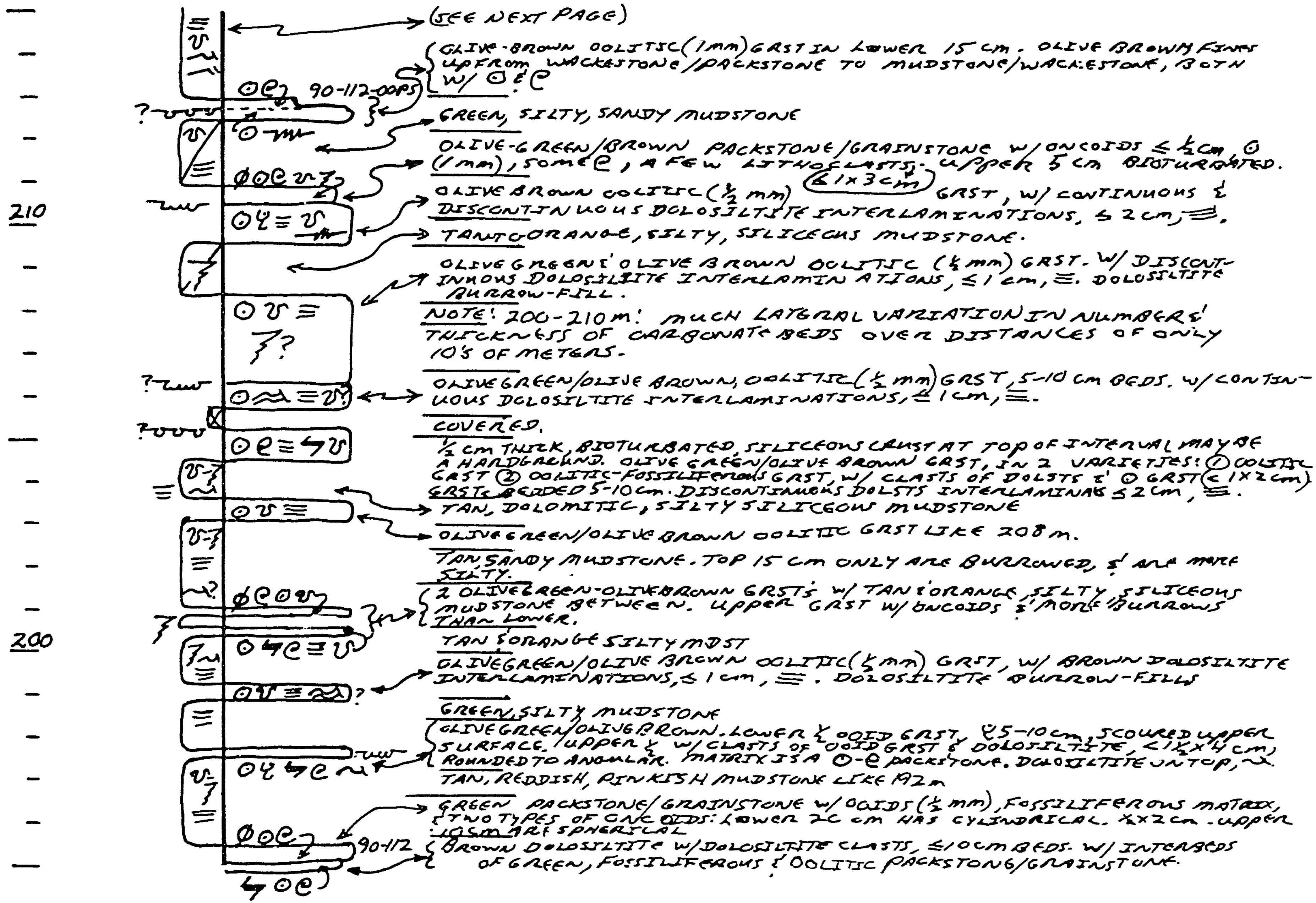
ORANGE-BROWN DOLOSILTITE W/ 2 OOLITE BEDS 1-2 CM THICK IN UPPER PART

GREEN & BROWN LENTICULAR UNIT. LOWER ½ IS A BROWN CONGLOMERATE W/ CLASTS OF BROWN DOLSTS & MUDST FROM UNIT BELOW, ≤ 1×3 cm. UPPER ½ IS GREEN FOSSILIFEROUS(?) PACK-GRAINSTONE W/ SOME CLASTS. UNIT IS 10-25 CM THICK & 10's OF METERS WIDE OVERALL.

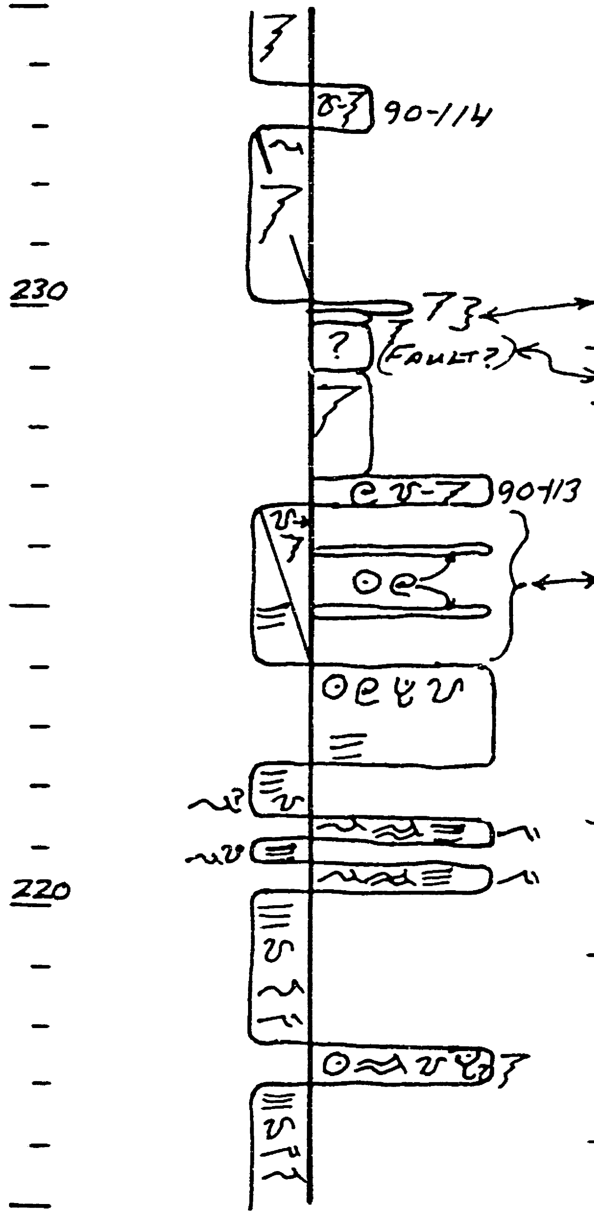
TAN MUDST, BEDDED ≤ 5MM TO 2 CM THICK

GREEN OOLITIC (½ mm) GRST W/ INTERLAMINATIONS ≤ 1CM THICK, OF RED DOLOSILTITE & ARE DISCONTINUOUS. POSSIBLE DOLOSILTITE LITHOCLASTS & BURROW-FILL. 15 CM FROM BOTTOM IS A 10 CM THICK MUDDY VF SS (≡ ʊ)

GREEN TO TAN SILTY MDST W/ OCCASIONAL VF SS INTERBEDS, ≤ 10cm (≈ ~ ≡). UNIT IS SILTIER & MORE BURROWED THAN 142.1-168.0 m & MORE SILTY THAN 113-142.1 m.



210
200
(SEE NEXT PAGE)
90-112-OOPS
OLIVE-BROWN OOLITIC (1 mm) GRST IN LOWER 15 cm. OLIVE BROWN FINES UP FROM WACKESTONE/PACKSTONE TO MUDSTONE/WACKESTONE, BOTH W/ ⊙ & ℓ
GREEN, SILTY, SANDY MUDSTONE
OLIVE-GREEN/BROWN PACKSTONE/GRAINSTONE W/ ONCOIDS ≤ ½ cm, ⊙ (1 mm), SOME ℓ, A FEW LITHOCLASTS (≤ 1x3 cm). UPPER 5 cm BIOTURBATED.
OLIVE BROWN OOLITIC (½ mm) GRST, W/ CONTINUOUS & DISCONTINUOUS DOLOSILTITE INTERLAMINATIONS, ≤ 2 cm, ≡.
TAN TO ORANGE, SILTY, SILICEOUS MUDSTONE.
OLIVE GREEN & OLIVE BROWN OOLITIC (½ mm) GRST. W/ DISCONTINUOUS DOLOSILTITE INTERLAMINATIONS, ≤ 1 cm, ≡. DOLOSILTITE BURROW-FILL.
NOTE: 200-210 m: MUCH LATERAL VARIATION IN NUMBERS & THICKNESS OF CARBONATE BEDS OVER DISTANCES OF ONLY 10'S OF METERS.
OLIVE GREEN/OLIVE BROWN, OOLITIC (½ mm) GRST, 5-10 cm BEDS. W/ CONTINUOUS DOLOSILTITE INTERLAMINATIONS, ≤ 1 cm, ≡.
COVERED.
½ cm THICK, BIOTURBATED, SILICEOUS CRUST AT TOP OF INTERVAL MAY BE A HARDGROUND. OLIVE GREEN/OLIVE BROWN GRST, IN 2 VARIETIES: (1) OOLITIC GRST (2) OOLITIC-FOSSILIFEROUS GRST, W/ CLASTS OF DOLSTS & ⊙ GRST (≤ 1x2 cm). GRSTS BEDDED 5-10 cm. DISCONTINUOUS DOLSTS INTERLAMINAE ≤ 2 cm, ≡.
TAN, DOLOMITIC, SILTY SILICEOUS MUDSTONE
OLIVE GREEN/OLIVE BROWN OOLITIC GRST LIKE 208 m.
TAN SANDY MUDSTONE. TOP 15 cm ONLY ARE BURROWED, & ARE MORE SILTY.
2 OLIVE GREEN-OLIVE BROWN GRSTS W/ TAN & ORANGE, SILTY SILICEOUS MUDSTONE BETWEEN. UPPER GRST W/ ONCOIDS & MORE BURROWS THAN LOWER.
TAN & ORANGE SILTY MDST
OLIVE GREEN/OLIVE BROWN OOLITIC (½ mm) GRST, W/ BROWN DOLOSILTITE INTERLAMINATIONS, ≤ 1 cm, ≡. DOLOSILTITE BURROW-FILLS
GREEN, SILTY MUDSTONE
OLIVE GREEN/OLIVE BROWN. LOWER ½ OOID GRST, ≈5-10 cm, SCOURED UPPER SURFACE. UPPER ½ W/ CLASTS OF OOID GRST & DOLOSILTITE, ≤ 1½ x 4 cm, ROUNDED TO ANGULAR. MATRIX IS A ⊙-ℓ PACKSTONE. DOLOSILTITE ON TOP, ~.
TAN, REDDISH, PINKISH MUDSTONE LIKE 192 m
GREEN PACKSTONE/GRAINSTONE W/ OOIDS (½ mm), FOSSILIFEROUS MATRIX, & TWO TYPES OF ONCOIDS: LOWER 2 cm HAS CYLINDRICAL, ≤ x 2 cm. UPPER 10 cm ARE SPHERICAL
90-112
BROWN DOLOSILTITE W/ DOLOSILTITE CLASTS, ≤ 10 cm BEDS. W/ INTERBEDS OF GREEN, FOSSILIFEROUS & OOLITIC PACKSTONE/GRAINSTONE.




ORANGE-BROWN, BLOCKY & UNBEDDED, BURROWED-TO-BIOTURBATED DOLOSILTITE.

GREEN, SILTY, SILICEOUS MDST. CRUDELY BEDDED ≤ 2CM IN UPPER 30-40 CM, NOT BIOTURBATED & HAS ~, IN 1-3CM BEDS OF ALTERNATING 3 & ~.

TAN, BIOTURBATED DOLOSILTITE ON TOP OF OLIVE-GREEN BIOTURBATED WACKESTONE. TAN DOLOSILTITE BURROW-FILL

WHITE, POWDERED "MDST". VERY SOFT, PUNKY, HIGHLY REACTIVE W/ DILUTE HCL. FAULTED?

TAN, DOLOMITIC SILTY MDST, CRUDELY BEDDED 1-5 CM.

OLIVE-BROWN, FOSSILIFEROUS GRST/CALCARENITE (5-10% @). BURROWING DECREASES UPWARD, UNTIL ONLY A FEW BURROWS IN TOP 15-20 CM. BROWN DOLOSILTITE BURROW-FILL

224.0 → 226.6 M: BEDS SCHEMATICALLY SHOWN. GREEN & GREENISH-BROWN, SANDY, SILICEOUS MDST, W/ A FEW INTERBEDS OF FOSSILIFEROUS-OOLITIC GRST/ARENITE, BEDDED ≤ 2 CM.

OLIVE-BROWN OOLITIC (1/4-1/2 MM) GRST W/ 5-10% FOSSIL FRAGMENTS, ≤ 15 CM. A FEW SCATTERED INTERLAMINATIONS, ≤ 5 MM, OF BROWN DOLOSILTITE, DISCONTINUOUS, ≡. DOLOSILTITE BURROW-FILL

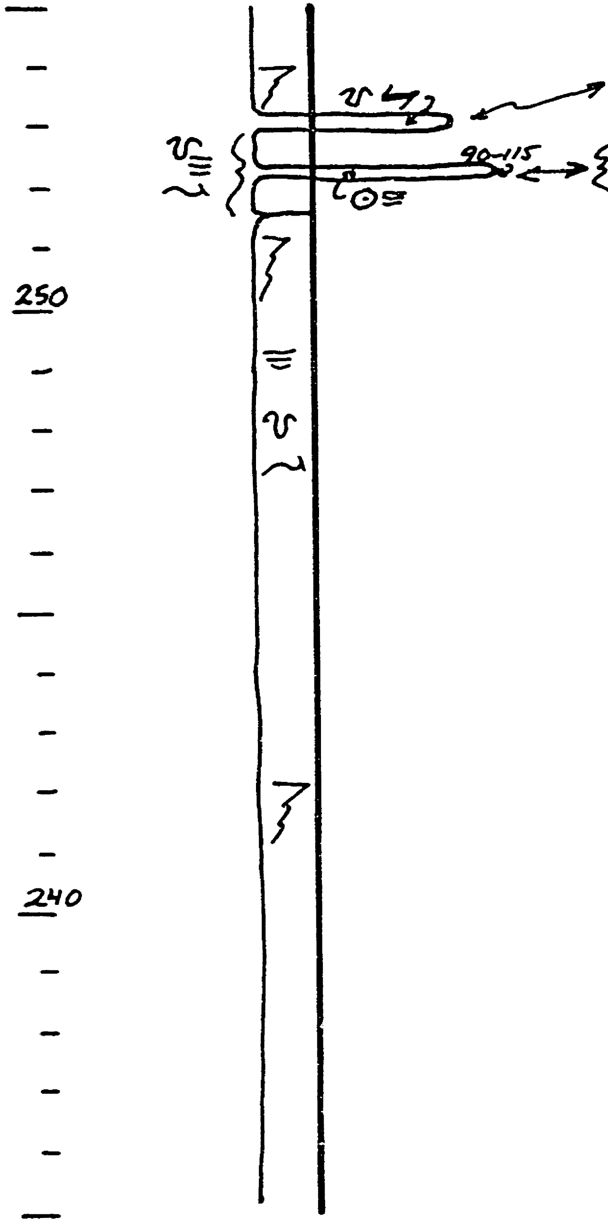
GREEN, SILTY MDST

2 UNITS OF OLIVE-BROWN, VF CALCARENITE, BEDDED 10-15 CM IN UPPER UNIT & ≤ 8 CM IN LOWER. BOTH HAVE INTERBEDDED SILICEOUS SS, VF QUARTZ SS & MUDDY SS. BETWEEN 2 ARENITE UNITS IS MOSTLY GREEN, SILTY, SANDY SILICEOUS MDST W/ INTERBEDDED CALCARENITE. MIDDLE INTERVAL BEDDED ≤ 8 CM.

GREEN, SILTY MUDSTONE LIKE 215 M. SS INTERBEDS ≤ 3 CM

OLIVE-GREEN OOLITIC (1/2-3/4 MM) GRST (?) W/ A 15 CM THICK DOLOSILTITE/DOLARENITE (VF) BED IN CENTER (≈). AT TOP OF INTERVAL IS A 5-10 CM THICK MIXTURE OF GRST & DOLOSILTITE/DOLARENITE.

GREEN, SILTY MUDSTONE, ≡. W/ INTERBEDS OF VF SS, ≤ 5 CM, ~. NUMBER OF SANDSTONE BEDS INCREASE UPWARDS. ABOUT 1 M FROM TOP IS A LENTICULAR, OOLITIC-FOSSILIFEROUS GRAINSTONE, 2 CM THICK. ⊙ 1/2-3/4 MM.




TAN TO GREEN, SILTY, SILICEOUS MDST., SIMILAR TO 240 m.

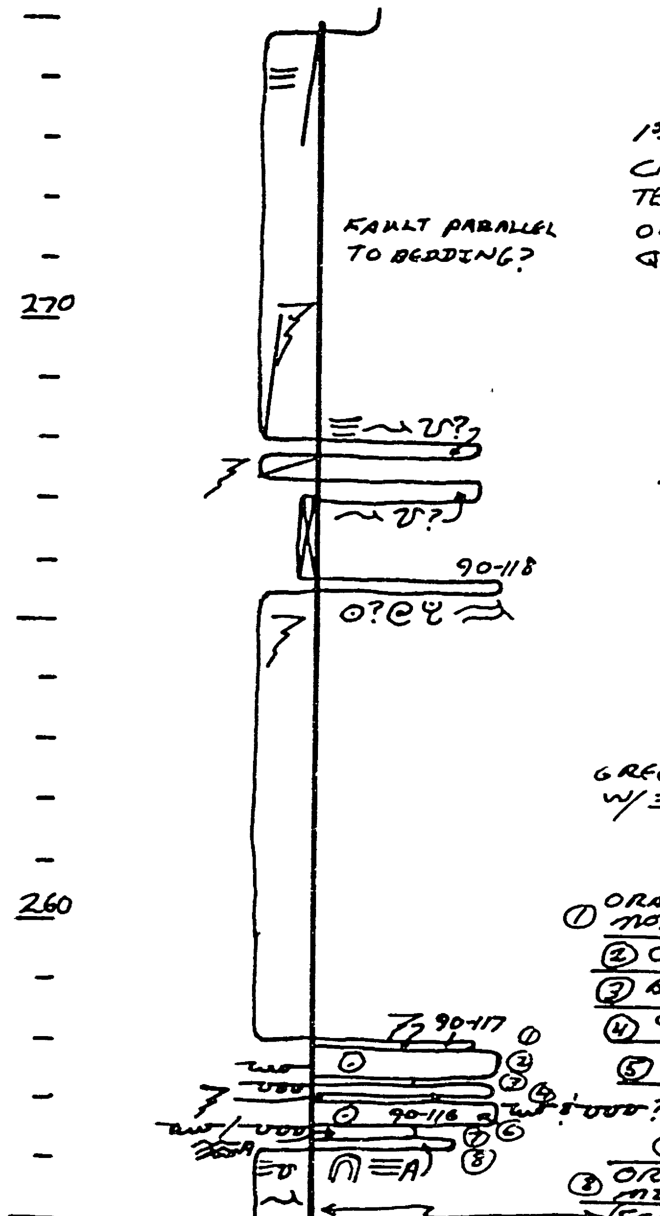
ORANGE DOLOSILTITE W/ LITHOCLASTS OF SAME, ≤ ½ x 1½ cm

GREEN MDST LIKE 251 m

ORANGE OOLITE (≤ ¼ mm) GRST W/ DOLOSILTITE INTERLAMINATIONS.
OOIDS ARE A LIMY DOLOMITE.

GREEN MDST LIKE 251 m

GREEN TO GRAY, SILTY, SILICEOUS MUDS. MORE BURROWED IN BASAL 15 m, THEN MORE ≡ (≤ 5 mm) & ~ (≤ 1 cm) STS/VF SS.




1st RED, BLOCKY, SILTY, SILICEOUS MUDSTONE. MORE BURROWED/CHURNED IN LOWER PART & MORE ≡ IN UPPER. ONE POSSIBLE TEPEE/MUDCRACK ABOUT 2cm HIGH. SMALL FLASER RIPPLES OF RED SILTSTONE. AT 272m, A 10cm THICK, FRACTURED QUARTZ VEIN W/ SLICKENSIDES – POSSIBLE FAULT.

CALCISILTITE & CALCARENITE LIKE 267.2m.

LIGHT GREEN, SILTY MDST LIKE 265m

OLIVE-GREEN/OLIVE BROWN CALCISILTITE TO VF CALCARENITE, ≤ 1mm-DIAMETER BURROWS(?)

COVERED

LIGHT GREEN GRAINSTONE W/ ¼-½ mm GRAINS. 2 SETS OF TROUGH-CROSS-BEDS 5 & 10 cm HIGH. POSSIBLE HUMMOCKY CROSS-BED AT TOP 2-3 cm HIGH.

GREEN, SILTY, SANDY, SILICEOUS MDST. UPPER ½ m IS ONLY BURROWED W/ ≡. POSSIBLY SOME MICROBIAL LAMINATION, BUT NOT CALCAREOUS

① ORANGE-BROWN DOLOSILTITE/VF DOLARENITE. SIMILAR TO UNIT ③ BUT MORE ORANGE & BETTER INDURATED.

② OOID GRST LIKE 257m (UNIT ⑥)

③ BROWN CALCISILTITE & DOLOSILTITE IN COARSE MICROBIAL LAMINATION.

④ ORANGE DOLOSILTITE. FINE MICROBIAL LAMINATION (≡A) & STROMATOLITES

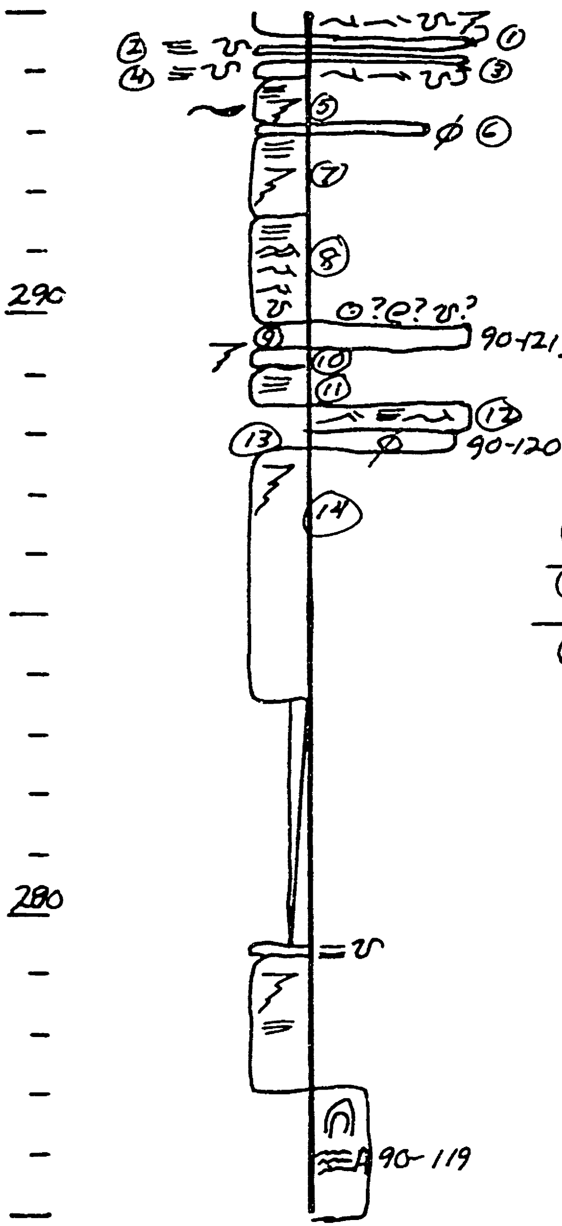
⑤ BROWN, BIOTURBATED PACKSTONE/CALCARENITE, W/ 1-3cm QUARTZ VEIN AT TOP (FAULT?)

⑥ OOID (½-2mm) GRST, W/ A FEW HARD BROWN DOLSTS INTERLAMINATIONS ESPECIALLY IN LOWER ½.

⑦ BROWN DOLSTS TO LIMESTONE MDST/WKST W/ COARSE MICROBIAL LAMINATION. HARDGROUND/EROSIVE SURFACE AT TOP CONTACT

⑧ ORANGE DOLOSILTITE W/ BROAD, LOW-RELIEF STROMATOLITES & FINAL MICROBIAL LAMINATION

(SEE PREVIOUS PAGE)




(1) OLIVE-BROWN, LIMY DOLOSILTITE TO DOLARENITE. BIOTURBATED TO ⌀ 10 CM

(2) PINK, SILTY, SANDY, SILICEOUS MUDSTONE

(3) OLIVE-BROWN LIMY DOLOSILTITE TO DOLARENITE

(4) TAN, PINK, SILTY, SANDY SILICEOUS MDST

(5) RED, BLOCKY, SILTY, SILICEOUS MDST

(6) GREEN-TAN, CALCAREOUS ONCOLITIC WACKESTONE/PACKSTONE W/ DISCONTINUOUS INTERLAMINATIONS OF PINK-TAN, BIOTURBATED, SILTY, SANDY, SILICEOUS MDST

(7) RED, SILTY, BLOCKY, SILICEOUS MDST, W/ A ≤ 5 cm GREEN STREAK AT 292.5 M

(8) GRAY-PURPLE SILTY, SILICEOUS MDST. MORE BURROWED TOWARDS BOTTOM. BEDDED ≤1–15 cm, MUCH 5-10 cm BEDDED.

(9) OLIVE-GREEN OOLITIC(?) (¼ COARSEN UP TO ½ mm) PACKSTONE/GRAINSTONE, W/ ABOUT 5% FOSSIL FRAGMENTS. OOIDS(?) MAY BE COATED GRAINS &/OR PELOIDS.

(10) LIGHT GREEN SILTY TO SANDY MDST } BOTH SILICEOUS

(11) LIGHT GREEN SILTY MDST

(12) OLIVE GREEN/OLIVE BROWN INTERBEDDED DOLOSILTITE & CALCARENITE. SOME POSSIBLE CALCAREOUS WACKESTONE/PACKSTONE, BEDDED ≤1 cm.

(13) GREEN ONCOLITIC (≤ ½–1½ cm) PACKSTONE W/ BROWN CALCISILTITE TO CALCARENITE (VF) MATRIX.

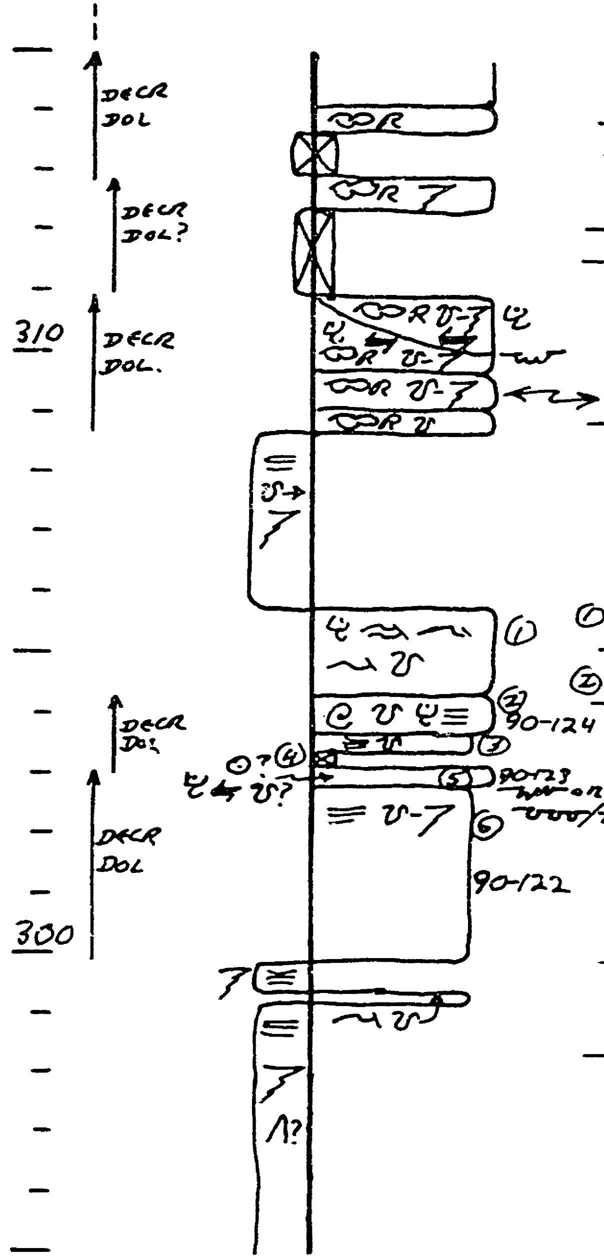
(14) RED, BLOCKY, SILTY, SILICEOUS MDST LIKE 268 m. AT 283.7 m, HAVE A GREEN SILTY MDST BED, 10 cm THICK, ≡.

COVERED. PROBABLY RED, SILTY MDST LIKE 268 m

10 cm GREEN/TAN SILTY SILICEOUS MDST

BLOCKY, RED, SILTY, SILICEOUS MDST. ≡ IN UPPER 10 cm. LIKE 268 m

GRAY CALCAREOUS MDST (POSSIBLY PELLETED INSTEAD), BEDDED ≤ ½ mm, W/ COARSE MICROBIAL, CRINKLY LAMINATION, & NARROW, HIGH-DOMED STROMATOLITES, ≤ 15 cm HIGH.




GRAY CALCARENITE/MDST, BEDDED 2-8 CM, W/ BROWN DOLOSILTITE INTERLAMINATIONS, < 1 CM, ~20% OF TOTAL INTERVAL.

COVERED

GRAY CALCARENITE/MDST IN BLOBS, ≤ 2 CM. ORANGE-BROWN DOLOSILTITE BURROW FILL. NO UNDISTURBED BEDDING, ALL IS BIOTURBATED. ABOUT 10% DOLOSILTITE. TOP 10 CM ONLY BURROWED.

COVERED

CHANNEL W/IN INTERVAL FILLED W/ SAME LITHOLOGY AS CUT INTO. RIBBON ROCK; LIMESTONE BROWNISH-GRAY, W/ ≤ 20 CM. INTERLAMINATIONS, ≤ 1 CM OF DOLOSILTITE. LITHOCLASTS OF DOLOSILTITE, AS ARE BURROW-FILLS. NO CLAST CONGLOMERATE BEDS.

LS BEDDED ≤ 5 CM. DISCONTINUOUS DOLSTS INTERLAMS, ≤ 1½ MM. SOME DOLSTS BURROW-FILL. ABOUT 15% DOLSTS.

GRAY LS, BEDDED ≤ 2 CM. ABOUT 20-25% INTERLAMINATIONS OF ORANGE-BROWN DOLOSILTITE, ≤ 5 MM, ≡.

GREEN, SILTY, SILICEOUS MDST

OLIVE-GREEN CALCARENITE, BEDDED ≤ 5 CM, W/ ≤ 25 ..., ⇝ 10-15 CM,
① ⌒, ⌒. W/ INTERBEDDED/INTERLAMINATED BROWN DOLOSILTITE/DOLARENITE, ≤ 2 CM) ≈ 20% OF TOTAL UNIT.

② GRAY-BROWN CALCARENITE, < 10 CM, ABOUT 5% Ⓒ. BURROWS ≤ 1-4 MM DIAMETER, MOST ≤ 1 MM, FILLED W/ BROWN DOLOSILTITE.

③ GREEN CALCARENITE, W/ SOME DISCONTINUOUS INTERLAMINATIONS & BURROW FILL OF BROWN DOLOSILTITE.

④ COVERED.

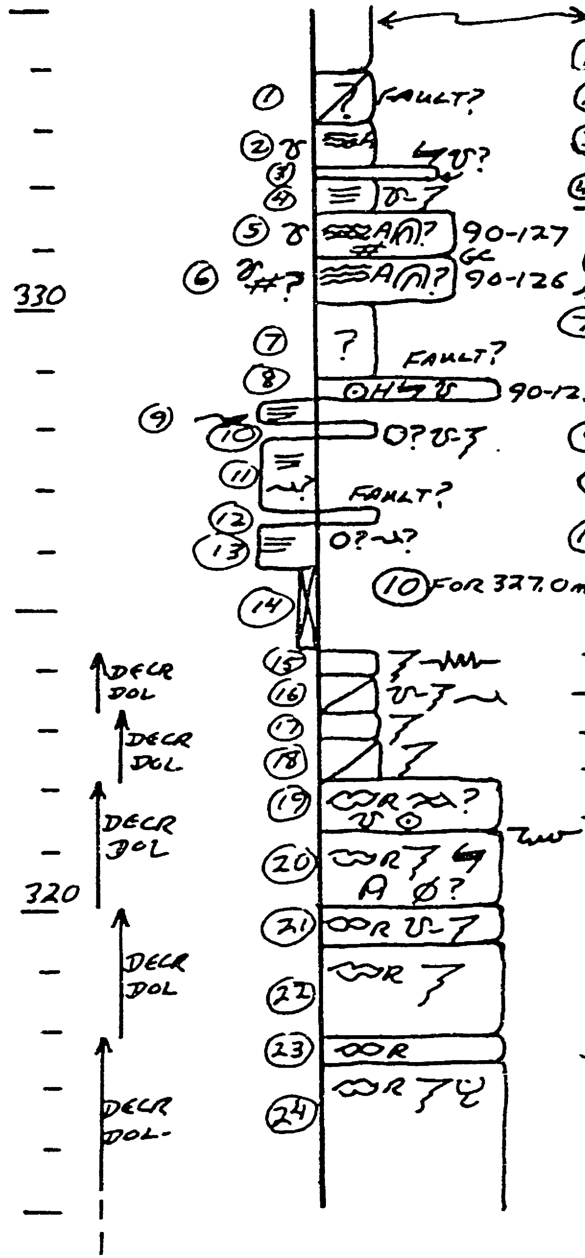
⑤ GRAY OOLITIC? (≤ ¼ MM) GRST. A 5 CM THICK LITHOCLAST BED IN CENTER W/ BURROWED, BROWN DOLOSILTITE MATRIX. UPPER GRST MORE BURROWED & COARSER THAN LOWER. BASAL CONTACT VERY IRREGULAR. DISSOLUTION &/OR EROSION &/OR HARDGROUND?

⑥ OLIVE-BROWN & OLIVE-GREEN, MUDDY CALCARENITE & BROWN DOLOSILTITE, MOSTLY BEDDED 2-5 CM, W/ A FEW BEDS ABOUT 10 CM. LOT OF QUARTZ SILT & SAND. MIDDLE IS LESS BURROWED & THICKER-BEDDED THAN TOP & BOTTOM. MUD IS CARBONATE MUD.

GREEN, SILTY, SILICEOUS MDST

GREEN & BROWN DOLOSILTITE W/ INTERBEDDED BROWN DOLOSILTITE. BEDDED ≤ 5 CM.

RED UP TO GREEN SILTY MDST. 2 INTERVALS, EACH 10-20 CM THICK, OF TAN TO PINK SILTY MDST • POSSIBLE TEPEES/MUDCRACKS IN RED MDST.

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(1) WHITE CALCAREOUS POWDER

(2) LIGHT GREEN SILTY MDST (CALCAREOUS). POSSIBLE PLANAR MICROBIAL LAMINAE IN ADDITION TO CRINKLEY.

(3) OLIVE BROWN/OLIVE GREEN LIMESTONE W/ POSSIBLE LITHOCLASTS (OR BURROW-FILL) OF < 1 X 2 cm

(4) LIGHT GREEN, SILTY, CALCAREOUS MDST, POSSIBLY CRINKLEY MICROBIAL LAMINAE

(5) (6) ORANGE DOLOSILTITE } CHANGE ↑ GRADUALLY } GREEN CALCISILTITE } LAMINATIONS 2-20cm WIDE, CUP-SHAPED MAY BE MUDCRACKS. COMMONLY LOOKS LIKE ITS TRYING TO FORM BROAD, LOW-RELIEF STROMATOLITES (5) & (6)

(7) WHITE, POWDERED, CALCAREOUS "MUDSTONE". MAY HAVE ORIGINALLY BEEN LIKE UNITS IMMEDIATELY ABOVE.

(8) LIGHT OLIVE-GREEN OOLITIC (1mm) GRST, W/ SOME CLASTS &/OR BURROW-FILL OF DOLOSILTITE IN LOWER ½

(9) GREEN-BROWN, SILTY, SILICEOUS MDST W/ SILTY FLASER RIPPLES < 8mm THICK

(11) GREEN, SILTY SILICEOUS MDST LIKE 326.0m. A FEW DOLOSILTITE WAVE RIPPLES, < 5mm, NEAR TOP. 10cm AT BASE IS A GREEN CALCITE VEIN, POSSIBLY A FAULT.

(12) OLIVE GREEN, PELOIDAL? (≤ ¼mm) MDST. 2 BEDS. POSSIBLE ~ ON TOP SURFACE.

(10) FOR 327.0m { OLIVE-GREEN, PELOIDAL? MDST. LIKE 326.6m. LOWER ½ BIOTURBATED-TO-BURROWED.

(13) GREEN, SILTY, SILICEOUS MDST, ≡, 1-5mm

(14) COVERED. PROBABLY LIKE UNIT ABOVE.

(15) GREEN, MARLY CALCAREOUS/DOLOMITIC MDST. LESS BURROWED THAN (17), (18)

(16) GREEN-TAN MARLY CALCAREOUS/DOLOMITIC MUDST., SILTY. LESS BURROWED THAN (17), (18).

(17) GREEN-TAN MARLY CALCAREOUS/DOLOMITIC MDST. MORE LIMESTONE. MASSIVE, NO BEDDING.

(18) TAN-GREEN MARLY CALCAREOUS/DOLOMITIC MDST, CRUDELY BEDDED 2-4cm.

(19) GRAY-BROWN OOLITIC (½ mm, DOLOMITIC) GRST, BROWN DOLSTS IN BURROWS & DISCONTINUOUS INTERLAMINATIONS ≤ 1cm. ABOUT 5% DOLOSILTITE, NOT COUNTING OOIDS.

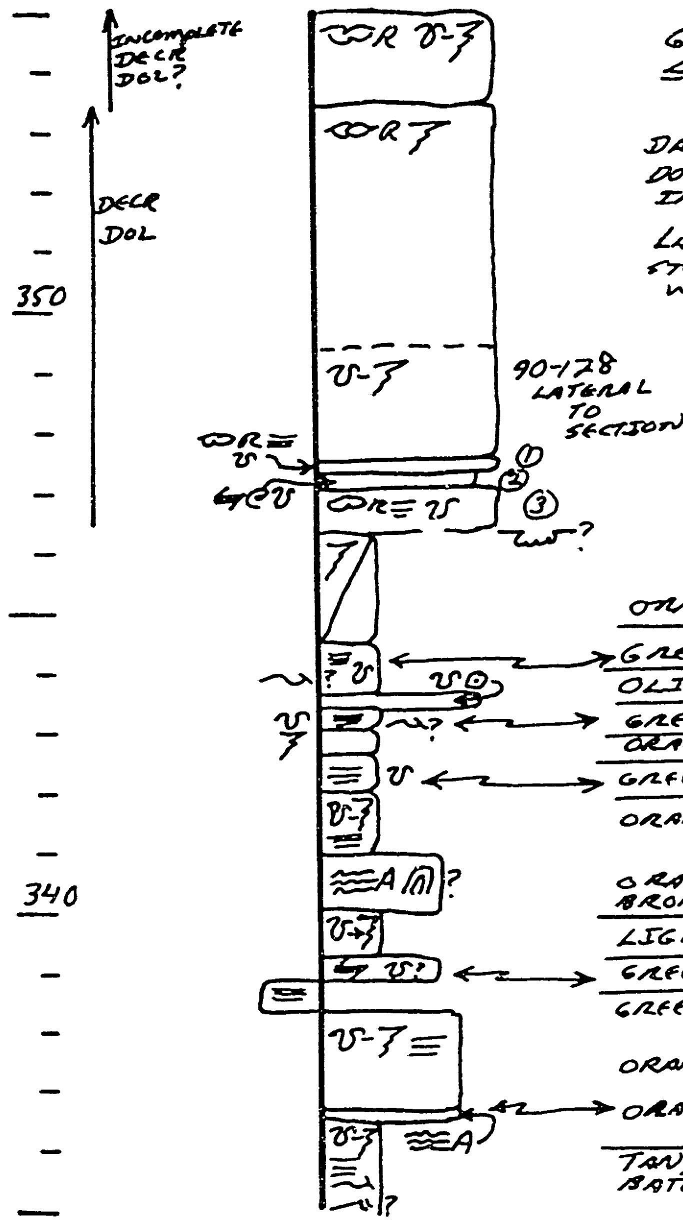
(20) GRAY CALCARENITE/MDST. W/ BURROW-FILL & DISCONTINUOUS INTERLAMINATIONS OF ORANGE DOLSTS, ≤ 1cm. REMNANTS OF A 10cm CLAST BED W/ POSSIBLE ONCOIDS (< 1cm) & FOSSIL FRAGMENTS.

(21) GRAY CALCARENITE/MDST. W/ BURROW FILLS & DISCONTINUOUS BLOBS OF BROWN DOLSTS, ≤ 5% DOLSTS OVERALL.

(22) GRAY CALCARENITE/MDST, BEDDED 3-15cm. W/ DISCONTINUOUS INTERLAMINATIONS OF BROWN DOLOSILTITE, < 2cm THICK, ∪-Ʒ. DOLSTS IN BURROW-FILL. ABOUT 20-25% DOLOSILTITE OVERALL

(23) GRAY CALCARENITE/MDST. < 5% DOLOSILTITE AT BASE.

(24) LIKE 312.6m. ABOUT 10-15% DOLOSILTITE. 10 cm HIGH Ꞩ IN TOP METER.




GRAY CALCARENITE/MDST, BEDDED 1-5CM. INTERLAMINATIONS, ≤1CM, & BURROW-FILL OF ORANGE-BROWN DOLOSILTITE (ABOUT 15-20%)

DARK GRAY CALCARENITE/MDST & IN LOWER 2 M IT BEDDED 5-10 CM. DOLOSILTITE DECREASES UP FROM 20-25% TO ≤5%. DOLSTS IN INTERBEDS ≤1-3 CM & BURROW-FILL.

LATERALLY HAVE AN OOLITIC(?)-FOSSILIFEROUS PACKSTONE/GRAINSTONE. EITHER A CHANNEL-FILL OR A FACIES CHANGE, CAN'T WALK CHANGE.

① LIKE 347 M.

② GRAY PACKSTONE/GRAINSTONE, W/CLASTS ≤ 1½ × 1½ CM.

③ GRAY CALCARENITE/MDST, BEDDED ½-5CM, W/INTERBEDS OF ORANGE DOLOSILTITE, BEDDED ≤ 5CM, ≡ & DOLSTS BURROW-FILL. ABOUT 20% DOLSTS OVERALL. BASAL CONTACT IS EITHER SCOURED OR FAULTED. LOWER 1.1 M OF UNIT NOT PRESENT LATERALLY.

ORANGE, SILTY, DOLOMITIC MDST

GREEN DOLOMITIC MDST

OLIVE-GREEN OOLITIC (½ MM) GRST

GREEN, SILTY DOLOMITIC & CALCAREOUS MDST

ORANGE, SILTY, DOLOMITIC MDST

GREEN, SILTY, CALCAREOUS MDST

ORANGE, SILTY DOLOMITIC MDST

ORANG DOLOSILTITE W/ COARSE, CRINKLEY, MICROBIAL LAMINAE, POSSIBLE BROAD, LOW-RELIEF, POOR QUALITY, STROMATOLITES.

LIGHT GREEN, SILTY, DOLOMITIC MDST

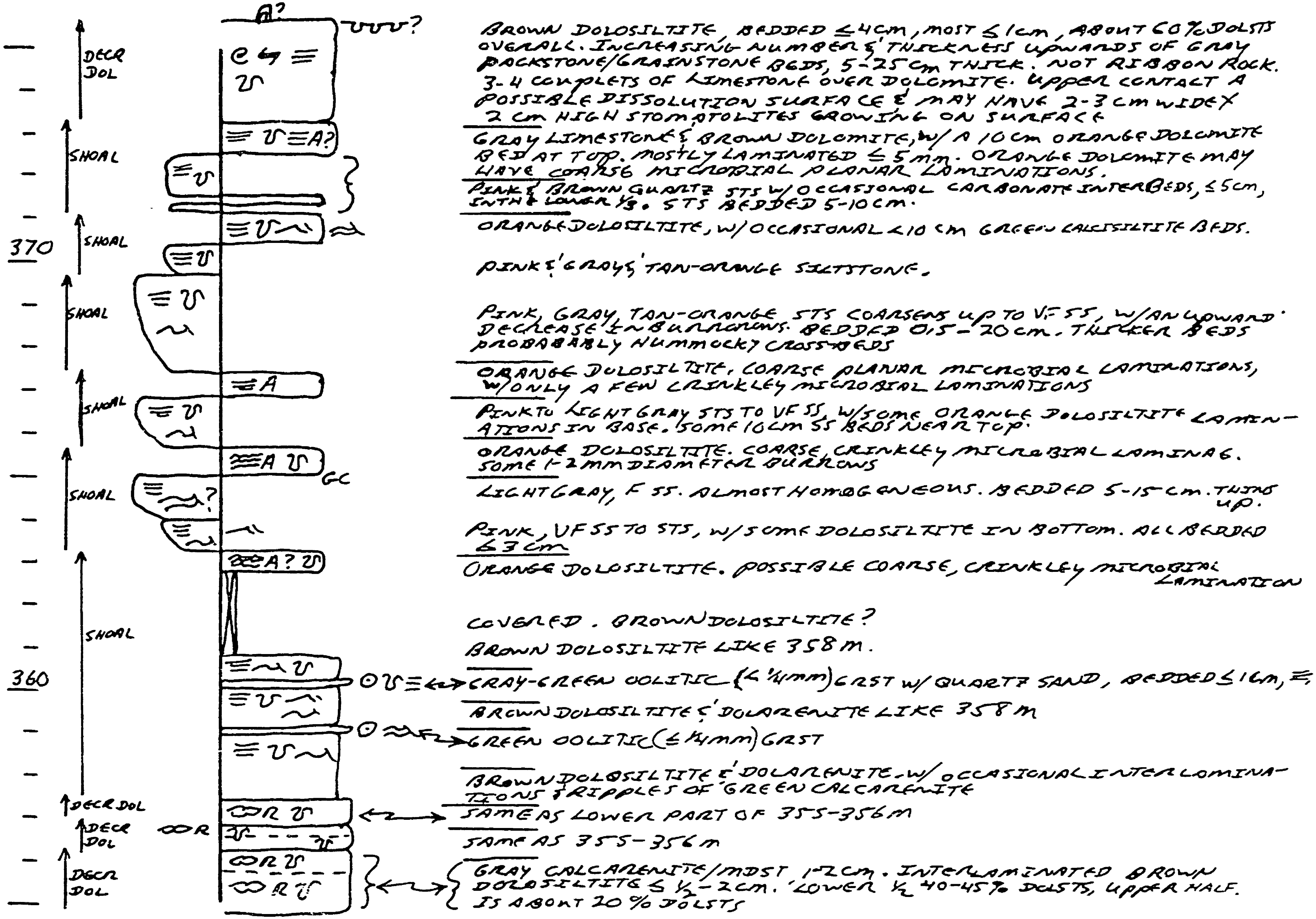
GREEN CALCISILTITE & BROWN DOLSTS LIKE 332.3 M. SIMILAR TO RIBBON ROCK AT 312.6 M

GREEN, SILTY, SILICEOUS MDST, LIKE 326 M

ORANGE, MUDDY DOLOSILTITE

ORANGE, MUDDY DOLOSILTITE. DISRUPTED LAMINATION

TAN, W/SOME ORANGE, SILTY, DOLOMITIC MDST. MOSTLY BURROWED TO BIOTURBATED, SOME ≡. IN BASAL 1 M, IS MORE OF A DOLOSILTITE.


A?
VVV?
DECR DOL
SHOAL
SHOAL
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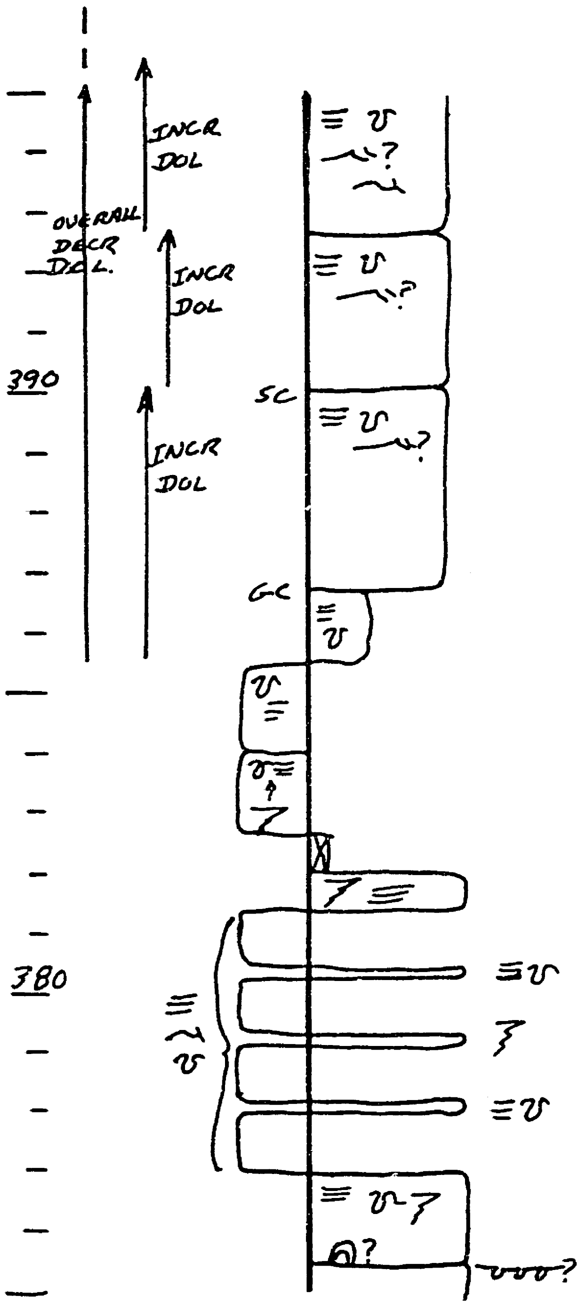
DECR DOL
DECR DOL
DECR DOL
370
360
GC
BROWN DOLOSILTITE, BEDDED ≤4CM, MOST ≤1CM, ABOUT 60% DOLSTS OVERALL. INCREASING NUMBERS & THICKNESS UPWARDS OF GRAY PACKSTONE/GRAINSTONE BEDS, 5-25 CM THICK. NOT RIBBON ROCK. 3-4 COUPLETS OF LIMESTONE OVER DOLOMITE. UPPER CONTACT A POSSIBLE DISSOLUTION SURFACE & MAY HAVE 2-3 CM WIDE X 2 CM HIGH STOMATOLITES GROWING ON SURFACE
GRAY LIMESTONE & BROWN DOLOMITE, W/ A 10 CM ORANGE DOLOMITE BED AT TOP. MOSTLY LAMINATED ≤5 MM. ORANGE DOLOMITE MAY HAVE COARSE MICROBIAL PLANAR LAMINATIONS.
PINK & BROWN QUARTZ STS W/ OCCASIONAL CARBONATE INTERBEDS, ≤5CM, IN THE LOWER 1/3. STS BEDDED 5-10CM.
ORANGE DOLOSILTITE, W/ OCCASIONAL ≤10 CM GREEN CALCISILTITE BEDS.
PINK & GRAYS TAN-ORANGE SILTSTONE.
PINK, GRAY, TAN-ORANGE STS COARSENS UP TO VF SS, W/ AN UPWARD DECREASE IN BURROWS. BEDDED 0.5-20 CM. THICKER BEDS PROBABLY HUMMOCKY CROSSBEDS
ORANGE DOLOSILTITE, COARSE PLANAR MICROBIAL LAMINATIONS, W/ ONLY A FEW CRINKLEY MICROBIAL LAMINATIONS
PINK TO LIGHT GRAY STS TO VF SS, W/ SOME ORANGE DOLOSILTITE LAMINATIONS IN BASE. SOME 10CM SS BEDS NEAR TOP.
ORANGE DOLOSILTITE. COARSE, CRINKLEY MICROBIAL LAMINAE. SOME 1-2 MM DIAMETER BURROWS
LIGHT GRAY, F SS. ALMOST HOMOGENEOUS. BEDDED 5-15 CM. THINS UP.
PINK, VF SS TO STS, W/ SOME DOLOSILTITE IN BOTTOM. ALL BEDDED ≤3 CM
ORANGE DOLOSILTITE. POSSIBLE COARSE, CRINKLEY MICROBIAL LAMINATION
COVERED. BROWN DOLOSILTITE?
BROWN DOLOSILTITE LIKE 358 M.
GRAY-GREEN OOLITIC (≤1/4 MM) GRST W/ QUARTZ SAND, BEDDED ≤1CM, ≡
BROWN DOLOSILTITE & DOLARENITE LIKE 358 M
GREEN OOLITIC (≤1/4 MM) GRST
BROWN DOLOSILTITE & DOLARENITE, W/ OCCASIONAL INTERLAMINATIONS & RIPPLES OF GREEN CALCARENITE
SAME AS LOWER PART OF 355-356 M
SAME AS 355-356 M
GRAY CALCARENITE/MOST 1-2 CM. INTERLAMINATED BROWN DOLOSILTITE ≤1/2-2 CM. LOWER 1/2 40-45% DOLSTS, UPPER HALF IS ABOUT 20% DOLSTS




LIKE 386.8–390.1 m. DOLOSILTITE BEDDED ≤2 mm TO 4 cm, ≡ V. LIMESTONE BEDDED ≤1–3 cm, ~ ≡ V ~? ABOUT 50% DOLOSILTITE OVERALL, FROM 40% UP TO 60% AT TOP.

LIKE 386.8 TO 390.1 m. ABOUT 60–70% DOLOMITE, FROM 50% AT BASE TO 100% IN TOP 20 cm

INTERLAMINATED GREEN CALCARENITE/MDST & PACKSTONE, & ORANGE DOLOSILTITE. ABOUT 80% OVERALL DOLSTS. LAMINAE MOSTLY ≤5 mm, SOME BEDS ≤ 2 cm

GREEN CALCAREOUS MUDSTONE

BROWN MUDDY STS

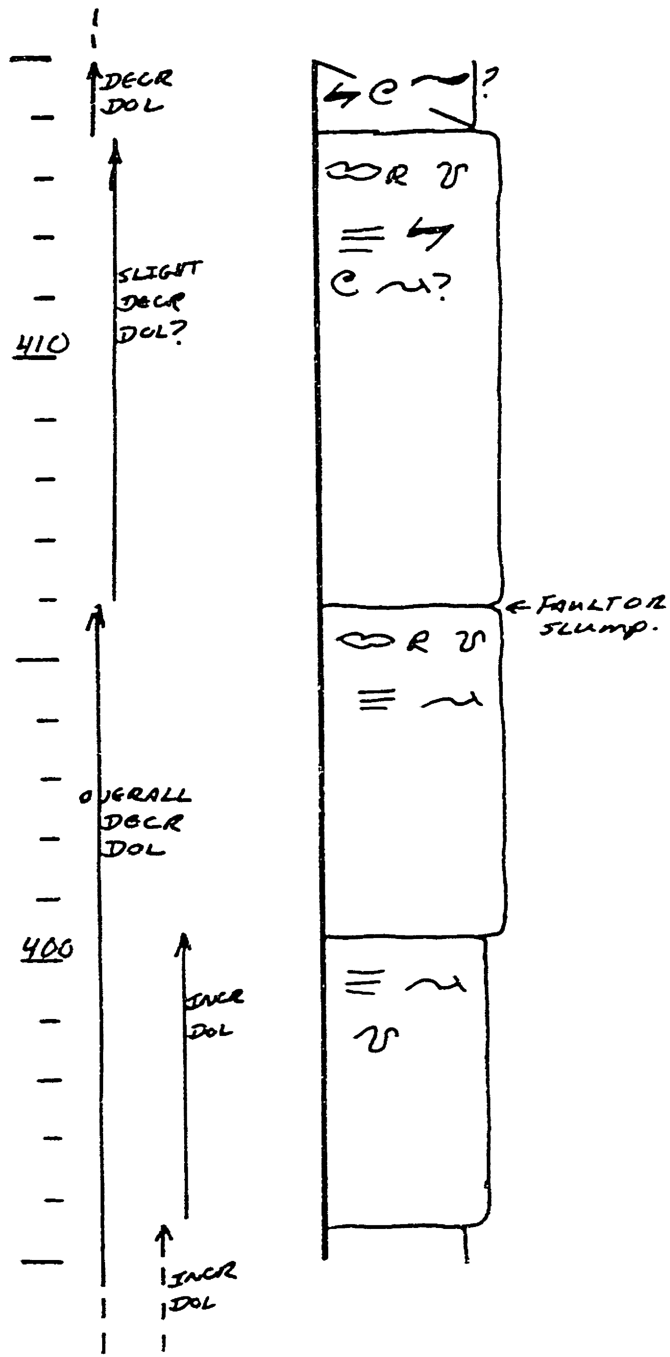
BROWN STS, W/ SEVERAL CALCAREOUS WACKESTONE/PACKSTONE BEDS, ≤2 cm. UPWARD DECREASE IN BURROWS & INCREASE IN WKST/PKST.

COVERED.

BROWN, BIOTURBATED WACKESTONE/PACKSTONE & CALCISILTITE TO CALCARENITE/DOLARENITE. ALL BEDDED <8 cm.

377–381.5 m: BEDS SHOWN SCHEMATICALLY. TAN-BROWN, MUDDY QUARTZ STS, BEDDED <5 cm W/ OCCASIONAL INTERBEDS OF TAN DOLOSILTITE & BIOTURBATED WACKESTONE/PACKSTONE

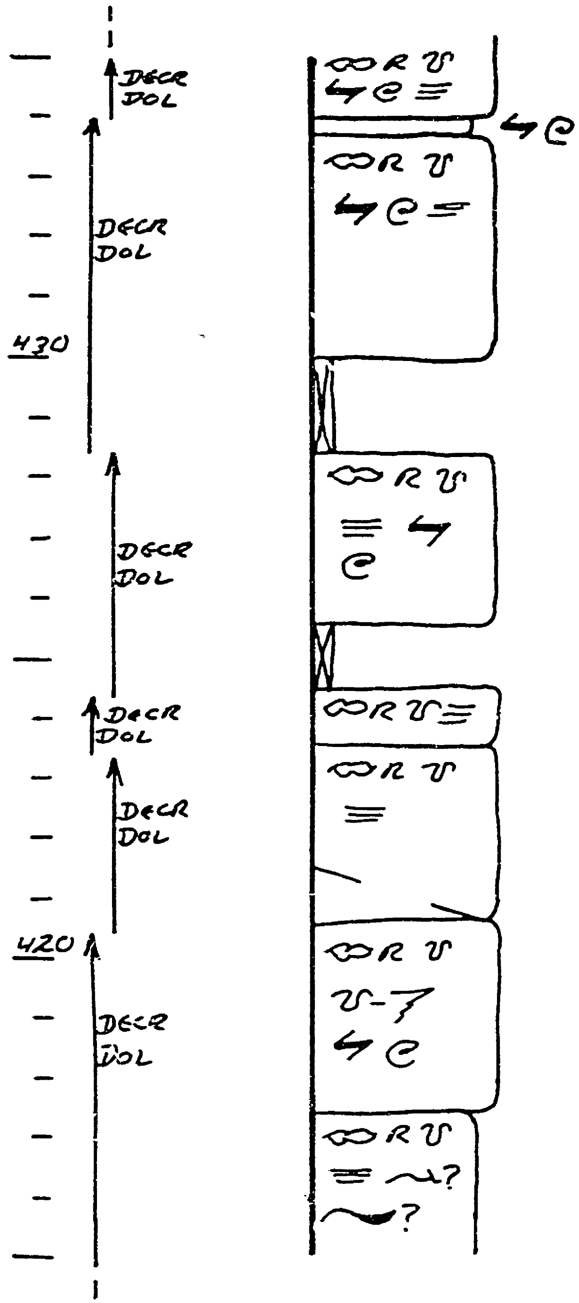
TAN DOLOSILTITE, BEDDED 1 cm, W/ 15–20% CALCARENITE/MDST IN INTERBEDS, ≤2 cm (≡ V)




DARK GRAY CALCARENITE/MDST, BEDDED 1-3cm, W/ INTERBEDS OF ORANGE DOLOSILTITE ≤ 2cm (≡ ᘔ). DOLSTS OVERALL 25%.
SEVERAL LITHOCLAST-FOSSILIFEROUS PACKSTONE/GRAINSTONE BEDS ≤10 cm THICK

LIMESTONE, BEDDED 1-5cm. DOLOSILTITE MOSTLY < 1cm, SOME 1-2cm. ABOUT 25% DOLSTS OVERALL. INCREASE BURROWING UPWARDS. DECREASE AMOUNT OF DOLSTS UPWARDS.

LITHOLOGIES LIKE 386.8-390.1m. LIMESTONE BEDDED ≤ 5cm. DOLOSILTITE BEDDED ½-2cm, IN VERY CONTINUOUS LAMINATIONS. ABOUT 40% DOLOSILTITE OVERALL. INCREASE UPWARDS FROM ABOUT 30% UP TO 60% DOLSTS.




LIKE 432 m

ORANGE-BROWN PACKSTONE/GRAINSTONE

LIKE 422 m. DOLOSILTITE 25-30%, BEDDED ≤ 1 cm

COVERED.

LIKE 422 m. DOLOSILTITE BEDDED ≤ 2 cm. A FEW LITHOCLAST-FOSSILIFEROUS BEDS.

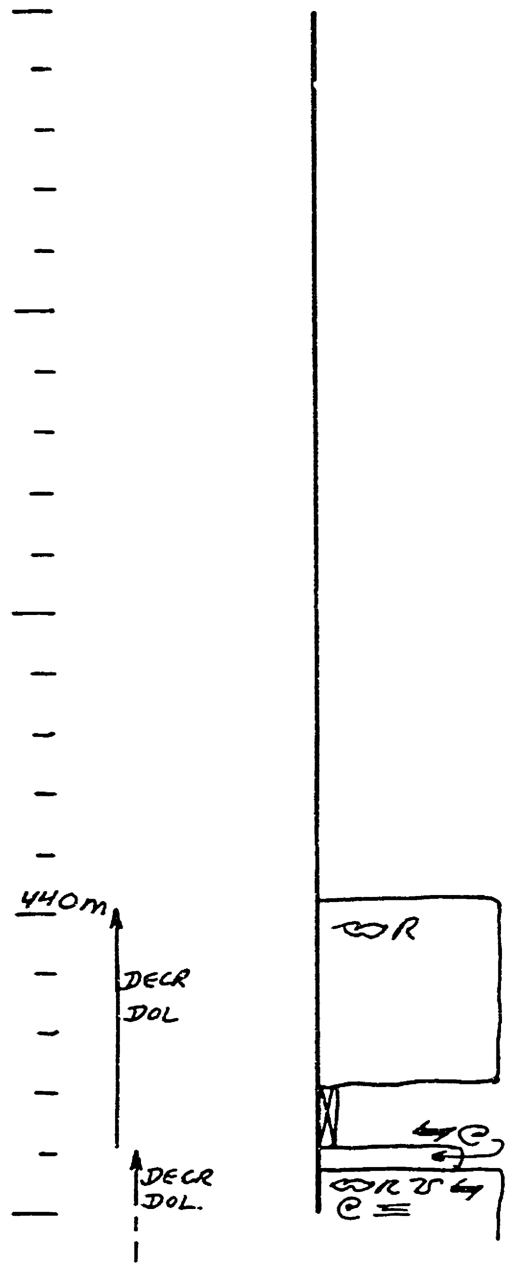
LIKE 422 m

LIMESTONE BEDDED ≤ 2 cm. DOLOSILTITE BEDDED ≤ 1 cm. BURROWS IN DOLOSILTITE FILLED W/ LIMESTONE

LIMESTONE BEDDED 1-3 cm. DOLOSILTITE BEDDED ≤ 1 cm & IN BURROW-FILL. ABOUT 20% DOLOSILTITE OVERALL. UPPER ½ m HAS ≤ 5% DOLOSILTITE. A FEW LITHOCLAST-FOSSILIFEROUS BEDS.

LIMESTONE, BEDDED ≤ 2-3 cm, SOME ABOUT 5 cm, ~(?). DOLOSILTITE ABOUT 50%, BEDDED ≤ 4 cm, MOST 1-2 cm, ~ OF LIMESTONE IN DOLSTS. SOME FOSSILIFEROUS-LITHOCLAST BEDS, ≤ 2 cm. NOT AS MUCH BURROWING AS UNITS ABOVE & BELOW.

SECTION 90-2, NOPAH RANGE, (NORTH OF SECTION 90-1), CALIFORNIA.




ONCOLITES JUST ABOVE CONTACT.

PAPOOSE LAKE MEMBER OF BONANZA KING FORMATION

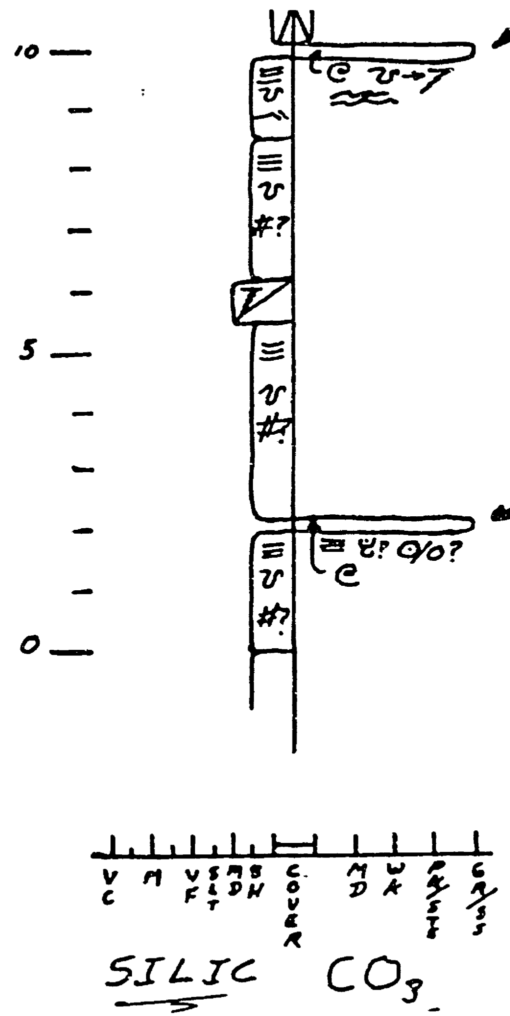
CARRARA FM —— FAULT OR UNCONFORMITY?

THICKNESS OF THIS LAST UNIT ESTIMATED FROM ABOUT 30 m LATERALLY. UNIT IS LATERALLY TRUNCATED.

COVERED.

LIKE 433.8 m

LIKE 432 m




SIZE. BEDS IRREG. CAN'T SEE PRIM. SED. STRUCS.

PINK-TAN BLEACHED VERSION OF SH @ 8m. DON'T SEE POSSIBLE # THO. GRADT'L UPPR 25cm TO $CO_3$ UNIT. ~ IN ≤ 2cm BEDS OF SLT-VF SIZE

RED SH LIKE 1m. UPPR 50-60cm WX MORE BLKY

AT LEAST 2 BEDS, ~10cm THK OF GREEN MARLY SEDS IN ORANGE-RED SH LIKE 1m

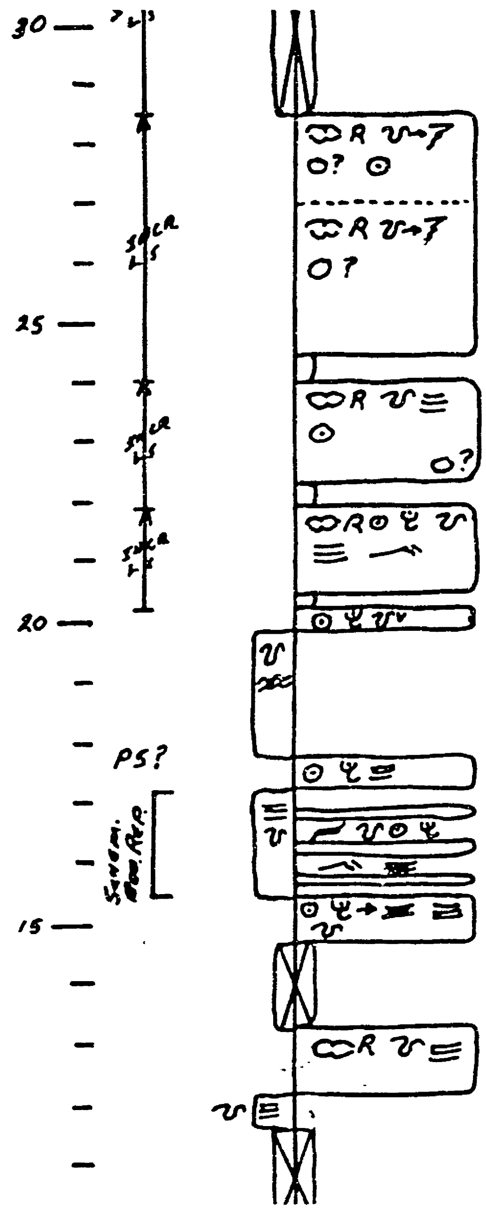
RED SH LIKE 1m.

MXT 2-7cm BEDS OF ALT. GREEN LS GRST (F-M) W/ A FEW ECHINODERM FRAGS, C/O (CAN'T TELL) ≡ & ? & THINNER BROWN VF SILT, ≡ DOL BEDS. ≈ 1/3 LS.

RED, mm-LAM'D (NOT BLKY) SH. HORIZ <1mm. POSSIBLE # BUT EXPOSURE MOD POOR. TOP 15cm MORE MARLY, 7? & GREEN.

GREEN SH.

SCTN 90-3, CHAPPO SPGS,
SO. RESTING SPG RNG




COVER

NOT MUCH DOLSTS, ~10-15% OVERALL W/ LITTLE CHANGE IN % ↑. MOSTLY IN ∪, FEW THRU-GOING DOLSTS LAYERS.

DK GRY LS TOTALLY RXLZD. ORIG ⊙? THIS ⊙R MORE ∪→7 THAN PREVIOUS BEDS. APPARENT BED THKNS THINS FROM 40-70cm IN LWR 3m TO ≅10-20cm IN UPPR 1½ m. ALSO HAVE CRSR LS GRNS IN PART OF UPPR 1m. ¼-½ mm ⊙

BASAL 30-40cm COVERED. GRY LS 2-10 cm ALT W/ ORNG DOLSTS < ½-2 cm THK. LWR PART GRY LS IS ⊙? (VF). UPPR ~50cm ¼-½ mm ⊙ W/ FEWER DOLSTS PARTINGS, STILL ∪ BUT NOT AS MUCH AS LWR. ~10% DOLSTS. TOP 10-20 cm ⊙ & ⊙? DOL ONLY IN ∪

BASAL 20cm COVERED. NEXT ~30cm = 1cm GRN-GRY LS ALT W/ 1-2cm RED STS, ⌒ & ≡. GOES ↑ TO ½ mm ⊙ Ψ W/ ∪, ⌒ & SOME ORNG DOLSTS INTERLAMS. TOP 30-40 cm = GRY GRST W/ ⊙ & UNID'D GRNS. ∪ & ½→2½ cm ORNG DOLSTS ≡. MORE '⊙R' TEXTURE THAN ⊙ SHOAL.

ORNG-STAINED ½ mm ⊙ GRST. LG (~25cm) Ψ (1ST LG BEDFORM) ∪ VERT → OBLIQUE, ≤ 7mm DIAM.

GREEN 2-5mm LAM'D SH. BASAL 40 cm W/ SCATTERED DISCONT (<1m) 1-5 cm THK ⊙ BEDS, ⌒ → Ψ.

GREEN ⊙ GRST, CLEANER THAN BEDS BELOW. MED (¼-½ mm). SOME <5mm DOLSTS PARTINGS 'TWEEN BEDS. BEDS 3-12 cm.

GREEN, mm-LAM'D, MICACEOUS SH W/ NUMEROUS 2-11cm, DISCONT OVER m'S, ⊙ BEDS Ψ ⌒ ≡. OFTEN W/ SLT-CLY DRAPES, SOME ∪. GRAINS LIKE 15m. A COUPLE OF BEDS W/ ⌐ OF STS, SH, GNST. FLATS, ≤10cm MAX DIMENSION. RECESSIVE WX

DK KHAKI-GREEN ⊙ GNST, 2-8 cm BEDS. MANY TRANSPORT DIRECTNS. SOME ∪. OR-BRWN DOLSTS ≤5cm AT SEVERAL PLACES. DISCONT & ≡. ⊙ = F SAND-SIZE. OTHER UNID'D $CO_3$ GRAINS. FORMS SMALL LEDGE

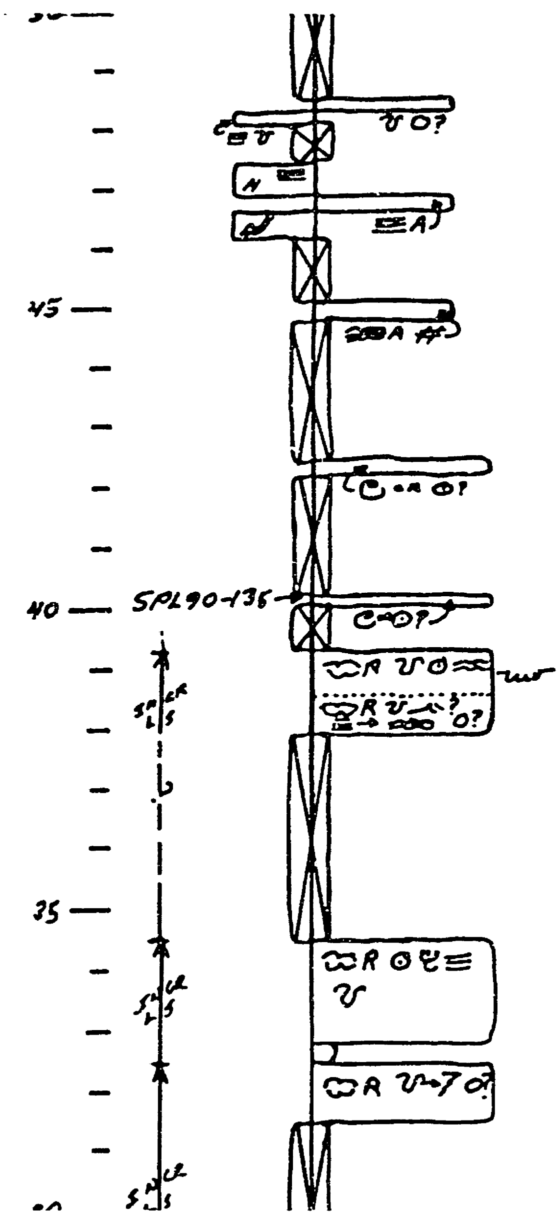
COVER. PROB AMT OF 1-2 cm LS GRNST & SH/MDST

1-5cm, MOSTLY 1-2 cm, GREEN LS BEDS ALT. W/ 2-5 mm BRWN DOLSTS INTERBEDS. GRAINS NOT ID'D BUT M-F SIZE. FORMS SMALL LEDGE.

ALT GREEN MARLY LS & RED SH. DISCONT LS BEDS <1cm

COVER

MARLY GREEN LS GRST. POSSIBLE FOSSIL FRAGS. BEDS 1-5cm. MED SAND SIZE. BEDS IRREG. CAN'T SEE PRIM. SED. STRUCS.




COVER

DK KHAKI GREEN ꝟ LS PKST. ⊙? VF-SAND SIZED

PINK SILSTS

COVER

PINK, ORANGE SIL. STS. POOR EXPOSURE

ORANGE DOLST.

COVER

ORANGE → PINK ALG. LAM'D DOLSTS. DEFINITE #.

COVER

LT GREEN LS GRST LIKE 40.1m. GRAINS SLIGHTLY SMALLER. ALSO DISCONT. SEVERAL BEDS LIKE THIS IN LOWER INTERVAL

COVER

ECHINODERM/CRINOID?-HASH GRST (OR RADIAL CONCENTRIC ⊙?) DISCONT LATERALLY OVER 10's METERS. NO SED STRUC. LT GREEN.

COVER

UPPR 75cm < 10% DOLSTS, MOSTLY IN LWR 25cm. ½-¾mm ⊙ LS GRST W/ AT LEAST 1 INTERNAL SCOUR SURFACE, BUT NOT A HARDGRND.

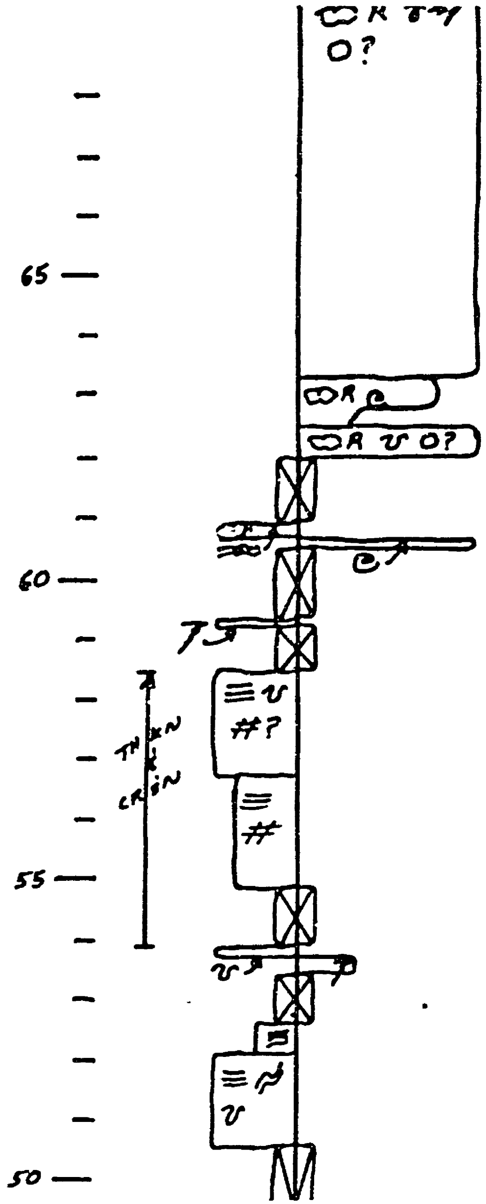
LWR 70cm ~50-55% DOLSTS IN ≡ → ≈ BEDS ≤ 4cm THK. LS IN DISCONT BLEBS TO CONT. LAYERS ≤ 3cm THK. CAN'T SEE GRAINS IN LS ⇒ ⊙?

COVER

10-15% ORANGE DOLSTS IN DISCONT & CONT BEDS ≤ 3cm & ꝟ. MORE DOL IN LWR ⅓ OF UNIT, LEAST IN MDL. ⅓. MUCH OF LS IS ¼-½mm ⊙. DOES NOT GET ꝟ → 7. ⊙ BEDS W/ LEAST AMT OF DOLSTS, UPPER ⅓, DOL IS MORE BLEBBY. BASAL 25cm COVERED

≈15% DOLSTS, MOSTLY IN ꝟ, BUT A FEW < 3mm CONT. INTERLAMS. LS RECRYSTALLIZED TO FINE SANDSIZED XLS. ○ ORIG?

Cov…




MASSIVE ⌒R W/O RECESSIVE INTERVALS CAN BE BROKEN INTO 4 INTERVALS OF ≈ 10-15% DOLSTS, MOSTLY IN V W/ 3 INTERVENING INTERVALS OF ≈ 45-60% DOLSTS WHICH ARE 7. 10-15% DOLSTS INTERVALS ARE ≈ 1 m THK EACH, WHEREAS INTERVENING INTERVALS ARE: UPPER ≈ 1-1.2 m, MDL ≈ 50-70 cm, LWR ≈ 30-40 cm. NOTE THAT INTERNAL CONTS ARE GRADATIONAL. IN DK GRY LS INTERVALS, THERE ARE SOME 2-3 mm DIAM V'S W/ SPAR FILLING. NO A FABRIC OR MORPHOLOGY NOTED. NO DISTINCTIVE SURFACES.

RECESSIVE WX ⌒R W/ LOTS OF DOLSTS. PARTIALLY COVERED. @ PAST 15-20 cm THK IN MDL & TOP

DK GRAY LS GRST. GRAINS NOT ID'D, O?. < 10% DOLSTS IN V ONLY

COVERED

LT GREEN SIL STS

LT GREEN ECHIN? LS GRNST. NO PRIM. SED STRUC RECOGNIZED

COVER

ORANGE SIL STS

COVER

ORANGE SIL. STS. BEDS THKN ↑ FROM 1-2 mm LAMS TO 5-10 cm BEDS. THICKER BEDS ARE V'D

TAN SIL MDST W/ MUDCRACKS

COVERED

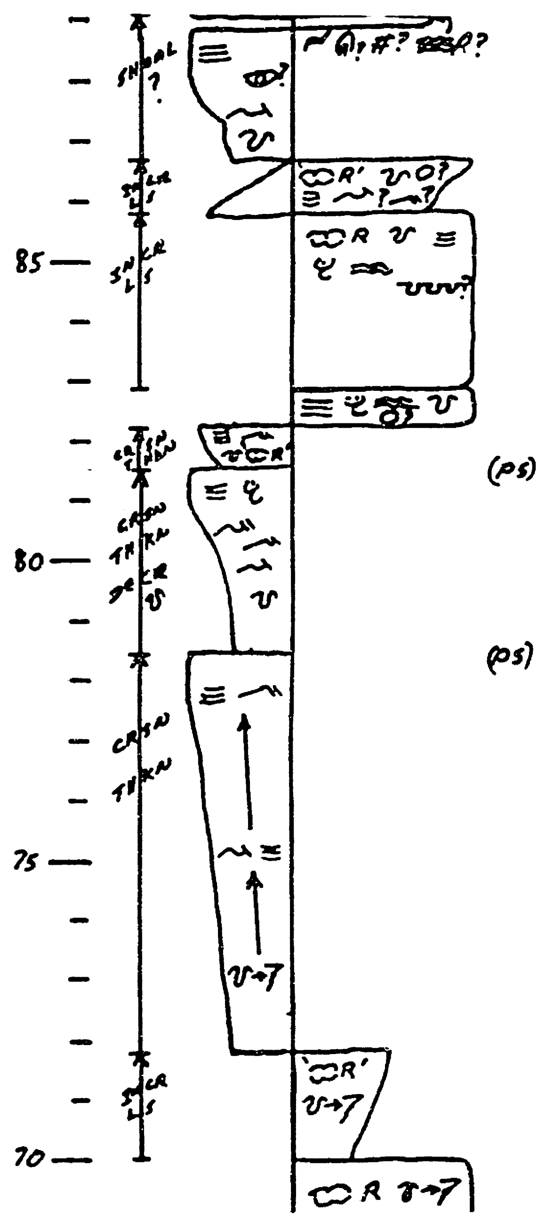
RED SIL. STS W/ SOME $CO_3$ STRINGERS

LT GRN & RED MARLY, 7 $CO_3$

COVER

GREEN, MM-LAM'D SH

ORANGE SIL STS. A FEW HORIZ. V < 1 cm. SOME ⌒ CRINKLED & FOLDED LAMS. LAMS 1-5 mm, MOST 1-2 mm




DOWN INTO:

OR-PINK-BROWN - LT GRAY SIL MDST, STS, VFSS. POSSIBLE ⊕? OR EVAP CASTS IN SOME BEDS IN UPPER PART. MUCH MM LAMS. MAX BED ≤10 CM, MOST ≤5 CM

MIX OF PINK SIL STS & LT GRAY LS. LIMES UP W/DECR OF STS. RIPPLES & ʊ VERY LIKE ⌒R, BUT SIL STS & NOT AS MUCH ʊ. MOSTLY $CO_3$ TOP 30 CM. RECESSIVE

ALT'NG GRAY LS GRST LIKE 82.5M & OR. DOLSTS, MOST ʊ IN DOLSTS. BASAL ≈60CM ~90% DOLSTS GOING ↑ TO ≈10% DOLSTS IN UPPR 80CM. INTERNAL SURFACES MAY BE HARDGANDS ACCENTUATED BY DISSOLN OR JUST DISSOLN SURFACES.

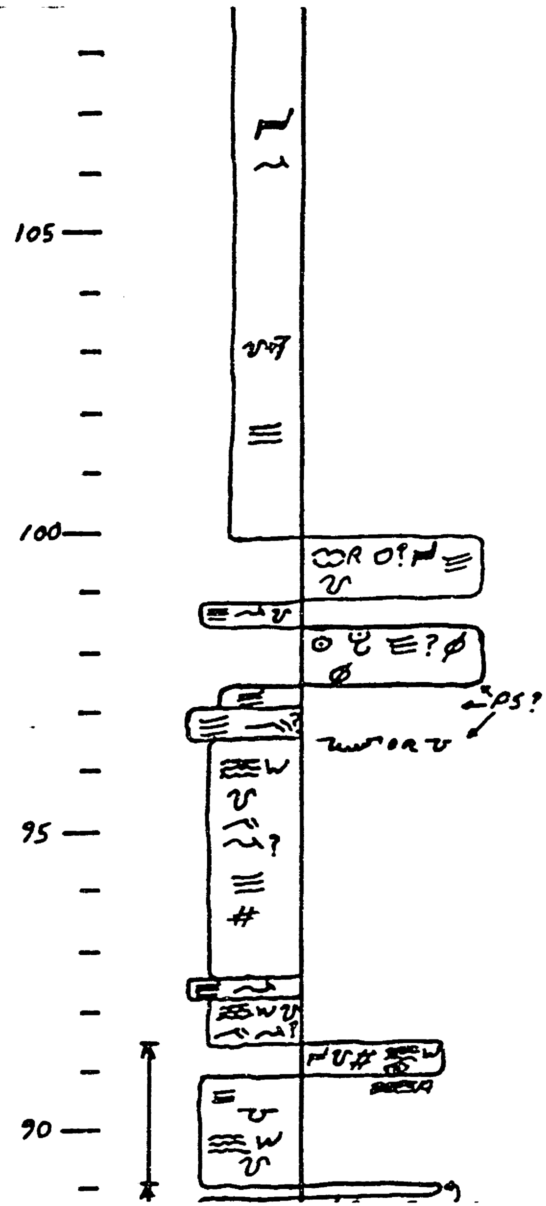
ALT'NG GRAY LS GRST (O? OR $CO_3$ VF-SAND PARTICLES) ≡, 4-15CM THK W/ OR. DOL

RED STS & LT GRAY-GREEN VF SS. LOOKS VERY MUCH LIKE ⌒R, BUT SIL-CLASTIC. AMT ʊ ± CONSTANT?

TAN-ORANGE BROWN SIL MDST ↑ STS ↑ VF SS. LESS VERT CHANGE THAN 72-78M, NOT AS FINE-GRAINED INITIALLY & NOT AS COARSE AT TOP. DOES HAVE MORE RIPPLES. INTERP. AS LOW WAVE-ENERGY DOM'D SHORELINE

A SINGLE TAN-ORANGE BROWN PACKAGE OF SIL-CLASTICS. SOME CARBONATE IN LWR PART, ʊ→7 MAKING IT SOMEWHAT MARLY. NO #. INTERP. AS A LOW WAVE-ENERGY, LOW TIDAL RANGE SHORELINE. LWR ½ TENDS TO BE RECESSIVE WX, WHEREAS UPPR ½ FORMS MORE CLIFFY OUTCROP.

RECESSIVE-WX, MARLY, VERY SILTY, ʊ→7. ⌒R-LIKE, BUT MUCH MORE SILTY. SILT LOOKS TO BE SIL & POSSIBLY $CO_3$ ALSO. REDDISH COLOR. LS IS GREEN-GRAY, NODULAR. ~25% ↑ 45% LS W/ REST BOTH SIL & DOL STS




PINK & BROWN MDST W/ THIN BEDS OF STS. BDDG ≤ →3cm, BUT MOST <1cm. OCCASSIONALLY, MOSTLY ɄS. SOME <5mm LAMS. OCCASSIONAL ⌒. OCCASSIONAL 2-3CM LENTIC'R BEDS, W/ A LITTLE VF-F SAND. SOME W/ LS MATRIX & LS CLASTS, ≤ 2x4 mm. INTERP: STORM EVENT BEDS?

≈ 50-55% DOLSTS. GRY LS IS O? & IN SOME BEDS O? & GRNST. CAN'T SEE PRIM. SED. STRUC IN LS

— — — —

F-VF SS. SOME ? ALSO. BROWN

— — — —

⊙ (½-1mm) LS GRST W/ SOME <1cm DOLSTS INTERLAMS. BEDS ≤ 10cm GENLY BASAL 10cm IS ≤ 1½cm ∅ PK/GRST

— — — —

RED-BROWN STS. NOTE 3 POSSIBLE POSITIONS FOR PS BNDRY ≈ 3-6 BEDS & ? OF VF-F SS, AMALG'MT'D TOGETHER. BTM CNTC MAY BE BROADLY & SHALLOWLY SCOURED OR MAY BE SLIGHT LOADING. INTERP:

BROWN & ORANGE STS & VF SS, MOSTLY 1-5mm LAM'D, BUT OCCAS'N'L ≤2cm VF SS BEDS. SOME ORANGE LAMS, VERY DOLSTS-LOOKING, BUT HAVE LOTS OF QTZ. MAY HAVE DOLSTS GRNS MXT IN OR MAY HAVE DOL CEM'T. SOME ≋W LOOKS ALMOST LIKE ≋A. RIPPLES UNCOMMON. MOST CM-THK SS BEDS ARE .

THK, NON-PLATY, 2-3 AMALGAMATED BEDS VERY UNLIKE 1-5mm BEDS ABOVE & BELOW: INTERP: DEEPER OR BIG STORM EVENT

BROWN VF SS & STS, IN 1-5mm, PLATY-WX BEDS. SMALL Ʉ?

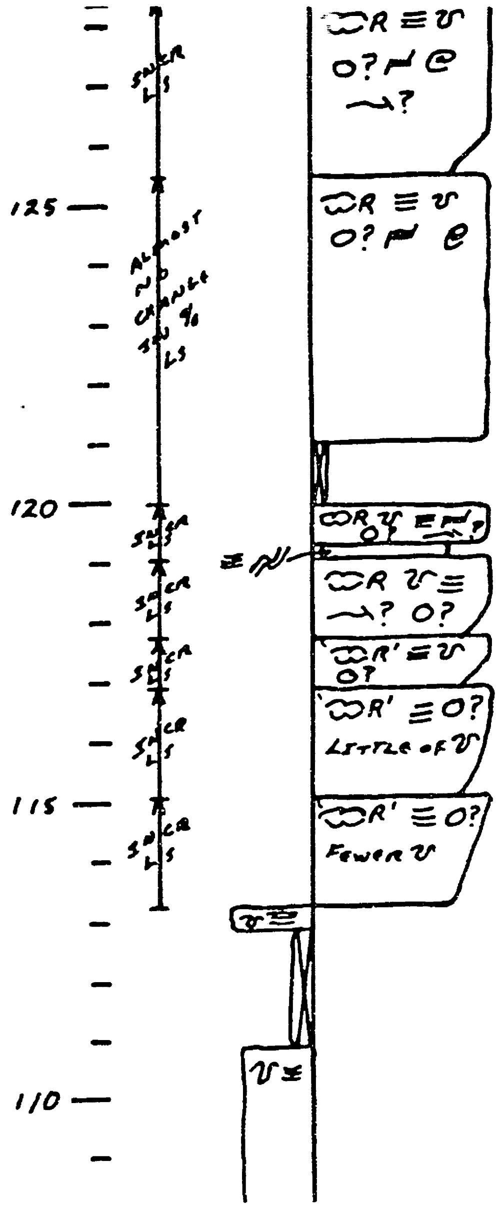
— — — —

OR & BROWN DOLSTS W/ DEFINITE EXPOSURE FEATURES. SIMILAR TO 89m

BROWN-PINK-LT GRY VF SS W/ MICROLOADS <1cm & WRINKLEY-CRINKLY BEDS. SIMILAR TO 86.65-88.85m.

— — — —

OR. DOLSTS. POSSIBLE <1cm ACROSS W/ 5mm RELIEF. GRADAT'N'L




LIKE 125m. DOLSTS DECR FROM ~20% TO ~10%.
2 ⌐@ EVENT BEDS, EACH ~4cm THK

≈60% GRY LS, <1cm → 6cm THK, MOST 1-3cm. LS GRAINS OR I&O?
CAN ONLY SEE FAINT LAMS.
≈40% ORNG DOLSTS, MOSTLY <1cm, FEW ≤ 2cm THK.

TOP BED IS A 6-7cm EVENT BED (LS) OF ⌐, <1×4cm, PLATY,
SOME @ FRAGS.
NO (T) TEXTURE OR MORPHOLOGY SEEN FROM 113.3 → 128.4m
LWRMOST PART HAS RED DOLSTS, AS MIGHT THE COVERED INTERVAL

COVER

≈80% O? GRY LS, ≈20% DOLSTS. A 4cm ⌐ EVENT BED IN MDL
BASAL 10cm IS 80-100% ORANGE DOLSTS W/UPPER ½-⅓ (⇒ DE-WATERING?)
LWR PART IS ≡. NO ⌐. NON-~ ATM. LATLY PERSISTANT BED.

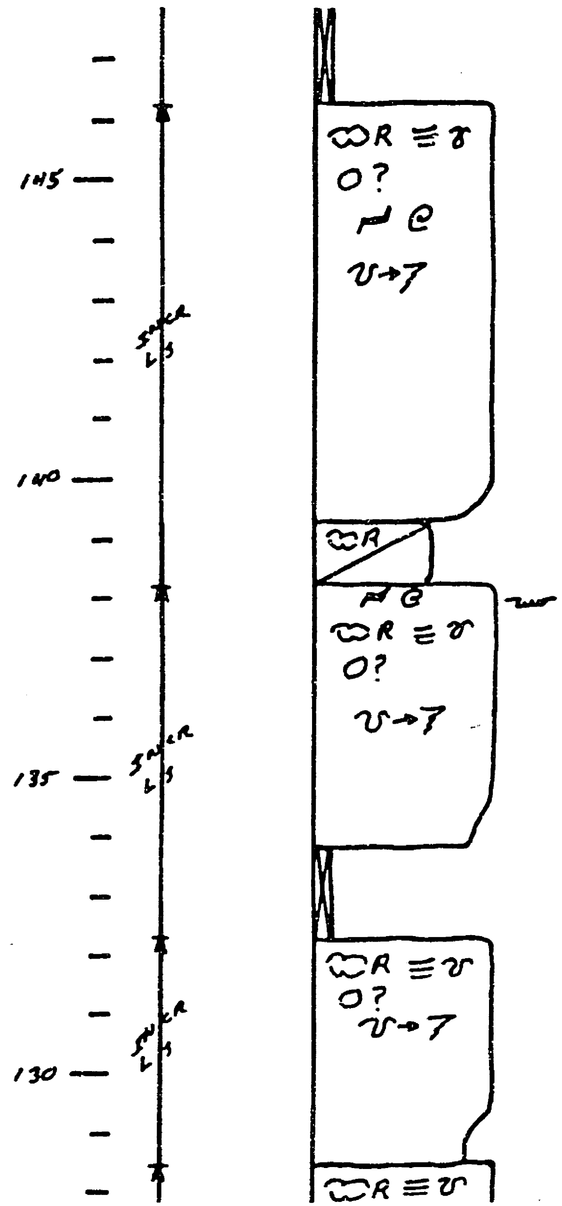
≈45-50% GRYLS, 50-55% DOLSTS OVERALL. MORE ~ THAN 3 BEDS IMMED
BELOW. CAN SEE LAMS/PRIM SED STRUC IN LS BUT NO GRAINS. O?

LIKE 2 UNITS IMMED. BELOW.

LOOKS LIKE UNBURROWED → BIOT. ⌐R. ONLY ~'s ARE 1-2mm. @ BASE
IS MOSTLY ≡ DOLSTS, BUT LS STRINGERS INCR ↑ TO MOSTLY LS BEDS.
≈90-95% DOLSTS ↑ ~50% DOLSTS. LS = 1-2cm THK, SOME ≡. CAN'T
RECOGNIZE RIPPLES

SEE DESCRIP. OF UNIT IMMED. ABOVE. BASAL CNTC SOMEWHAT GRAD'L
W/ SIL STS OVER ~1m.

LIKE 110m.




COVERED

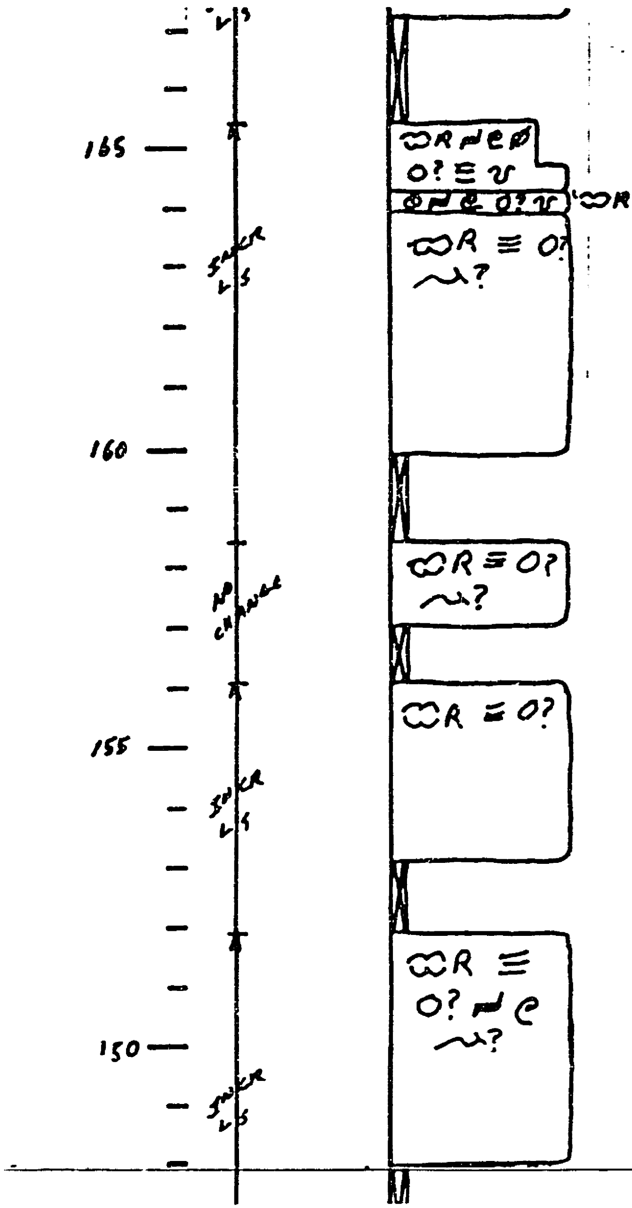
LIKE 130m. DOLSTS ↑DECR FROM ~30-35% TO ~15-20%. NOTE THAT DOLSTS MORE ORANGE-RED FROM 120m TO TOP. 2 OR 3 3-5cm THK @ EVENT BEDS

PARTIALLY COVERED

LIKE 130m. DOLSTS DECR UP↑FROM ~30-35% TO ~15%. MOST GRY LS BDDG 1→3cm THK, SOME ≤ 8cm. OR-RED DOLSTS MOSTLY ≤1cm, SOME ≤ 3cm. NO @ EVENT BEDS EXCEPT AT TOP WHICH IS AN ≈ 20cm THK BED THAT SCOURS ≈5cm INTO R. PLATY, < 1x4cm. GRY LS BEDS 5-8cm THK MAY STILL BE O? NO SEEN & NO SEEN.

LIKE 125m. ~40% DOLSTS @ BASE DECR ↑ TO ~25-30%. NO EVENT BED & NO . BASE PARTIALLY COVERED. MORE IN PART, THAN IN UNITS FROM 120→128.4m. NOW → IN PLACES. NO RECOGNIZED.

LIKE 125m. DOLSTS DECR ↑FROM ~20% TO ~10%.




COVER

LIKE 130m. 6cm THK ≠@ EVENT BED IN LWR 50cm. TOP 60cm IS AN Ø≠@ PK/GRST W/ Ø DOLOMITIZAN. Ø ≤ 2cm

A?PK/GRST W/ ⌀R-TEXTURE, ESPECIALLY IN UPPR ⅓. LENSES ~1-3cm × 20-50cm W/ @ & SOME ⊙ IN A DOMINANTLY O? LENS. ʊ's IN LWR PART W/ ORNG-RED DOLSTS FILL.

LIKE 130m. DOLSTS DECR ↑ FROM ~20-30% TO 5-10% ONLY IN ʊ IN THE TOP 60 cm.

COVER

LIKE 130m. ~30% DOLSTS THRUOUT IF DON'T COUNT COVERED INTERVAL. ∴ NO CHANGE IN LS/DOL RATIO.

COVER

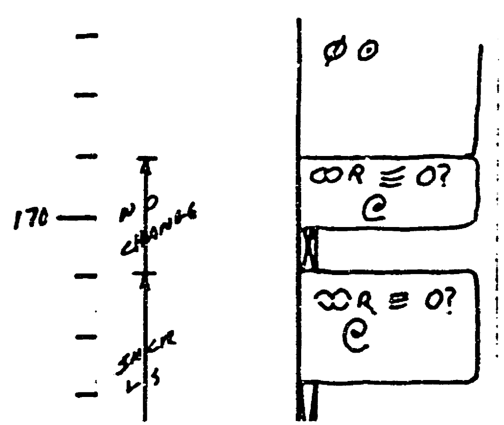
≈ 40% DOLSTS DECR ↑ 30%. NO ≠@ EVENT BEDS. NO ~. NO A. LIKE 130m.

COVER

≈ 50-60% DOLSTS DECR ↑ < 10%, MOSTLY IN ʊ. 2 ≠@ EVENT BEDS, 5 & 10 cm THK. EDGE OF 5cm BED THINS TO < 2cm & HAS SCOUR AT BASE OF IT.

# SECTION 90-3

CHAPPO SPRING, SO. RESTING SPG. RNG.



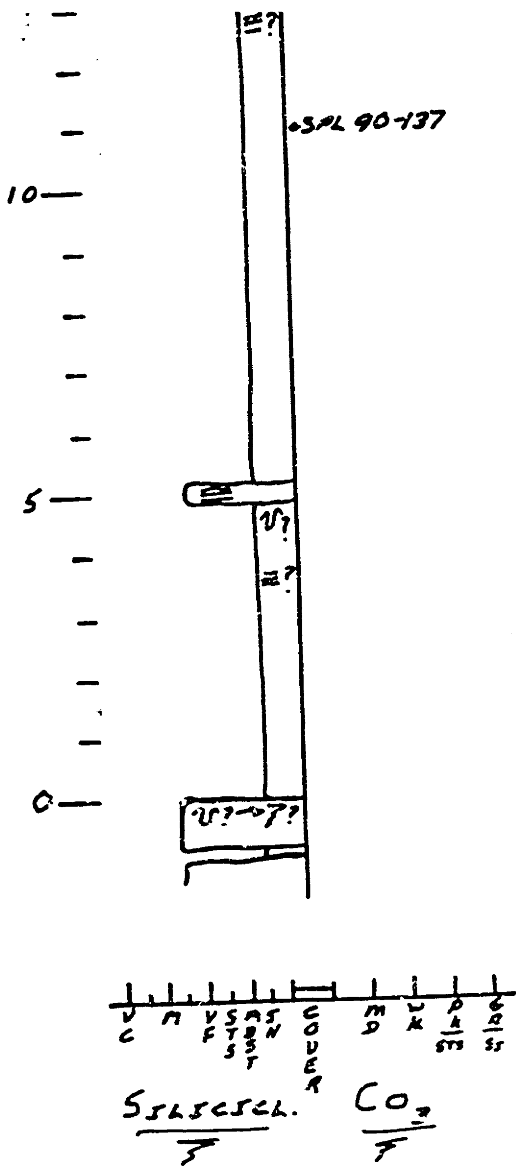

DK GRY PK/GRST W/ ONLY SCATTERED & DISSEMINATED RED DOL.

BONANZA KING
(DEPOSITIONAL CONTACT)

LIKE 130m. ~15% DOLSTS. SOME SCATTERED @ IN SOME OF THE O? BEDS.

COVER

LIKE 130m. DOLSTS DECR ↑ FROM 35% TO 25%



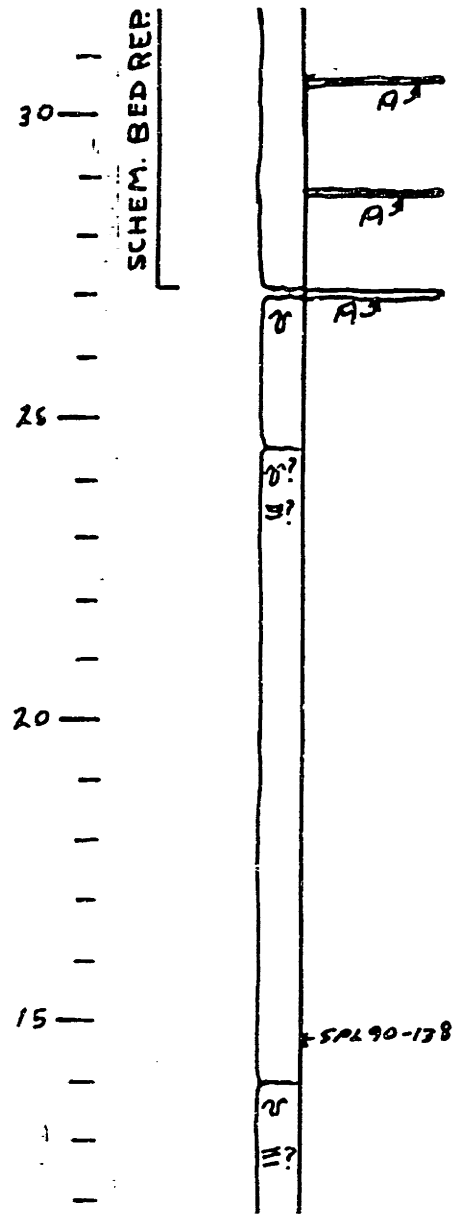

SPL 90-137: STRINGERS OF GREEN, POSSIBLY GLAUCONITIC GRAINS, ≤2cm THK, SCATTERED OVER ~1m. SS ≤5cm THK, ≡, VF-F, w/some V

GREEN VF-F QTZ SS. POORLY EXPOSED

GREEN, CLEAVED, CHLORITIC SH. OCCASIONAL <1cm → 5cm THK SS STRINGERS, ≡ & THICKER BEDS H. SH PROB. ORIG'LY ≡.

GREENISH F-VF QTZITE w/SOME GRAINS WX'D TO RED & SOME DARK GREEN + BLK, POSSIBLY MAFIC, GRAINS. CAN'T MAKE OUT PRIMARY SED STRUC. MAY BE V→?, BUT V NOT VERTICAL. ≈ 90cm THK w/~20cm SH BENEATH, UNDERLAIN BY MORE SS

SECTION 90-4, REDWING MINE,
NO. RESTING SPGS. RNG




GREEN GLAUC'C? GRAINS FILLING. ONE MAJOR DIFFERENCE: NOW GET OCCAS'L 1-2CM, A FEW ≤ 4 CM, BROWN DOL. PKST LIKE 27M. POSSIBLY SOME RIPPLES ALSO.

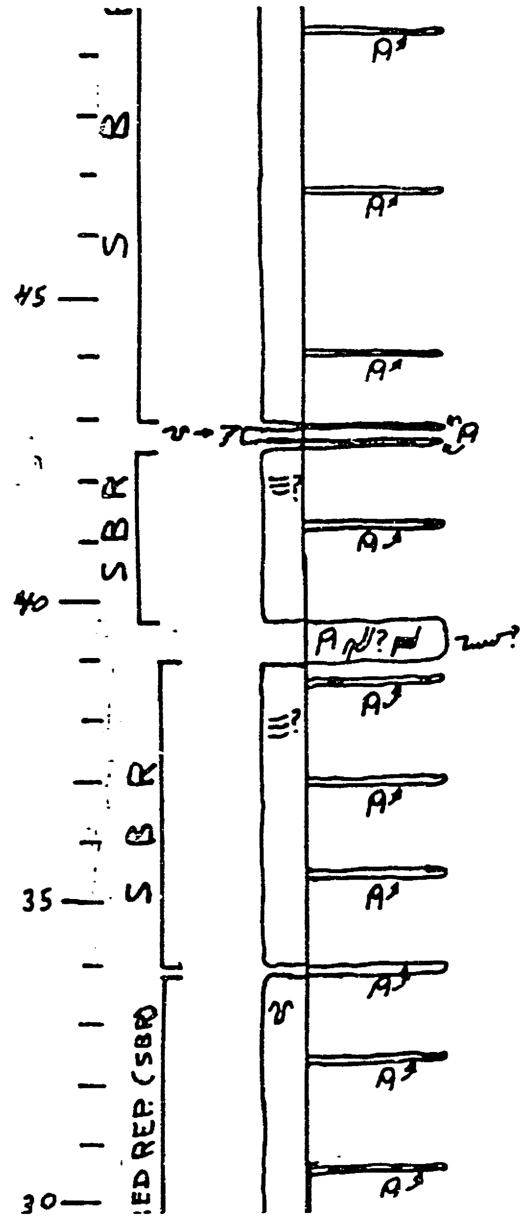
1ST $CO_3$ BED. BROWN DOL. PKST W/ A FRAGMENTS & F-MQTZ SAND GRAINS. PROB'LY A LENTICULAR EVENT BED. NO PRIM. SED STRUC'S

GREENISH-TAN GRAY (NO YELLOW) CLEAV'D CHLOR'C SH. SCATTERED STRINGERS OF GREEN, GLAUC'C SAND < 1CM, LIKE 24M.

YELLOWISH-GREENISH-TAN, CLEAV'D CHLOR'C SH W/ OCCAS'L < 2CM STRINGERS OF GREEN (GLAUC'C?) C-VC SS. POSSIBLY A METAMORPHIC MINERAL OR ALTERED SH RIPUP CLASTS. SH PROB ORIG. B, W/ POSSIBLE V. GRAD'L CHANGE ↑ TO MORE GREENISH SH.

SPL90-138: ANOTHER ~1 CM THK GREEN SS.

GRN, CLEAV'D, CHLOR'C SH W/ OCCAS'L SS STRINGERS LIKE 3M.




GREENISH-TAN-GRY, CLEAV'D, CHLOR'C SH LIKE 35 m. FEWER $CO_3$ BEDS OR SS BEDS. NO ∇ SEEN

GRY ∇→7 MDST ~ 20 cm THK w/ ~ 5 cm BROWN DOL PKST BOUNDING TOP & BTM. MDST W/ BROWN DOL MM-THK STRINGERS & SOME GREEN, GLAUC'C? GRAINS. DOL LIKE 27 M, BUT PROBLY > % SAND & < % A.

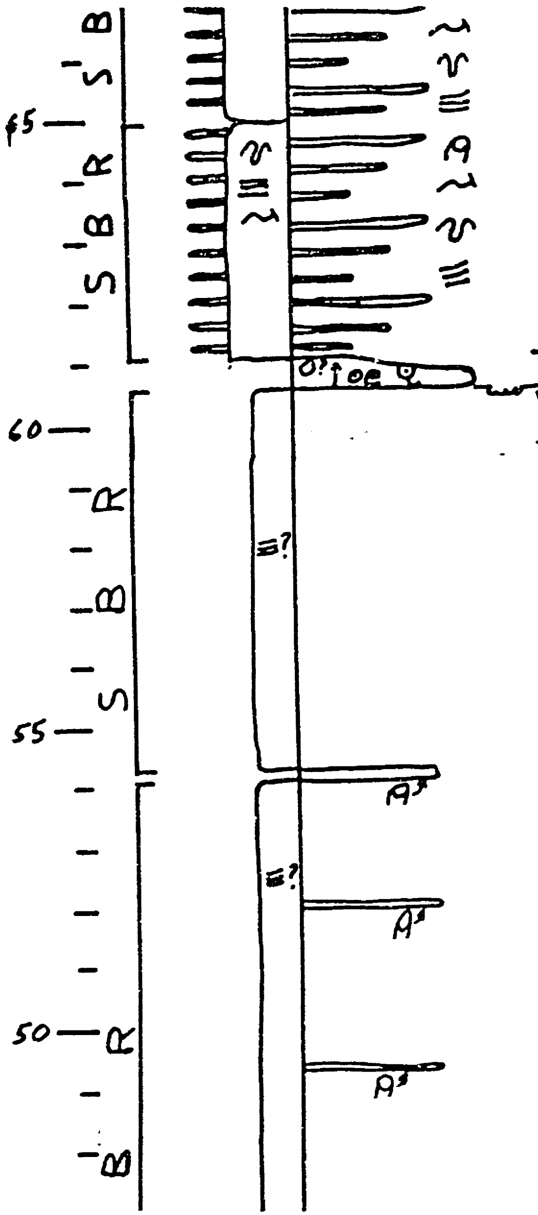
SH LIKE 35 m. ONE DOL BED UNUSUALLY THK, ~ 3½ cm. NO ∇. CLEAV'D, CHLOR'C

BROWN DOL A PKST LIKE 27 m. ? MAY BE CLEAVAGE, NOT SED. UPPR 15 cm MOSTLY M→GRANULE QTZ & SAND W/ DOL MATRIX. POSSIBLE BASE TO SS PART. LWR 50 cm SS A PKST W/ ≤ VC QTZ GRAINS, SOME OF SH &/OR DOL.

GREENISH-TAN-GRY CLEAV'D, CHLOR'C SH LIKE 30 M BUT W/O ∇

BROWN DOL PKST W/ A FRAGS & F-VF SAND. PROB. LENTICULAR LIKE 27 m

GREENISH-TAN-GRY CLEAV'D, CHLOR'C SH LIKE 27 m. OCCAS'L ∇ W/ GREEN GLAUC'C? GRAINS FILLING. ONE MAJOR DIFFERENCE: NOW GET OCCAS'L 1-2 cm, A FEW ≤ 4 cm, BROWN DOL. PKST LIKE 27 m. POSSIBLY SOME RIPPLES ALSO.




1/2 m THAT IS SLIGHTLY MORE RESISTANT.

NOTE: FROM 60.6m → 69.5m WOULD OVERALL CONSIDER AS A $CO_3$ UNIT. POSSIBLY THIMBLE LS. COLOR, ORNG-BRWN, DIFFERS FROM GREENISH COLORS OF BEDS ABOVE & BELOW

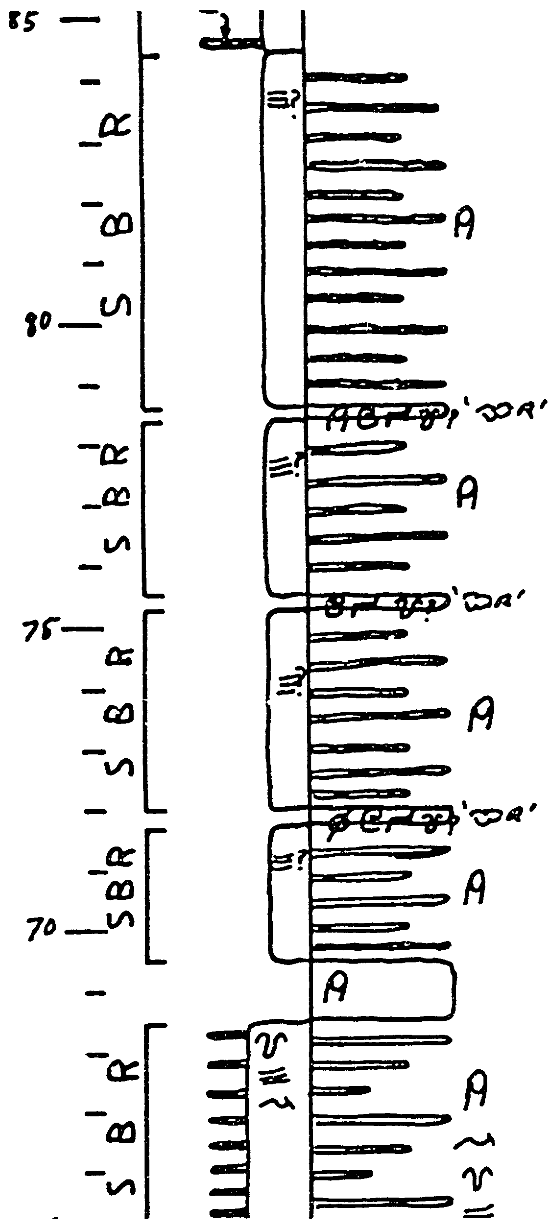
OVERALL AN ORNG-BROWN COLOR. INTIMATE INTERMIX OF BACKGROUND GRAY DOL'C SLTY, SSL MDST W/ PKST, WKST, & MDST LIMEY DOL ($CO_3$ DOL'C LS) BDDS FROM ≤ 1cm → 5cm. NO RECOGNIZABLE ORDER TO VERT SEQ OF $CO_3$ BEDS. ALSO ≤ 1cm STRINGERS OF VF SS, ≡ ~. MOST COMMON BEDS ARE PKST & VF SS. W/IN THIS UNIT ARE 5 INDISTINCT GRPS OF SLIGHTLY MORE RESISTIVE BEDS. NET EFFECT IS OF 5 GRPS THAT THIN ↑ FROM 30cm TO 10cm THK, & GIVES OVERALL IMPRESSION OF FINING, THINNING ↑. SS & SH MORE PINKISH, $CO_3$ MORE GREENISH

LIMEY DOL, KHAKI-GREEN, GRADES UP FROM O GRST AT BASE TO FEATURELESS MDST @ TOP. MAY HAVE O AS GRAINS IN UPPR PART & MAY BE A PK- OR GRST. PROB ~ BASE. COATED GRAINS & O IN ∪ SETS 10-20cm HI. LATERAL TO SOUTH OF SCTN, BED IS GRNST THRU-OUT & HAS LINEAR CRESTED (2 & D) DUNES PRESERVED ON TOP OF UNIT. ALSO O & COATED GRAINS THRUOUT, 1/2-1mm DIAM & ≤ 2mm LENGTH.

GREENISH-TAN-GRY CLEAV'D, CHLOR'C SH LIKE 35m. NO ∪ SEEN

BROWN DOL PKST LIKE 27m.

GREENISH-TAN-GRY, CLEAV'D, CHLOR'C SH LIKE 35m. FEWER $CO_3$ BEDS OR SS BEDS. NO ∪ SEEN




SIMILAR TO 70.0m. SH w/ PKST & WKST INTERBEDS
NOTE! MORE QTZ VEINS ⇒ FAULT &/OR HYDROTH. ACT.

OL-GRN, LIMY DOL PKST w/ A & UNID'D FOSSIL CHUNKS. A FEW $CO_3$ ▬. BTM ½ w/ ALGBY PINK SIL STS INTERLAMS LIKE 71.7m. UPPR ½ A CLEAN PKST, TRYING TO BE OR

GREENISH-TAN-GRY CLV'D & CHLRTC SH w/ $CO_3$ INTERBEDS. LIKE 70m.

OL.GREEN LIMY DOL PKST w/ $CO_3$ ▬. NO Ø, OTHERWISE SIMILAR TO 71.7m
TRYING TO BE OR

GREENISH-TAN-GRAY CLV'D, CHLRTC SH w/ $CO_3$ INTERBEDS LIKE 70.0m.
NOTE! MORE VEIN QTZ ⇒ FAULT &/OR HYDROTH. ACT.

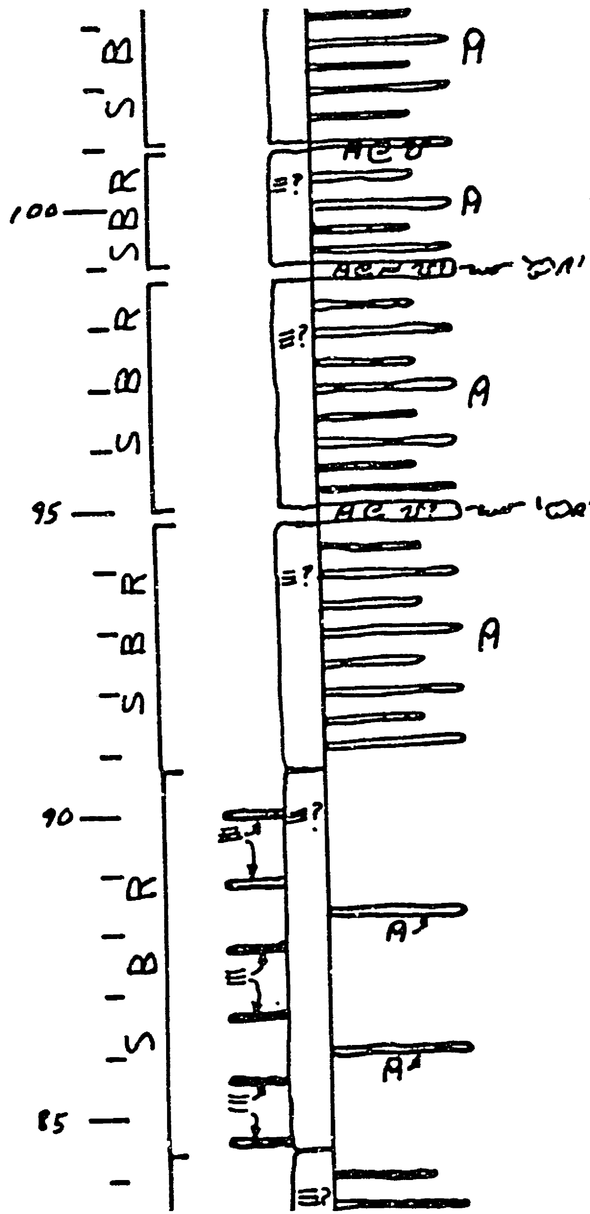
OL-GREEN, LIMEY DOL-Ø PKST. Ø, 2-4cm, CONCENTRATED IN UPPR ½. SCATTERED, ≤1cm THK, IRREG INTERLAMS OF PINK SIL. STS. MUCH OF Ⓔ IS UNIDENTIFIABLE. ▬ ARE $CO_3$. TRYING TO BE OR

GREENISH-TAN-GRY CLEAVED, CHLORITIC SH w/ $CO_3$ INTERBEDS (PK-, WKST) POORLY EXPOSED, ≈ 2-3cm THK. PKST MORE COMMON THAN WKST.
NOTE! VEIN QTZ ⇒ FAULT &/OR HYDROTH. ACTIVITY, FAULT WOULD BE SUB// → // TO BDDG

STILL INTIMATELY INTERBEDD, BUT A MIX OF ORNG DOLSTS (1-3cm) w/ PK & WKST (A FRAGS) (OL-GRN) OF LIMEY DOL (OR DOL'C LS). PK & WKST LIKE 61.1 → 68.5m, JUST w/ DOLSTS INSTEAD OF SIL. MDST. INTERP: SHALLOWEST PART OF THIMBLE(?) LS - INTERTIDAL.

SAME MXT LITH. AS 63.0m, EXCEPT IN ≈ MIDDLE HAVE A 1½ m THAT IS SLIGHTLY MORE RESISTIVE.

NOTE: FROM 60.6m → 69.5m, WOULD OVERALL CONSIDER AS A $CO_3$ UNIT. POSSIBLY THIMBLE LS. COLOR, ORNG-BRWN, DIFFERS FROM GREENISH COLORS OF BEDS ABOVE & BELOW




NOTE THIN QTZ VEINS ⇒ FAULTS &/OR HYDROTH. ACT.

OL-GREEN LIMEY DOL PKST W/ ∇ IN LWR PART

GRNISH-TAN-GRY, CLVD, CHRTC SH & $CO_3$ INTERBEDS LIKE 80m

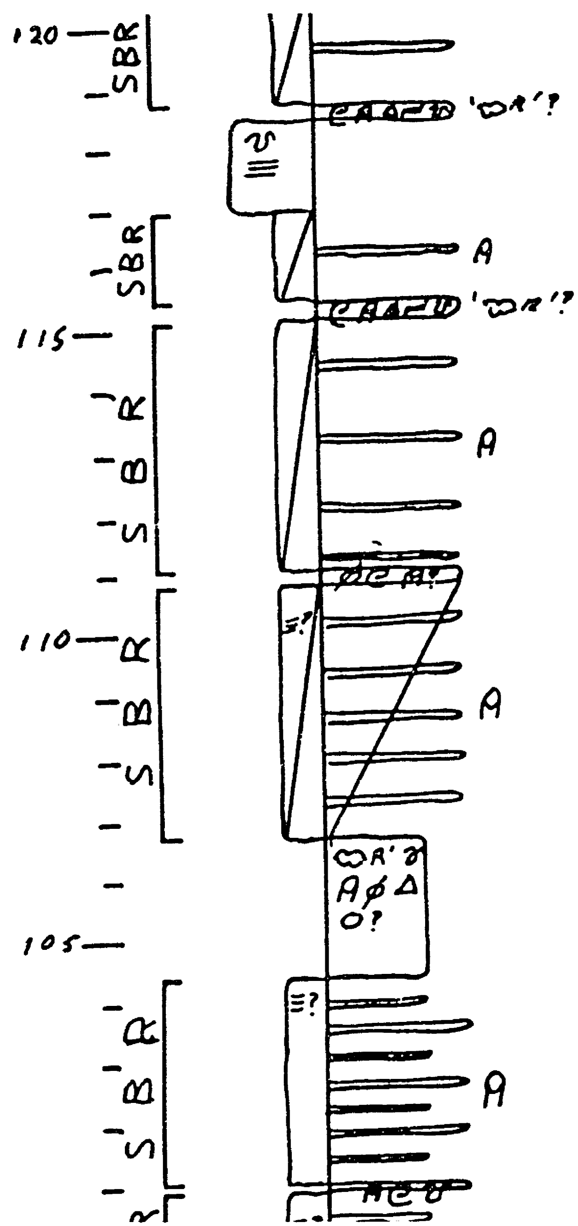
OL-GREEN LIMEY DOL PKST LIKE 94.7m W/ UPPR CLEAN PKST SCOURED INTO LWR SLTY PKST. NOTE $CO_3$ IN UPPR PART (≤1×3cm).

GREENISH-TAN-GRY, CLVD, CHLORIC SH & INTERBED $CO_3$ LIKE 80m
NOTE: QTZ VEIN ⇒ FAULT &/OR HYDROTH. ACT.

OL-GREEN LIMY DOL PKST. UPPR ½ W/O STS PEBBS. POSSIBLE SCOUR BETWEEN UPPR & LWR ½. LWR ½ A SIMILAR PKST BUT W/ ≤ 1cm IRREG PEBBLY INTERLAMS OF STS. TRYING TO BE OR.

SH & $CO_3$ LIKE 80m. $CO_3$ BEDS 2-5cm THK
NOTE: QTZ VEIN ⇒ FAULTING &/OR HYDROTH. ACT.

GREENISH-TAN-GRY CLVD, CHRTC SH SIMILAR TO 70.0m, BUT ONLY A FEW 1-2cm THK LIMY DOL, OL-GREEN, A PKST. SOME 1-4cm ≡ VF SS INTERBEDS. MORE SS INTERBEDS THAN $CO_3$ INTERBEDS.



YELLOW-GRY, CLVD, CHLRTC SH LIKE 110M

OL-GREEN LS PKST LIKE 115.2M

YELLOW-GRY SIL., SLTY MDST. CLEAVED, SLIGHTLY CHLORITIC

YELLOW-GRY, CLVD, CHLRTC SH, LIKE 110M

OL-GREEN LS PKST, W/ BLEBBY ORNG-BROWN DOLSTS, IRREG INTERLAMS. TRYING TO BE ⓌR AGAIN?

YELLOW-GRY, CLVD, CHLRTC SH, GOING TO TALC ABOVE 112.6M. OTHERWISE LIKE 110M

NOTE:
@ ~112.6m ~25cm THK QTZ+DOL+? VEIN, SUB// TO BDDG, N18W ∠73.
ALSO HAVE LOTS OF THIN, ≤3cm QTZ VEINS. ⟹ FAULTING &/OR HYDROTH. ACT.

OL-BRN LSφ PKST, φ1-4cm. ~3 CM ORNG-BRWN LS STS AT BTM

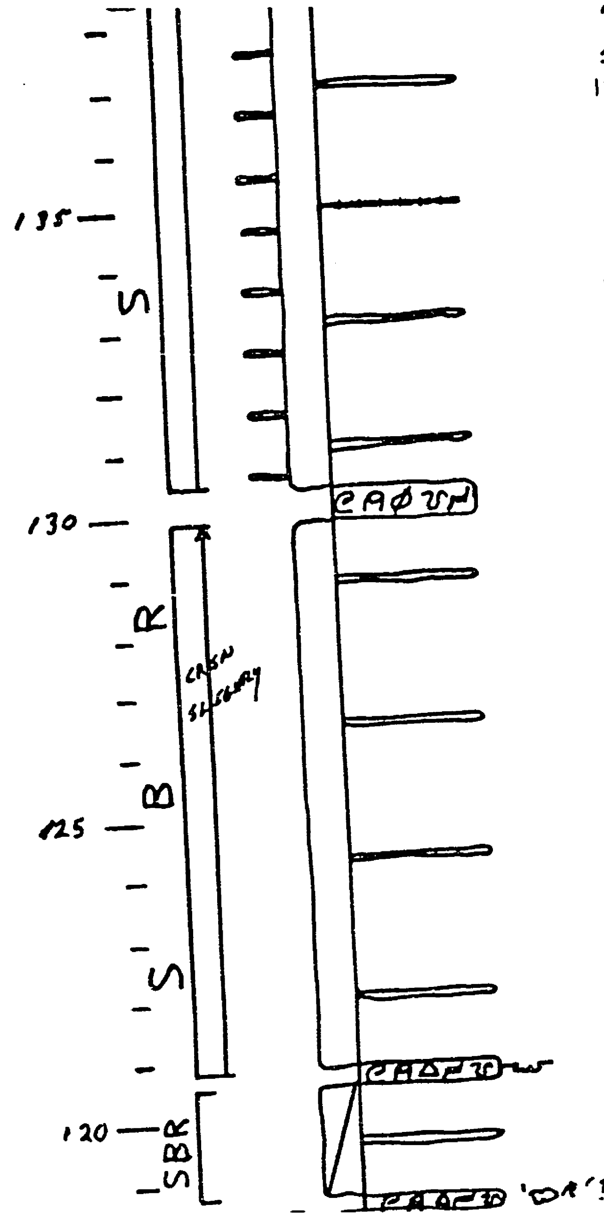
YELLOW-GRY, CLVD, CHLRTC SH W/ LOTS OF $CO_3$ INTERBEDS, INCL PINK DOLSTS & GREEN A PKST. BOTH 1-5cm THK. INTERVAL PARTIALLY COVERED, SO LITH PROPORTIONS SOMEWHAT UNCERTAIN.

NOTE: QTZ VEIN ⟹ FAULT &/OR HYDROTH. ACT.

ALMOST ⓌR. TYPICAL GRT WALL VARIATION ON ⓌR-THEME ~15% DOLSTS. POSSIBLE THAT $CO_3$ MUD ORIG ◯, BUT NO EVIDENCE. NOTE THAT OUTCROP OF THIS UNIT THINS TO NORTH. ≤1m THK LEDGE @ SADDLE, THO MAYBE MOSTLY DUE TO WX & RECESSIVE OUTCROP. ALSO NOTE THERE IS NO DOUBLE WALL (⌒⌒) WX PROFILE Δ (HYOLITHIDS) SILICIFIED.

GRNSH-TAN-GRY, CLVD CHLRTC SH & INTERBDD $CO_3$ LIKE 80M
NOTE THIN QTZ VEINS ⟹ FAULTS &/OR HYDROTH. ACT.

OL-GREEN LIMEY DOL PKST W/ ⩔ IN LWR PART




NOTE: 3 OCCURANCES OF VEIN QTZ ⇒ FAULTS &/OR HYDROTH. ACT. EACH VEIN 5-10cm THK

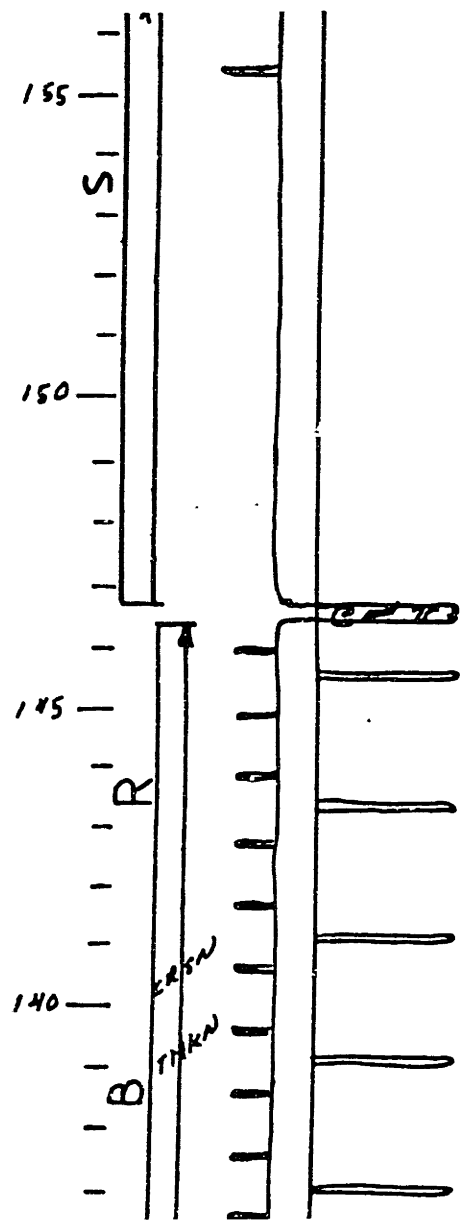
YELLOWISH-GREEN LS PKST, SOME ⊨ & @FRAGS SILICIFIED. NO A SEEN. SOME ALGAE? OR-BRWN DOLSTS. ALMOST A WKST IN PARTS

YELLOWISH-GRAYISH CHLORTC, CLVD SH W/ OCCAS'L DOLSTS, ≤2cm THK, INTERBEDS. SH GETS SLTY ↑. BARELY GOING TALCISH IN LWR ¼.

OL-GREEN LS PKST W/ 2-5cm OR-BRWN DOLSTS @ BASE, CUT INTO BY PKST W/ ⊨ OF DOLSTS, SOME FINE ↑ W/IN PKST AS ⊨ ARE CONCENTRATED IN LWR 2/3 OF PKST.

YELLOW-GRY, CLVD, CHLRTC SH LIKE 110m

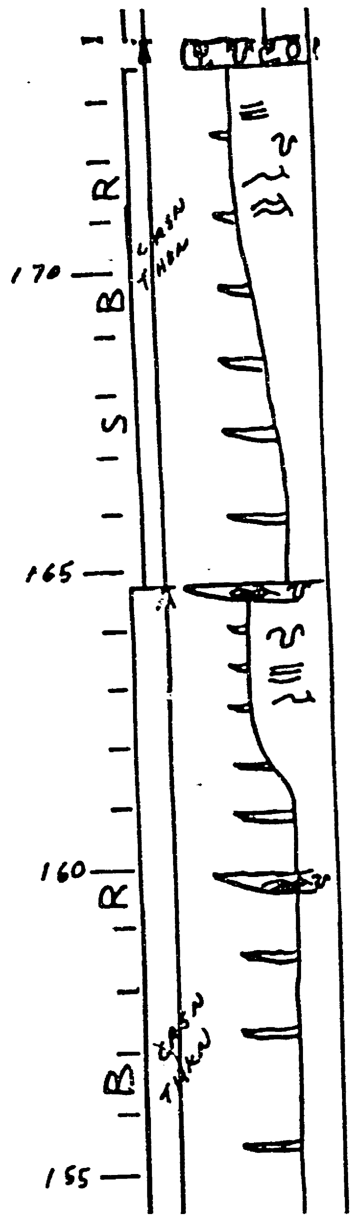
OL-GREEN LS PKST LIKE 115.2 m




YELLOW-GREEN LS PKST W/ <5MM DOLSTS IRREG. INTERLAMS.

BASICALLY YELLOW & GRYISH CLVD, CHLRTC SH. GETTING TALCY IN LWR ½. UPPR ½ GETS TO BE SLTY SH. ALSO GET OCCAS'L INTERBEDS OF SIL. STS & LS WK/PKST. LS BEDS & STS BEDS THICKEN ↑ FROM ~1cm → ~10cm.

NOTE: 3 OCCURANCES OF VEIN QTZ ⇒ FAULTS &/OR HYDROTH. ACT. EACH VEIN 5-10cm THK

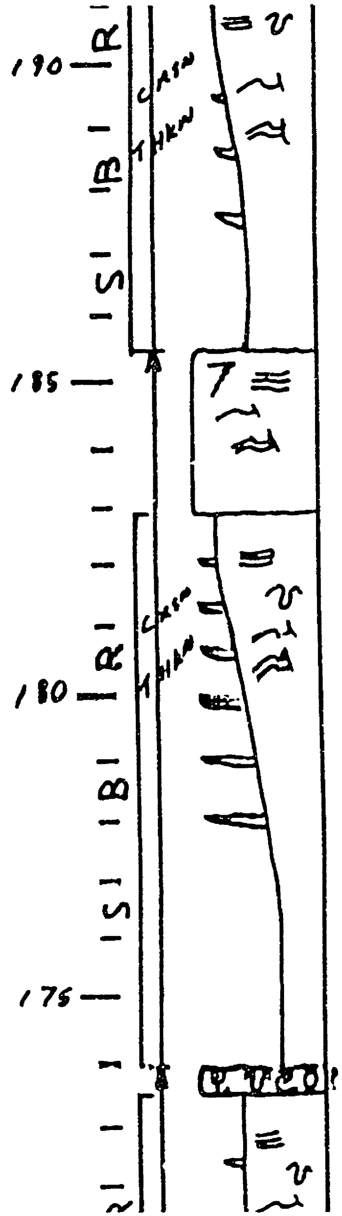



M? F-M QTZ SS W/ HERRINGBONE (SET: 10cm) IN UPPR PART — MXT M-F QTZ GRAINS & $CO_3$ @ 60% GRAINS. LWR & MORE SILIC. & ꝟ'D, BUT STILL SOME $CO_3$ GRAINS. SEEMS TO BE MORE LATERALLY CONTINUOUS THAN MOST BEDS. [illegible] $CO_3$ GRAINS & ꝟ FROM FLOODING & SHUTTING DOWN SIL. SEDTN?

[illegible] BACKGROUND SEDT'N, W/ LOTS OF LENTICULAR VF-F SS BEDS, ≤10cm THK, ≡, ~, ≈.

PS? 10-15 cm THK M-F QTZ SS IN LG ~. LENTICULAR OVER M→10'S M

YELLOW-GRAYISH CLEAVED, CHLRTC SH & MUDDY STS. @ ≈155m, START GETTING VF-F ~ & ≡, DISCONT. SS STRINGERS ≤ 7cm THK, SOME-TIMES ꝟ→7. INCR IN FREQ & THKNSS ABOVE 155m. AT 159.7m HAVE ~20cm THK LENT'R F-VF QTZ SS W/ ~10-15% $CO_3$ GRAINS IN UPPR PART. OUTCROPS FOR 10-15m LATERALLY. SOME SH BELOW 160m GOING TO TALC. BY 164m, BACKGROUND SED. IS A MUDDY STS, ≡, ꝟ, ~. STILL CHLRTC & CLVD IN FINER PARTS - LOTS OF LATERALLY DISCONT STS BEDS (GREENISH GRAY)

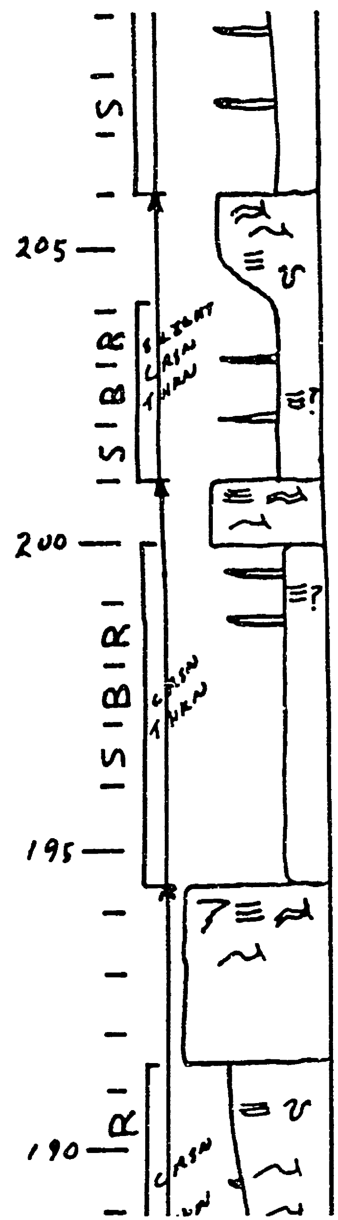



PS

MUDDY, SLTY VF-F SS, MOSTLY 7 BUT OCCAS'L REMNANTS OF [illegible], ~, [illegible]. PROBABLY SLOW, EPISODIC SEDT'N TO ALLOW 7 THAN A PERIOD OF TIME

CRSNS↑ FROM GREENISH-GRY, CLUD, CHLRTC SH TO GRY SLTY SH (UNDER 2-3 M) TO MUDDY VF SS, ARE ↑' MICACEOUS (POSSIBLY CHLRTC ALSO, BUT NO GREEN SCREEN.) UPPER PART HAS VF, =, ~, [illegible] SS IN LENT'R INTERBEDS.

RI? F-M QTZ SS W/ HERRINGBONE ψ (1 SET: 10 cm [illegible]) IN UPPER PART OF MXT M-F QTZ GRAINS & $CO_3$ @ 50? GRAINS. LWR & MORE SILIC. & ψ'D, BUT STILL SOME $CO_3$ GRAINS. SEEMS TO BE MORE LATERALLY CONTINUOUS THAN MOST BEDS. [illegible] $CO_3$ GRAINS & ψ FROM FLOODING & SHUTTING DOWN SIL. SEDT'N?



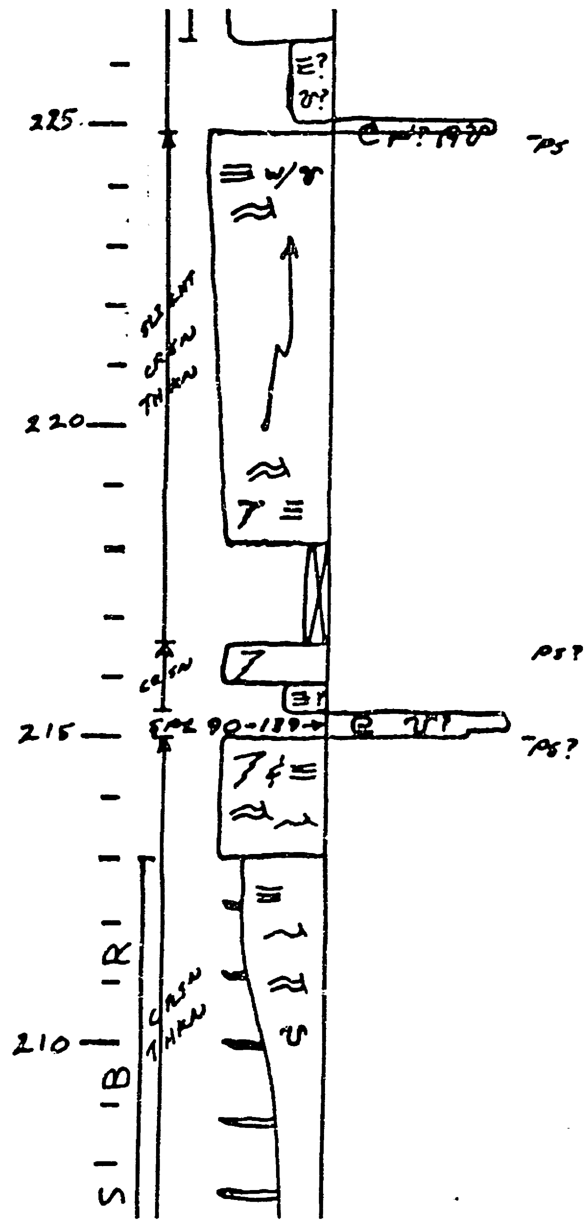

PS UPPR 1-2 m MORE VF SS (≈, ~, ≡) THAN SLTY SH & SLT BEDS

GRY CLEAVED, MSC., SLTY SH w/ VF SS LENTIC INTERBEDS LIKE 197m, 187m, 177m

PS? VF-F QTZ SAND INTERBDD w/ GRY, CLVD, MIC., SLTY SH. MOSTLY SS, POSSIBLY SOME CRSE SLTST.

GRY, CLEAVED, MICACEOUS SLTY SH. IN UPPR 1-2 m, GET SOME VF QTZ SS w/ ≈, ≡, ≤ 4cm THK BEDS.

PS M-F SS w/ ALT 7 (~10-15cm THK) & PRIM. SED. STRUC (~5-15cm THK) OF ≡, ≈, ~ FOR ≈ 3m. BELOW COARSENS ↑ FROM MUDDY STS TO VF SS OVER ~6 m. LIKE 173.9-182.9m.




GREEN, CLUD SH. NOT CHRTC

VERY WX'D, BROWN, 19 & ECNSNOSD? PK/GRNST W/F QTZ SAND. LS

QTZ SS. SLIGHT ↑ INCR IN GRN-SIZE & BED THKNSS. MOST NOTICABLE IS ↑ DECR IN ʊ's. TOP 15 CM ARE PLATY. MAY BE WX OR MAY WANT TO PUT PS ABOUT 15 CM BELOW BASE OF Cr.

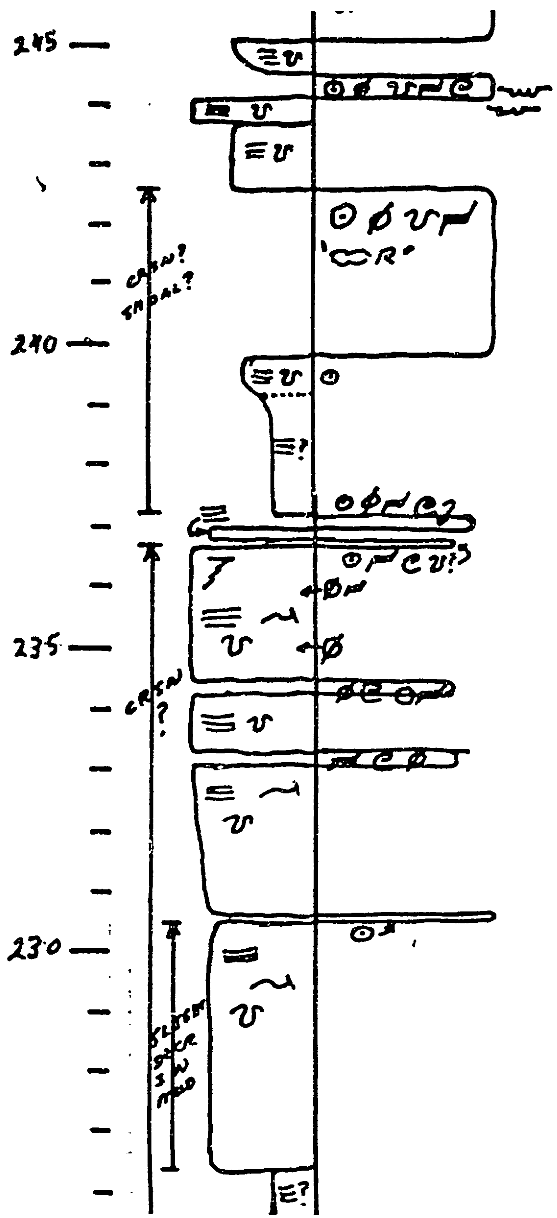
COVRD. PROBABLY SH.

GRY SH ↑ VF MUDDY, 7, SS
GREENISH

GREY & YELLOW-GRAY GRST (LS) W/~ 5CM DOLSTS @ BASE. @ MOSTLY ECNSNOD ? PIECES. SPL 90-139 FOR THN-SCTN. LARGE & DISCONT, 6 KM THK DOLSTS INTERBEDS. ʊ's ALSO W/ DOLSTS.

VF MUDDY QTZ SS, MOSTLY 7, BUT OCCAS'L REMNANTS OF PRIM. SED. STRUCS. LIKE 184 M.

GRY, CLUD, MSC. SLTY SH ↑ MUDDY, CLUD, STS W/ VF SS INTER-BEDS LIKE 203 M, ETC.




ØQUIETER $H_2O$

GREEN-TAN SLTY MDST ↑STS

OL-GREEN ⊙LS GRST W/ COATED GRAINS, ETC. INCL ≤2cm DISCONT. DOLSTS INTERLAMS & [illegible] & V-FILL. LWR 10cm A BIT FINER. ~~ TWEEN IT & UPPR PART

BROWN, $CO_3$-CEMTD FSS(QTZ) IN ~2cm BEDS. UPPR CNTC ~~, ~8cm RELIEF.

GREEN-TAN MUDDY SIL STS W/SOME $CO_3$-CEMTD BEDS, RECESSIVE.

⊙LS GRST. OL-GREEN. SLIGHT ↑ INCR IN ⊙, ½↑1mm. ≤ 2cm ORNG DOLSTS DISCONT INTERLAMS, TRYING TO LOOK LIKE ⌒R. Ø MOSTLY ~1cm, ≤2cm MAX. CAN'T SEE XBDDG OR RIPPLES. [illegible] OF DOLSTS. UPPR ~50cm ≈ 50% DOLSTS. LWR 2.3m ~10-15% DOLSTS.

Ø TEND TO CONCENTRATE IN BEDS ~20cm THK. INTERP: NOT AN ACTIVE ⊙ SHOAL, BUT RATHER A DEEPER, SUBTIDAL ACCUMULATION; ∴ ACT AS ⌒R?

MOSTLY CLUD, GREEN SH EXCEPT TOP 40cm WHICH HAS SIL STS & DOLSTS W/≤4cm DISCONT BEDS OF ⊙. 40 cm ACTS AS A GRAD'L BNDRY BETWEEN SH & ⊙ BEDS ABOVE.

LS PK/GRST W/ QTZ GRNS ALSO

VF QTZ SS, SOME $CO_3$-CEMTD BEDS

GREEN, LS PKST W/MOSTLY ⊙

F-VF QTZ SS W/ A 10cm THK LS-CEMTD BED W/ A FEW Ø @ 235m & ONE W/ $CO_3$-STS [illegible] & [illegible], ~8cm THK @ 236m. [illegible] IN TOP 70→100cm.

GREEN Ø, LS, PKST. MORE [illegible] IN LWR ½, MORE Ø IN UPPR

F QTZ SS

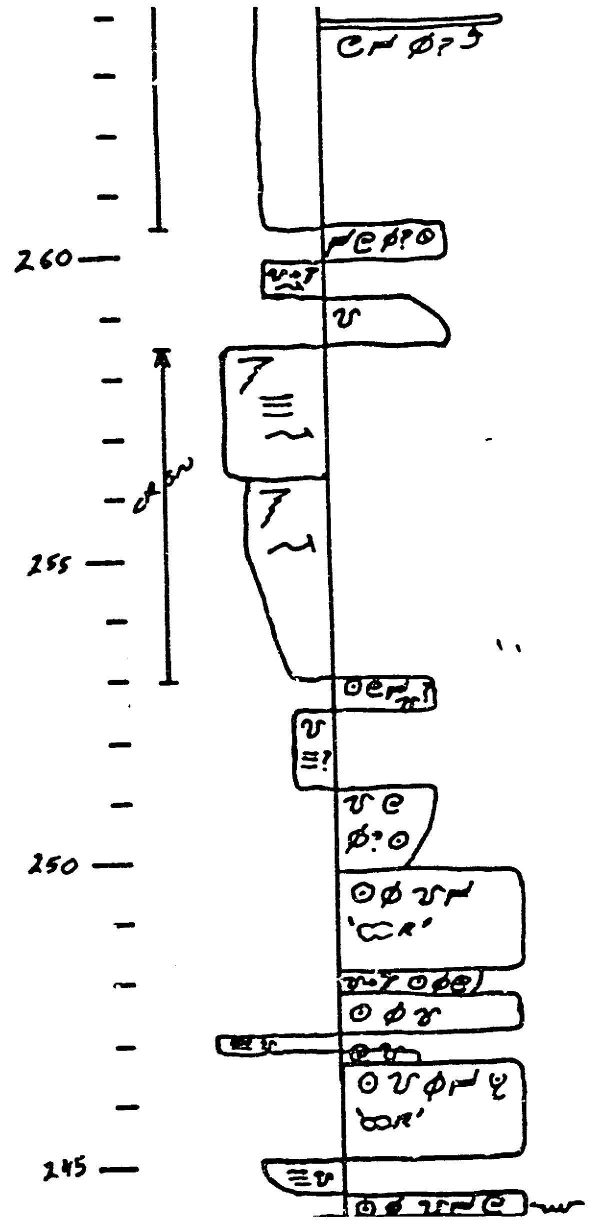
GREEN→BROWN LS PKST W/ IRREG BULBOUS UPPR BNDRY. (NOT A TEXTURE, I DON'T THINK) LIKELY TO BE SLUMPED/SOFT SED. DEFORMATN. LG [illegible] IN 10cm BASE BELOW BULBOUS PART. Ø IN LWR PART.

QTZ SS. SLIGHT CRSN ↑, VF→F. ≡ IS DOMINANT BEDFORM. A 3cm THK, $CO_3$-CEMTD SS IN UNIT.

BROWN ⊙(½-¼mm) LS GRST. W/ A COUPLE BLEBS OF DOLSTS. THICKENS LATLY TO AT LEAST 20cm

QTZ SS, VF. SLT DECR ↑ FROM MUDDY VF SS TO CLEAN VF SS. A COUPLE OF 1-2 cm $CO_3$-CEMENTED SS BEDS, & 1 3-cm THK @ PKST W/QTZ SAND GRAINS

GREEN, CLUD SH. NOT CHRTC




TAN-GRAY, SLTY, SIL MDST. LWR CNTC GRADATIONAL

BRWN LS WK/PKST OF VF-F QTZ SAND THAT GRADATIONALLY GETS MORE SILICIOUS ↑, TIL FINALLY AS A SLTY $CO_3$ MDST THAT GOES TO A SIL. SLTY MDST. ORNG-BRWN DOLSTS INTERLAMS

GREEN SILTY, MUDDY, CLEAVED SH ↑ MUDDY STS ↑ MUDDY VF SS.

OCCASIONAL VF SS ~ IN SH & STS.

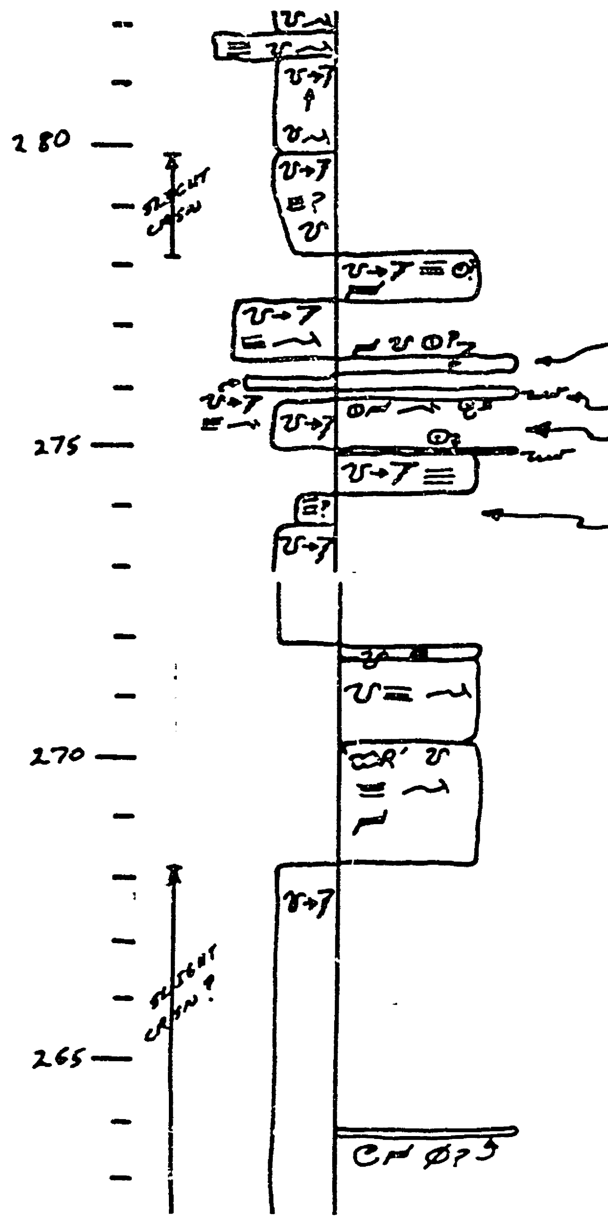
LT YELLOWISH-GREEN DOL'C LS WKST W/ SOME ⊙(< ½ mm) & SOME ℮.
LOTS OF DISCONT. DOLSTS STRINGERS ≤ 3 mm THICK

GREEN, SIL., CLVD, POSSIBLY CHLRTC, ϑ'D SH

TAN ↑ GREEN, CLEANING ↑ $CO_3$ & SIL UNIT. TOP 20 cm MOSTLY GREEN CLEAN WKST W/ 1-4 mm DOLSTS STRINGERS. LWR 1.2 m IS A REAL MESSY, RECESSIVE MIX OF $CO_3$ & SIL. SLT, MUD & SAND. POSSIBLY SOME Ø IN LWR PART. OVERALL CHARACTER IS ↑ DECR. IN SILICIOUS COMPONENTS

OL-GREEN ⊙ (~½-1 mm) LS GRST W/ SOME Ø, ≤ 1 cm, ~10-15% ORNG DOLSTS, TRYING TO BE ⋘R. [illegible] OF ORNG DOLSTS.

LS PKST & DOLSTS WELL-MXT BY ϑ. RECESSIVE
⊙ GRST W/ ≤ 1 cm Ø. LS GRST W/ ~25% ORNG DOLSTS IN 2-3 cm LAYERS
BROWN, $CO_3$-CEMTD QTZ. RECESSIVE
IS WKST OR STS
OL-GRN ⊙ LS GRST SIM. TO 241 m, BUT FEWER Ø. ~15%-20% DOLSTS W/ MOST @ TOP. MORE ϑ. CAN'T SEE PRIM. SED. STRUC. TRYING TO BE ⋘R. ONE SCT ≈ 15 cm OF ℓ AT TOP OF UNIT. INTERP: NOT AN ⊙ SHOAL, BUT TRANSPORTED TO DEEPER & QUIETER $H_2O$
GREEN-TAN SLTY MDST ↑ STS
OL-GREEN ⊙ LS GRST W/ COATED GRAINS, ETC. INCL ≤ 2 cm DISCONT. DOLSTS
[illegible] LWR 10 cm A BIT FINER. ~ 'TWEEN IT & UPPER PART




ORNG. UPPR VF SS ALT. Ʊ'D & PRSM. SED STRUC. ~5 cm BDDG

GREEN, SLTY, CLVD MDST W/ SLIGHT INCR ↑ IN Ʊ & POSSIBLY IN GRN-SIZE

CRSN ↑ FROM GREEN, SLTY, CLVD SH TO SLTY MDST, Ʊ→7 & SOMEWHAT CLEAVED. INCR ↑ IN Ʊ ALSO

OVERALL A BRWN DOLSTS W/ INCR ↑ IN ?. BASAL 5-10 cm LIKE 276.5 m, THEN INCR SLT & Ʊ ↑

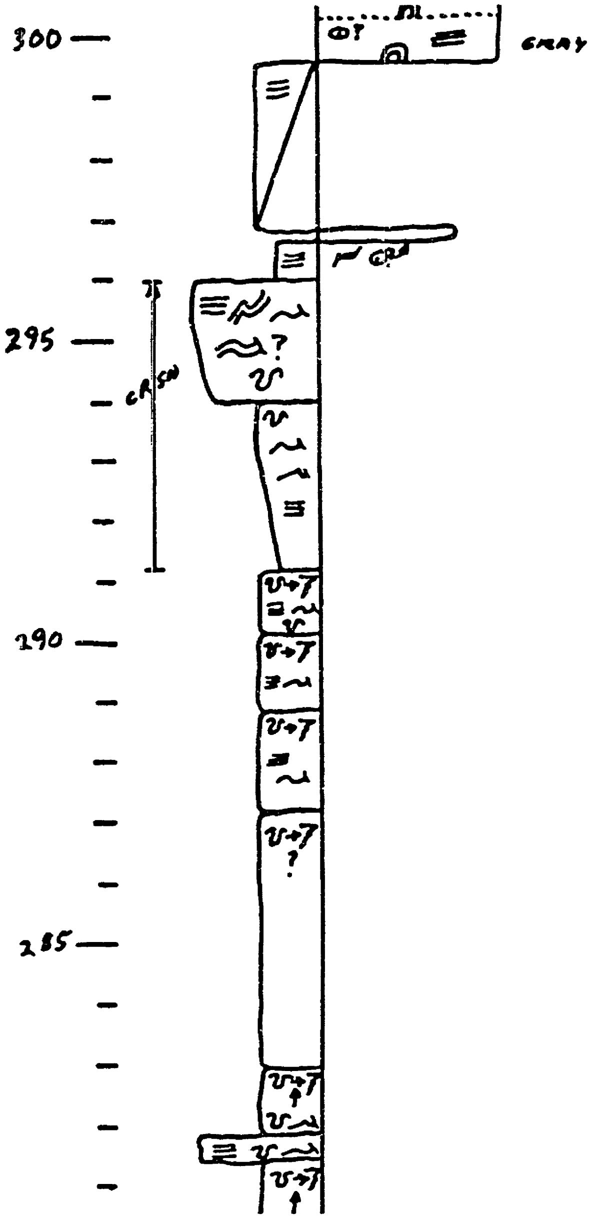
BROWN VF QTZ SS. Ʊ↑ TO Ʊ→7. SLIGHT DECR ↑ IN MUD. UPPR & LWR CNTS GRAD'L.
DOL GRST W/ POSSIBLE ⊙. DEFINITE ? & Ʊ & F-VF QTZ SAND
DOL CEM'TD MUDDY STS + VF SS. BROWN
GREEN-BRWN ⊙ LS GRST. BASAL 0-8 cm ? ? ⊙. ABOVE AN INTERNAL ? CNTC IS ⊙ ? (≤ 1½×2 cm) GRST W/ SOME CLEAN ⊙ GRST → @ TOP (DISCONT)
GREEN, SLTY, SIL. MDST
GREEN ⊙ LS GRNST W/ OCCAS'L Ʊ. ⊙ ~½-1 mm. 1-2 cm ? @ BASE
ORNG-BRWN DOLSTS, ~90% W/ DISCONT GREEN LS PKST W/ QTZ GRNS, ≡. SOME DOLSTS ALSO ≡.
GREEN, CLEAVED, CHLORITIC, SILTY SH

GREEN, SILTY, SIL. MDST
GREEN LS PKST OF VF QTZ SAND W/ ≤ 2 mm THK, ORNG-BROWN DOLST INTERLAMS

ORNG-TAN LIMY DOLSTS W/ LOTS OF SIL. GRNS (ALMOST A CALC SIL. STS). OVERALL, AN ↑ CHANGE FROM CLEANER TO MORE SIL-GRAND (DETRITAL) CO3.

?-LIKE TEXTURE W/ < NORMAL Ʊ'S. 1-3 cm GREEN LS PKST OF F-VF QTZ SAND ALT. W/ SILSTS + DOLSTS (ORNG-BRWN), ≤ 1 cm-3 cm THK, ≈ 50-60% STS. ≡ & ~ IN LS SAND, WHEREAS STS ≡ → Ʊ. Ʊ ALSO IN LS. OVERALL COLOR IS ORANGE-BROWN + DK BROWN DESERT VARNISH. GRADATIONAL UPPR CONTC.

GREENISH-GRAY, SLTY MDST W/ AN 8 cm THK LS @ GRST @ 263.8 m. MOSTLY @ ECHINOIDS? W/ DOLSTS ? & Ø?. ALSO NOT SURE OF LATERAL CONTINUITY DUE TO PARTIAL COVER OF UNIT. MORE MUDDY PARTS OF SIL. UNIT CLEAVED. POSSIBLY SLIGHT CRSN UP




GRAY: BASAL ½ IS SMALL (5-10cm ACROSS X-Y-2cm SYNOPTIC RELIEF) [illegible]. UPPR ½ IS Ф? GRST W/ ORNG STREAKS, [illegible]. LS. ФT ~1mm DIAM.

GREEN-GREY, CLUD, SLTY, SIL. MDST, PARTIALLY COVERED

ORNG-GRY LIMY DOL PKST

LT GRY-GREEN SLTY SH W/ SOME OR. DOLSTS @ TOP

LT GRY VF & F SS. [illegible] NEAR TOP (~295.6m). MAY BE FLUID-ESCAPE. A FEW [illegible].

GRY SLTY SH ↑ SLTY, SANDY MDST. LESS [illegible] THAN IMMED. LWR UNITS.

MDST, BROWN, LIKE 282.5m

GREEN MDST LIKE 282.5m

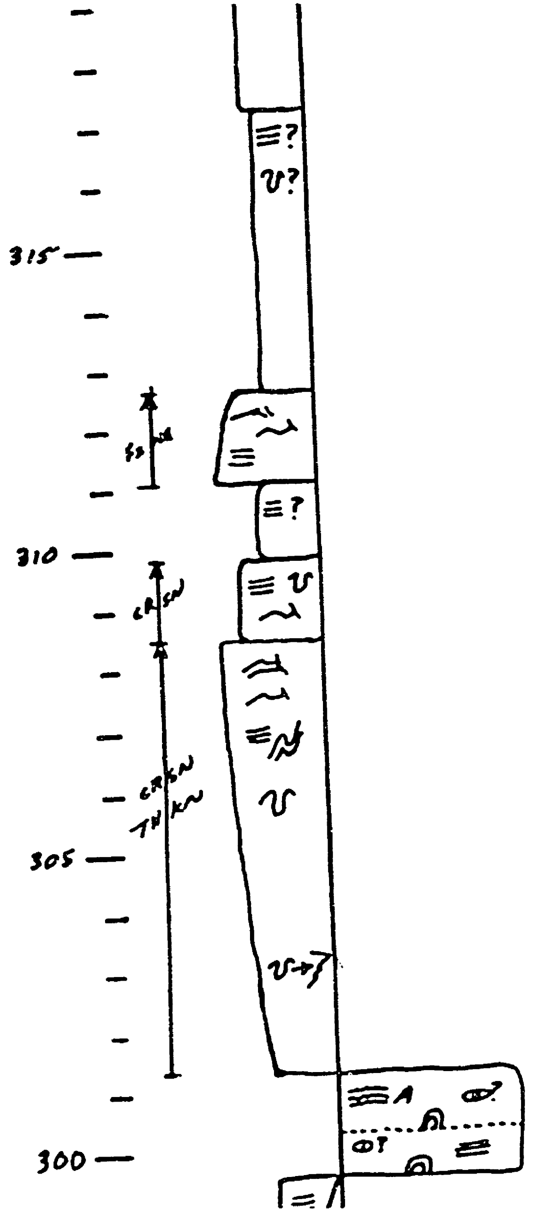
ORNG-BRWN, OTHERWISE LIKE 285m, ETC, BUT A BIT MORE SILTY. COLOR DUE EITHER TO DOL. CEMENT OR HYDROTH. ALT'N, LOCALIZED LIKE TALC ZONES.

GREEN MDST, SLTY & CLUD, LIKE 282.5m, ETC. A BIT MORE FINE-GRAINED. CAN'T REALLY DISTINGUISH MUCH. MAY HAVE A MORE [illegible] ZONE AT ~285.5m

GREEN, SLTY, CLUD, MDST LIKE 279m, 281m

ORNG. UPPR VF SS ALT. [illegible] & PRIM. SED STRUC. ~5cm BDDG

GREEN, SLTY, CLUD MDST W/ SLIGHT INCR ↑ IN [illegible] & POSSIBLY IN




A MXT BAG OF CLEAVED SH & NOT-AS-CLEAVED MDST - SEVERAL COLOR CHANGES W/IN UNIT. ALSO FAULT & HYDROTH. ALTN. BASAL ~3C CMS IS LT BROWN SH OVERLAIN BY ~2 M OF PURPLE SH → MDST, IN TURN OVERLAIN BY GREEN SH → MDST. UPPR 2 M HAVE HYDROTH ALT'D TO ALMOST-TALC. SEVERAL QTZ + $CO_3$ VEINS ≤10 CM THK EXPOSED IN TOP ~50 CM.

COLOR CHANGE TO ORNG-BRWN. STS W/ STRINGERS OF VF-F SS (RIPPLES, ≡) COLOR INDICATES DOL. CMT. QTZ GRAINS. BDDG ≤1½ CM. ∪ NOT SEEN. SLIGHT FINING ↑, W/ MORE SS BEDS AT BASE, MORE STS BEDS AT TOP. STS MORE ≡ THAN RIPPLED INTBD: INTERTIDAL

— — —

COLOR CHANGE TO YELLOWISH GREEN. FINER GRAINED. GOING TO TALC. MORE RECESSIVE. SLTY MDST. CLEAVED, MICACEOUS. CAN'T SEE MUCH SED. STRUC DUE TO CLEAVAGE, HYDROTH. ALTN & COVER.

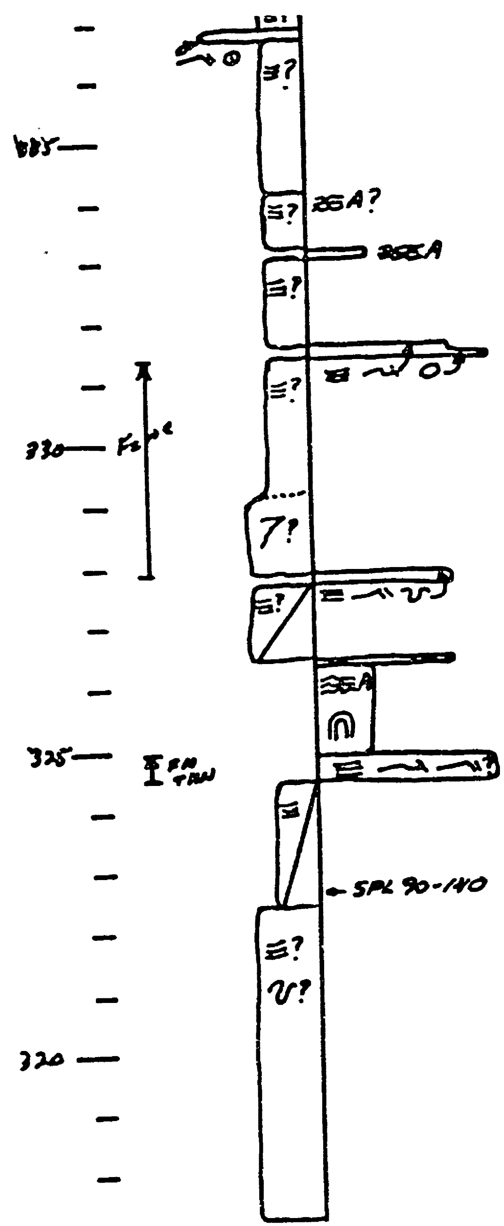
— — —

GREEN STS W/ SOME VF SS BEDS LIKE 307 M. BDDG ≤1½ CM. SLIGHT CRSN ↑ DUE TO DECR IN MUD.

GREEN, CRSNING, THICKENING ↑ PKG OF MDST TO VF SS. BEDDG ≤10-15 CM. ≡ ARE BROAD & LOW-RELIEF. SOME BEDS ∪ → ∼, BUT MORE SO LOWER IN UNIT. ALWAYS INTERBDD W/ PRIM. SED STRUC. WHERE MORE MUDDY, BEDS CLEAVED & ALMOST CHLORITIC, MOSTLY IN BASAL FEW 10'S CM. ∿ ON SCALE OF CMS, PROBLY DEWATERING OF A BED OR TWO.

ORANGE: SMALL (~5 CM X 2 CM) ⋒ @ BASE W/ POSSIBLE ⊕ ABOVE. DOLSTS. UPPR 20-30 CM MORE PLATY & RECESSIVE WX. MORE SIL?

GRAY: BASAL ½ IS SMALL (5-10 CM ACROSS X ~1-2 CM SYNOPTIC RELIEF) ⋒. UPPR ½ IS ⊕? GRST W/ ORNG STREAKS, ≈ ≡ → ≡. LS. OT ~1 MM DIAM.




BRWN, LS-CMTD VF QTZ SS, ~. INTIMATELY INTERLAM'D W/GREEN, CHLRTC SH. INCL ~ OF ≤ ½ mm Ø

RED-PURPLE, CLVD SLTY SH. PARTIALLY TALC IN UPPR ½.

ALT ≤3 mm LS & GREEN, CLVD, CHLRTC SH. LIKE 332 m. QTZ VEIN ⇒ FAULT, HYD. ALTN. UPPR ½ OF BED GOING TO PURPLE. TOP 1-5 cm MAY BE BROWN A.

BROWN ALG. LAM DOL ~2-8 cm THK

BASAL ~40 cm 1-2 mm ALT. LAMS TAN LS & GREEN, CHLRTC SH, ALL CLVD LIKE ~330.7-331.4 m. REST OF INTERVAL GONE TO TALC W/QTZ VEIN @ TOP ⇒ FAULT, HYD ALTN

BASAL 5-10 cm = GREEN LS GRNST OF Ø. OVERLAIN BY DOLSTS W/ A SMALL AMT OF QTZ GRAINS (~10-15 cm THK). DOLSTS BDDG ≤ 1 cm; & CAN'T SEE SED. STRUC IN DOLSTS.

GREEN, SANDY, SIL, CLEAVED, ? MDST IN BASAL ~1 m, ↑ CLVD, GREEN CHLORITIC SH. UPPR 50-70 cm HAS LS INTERLAMS (TAN). CAN'T SEE ANY FEATURES (HYD. ALTN?). TOP ~30 cm GOING TO TALC. ALSO HAVE QTZ VEIN IN UPPR METER. DISCONT. LAT'LY. ⇒ FAULT &/OR HYD. ALTN.

ORNG DOLSTS & LIMY ∞ CMTD VF QTZ SS.

GREEN-TAN, SLTY, SSL MDST. CLVD. MAY BE DOL'C

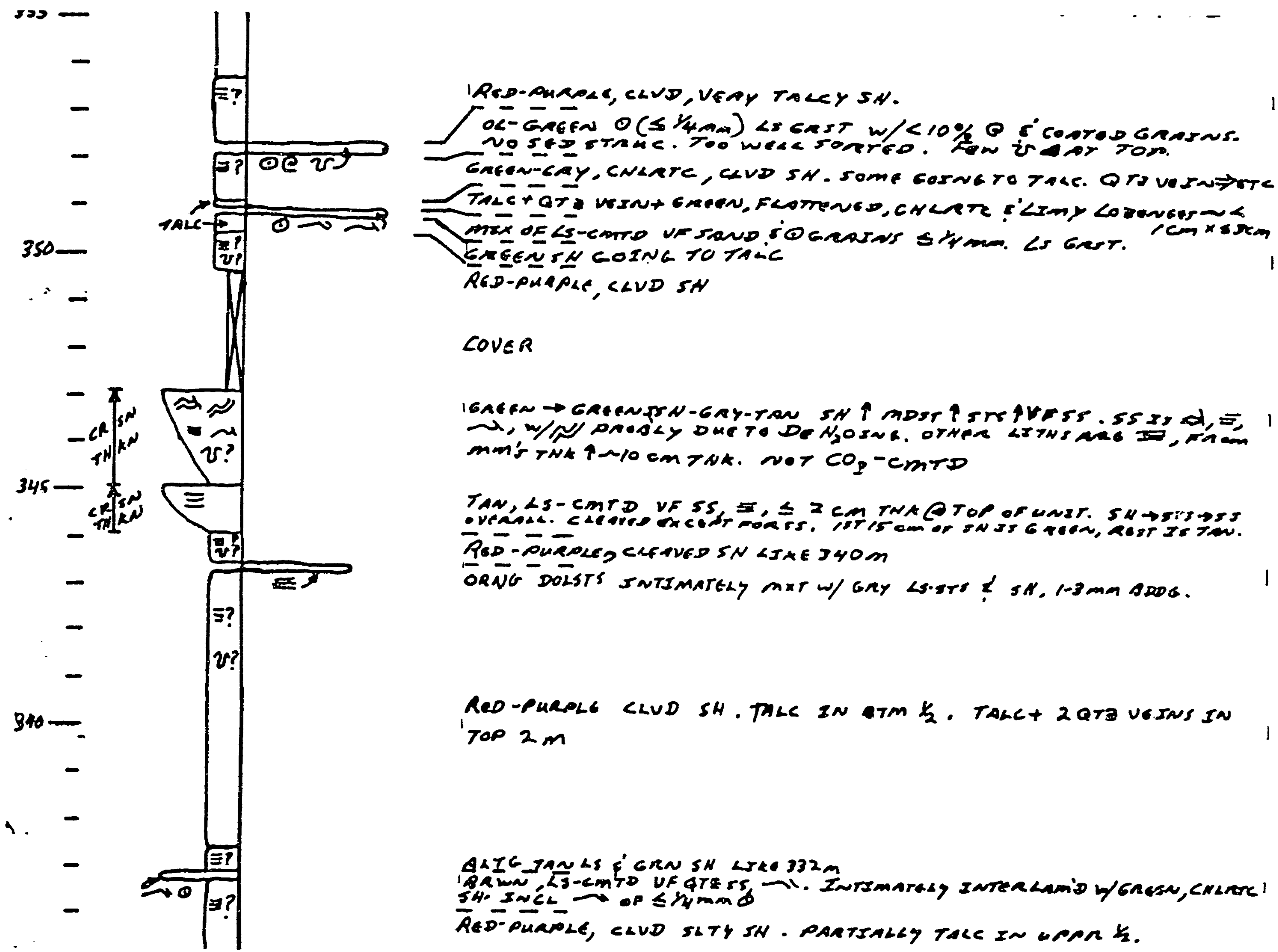
ORNG DOLSTS CAP TO LS BELOW. ≤5 cm → 10 cm THK. MAY JUST BE ALTN CAP TO LS

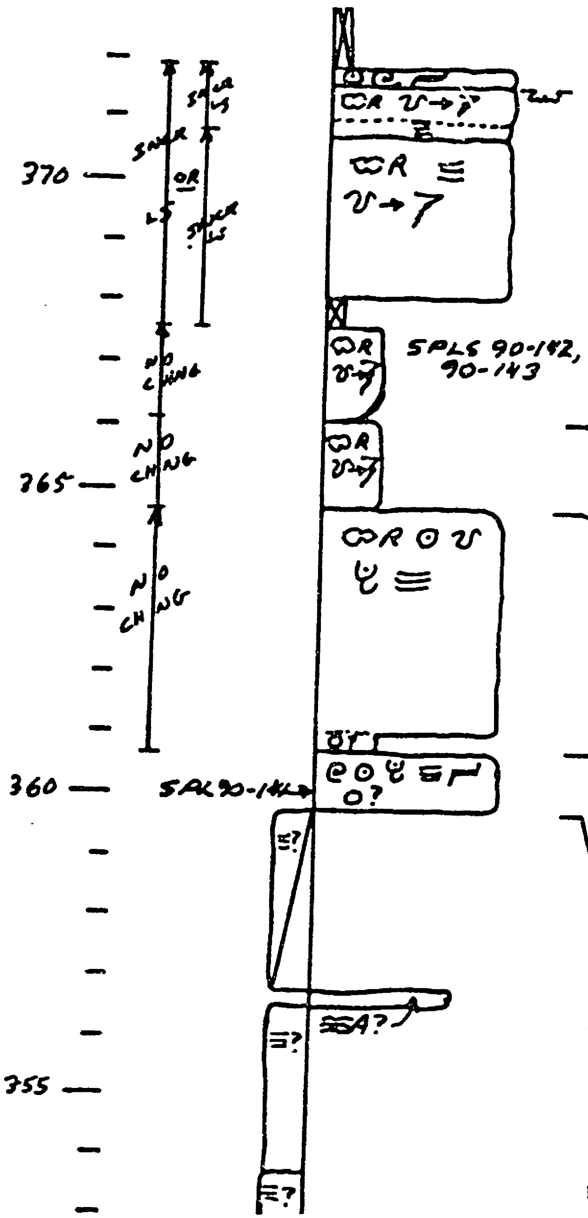
GRY LS. Ⓐ (~55 cm x ~10-15 cm) IN LWR ~60-70 cm W/ ~20% VF & F QTZ GRAINS OVERLAIN BY LAM'D GRY LS THAT HAS SAME XL'N APPEARANCE AS Ⓐ W/ ≤10% VF-F QTZ GRAINS. INTERP: UPPR AS A.

GRY-GREEN LS AREN. W/ 40-50% F QTZ GRNS. FINES ↑ MORE MDDY SS. THINNER BDD ↑, 3-4 cm ↑ < ½ cm. SOME 1-3 mm ORNG DOLSTS INTERLAMS, BUT NOT R TEXTURE

MOSTLY COVERED. GREEN-GRY, CHLRTC CLVD SH. ~20 cm FROM BASE, HAVE A DK GREEN, GLAUC? BED ~1 cm THK (SPL 90-140). MAY TIE INTO MONT. WELL GLAUC? BED.

1st RED-PURPLE MDST → SH. STILL SOMEWHAT CLEAVED. MORE MDST THAN SH (VS MORE SH THAN MDST IN UNIT IMMED. BELOW). IN UPPR 20-30 cm ARE STRINGERS OF GREEN CHLORITE? (ORIG GLAUC?).


350
345
340
TALC
CR SN TH KN
CR SN TH KN
RED-PURPLE, CLVD, VERY TALCY SH.
OL-GREEN ⊙(≤ 1/4mm) LS GRST W/<10% ⊙ & COATED GRAINS. NO SED STRUC. TOO WELL SORTED. FEW ∪ AT TOP.
GREEN-GRAY, CHLRTC, CLVD SH. SOME GOING TO TALC. QTZ VEIN ETC
TALC + QTZ VEIN + GREEN, FLATTENED, CHLRTC & LIMY LOZENGES ~ 1CM x 3CM
MIX OF LS-CMTD VF SAND & ⊙ GRAINS ≤ 1/4mm. LS GRST.
GREEN SH GOING TO TALC
RED-PURPLE, CLVD SH
COVER
GREEN → GREENISH-GRAY-TAN SH ↑ MDST ↑ STS ↑ VFSS. SS IS, W/ PROBLY DUE TO DEH2OING. OTHER LITHS ARE, FROM MM'S THK ↑ ~10 CM THK. NOT CO3-CMTD
TAN, LS-CMTD VF SS, ≤ 2 CM THK @ TOP OF UNIT. SH → SLTS → SS OVERALL. CLEAVED EXCEPT FOR SS. 1ST 15 cm OF SH IS GREEN, REST IS TAN.
RED-PURPLE, CLEAVED SH LIKE 340m
ORNG DOLSTS INTIMATELY MXT W/ GRY LS-STS & SH, 1-3mm ADDG.
RED-PURPLE CLVD SH. TALC IN BTM 1/2. TALC + 2 QTZ VEINS IN TOP 2 M
ALTG TAN LS & GRN SH LIKE 332m
BRWN, LS-CMTD VF QTZ SS. INTIMATELY INTERLAM'D W/ GREEN, CHLRTC SH. INCL OF ≤ 1/4mm ⊙
RED-PURPLE, CLVD SLTY SH. PARTIALLY TALC IN UPPR 1/2.




. . . , ~ ½×1 cm. . . . . . . . DOLSTS. ≈ 10 M UNIDD @.

COVER

OL-GREEN GRST. SCOURED A FEW CM INTO ΦR W/ SMALL ⌐ OF ΦR.

≈ 60-70% ORNG-BRWN DOLSTS IN BASAL 10-15 CM, W/ REST OF UNIT ~ 10-15% DOLSTS IN DISCONT. BLEBS & V'S. GRY LS EITHER LS-ARENITE OR MDST. BASAL 10-15 CM, LS IS ARENITE.

≈ 80% ↑ 60% DOLSTS, ORNG-BRWN. IN LAMS ≤ 2 CM & V'S. LAMI ≡. GRY LS TENDS TO BE LS-ARENITE W/ 10-30% VF QTZ SAND, IN BEDS ≤ 3 CM, MOST ≤ 1½ CM. BASAL ½-1 M WX RECESSIVELY.

COVER

NO DISTINCT LWR SURF, BUT DOLSTS (10-15%) NOW MOSTLY IN ≤ 2 CM BLEBS & V'S. STILL CAN'T DISTINGUISH ANY SED STRUC OR GRAINS IN DK GRY LS. LATERALLY GET MOR AMT OF RED STS IN THIS & 2 LOWER UNITS, USUALLY ⊥ TO OBLIQUE TO BDDG.

5-10% DOLSTS ONLY IN ≤ 1 CM BLEBS & V'S & DISCONT, ≈ HORIZ, VERY THREE LAYERS, W/ MOST DOLSTS OCCURANCES ≤ ½ CM. THIS INTERVAL LOOKS ALMOST CLEAVED, OR SHEARED. SOME < ½ CM V'S FILLED W/ SPAR. CAN'T SEE LAMS OR GRAINS IN DK GRY LS. RED STS VEIN CUTS COMPLETELY THRU THIS UNIT & ENDS ≈ 10 CM INTO THE NEXT UP.

ΦR. ≈ 10-15% ORNG-BRWN DOLSTS OVERALL. MOST DOLSTS IN V'S & IRREG BLEBBY HORIZONS, BUT SELDOM IN ≡ LAMS. BASAL 25 CM OF GRY LS IS O?, OR MDST. REST OF UNIT HAS ⊙ GRST AS GRY LS, W/ SOME ⊙ DOL'TZD. ALL ⊙ ≤ ½ MM. ≤ 30 CM, MOST SMALLER & OFTEN V'D ENOUGH TO BE HARD TO RECOGNIZE.

NOTE! A SWATH OF REDDISH, LIMEY DOLSTS CUTS DIAG'LY THRU THIS & UPPER UNIT OF ΦR. HAS CHERT CLASTS, SOME BRECCIA. MAY BE HYD. ALTN. PROBLY NOT TERRA ROSA. "VEIN" ~ 5-20 CM WIDE W/ OCCASL SIDE-BRANCHING ALONG DOLSTS INTERVALS.

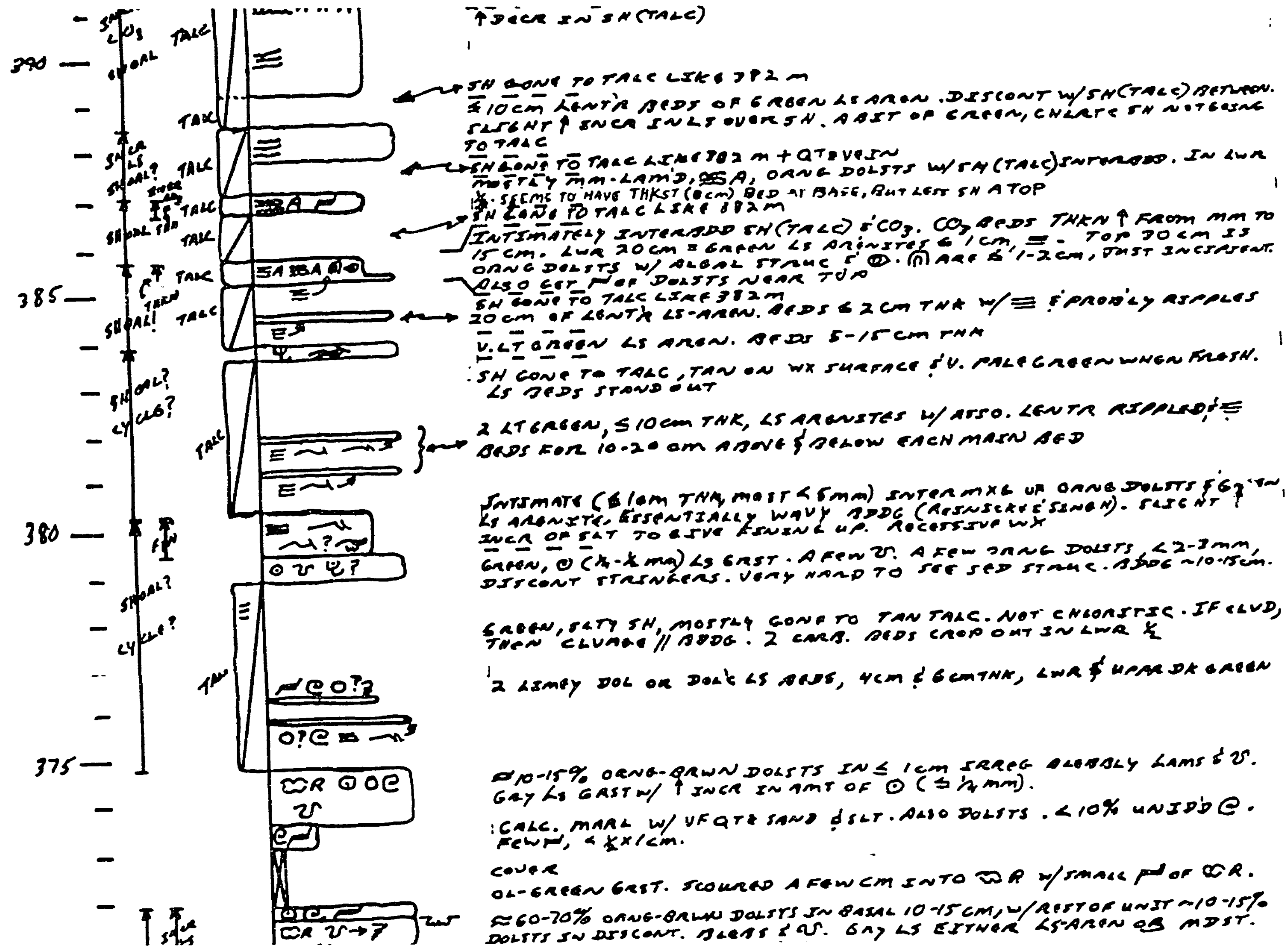
VARIABLE UNIT LATERALLY. .15 → 1.0 M EXPOSED, W/ 1.0 M PROBABLE MAX THICKNESS. FROM A @ UPNGRST TO A ⊙ GRST (LS). @ INCL. POSSIBLE ECHINOID FRAGS. ≈ 15-20% DOLSTS OVERALL, W/ DOLSTS ≤ 10 CM. @ 15-20 CM HI, OFTEN W/ REACTIVATN SURFACES (SEE SPL 90-141). ⊙ ARE F SAND-SIZED (~⅛ MM). LS'S GREEN, DOLSTS BRWN. ≡, , ~ IN LS. GRST W/ ≤ 20% F QTZ SAND. ⌐ OF DOLSTS ≤ 1×2 CM.

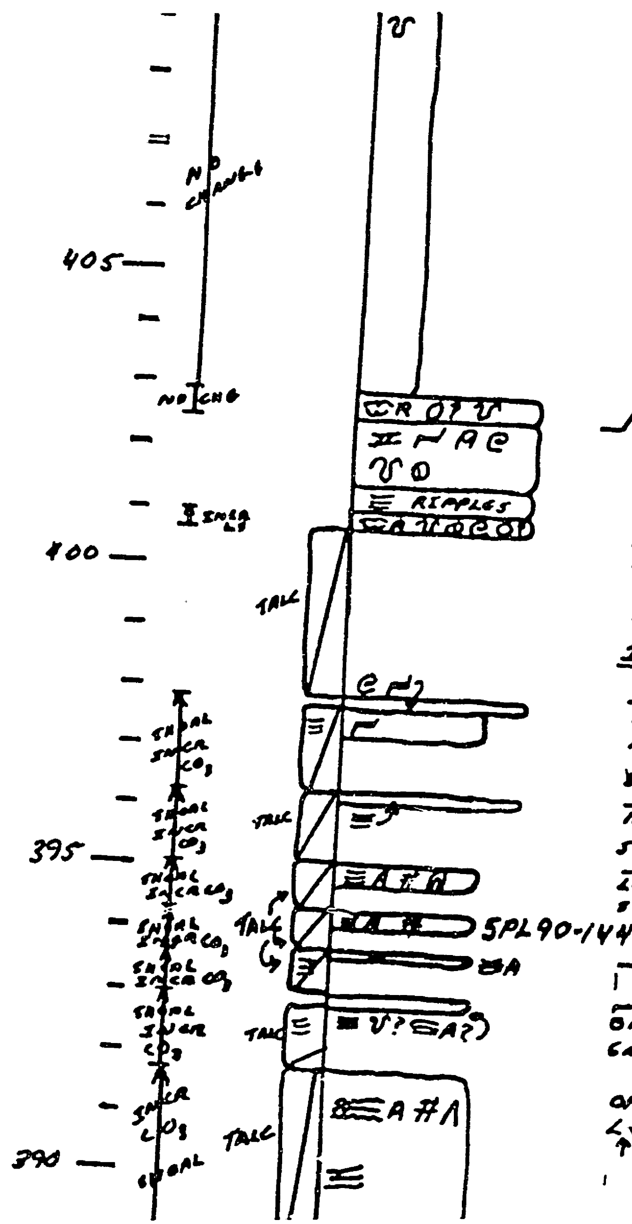
PARTIALLY COVERED GREEN, CLVD, CHLRTC SH GOING TO TALC W/ ≥ 1 QTZ VEIN

ORNG-TAN, SANDY DOLSTS W/ QTZ GRAINS. POSSIBLE ≋A INTER-LAM'D W/ SIL. SH BSTS. MAY BE JUST ≡ SLT W/ SMALL ≈ SUPERIMPOSED.

TAN ↑ GREEN ↑ TAN CLVD, CHLRTC SH. ≈ 40% GONE TO TALC

RED-PURPLE, CLVD. VERY TALC . . .


390
385
380
375
SHOAL
TALC
SHOAL?
SHOAL!
SHOAL? CYCLE?
↑ DECR IN SH (TALC)
SH GONE TO TALC LIKE 392 m
≤10cm LENT'R BEDS OF GREEN LS AREN. DISCONT W/ SH (TALC) BETWEEN. SLIGHT ↑ INCR IN SLT OVER SH. A BIT OF GREEN, CHLRTC SH NOT GONE TO TALC
SH GONE TO TALC LIKE 382 m + QTZ VEIN
MOSTLY MM-LAM'D, A, ORNG DOLSTS W/ SH (TALC) INTERBDD. IN LWR ½ SEEMS TO HAVE THKST (8cm) BED AT BASE, BUT LESS SH AT TOP
SH GONE TO TALC LIKE 382 m
INTIMATELY INTERBDD SH (TALC) & CO3. CO3 BEDS THKN ↑ FROM MM TO 15 CM. LWR 20 CM = GREEN LS ARENITES ≤ 1 CM, ≡. TOP 30 CM IS ORNG DOLSTS W/ ALGAL STRUC & . ARE ≤ 1-2 CM, JUST INCIPIENT. ALSO GET OF DOLSTS NEAR TOP
SH GONE TO TALC LIKE 382 m
20 CM OF LENT'R LS-AREN. BEDS ≤ 2 CM THK W/ ≡ & PROB'LY RIPPLES
V. LT GREEN LS AREN. BEDS 5-15 CM THK
SH GONE TO TALC, TAN ON WX SURFACE & V. PALE GREEN WHEN FRESH. LS BEDS STAND OUT
2 LT GREEN, ≤10cm THK, LS ARENITES W/ ASSO. LENTR RIPPLED & ≡ BEDS FOR 10-20 CM ABOVE & BELOW EACH MAIN BED
INTIMATE (≤ 1cm THK, MOST < 5mm) INTERMXG OF ORNG DOLSTS & GREEN LS ARENITE, ESSENTIALLY WAVY BDDG (RESINSCREENING). SLIGHT ↑ INCR OF SLT TO GIVE FINING UP. RECESSIVE WX
GREEN, (½-¼ mm) LS GRST. A FEW. A FEW ORNG DOLSTS < 2-3 mm, DISCONT STRINGERS. VERY HARD TO SEE SED STRUC. BDDG ~10-15 cm.
GREEN, SLTY SH, MOSTLY GONE TO TAN TALC. NOT CHLORITIC. IF CLVD, THEN CLVAGE // BDDG. 2 CARB. BEDS CROP OUT IN LWR ½
2 LSMSY DOL OR DOL'C LS BEDS, 4cm & 6cm THK, LWR & UPPR DK GREEN
≈10-15% ORNG-BRWN DOLSTS IN ≤ 1cm IRREG ALGALLY LAMS & . GRY LS GRST W/ ↑ INCR IN AMT OF (≤ ¼ mm).
CALC. MARL W/ VF QTZ SAND & SLT. ALSO DOLSTS. < 10% UNID'D . FEW, < ½ X/cm.
COVER
OL-GREEN GRST. SCOURED A FEW CM INTO R W/ SMALL OF R.
≈60-70% ORNG-BRWN DOLSTS IN BASAL 10-15 CM, W/ REST OF UNIT ~10-15% DOLSTS IN DISCONT. BLEBS & . GRY LS EITHER LS-AREN OR MDST.




(UR ORNG LS GRST ... MOST, POSSIBLY REWKD TO VF-SLT SIZED LS XLS ≤ 1-3cm, MOSTLY IRREG & OFTEN BLEBBY. BRWN DOLSTS INTERLAMS & V-FILLS ≈ 15% DOLSTS. BDDG: LS ≤ 5cm, DOLSTS IN MM'S. NO Ⓟ TEXTURE OR MORPH.

NOTE: PROBABLY 2-4 SUBUNITS IN THIS INTERVAL, BUT COULDN'T BREAK OUT DUE TO LIGHT & EXPOSURE & COLOR OF DOLSTS.

|GRY, O?, LS GRST W/ ~10% BRWN DOLSTS IN IRREG LAMS & V-FILL

AT LEAST 8 BEDS ≤ 10cm OF LS GRST. GRNS FROM Ⓟ (VF & F), COATED GRAINS, TO CO₃ ~1 X 10cm. BOTH LS & ORNG DOLSTS. MOST DOLSTS IN 1 OR 2 BEDS & IN BOTH V-FILL & IRREG LAMS. NOT OR. II IN Ⓟ. SOME HEARINGBONE.

RECESSIVE WX LS AREN, VF SAND SIZE, ≡, RIPPLES. W/ 1-2 mm ≡ ORNG DOLS LAMS. ≤5% ORNG DOLSTS IN V IN TOP 25cm. BTM 10cm ≈ 50% DOLSTS IN IRREG LAMS & V. LS MOSTLY Ⓟ & O? < ¼ mm. HARD TO SEE

SH GONE TO TALC LIKE 392m

INTERA NOTE! DO CYCLES START TO GET DEEPER & THICKER @ 395.1m, ↗ FROM LOW STD. SYSTRT TO HISTND SYSTRK?

LT GREEN, LS GRST W/ MOST @ PROBLY ECHINOID, ~1X1mm. ≤ 2-3mm X 1cm LT GREEN LS-CLAST PKST. PLATY, < 2mm X 1-2cm W/ INTERLAMS OF SH

SH GONE TO TALC LIKE 392m

MM-LAM'D GREEN LS AREN INTIMATELY INTERBDD W/ TALC (SH)

SH GONE TO TALC LIKE 392m

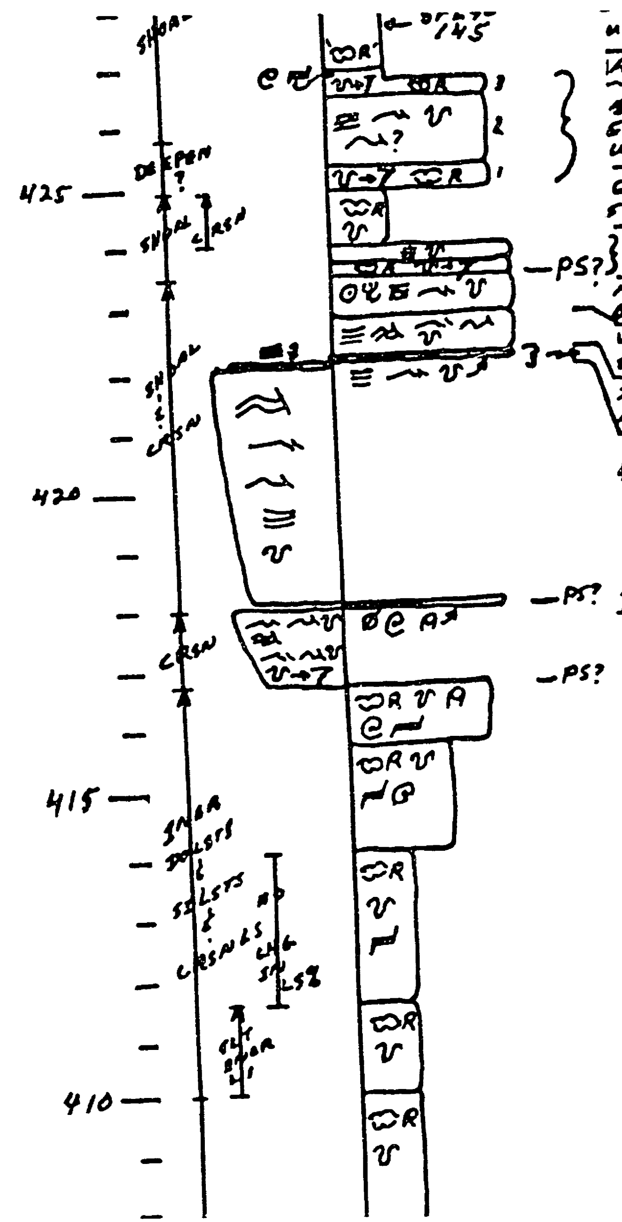
LIKE 391.7-392.0. NO SH.
SH GONE TO TALC.

SPL90-144 LIKE 391.7-393.0, STILL SOME SH

LIKE 391.7-393.0 STILL SOME SH

ORNG DOLSTS. POSSIBLE CONCRIC RIPPLES. NOT DEFINITE ≡A
GREEN, CLVD, CHLRTC SH, GONE TO TALC IN LWR 30cm

ORNG DOLSTS W/ # & Λ IN UPPR ~20cm. DOLSTS MOSTLY MM LAM'D IN LWR 2-2½ m. UPPR ~70cm GET ≡A, W/ # & Λ IN TOP 20 cm. ↑DECR IN SH (TALC)




UNIT

A SORT OF GRAD'L UPPR & LWR CNTC FROM LS & DOLSTS & LS. ① & LWR ③: ~60-75% DOLSTS. ② ~90-95% DOLSTS. MOD. AMT VF SAND MATERIAL IN BOTH W/ PROBLY SOME SSL. GRNS IN DOLSTS. ② IS TOO SLTY, NOT Ѵ'D ENOUGH TO BE R. ① & INCR IN DOLSTS, ③ & DECR IN DOLSTS, TSL IN UPPR 20 CM, ~20% DOLSTS

GRY LS MOST REXLZD TO VF XLS (OR VF LS-AREN. T ENOUGH TO REMOVE SED STRUC) INTER LAM'D W/ ORNG-BRWN DOLSTS. ~20% & 5%, IN Ѵ.

2 VF LS-AREN W/ DOLSTS INTERLAMS. LWR UNIT Ѵ'D ENOUGH TO BE R UPPR UNIT W/ FEW Ѵ. LS GRAY. DOLSTS ORNG-BRWN MOSTLY LT OL-GRN ⊙ LS GRST W/ & 5-20 CM. BASAL 5 CM. SOME ORNG-BRWN DOLSTS, MOSTLY IN TOP 15 CM. ⊙ 1/4-1/2 MM

VF & F LS AREN. LT OL-GREEN W/ BRWN-TAN DOLSTS & SSL STS. 4 SUBUNITS: STS/LS/STS/LS, TOP → BTM. 10-20 CM INTERBDD W/ IN ANY OF 4 SUBUNITS.

20 CM GRAD'L CNTC: MOSTLY VF-F QTZ SAND @ BASE & MOSTLY VF-F LS-AREN AT TOP. ≤ 1 CM BDDG. BRWN-TAN & LT OL. GREEN. A FEW Ѵ

BRWN-TAN QTZ SS. MORE Ѵ IN LWR PART. & INCR IN BEDFORMS W/ DECR. IN Ѵ, ALONG W/ GRNSIZE INCR. NEAR TOP, A FEW DISCONT $CO_3$/$CO_3$-CMTD BEDS ≤ 1 CM THK

1-8 CM LS PK/GRST. VARIES IN THKNSS. SEEMS LAT'LY CONT. FOR AT LEAST 10'S M. RELATIVELY FLAT BTM & IRREG TOP. INTORP HIATUS IN DEPSTN @ PS ANDRY

QTZ, MUDDY STS. Ѵ → T & VF SS W/ SOME BEDS F SS, Ѵ'D.

LT GAY, LS PKST, FROM 60-70% @ BTM & 0%-5% @ TOP IS 95% DOLSTS. ORNG-BRWN DOLSTS W/ SSL. STS, ≥ 1/2 CM BDDG. LS BDDG ≤ 2 CM. THIS TOP 1 M ACTS AS GRAD'L CNTC TO SILICICLASTICS.

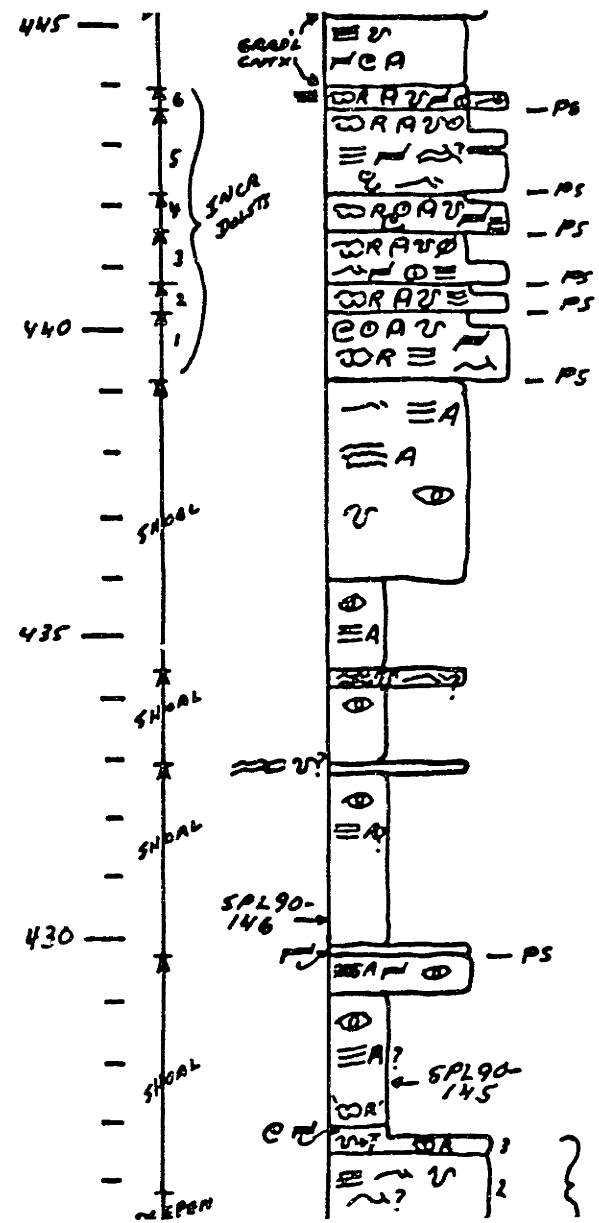
LT GAY LS WKST W/ ~15% UNID'D GRNS. OF LS. BDDG LIKE 413 M & 1-3 CM, IRREG, ALMOST NODULAR. ORNG-BRWN DOLSTS IN ≤ 1/2 CM INTER-LAMS, ALSO IRREG. ALSO IN Ѵ-FILL. QTZ SLT INCL IN DOLSTS

GRAY, LS MDST LIKE 405 M. 15-20% BRWN DOLSTS, MOST IN 2-5 MM IRREG. LAMS. LS BDDG 1-2 CM, IRREG. & ALMOST NODULAR ALSO. LWR 80 CM WX RECESSIVE. NO & CHANGE IN % DOL. A FEW SMALL LS & A FEW LS GRNS, UNID'D, < 10%

LT GRY & GAY, LS MDST LIKE 405 M. ≈ 10-15% BRWN DOLSTS IN BASAL 20-30 CM. W/ ≤ 5% IN REST OF UNIT. ALMOST ALL DOLSTS IN Ѵ. SOME SPAR-FILLED Ѵ.

GRAY APPARENT LS MDST, POSSIBLY REXLZD TO VF-SLT SIZED LS XLS (OR ORIG LS GRST OF THAT SIZE). BRWN DOLSTS INTERLAMS & Ѵ-FILLS ≤ 1-3 CM, MOSTLY IRREG & OFTEN ~ BLEBBY. SOME Ѵ FILLED W/ SPAR. ≈ 15% DOLSTS. BDDG: LS ≤ 5 CM, DOLSTS IN MM'S. NO TEXTURE OR MORPH.

NOTE: PROBABLY 2-4 SUBUNITS IN THIS INTERVAL, BUT COULDN'T ... LIGHT & EXPOSURE & COLOR OF DOLSTS.




GRNS; ≡, OCCAS'L, ⌐, A'. LS PROX EVENT BEDS ≤ 8 CM THK, GRY-GREEN DOLSTS BDDG ≤ 2 CM

6 SIMILAR UNITS. GRY LS GRST & ARENITES (≡ ∼) W/ ORNG-BRWN DOLSTS, W/ QTZ GRNS (≡ ∼ ?). ⌐ OF DOLSTS MOSTLY. ⊙ ≤ ¼ MM LS GENLLY W/ ≤ 10-20% DOLSTS IN Ʊ-FILL, INTERLAMS (& DON'T COUNT DOL'ED ⊙). DOLSTS W/ ≤ ~15-35% LS. LS MOSTLY GRST, SOME PK/GRST. LS-AREN USUALLY TOWARDS OR AT BASE OF A UNIT. SHARP LS/DOLSTS CNTX, BUT GRAD'L DOLSTS/LS CNTX.

MM-LAM'D ORNG-BRWN DOLSTS. MOSTLY ≡A, THOUGH LOTS OF SMALL DISRUPTIONS; ∼. NO DEFINITE #. SOME SIL SLT GRNS.

NOTE: 426.9 → 436.3 M: A NEW LITHOFACIES, THE LT GRY ⊕ LS. ALSO SEEN AT EAGLE MTN. HAVE A NEW LS UNIT REPLACING MXT $CO_3$ & SILICICLASTICS.

GRY LS MDST W/ TONS OF ⊕ LIKE 427 M. A BIT OF ≡A SCATTERED THRU-OUT ≤ 10 CM THK. SCATTERED, < ½ CM THK ORNG-BRWN DOLSTS.

ORNG-BRWN DOLSTS. POSSIBLY SOME ∼. HARD TO TELL. DEF'LY Ʊ.

LT GRY LS MDST W/ ⊕ LIKE 427 M, BUT W/O ≡A? & W/ LOTS OF < 1 CM ORNG-BRWN DOLSTS INTERLAMS

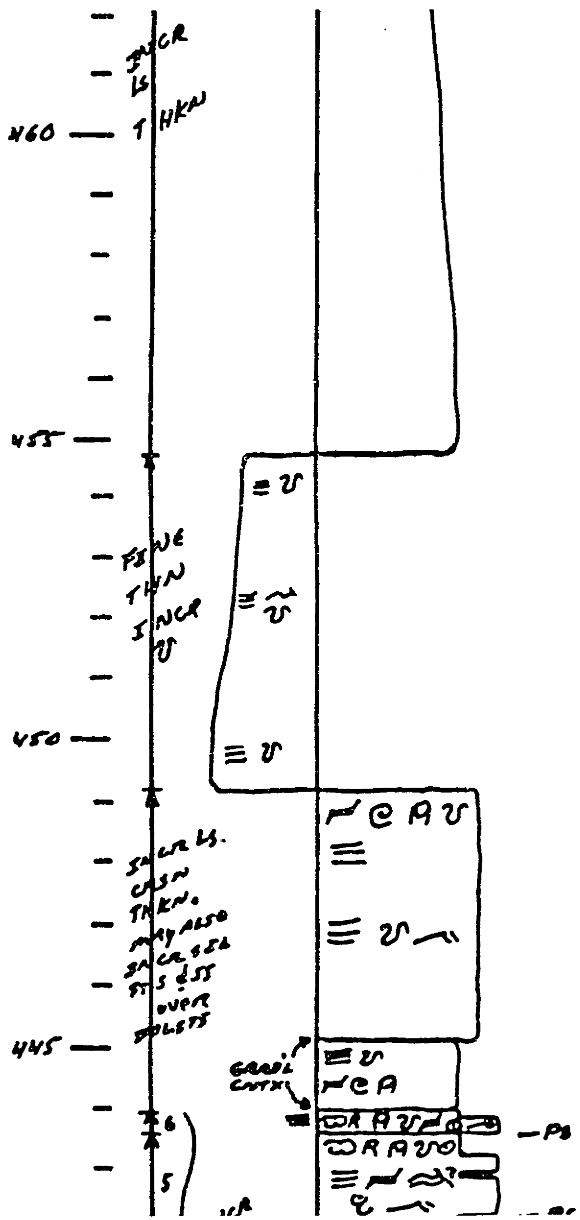
ORNG-BRWN DOLSTS MAINLY. MM-LAM'D. WAVY. POSSIBLY SMALL Ʊ

LT GRY LS MDST W/ SOME THIN ORNG-BRWN DOLSTS 1-2 MM INTERLAMS. MOST OF CYCLE LIKE 426.9 - 429.7

ORNG-GRY DOL'C LS TRANSITION ZONE
ORNG DOLSTS W/ INTERLAMS ≤ 2-3 MM OF LT GRN LS. A FEW ⊕. ⌐ ARE THN FLAKES OF DOLSTS.

LT GRY LS & LT ORNG-YELLOW-GRY DOL'C LS. BASAL ~30-40 CM Ʊ-T & TRANSITORY ⊕R, W/ ORNG-BRWN DOLSTS IN Ʊ'S & INTERLAMS. GRAD'LY ↑ TO ≡A & ⊕ IN LT GRY LS. ⊕ ≤ 1½ MM & CAN BE QUITE DENSE. UPPR 10-15 CM GRAD'L W/ SHCR DOLSTS INTO NEXT UNIT

A SORT OF GRAD'L UPPR & LWR CNTC FROM LS ↑ DOLSTS ↑ LS. ① & LWR ③: ~60-75% DOLSTS. ② ~90-95% DOLSTS. MOD. AMT VF SAND MATERIAL IN BOTH W/ PROB'LY SOME SIL. GRNS IN DOLSTS. ③ IS TOO SILTY, NOT Ʊ'D ENOUGH TO BE ⊕R. ① ↑ SHCR IN DOLSTS, ③ ↑ DECR IN DOLSTS, SIL IN




WT, BUT FEW OS. DOLSTS ≡ & U. LS H, ?, ?, U. IN TOP ≈2m, HAVE SEVERAL GRADED BEDS, ↑FN, MOSTLY DOLSTS, THAT HAVE 1-2 mm LONG BLEBS OF LS. SEE SPL 90-147.

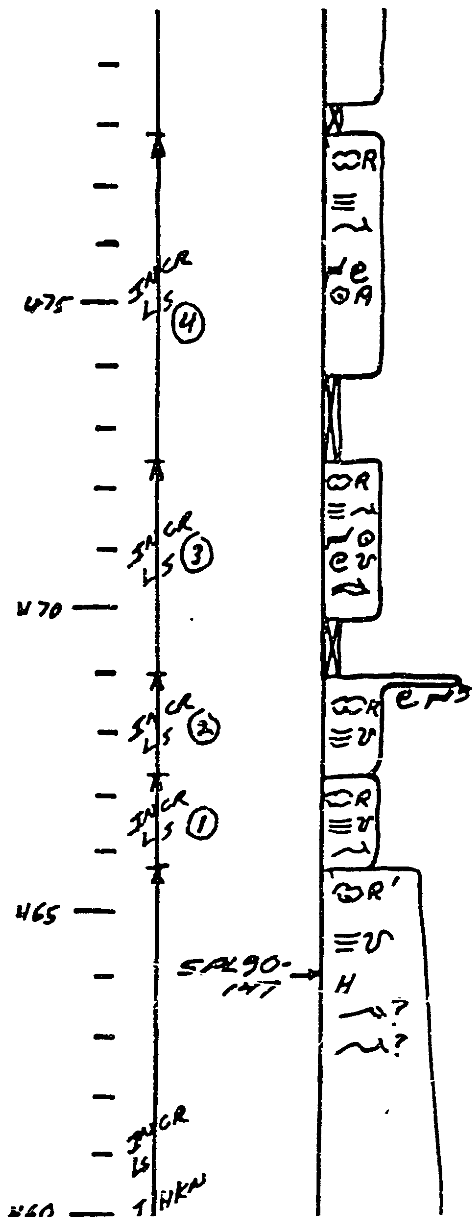
NOTE: CAN'T SEE SUBDIV'SNS ALONG SCTN OR LOOKING AT ONE RIDGE NORTH.

GREENISH-BROWN (D VAR = DK BRWN) VF SS ↑ SLTY MDST. MOSTLY QTZ. MAY HAVE SOME DOLSTS BEDS. OCCAS'L LS-CMTD SS BEDS < 1 cm THK, ≡. BDDG DECR FROM ~ 1cm ↑ mm's. MDST MORE U'D THAN SS & STS.

LS PK/GRST, ~60-70%. DOLSTS & DOLAREN (VF) W/ QTZ, ~30-40%. ALSO HAVE LS-CMTD VF QTZ SS, ≡. CF W/ 440-44 & 2m. & SS MORE LS RICH, CRSR IN DOL & SSL. & LS GRNS. BD-THKNSS INCR, ≤ 10cm, MOST 2-5cm FOR LS, ≤ 2cm FOR DOLSTS & $CO_3$-CMTD SSL. SLT & VF SS. LS GRY-GREEN. DOLSTS/SS ORNG-BRWN (D. VARN. = DK BRWN). LS-CMTD VF SS & STS = LT GREEN

DOMINANTLY AN ORNG-BRWN (D. VARN = DK BRWN) DOLSTS W/ SLT → VF QTZ GRNS, ≡, U. OCCAS'L ?, @, A' LS PKST EVENT BEDS ≤ 8cm THK, GRY-GREEN. DOLSTS BDDG ≤ 2 cm

6 SIMILAR UNITS. GRY LS GRST & ARENITES (≡ ? ?) W/ ORNG-BRWN DOLSTS, W/ QTZ GRNS (≡ ? ? ? ?). ? OF DOLSTS MOSTLY, ⊙ ≤ 3/4 mm LS GEN'LLY W/ ≤ 10-20% DOLSTS IN U-FILL, INTERLAMS (& DON'T COUNT DOL'ED ⊙). DOLSTS W/ [illegible]




COVER

⊂⊃R LIKE 467 m. 2 LS PK/GRST EVENT BEDS, 5 ± 2 cm THK, W/ ⁄, e, ⊙, A. ≡, ~ MOSTLY IN LS, ⇒ O? GR/PKST ORIGINALLY. A COUPLE ≤ 2 cm LS-ARENITES AT BASE (VF). BASAL ~50-70% DOLSTS IN LWR 20 cm OF EXP. UNIT ↑ 20-30% DOLSTS THRU-OUT MOST OF UNIT. 1-7 cm LS BDDG. ≤ 1 cm DOLSTS BDDG W/ MOST < ½ cm. SOME VERT Ʊ IN LS BEDS, W/ DOLSTS FILL. Ʊ CUT THROUGH UPPER SURFACE OF LS BED BUT NOT LWR SURF.

COVER

⊂⊃R LIKE 467 m. 4 LS PKST BEDS 1-5 cm THK W/ ⁄ ⊙e LIKE 468.5 m. SCATTERED THRUOUT UNIT. LS BDDG 1-5 cm. DOLSTS ≤ 5 mm. DOLSTS ≈ 40% IN BASAL 30 cm OF EXPOSED UNIT, ↑ ~10-15% IN TOP 30 cm IN INTERLAMS & Ʊ-FILL

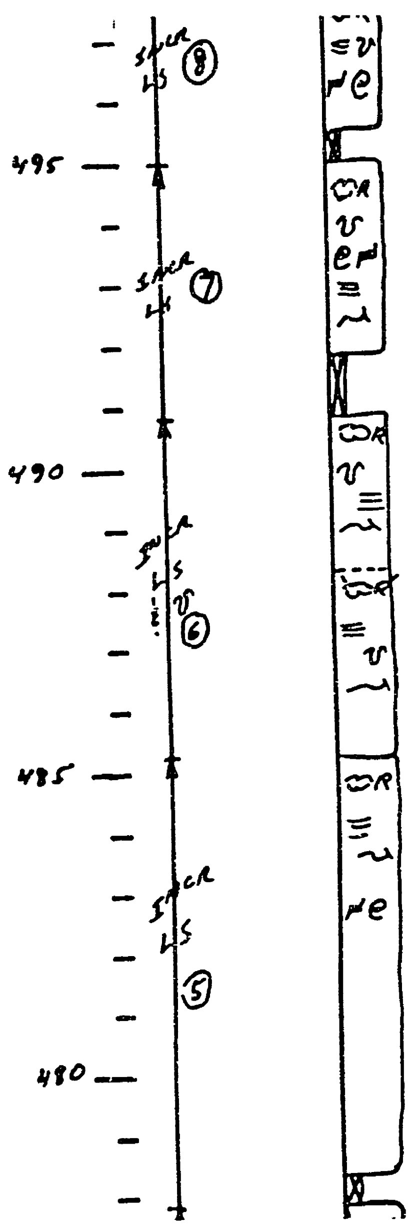
COVER

⊂⊃R LIKE 467 m. % DOL ≈ SAME ALSO. ONLY DIFF. IS 10 cm-THK ⁄ e PKST AT TOP. ⁄ RNDD PLATES ~ ½ x 3-4 cm.

GRY LS MOST (OR O? GR/PKST) & ORNG DOLSTS. SED STRUC SEEN IN BOTH LITH. ~50% DOLSTS AT BTM ↑ ~20-25% DOLSTS IN TOP 30 cm. LS BDDG 1-3 cm. DOL BDDG 2-5 mm. DOLSTS ALSO Ʊ-FILL. BTM 20 cm SOMEWHAT RECESSIVE. NO (?) TEXTURE OR MORPHOLOGY.

2 LITHS: GRY LS MOST & ORNG DOLSTS. A GRAD'L CHANGE ↑ FROM 80-90% DOLSTS ↑ ~25-30% DOLSTS (70-75% LS). BDDG THKNS FROM 2-3 mm ↑ 2-3 cm W/ A FEW 5-15 cm BEDS OF EITHER LITH. LIKE ⊂⊃R, BUT FEW Ʊ'S. DOLSTS ≡ & Ʊ. LS H, ~?, ~?, Ʊ. IN TOP ≈2 m, HAVE SEVERAL GRADED BEDS, ↑FN, MOSTLY DOLSTS, THAT HAVE 1-2 mm LONG FLECKS OF LS. SEE SPL 90-147.

NOTE: [illegible]




ΘR LIKE 467m. ≈ 30-35% DOLSTS ↑ 20-25% DOLSTS. 1 ⊏ LS PKST EVENT BED, 5-8 CM THK.

COVER

ΘR LIKE 467 m. DOLSTS ~45% BTM 40 cm EXPOSED, ↑ ~10-15% IN TOP 40 cm. 2 LS PKST @ EVENT BEDS, 1-2 cm THK. LS BDDG ~1-3 cm. DOLSTS ≤ 1 cm, MOST < ½ cm

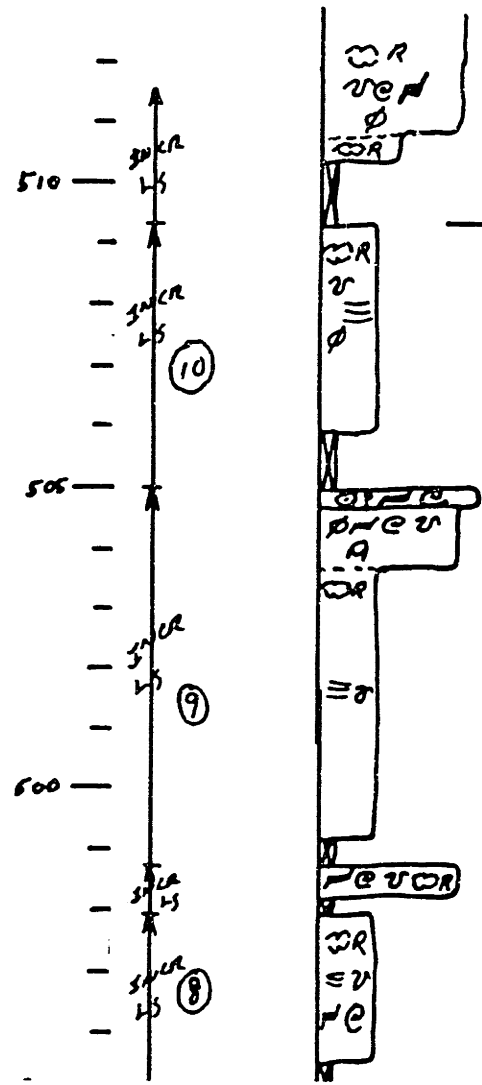
COVER

ΘR LIKE 467m, EXCEPT LWR ~3m W/MUCH LESS V, SO ONLY "ΘR-LIKE". SIMILAR TO ~462→465.7m. DOLSTS ~50% IN LWR ½ ↑ ~10% IN INTERLAMS & V-FILL IN TOP 50 cm.

ΘR LIKE 467m. DOLSTS ~ ≥50% BASAL 10-20 cm EXPOSED, ↑ ~15-20% AT TOP. ONE LS PKST EVENTBED W/ ⊏, @, ≈ 10 cm THK. BDDG: LS 1-5 cm, DOLSTS ≤ 1 cm, MOSTLY < ½ cm.

COVER

SECTION 90-4, REDWING MINE, NORTHERN RESTING SPRING RANGE, CALIF.




5-10CM BDDG OF PKST & DK OL-GREEN TO KHAKI-BROWN DOLSTS, ≤1CM. Ø START TO COME IN W/IN 5M OF CONTACT. BON. K. SEEMS TO HAVE A LOT OF FAULT BRECCIA.

R AT 510.5M RATHER MORE CARRARA-STYLE THAN BON. K. STYLE

BONANZA KING (PROBABLY DEPOSITIONAL CONTACT)

R LIKE 467m. DOLSTS 30% ↑ ~10%. LS BDDG 1-3CM. DOLST ≤1CM. RARE <1CM Ø FLOATING IN LS. NO PKST EVENT BEDS.

COVER

LS PK/GRST. CLEANER THAN BED BENEATH

LS PKST W/ DOLSTS IN V & DOL'C REPLACEMENT OF Ø, & DISCONT. BLEBS. Ø ≤ 2CM.

R LIKE 467M, EXCEPT DOLSTS NOW KHAKI-BROWN IN UPPR ½. DOLSTS ORNG-BRWN IN LWR ½. DOLSTS ~35% AT BASE, ↑ 5-10%, MOSTLY V-FILL & Ø-REPLACEMENT.

CNTC BETWEEN R & PKST COVERED BY TALUS & DIRT.

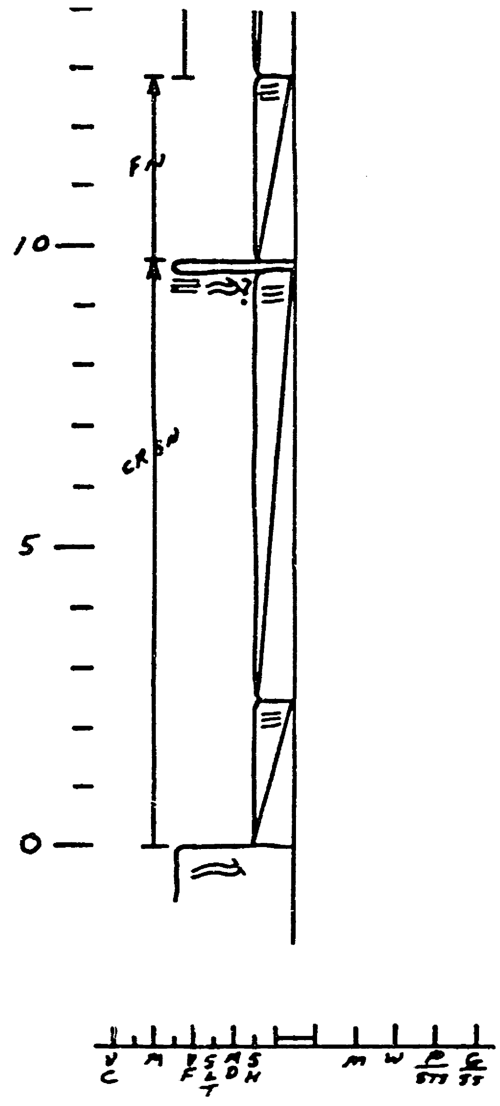
COVER

GRY LS PKST, MOSTLY. ~4 BEDS 5→10CM THK. DOLSTS INTERLAMS ≤1CM & ~10-20 CM OF R AT BTM. SOMEWHAT RECESSIVE WX.

COVER

R LIKE 467M. ≈30-35% DOLSTS ↑ 20-25% DOLSTS. 1 FC LS PKST EVENT BED, 5-8 CM THK.

COVER




GRN-GRAY, MIC., SLTY SH. SOMEWHAT MORE SLTY IN LWR ½. GRAD'L CHANGE (IN COVER) OVER ~½-1M FROM GRN-GRAY, UP TO YELLOWISH GREEN IN OVERLYING UNIT.

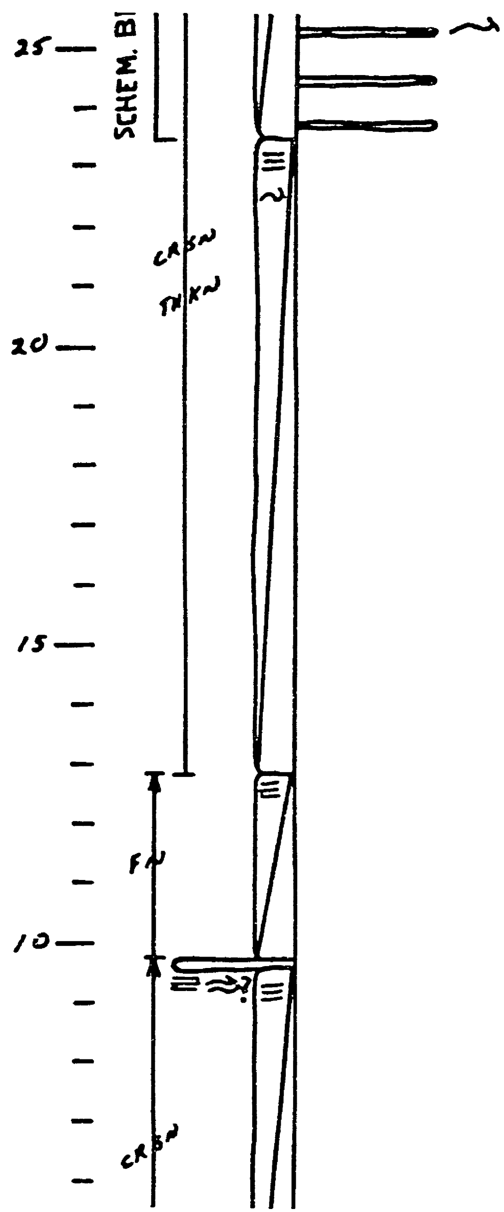
F-VF, MIC., QTZ SS. VARIABLE THKNSS, 10-15 CM. PROBLY A LENTIC EVENT BED. PROBLY '≡' ARE ACTUALLY BROAD, LOW-RELIEF ≈.

GREEN SH, LIKE 2.0 m w/ INCR ↑ SLTY SH. 1-2 MM LAMS ALMOST CHLORITIC IN LWR PART

RED SH w/ PAPER-THIN LAMS, ≤ MM THK. SLIGHTLY MIC.

F-VF QTZITE. LAST BED IN INTERVAL OF 25-30 m OF ↑-CRSN PKGS OF SH TO SS w/ ≈. NO SKOLITHOS Ʊ NOTED IN THIS 25-30 m INTERVAL OF ZABRISKIE. UNWXD COLOR IS WH TO RED. DESERT VARNISH WX IS DARK BRWN TO DK REDDISH-BROWN

SECTION 90-5
EAGLE MTN



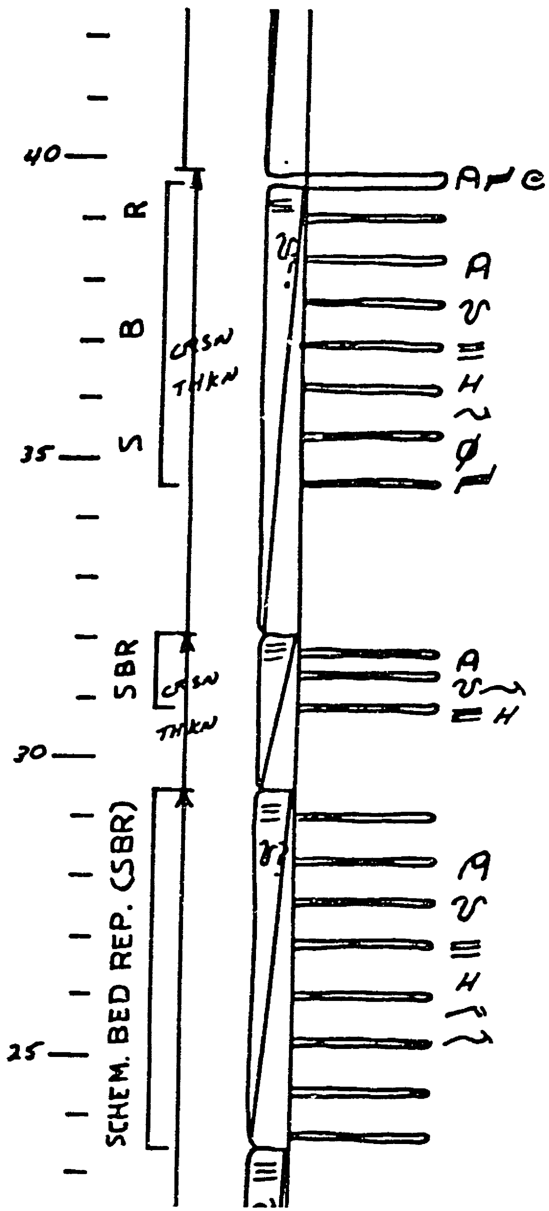

THE TOP OF THE INTERVAL.

GRAD'L ↑ COLOR-CHANGE FROM YELLOWISH GREEN UPWARDS TO PINKISH TAN. SLIGHTLY SLTY SH W/ OCCAS'L LENTR BEDS OF VF & F, ~ SS, ≤ 1/CM THK. SOME W/ LS-CMT IN UPPR PART.

GRN-GRY, MIC., SLTY SH. SOMEWHAT MORE SLTY IN LWR ½. GRAD'L CHANGE (IN COVER) OVER ~½-1M FROM GRN-GRY, UP TO YELLOWISH GREEN IN OVERLYING UNIT.

F-VF, MIC., QTZ SS. VARIABLE THKNSS, 10-15 CM. PROBLY A LENTR EVENT BED. PROBLY '≡' ARE ACTUALLY BROAD, LOW-RELIEF ≈.

GREEN SH, LIKE 2.0 M W/ INCR ↑ SLTY SH. 1-2 MM LAM'D ALMOST CHLORITIC IN LWR PART




KHAKI-BRWN LS, A-PKST w/ FEW STS-CLASTS (≤ 1x4cm). POSSIBLE OTHER UNID'D G.

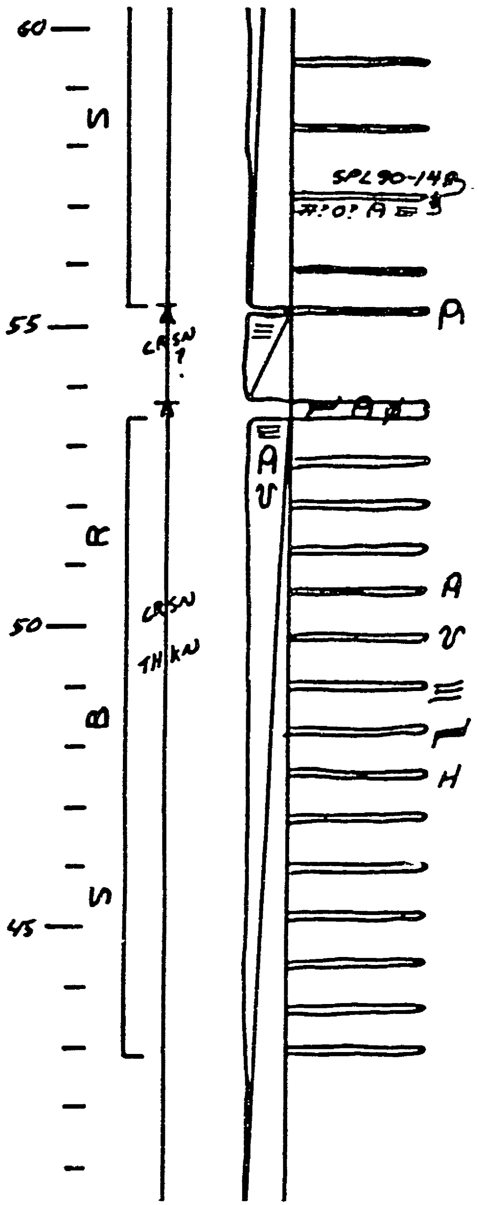
AT 37.1m, HAVE A 10 cm THK A-CO3 PKST w/ Ø (≤ 1½ cm) & SLT (≤ 1x5cm), PLATY. FLAT BASE TO BED, IRREG TOP!

NOTE: THESE THIN CO3 (LSMY DOL OR DOL'C LS) BEDS OFTEN HAVE SILICIFIED UPPER & LWR SURFACES w/ A-SPINES WXD-OUT IN RELIEF

SHORT INTERVAL LIKE 12.8 → 29.5m. LWR 1.6m w/ NO CO3 BEDS, ONLY YEL-GRN SLTY, MIC. SH. UPPER 1.0m w/ 6 2cm LENTIC EVENT BEDS OF A-SAND & CO3-CMTD QTZ SS.

BACKGRND SED. IS YELLOWISH-GRN, MIC., SSLTY (SLIGHTLY) SH. FREQ. LENTIC, ≤ 2cm (MOST ≤ ½cm), CO3 & CO3-CMTD, EVENT BEDS OF A FRAGS & VF-M QTZ GRAINS, OFTEN MXT. A-BEDS ARE H &/OR RIPPLED. SS BEDS ARE ≡, ~, ~. BOTH ARE V. ALL ARE KHAKI-BROWN.

2 THKR CO3 A BEDS, 5 & 10cm THK, ARE AT 27.4m & 28.2m. THERE ARE 5 BEDS, 5-10cm THK, A-CO3 AT THE TOP OF THE INTERVAL.



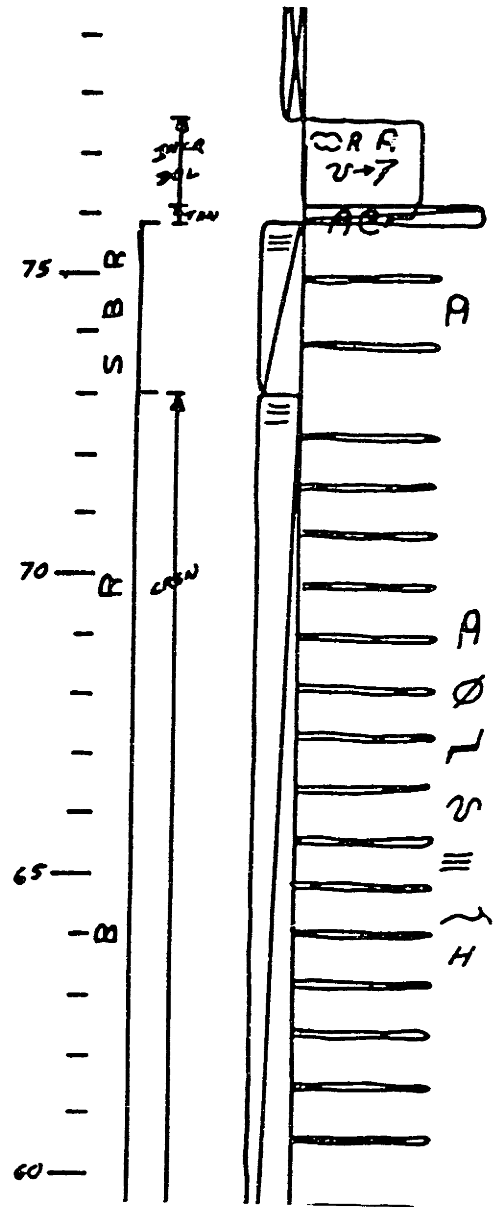

AT ~57m, POSSIBLE MUDCRACKED OR SYNERESIS-CRACKED BEDS OF $CO_3$ w/ A. OTHER THAN #?, BEDS SIMILAR TO OTHERS IN INTERVAL. ESTHER A A WKST OR A A O PKST. SPL w/ #?

$CO_3$ PKST. ~10cm THK, LIKE OTHERS BELOW

MOSTLY COVERED SH. LIKE BELOW?

KHAKI-GREEN, 30cm, LS PKST w/ REDDISH DOLSTS. GRDD ↑ IN PKST. Ø < 1cm, SOME ELONGATE. MAY BE 2 BEDS: Ø SCOURED INTO ≡.

INTERBDD $CO_3$ & SIL SH. SH COLOR FROM YELLOWISH GREEN ↑ PINKISH-TAN, & MUCH MORE SLTY. A NOW SEEN IN BACKGRND SH. LWR 2.8m ESSENTIALLY W/O CRSR INTERBEDS. LENT'R INTERBEDS STILL ≤ 2cm MOSTLY, w/ SOME 2-6 cm PKST BEDS IN UPPER PART. UPPER PART ALSO w/ MORE $CO_3$-CMTD SS BEDS. THKR PKST BEDS w/ STS. ≡ ONLY. COULD NOT ID RIPPLES




⌐ < ½ x 2 cm & SOMEWHAT IMBRICATED.

COVER

GRY LS VARIES FROM MDST TO WKST TO PKST. MOSTLY WKS & PKST IN THIN (≤ ½-1 cm), ∿→⌐ BEDS. DOLSTS, ORNG, < 1 cm, MOSTLY VERY IRREG DUE TO ∿. 5% ↑ 15-20%. LS FROM ½ → 5 cm BEDS.

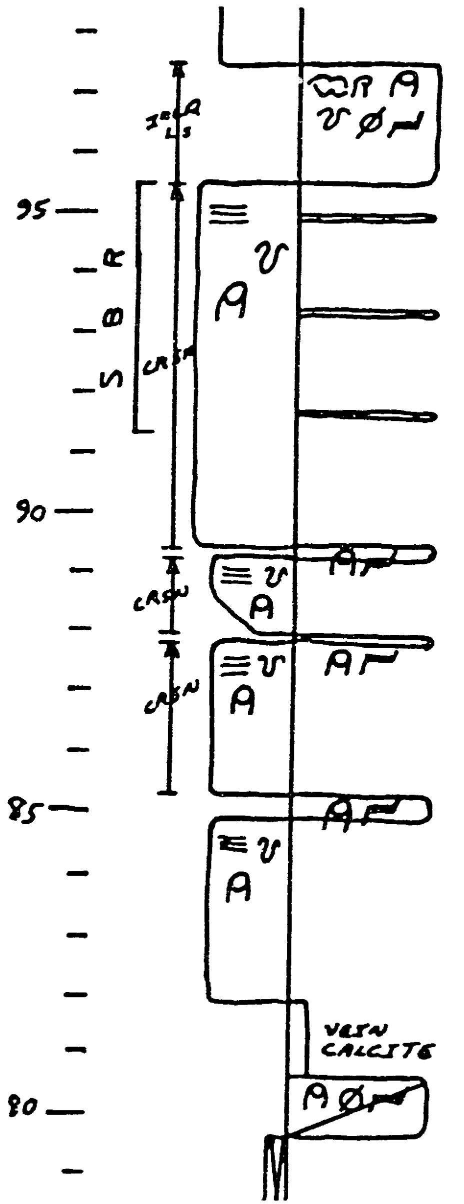
SEVERAL GREEN, LS GRST BEDS 2-10 cm THK, POORLY EXPOSED ⌐ ≤ ½ x 2 cm, RNDD & PLATY. POSSIBLY SOME INVERSE GRDD BEDS, ↑ CALC. BEDS THIN UP

MXT LITH LIKE BELOW. ONLY OCCAS'L $CO_3$ INTERBEDS 1-3 cm THK. SH SS BACKGRND SED LIKE BELOW. 1 PKST BED, 5 cm THK, W/ ⌐, A AT ~ 75.7 m. ⌐, ≤ 1 x 6 cm, MOST ~ ½ x 2 cm, IMBRICATED.

SIMILAR TO BEDS BELOW. BACKGRND SED. OF YELLOWISH-GRN, SLIGHTLY SLTY, MIC. SN W/ ≤ 2 cm KHAKI-GRN OR LT.-BRWN $CO_3$ & $CO_3$-CMTD QTZ SS INTERBEDS. LENTIC, & EVEN BEDS.
SPARSE INTERBEDS 55.3 → ~61 m, THEN INCR NUMBERS OF BEDS ABOVE.

AT ~70 m, A 15-20 cm Ø ⌐ A $CO_3$ PKST. Ø ≤ 3 cm. ⌐ OF $CO_3$ ARE LG & PLATY (≤ 1 x 5 cm, MOST ~ ½ x 3 cm) & SLIGHTLY IMBRICATED. MOST ⌐ IN LWR 10-15 cm & MOST Ø IN UPPR 5 cm, MAY BE 2 BEDS. ONE LARGE Ø LOOKS MORE LIKE 6 cm WIDE, 4 cm HI A IN VERT. POSIT.

AT ~67 m HAVE 6 & 12 cm THK, A ⌐ H $CO_3$ PKST. LIMY DOL OR DOL'C LS. ⌐ OF STS, ≤ 1 x 3 cm.




GRY LS IS A A-PKST W/ SOME WKST. Ø (≤ 2cm) IN UPPR ~40-50cm. LS BDDG ~2-10cm THK. ORNG DOLSTS IN V & V-7, ≤ 1cm THK, INTERLAMS. ~50% DOLSTS & ~10% DOLSTS.

A MUDDY, FINE STS LIKE 83m. A SLIGHT CRSN↑ IN THAT AS GO UPSCTN, PICK UP ≤ 2cm A PKST BEDS OCCASLY

20cm OR-KH-GRN LS PKST W/ FEW Ø (< ½ cm), OTHERWISE SIM 85m.

YELLOWISH-GRN, MUDDY STS LIKE 83m, BUT STARTS AS A CLEAN SN AT BASE. NO SS INTERBEDS.

10-15 cm OL-KHAKI-GRN LS PKST LIKE 85m

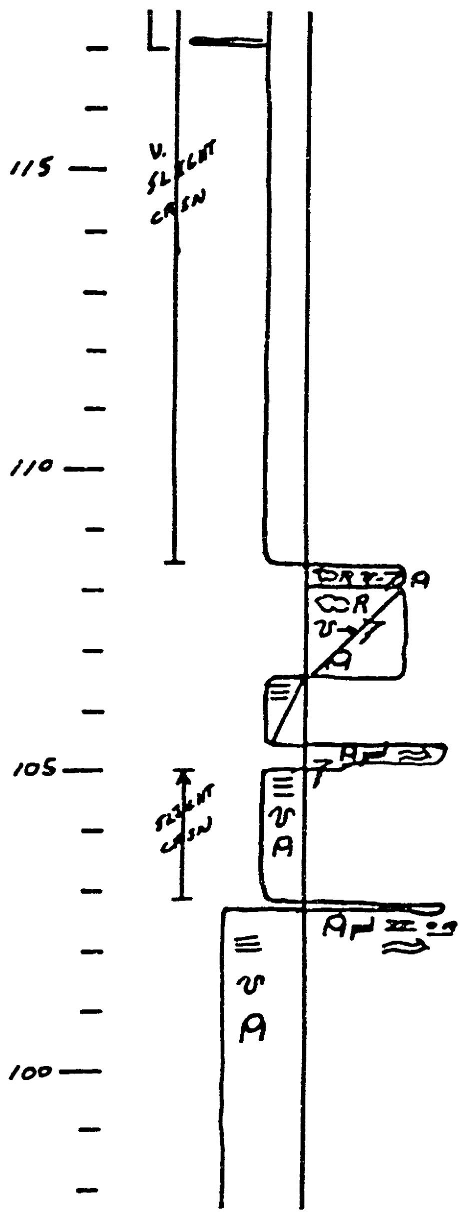
YELLOWISH-GRN, MUDDY, VF STS LIKE 83m, BUT A LITTLE FINER-GRAINED. IN ADDITION TO A-STRINGERS, ALSO GET A COUPLE OF 2-3 cm, ≡, VF SS INTERBEDS

OL-KHAKI GREEN (W/ YELLOW STAIN) LS PKST. SEVERAL BEDS ~5 & 15cm THK. SOMEWHAT ↑THAN. , MORE OF WKST, ≤ 1X10 cm, MOST < ½ x 2cm.

YELLOWISH-GREEN-TAN, MUDDY, VF STS W/ OCCAS'L ≤ 5mm BEDS OF A HASH. BDDG IN STS ≤ 5mm ALSO.

STRONGLY SLICKENSIDED VEIN CALCITE SUBPARALLEL TO BDDG

MOSTLY RECESSIVE WX, BUT Ø WX OUT LIKE PEBBLES, GIVING APPEARANCE OF A PEBBLE CONGL. TO SLOPE. MOST WX-OUT Ø GRY. MORE INDURATED PARTS ARE GRY & OL-GREEN. LS PKST, BDD ~10cm THK. SOME RED & YELLOW STAINING, STREAKY & DISSEMINATED. Ø < 3cm < ½ x 2cm & SOMEWHAT IMBRICATED.




SAME AS IMMED. BELOW, BUT NOT AS MARLY, NOT RECESSIVE. ~10% ARE DOLSTS

GRY, MARLY, REC. WX ⌣R. HARD TO EST % DOLSTS. LS = WKST, BDD 1-2 CM. DOLSTS INTERLAMS < ½ CM. SOME DOLSTS LIKELY TO BE SIL. STS.

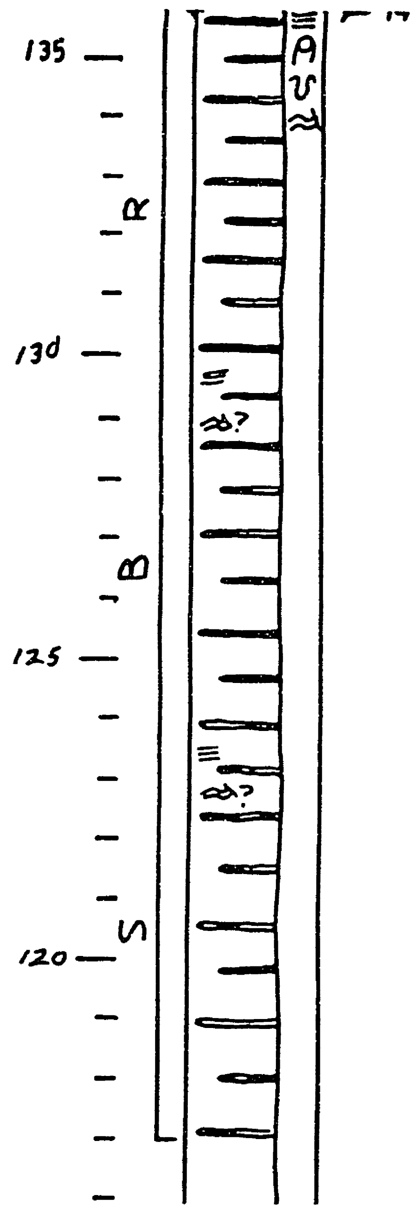
LT YELLOWISH-GREEN SLTY SH

UPR 30 cm OL-GRN, LS PKST, W/ TOP POSSIBLY MOLDED BY ⇝. FEW ⊣; THOSE SMALL, < ½ × 2 cm. LWR 20 cm MARLY & 7.

YELLOWISH-GREENSH ↑ SLTY SH. ASIDE FROM FINER GRAIN-SIZE, LIKE 83 m. TOP 10 cm HAS 2 LS A PKST BEDS, EA. 3 cm THK.

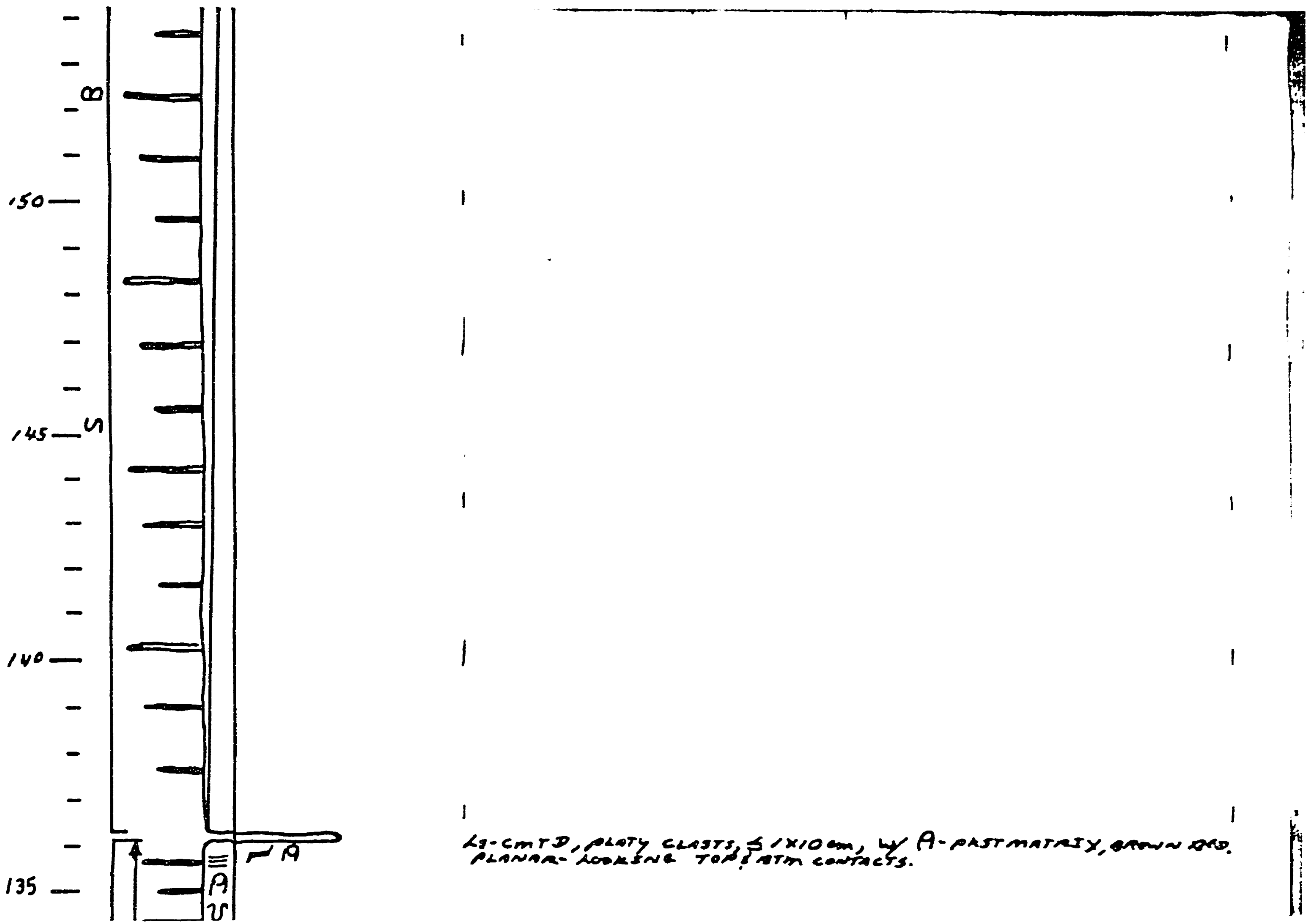
OL-GRN, LS, A PKST, 6-12 cm THK. POSSIBLY MOLDED INTO 2-D DUNES OR ⇝. CAN ONLY SEE X-SCTN OF BED, NOT INTERNAL LAMI OR 3RD DIMENSION. ⊣ < 1 × 3 cm IN BTM ⅓-¼ OF BED. RATHER LIKE 85 m.

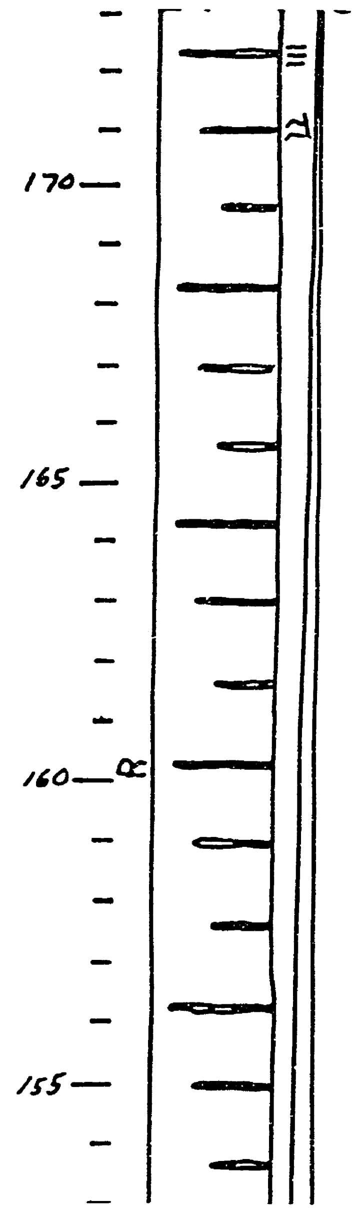
YELLOW-GREEN, MUDDY, FINE STS LIKE 83 m. FEW A-HASH BEDS EXCEPT TOP 1-2 m.




PLANAR-LOOKING TOP & BTM CONTACTS.

LT GREEN → GREENISH GRY SH & SLTY SH. LOTS OF A-HEADS & A FEW RARE WHOLE-BODY A. SLIGHT CRSN UP W/ CHANGE FROM SH & SLTY SH. ALSO GET OCCAS'L F & VF SS INTERBEDS OF ≡ & ≈? IN UPPER 3/8 OF INTERVAL. BED THKNESS 1→10 cm.

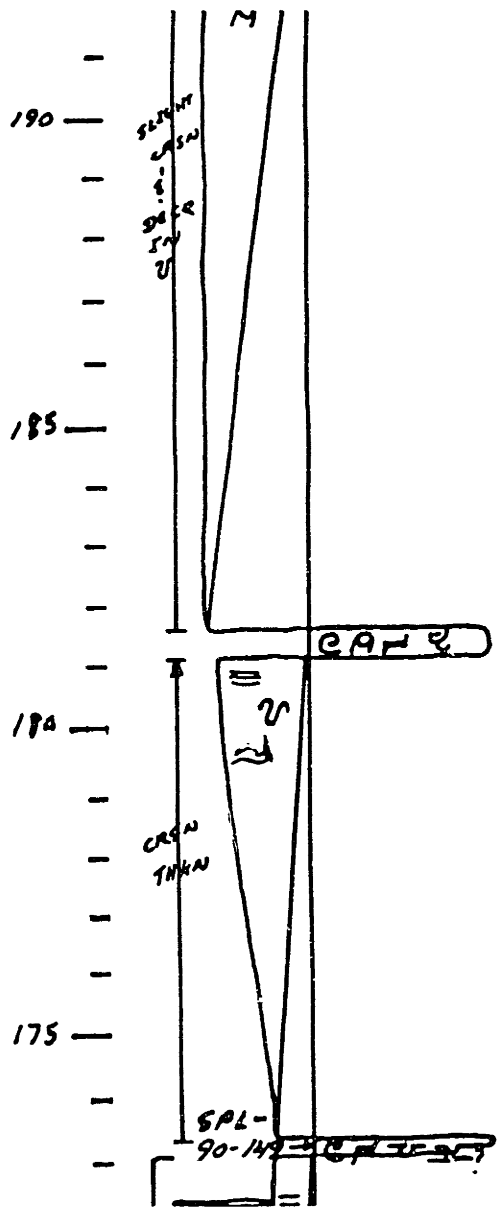

B
150
S
145
140
135
A
A
Ls-CMTD, PLATY CLASTS, ≤ 1X10 cm, W/ A-PAST MATRIX, BROWN ORD.
PLANAR-LOOKING TOP & BTM CONTACTS.




CRSE, POSSIBLY ECHINOID FRAGS, LS GRST. GRST LOADED INTO PKST, W/ POSSIBLE FLAME STRUC ([symbol]). 3 BEDS TOTAL: (BTM TO TOP) 8-10cm PKST; 8-10cm CRS-SAND-SIZED GRST; ~5cm, MED-SAND-SIZED GRST. [symbol] SN PKST ARE LG, ≅ ~1×8cm, PLATY, HORIZ, & OF VF SS/SLTS

MOSTLY GRAY SH SIMILAR TO 130m BUT NO [symbol]. M-VF SS INTERBEDS, 15 cm → 1cm, [symbol], [symbol] BUT FEWER THAN 130m

BTM 2-3m ARE SLTY, GREY-GREEN SH.

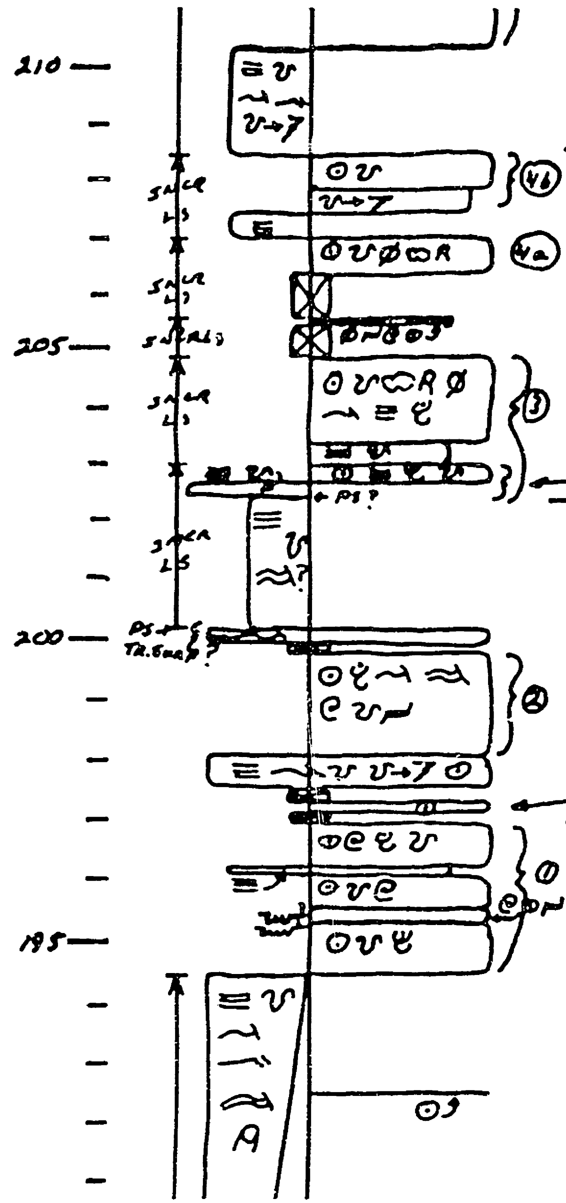



...MUDDY VF SS; CLEANER VF SS. [illegible]
= & V. RIPPLES UNCOMMON. AT LEAST 1 LS-CMTD, VF SS W/
& A SPINES

GRAY LS GRST LIKE 173.25 m. GRNS ≤ CRS-SAND-SIZE. SOME BROWN SS/STS [illegible] < 1X3CM. 2 OR 3 SETS OF ₰, ≤ 10 cm HT. IN OPPOSING DIRECTIONS.

GRAY & GRAY-BROWN: [illegible] ~ 1m VF SS/SH, CHANGES UP TO MUDDY, MUDDY STS, & MUDDY VF SS. A FEW SS BEDS W/ DOL CEMENT. BEDS ≤ 10 cm, MOSTLY LESS.

BROWN, LS, [illegible] PKST W/A MUDDY & SANDY MATRIX OVERLAIN BY A GRAY, CRSE, POSSIBLY ECHINOID FRAGS, LS GRST. GRST LOADED INTO PKST, W/ POSSIBLE FLAME STRUC. 3 BEDS TOTAL (ATM TOTAL 8-10 cm



LT GREEN-TAN, MUDDY STS. ∪ DECR ↑. MOST BEDS < 5 MM. RECESSIVE WX

GRN-GRY, LS, ⊙ (½-¾ mm) GRST IN LWR ⅓. TOP ⅔ IS A RST DARKER LS AREN, VF. BOTH LITHS ∪.

TAN & GRY MIX OF LS, DOL & SIL SS & STS. PROBLY RIPPLED. REC. WX

GRY-TAN SLTY SH. MM-LAM'D

BASICALLY ⊂R W/ LS A GRY, ⊙(½-⅜ mm) GRST W/ SCATTERED Ø (≤ ½ cm).

ORNG DOLSTS < 1 CM THK & IN ∪

COVER. PROBLY LIKE 196.2 M

GRN-GRY LT RST W/ STSP < ⅝ V 4 cm & Ø < 1 cm

COVER. PROBLY LIKE 196.2 M

⊂R. GRY-GRN, LS, ⊙ GRST & ORNG DOLSTS (▦, ~). IN LWR ½ m, HAVE 3 DOLSTS BEDS, 3-5 cm THK, W/ ~. OTHERWISE IN ∪. ~10 cm HIGH, & IN ⊙ GRST. Ø, < 1 cm, IN 20 CM THK BED NEAR TOP.

GRY LS & ORNG DOLSTS, ≤ 1 CM BEDS. ↑ INCR LS & ↑ THAN. FEW ∪. REC WX

GRN-GRY, LS, ⊙(¾-1 mm) GRST IN UPPR PART W/ F-VF QTZ SS CMTD W/ LS IN LWR PART. TREAT AS 1 UNIT. ORNG DOLSTS INTERBEDS ≤ 1 CM THK IN BOTH. LESS DOLSTS IN ⊙. INCR LS ↑.

BACKGROUND SED OF GREEN, SLTY SH W/ ≤ 2 CM INTERBEDS OF STS & VF SS. TOWARDS TOP, A FEW SS BEDS ARE $CO_3$-CMTD. NOTE: PROBLY A FLODG SURF (FS) AT 199.8 M W/ 40 CM BED ABOVE A REWORKED TRANSGRESSIVE LAG OF SORTS. ALTERNATELY A FS AT 202.4 M. SHARP CNTC SEEMS TO BE AT TOP OF GRY ⊙ GRST.

MIX OF ⊙ GRST, ⊂ PKST & ~ VF SS. MOSTLY PKST, NO DSTS, ≤ 1×2 cm

COVER

GRN-GRY, LS, ⊙(½-1 mm) GRST. A DISCONT, 0→20 CM ORNG DOLSTS BAND W/ ⊂ OF SAME, & ⊂ ⊙ PKST BEDS IN MIDDLE. ⊂ OF ⊙ GRST IN BED BENEATH. ALSO DISCONT, BUT NOT AS MUCH. ~ & ∪ IN GRST.

MIXT VF SS & LS ARENT DOLSTS IN ≤ 2 CM BEDS & ⊙ GRST - REC. WX.

COVER. LIKE 196.2 M?

LS, ⊙ (≤ 1 mm) GRST

COVER. LIKE 196.2 M?

GRN-GRY LS, ⊙ (½-¾ mm) GRST

ORNG DOLSTS, LT GRN LS-STS & GRY, SIL STS. ≡. ≤ 1 cm BEDG. VERY REC. WX

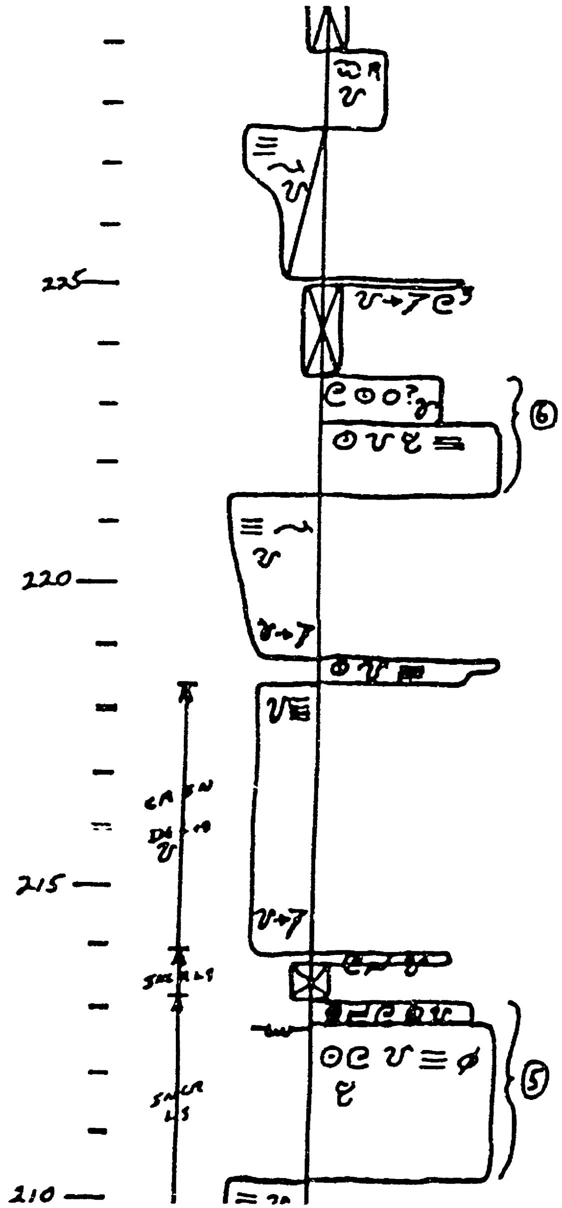
LS, ⊙ (¾ mm) GRST W/ SOME ⊂. ORNG DOLSTS INTERLAMS ≤ 1 cm IN BEDS. LWR 5 cm LS GRST W/ ⊂ ⊙ & ⊂ ≤ 1×1 cm. GRADE INTO UPPR BED &/OR SCOURED INTO. ⊂ CNTC ALSO POSSIBLY SCOURED.

UPPR 15 cm LS, ⊙ (~¾ mm) GRST. ⊂ ≤ 2×6 cm OF ¾ mm ⊙ GRST.

GRN-GRY LS, ⊙ (~½ mm) GRST W/ ~. ORNG DOLSTS INTERLAMS ≤ 1 cm

A 2-3 CM THK ⊙ (~½ mm) GRST AT ~193.8 M

LT GRY, MUDDY VF SS ↑ CLEANER VF SS. SLIGHT ↑ DECR IN ∪. MOSTLY ≡ & ∪. RIPPLES UNCOMMON. AT LEAST 1 LS-CMTD VF SS




COVER. PROBABLY SIL, SLTY MDST W/CO3 INTERBEDS.

R W/ GRAY LS MDST (ORIG O & A PK/GRST?). LS BDD ≡ ~1cm W/ 2-3 mm IRREG BRWN DOLSTS INTERLAMS, EXCEPT 1 ≡15cm THK BED AT ~228.2 m. ≈15-20% DOLSTS ON EITHER SIDE OF 15cm-BED, WHICH IS A CLEAN LS.

LT GRNISH-TAN SLTY SH↑ MUDDY & CLEAN STS. MOST. Y COVERED

MIX OF GRN LS WK/PKST W/ ORNG-BRWN DOLSTS. BDDG 1-3cm. (STICKS UP IN SMALL FINS)

COVERED. TAN, V, MUDDY STS.

GRN-GRAY LS WK/PKST W/ INCR↑ OF AMT OF DOLSTS INTERLAMS. BASAL 20-30 cm W/O INTERLAMS & RESISTANT TO WX. TOP 50-60cm RO ≡ WX.
GRN-GRAY LS O (½-¾ mm) GRST. TOP & BASAL 20-30cm, O ¼-1mm. FULL OF ORNG DOLSTS, FEW DISCONT LAMS, ≤ ½ cm THK MOST TOP.

PALE GREENISH-GRAY, SLTY MDST ↑ CRS STS TO LWR VF SS. STS & SS CLEAN

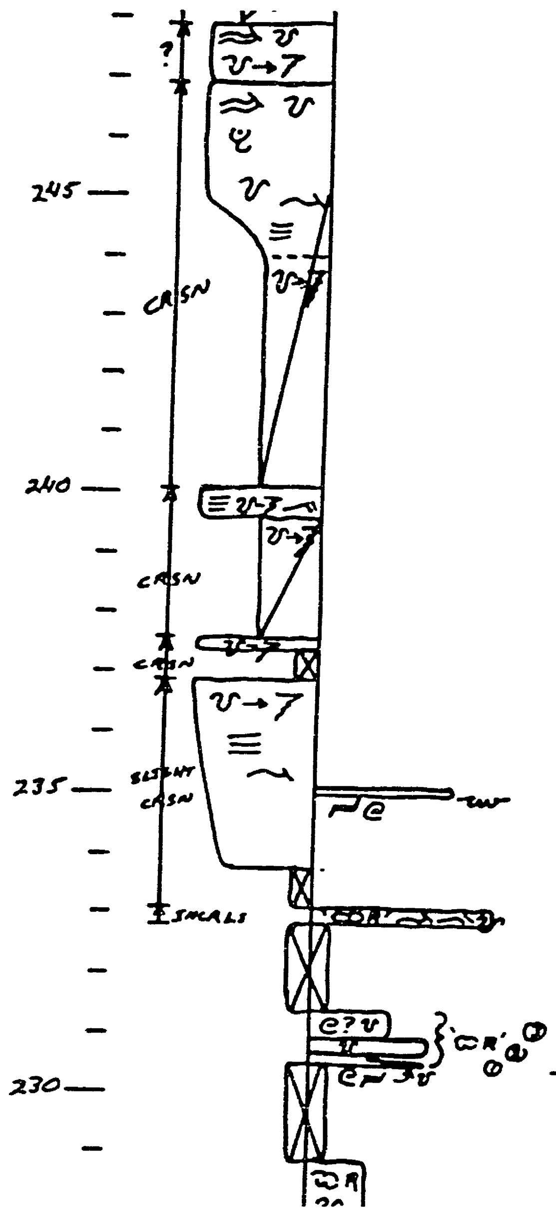
20 cm GRY-GRN LS O (½-¾mm) GRST. 10 cm TRANSITIONAL ZONE. MIX OF VF QTZ SAND W/ LS CMT & STS W/ DOL CMT. 10 cm STS & VF SAND W/ DOL CEMENT

TAN, SLTY MDST. DECR V↑ & SLT CRSN↑ W/ MORE STS, VF SS INTERBEDS, ≡, ≤ 3cm THK IN UPPR ½ THAN IN LWR ½

SANDY (VF,F) LS PKST. BDD ≤5 cm. STSH ≤1X1cm. INTERLAMS OF ORNG-BRWN DOLSTS
COVER. LIKE 196.2 OR 209m?
GRN-GRAY LS PK/GRST, MORE ORNG DOLSTS THAN BELOW. LWR CNTC SCOURED W/ BROAD, LOW RELIEF, ≤ 10cm?

GRN-GRAY, LS O GRST. BASAL 20-30cm, O ⅛-¼ mm. REST OF UNIT, O ¼-1mm. ≤ 1/cm, MOST ≤ ½ cm. SCATTERED BLEBS OF ORNG DOLSTS & IN V. OCCASIONALLY CONCENTRATED IN BEDS 5-20cm THK.

LT GREEN-TAN . MUDDY ...




MORE MUDDY, MORE ʊ, GRY SS. MORE RECESSIVE. SOMEWHAT LIKE 246m.

MIC.
GRY F SS, W/SOME MUD. ⥲. UPPER ~1m W/$CO_3$-CMTD LAMS & W/IN BEDS. ⥲ UP TO 10-15 cm THK. RARE ♆, ~5cm HIGH. MORE BROWN WHERE $CO_3$-CMTD.

GRAD'L CNTC TO F SS OVER ≤ 1m

LT GRN & GRY, MIC., SLTY & SANDY MDST

LT GRY, SOMEWHAT MUDDY, F SS. MICACEOUS. ʊ→7, W/ ≡ & AFEW ~

GREEN, MICACEOUS, SANDY, SILTY MDST.

LT GRN, ≡ W/SOME m, MUDDY SS.
COVER

MIC.
LT GRY → LT GRN MUDDY SS & STS. SLIGHT ↑ INCR IN GRN-SIZE. ↑ INCR IN $CO_3$-CMTD SS BEDS. VARIABLE IN RESIST, ESP. IN LWR 2-2½m. MORE 1-3cm THK, $CO_3$-CMTD BEDS IN TOP ⅓m. AT ~235m, HAVE 2 LS PAST BEDS, ~5-10cm THK, W/ RANDOM ⁓ OF SS & STS, < 1cm. PROBLY SCOURED AT BASE.

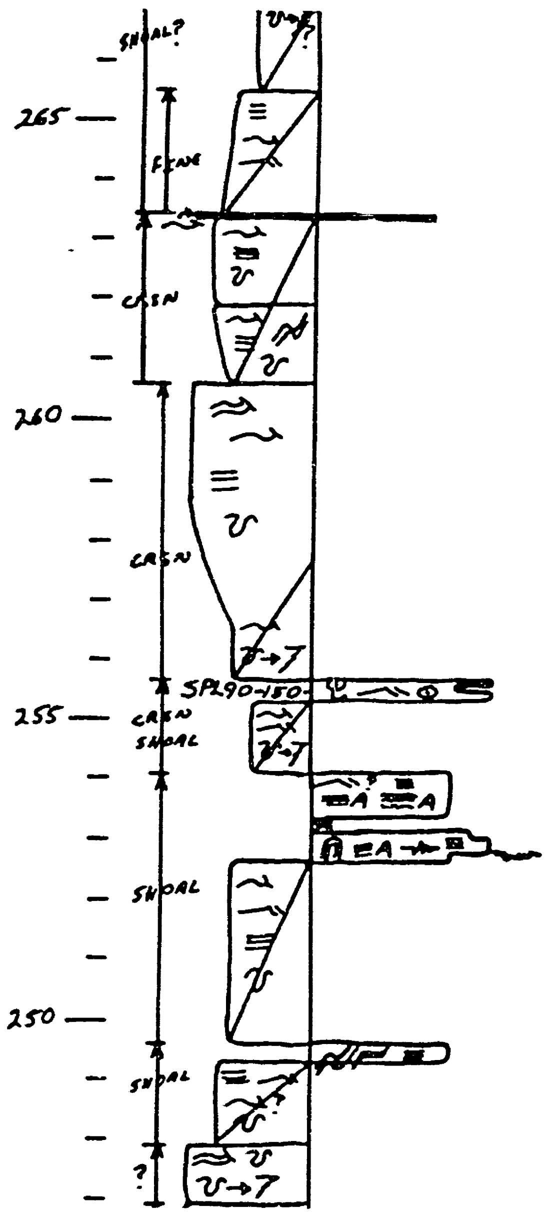
COVER. LIKE 234m?
LT GRN LS AREN W/ORNG DOLSTS, IN ALMOST WAVY-BDD MIX. ⥀R QRTW/FEW ʊ. AREN BDDG ≤ 1cm, DOLSTS BDDG ≤ 6mm. AREN W/ ~30% VF-SLT QTZ GRNS. LS GRAINS ALSO VF-SLT.

COVER. LIKE 230m?

3 $CO_3$-UNITS: ① 5cm @⁓ W/PAST. LS. GREEN. W/ VF & F QTZ GRNS OVERLAIN BY 10cm OF MDST, ALSO GREEN LS. 5-10% ORNG DOLSTS IN DISCONT. ≤ 2mm INTERLAMS & ʊ-FILL. ② 30cm, MOSTLY BROWN DOLSTS W/ BLEBS (REMNANTS) OF ~1cm THK GREEN MDST, LS. ③ 45cm. GREEN, LS, MD/WKST W/ SOME VF, F QTZ GRAINS & POSSIBLE @-FRAGS. ALL SOMEWHAT ⥀R-LIKE. MOD RESIST.

COVER. PROBLY SIL, SLTY MDST W/$CO_3$ INTERBEDS.

⥀R W/ GRY LS MDST (ORIG O & A PK/GRST?). LS BDD ≤ ~1cm W/ 2-3 mm IRREG BRWN DOLSTS INTERLAMS ...




RED-PURPLE MDST

ORNG-BRWN & PINKISH VF SS & STS W/ $CO_3$ CMT. IN UPPR PART, HAVE MM-LAMS. IN LWR PART, HAVE LAMS & BEDS ≤ 1-3 cm. MOST ≤ 1 cm.

5 cm OF F & VF QTZ GRAINS FLOATING IN ORNG DOLSTS MATRIX (W/ FRST TEXTURE)

LT GRN, MIC, MUDDY VF SS - $CO_3$-CMTD

GRN STS ↑ VF SS. MIC. FEW [symbol]. [symbol] ONLY 5 cm THK, PROBLY DE-$H_2O$ VF SS.

GRAY, MIC., SS & STS. FEW [symbol].

GREEN, SLTY, MIC, SANDY MDST W/ VF SS ~ BEDS, ≤ 2 cm THK.

GRN LS, ⊙ (1mm, ABBRAD) GAST IN TOP 5-8 cm & BTM 12-15 cm. MDL IS A BROWN, LSMY DOLSTS W/ [symbol]

GRN, SANDY & SLTY, MIC. MDST W/ A FEW < 5 cm F & VF SS BEDS W/ [symbol] & [symbol], IN UPPR PART

ORNG DOLSTS. UPPR ~30 cm WX INTO PLATES. MORE ORNG-BROWN, [symbol] & [symbol]. PROBLY MECH-DEPOSITED VS ALGAL IN LWR 50 cm. COVER. DOLSTS?

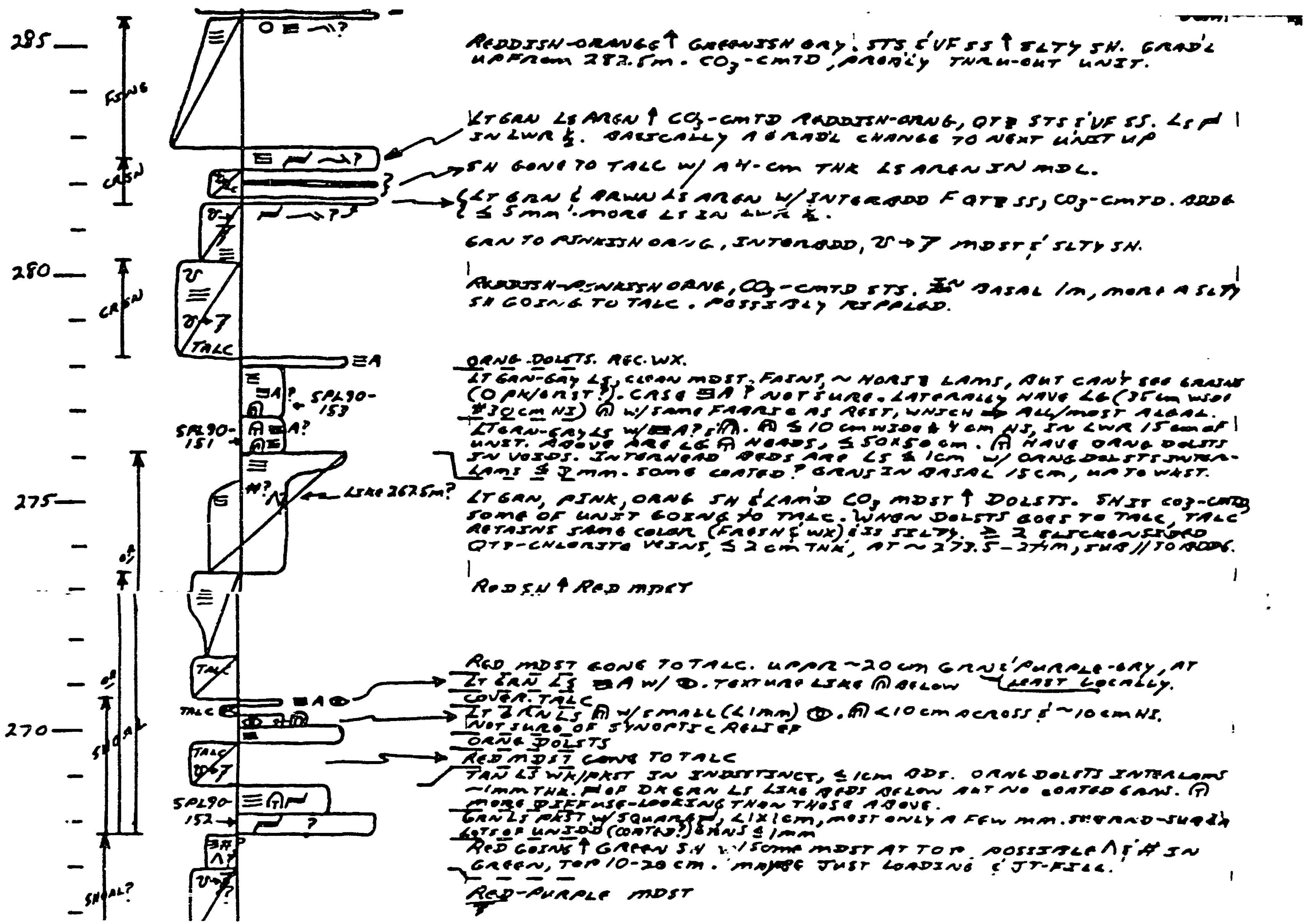
ORNG DOLSTS IN TOP & BTM, ~10 cm THK. MDL 30 cm OF GRN-GRY LS AREN. [symbol] A IN TOP & BTM DOLSTS. [symbol] IN TOP DOLSTS W/ SOME LS LAMS (LT GREEN) IN MDL AREN, CAN'T SEE GRN-TYPE. BASICALLY [symbol], MISSBLY CASE [symbol] A. [symbol] BROAD W/ LOW-RELIEF. LOTS OF DISSOLN SEAMS & [symbol]. BTM DOLSTS REPLACED IN PLACES BY LS. A SMALL 1-2 m WIDE SCOUR CHANNEL IN AREN. NO STS [symbol]

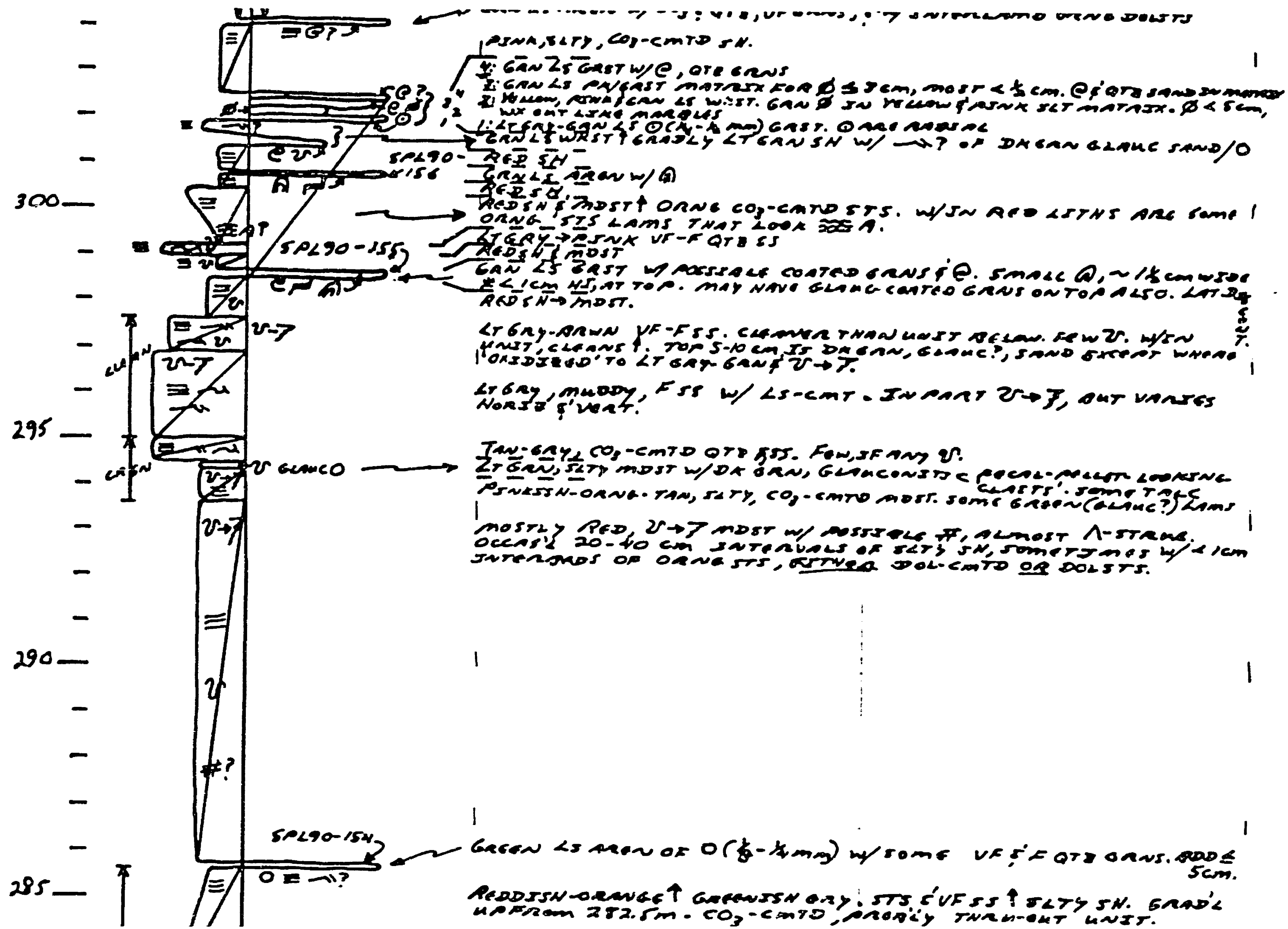
PINK & LT GRAY, MUDDY STS. LS-CMTD

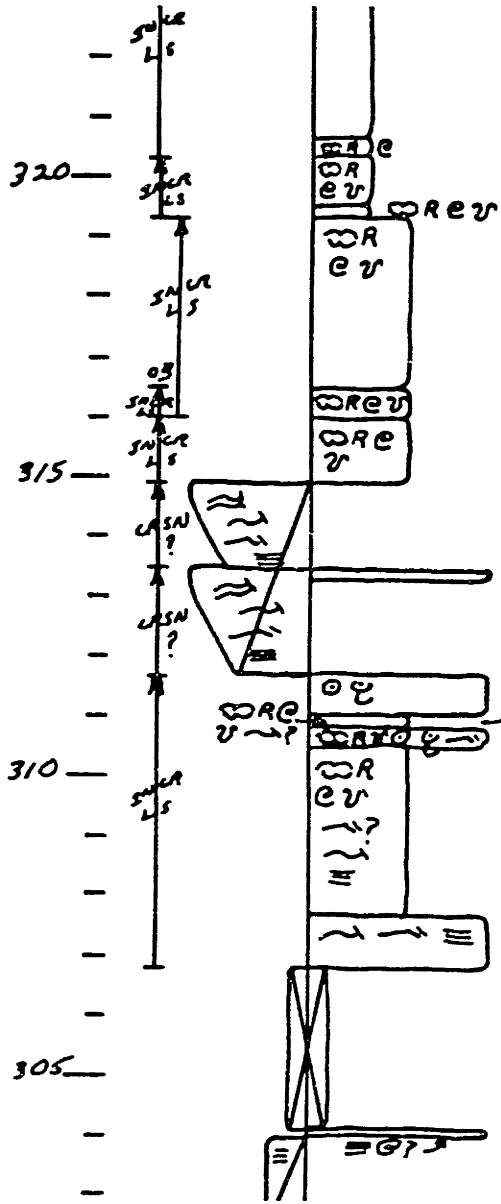
ORNG DOLSTS W/ LG [symbol] & DOLSTS [symbol]. GEN'LY [symbol] WHEN NOT [symbol]. ≤ 1 cm IRREG LENSES OF SAND WASH.

LT GRN & GRY VF SS & STS W/ OCCAS'L LAM'D & RIPPLED BEDS OF F SS. FEW [symbol].

MORE MUDDY, MORE [symbol], GRY SS. MORE RECESSIVE. SOMEWHAT LIKE 246 m.


285
280
275
270
FSWG
CRSN
CRSN
SHOAL?
SPL90-153
SPL90-151
SPL90-152
LIKE 267.5m?
TALC
REDDISH-ORANGE ↑ GREENISH GRY. STS & VF SS ↑ SLTY SH. GRAD'L UP FROM 283.5m. CO3-CMTD, PROBLY THRU-OUT UNIT.
LT GRN LS ARGN ↑ CO3-CMTD REDDISH-ORNG, QTZ STS & VF SS. LS IN LWR ½. BASICALLY A GRAD'L CHANGE TO NEXT UNIT UP
SH GONE TO TALC W/ A 4-CM THK LS ARGN IN MDL.
LT GRN & BRWN LS ARGN W/ INTERBDD F QTZ SS, CO3-CMTD. BDDG ≤ 5mm. MORE LS IN LWR ½.
GRN TO PINKISH ORNG, INTERBDD, MDST & SLTY SH.
REDDISH-PINKISH ORNG, CO3-CMTD STS. IN BASAL 1m, MORE A SLTY SH GOING TO TALC. POSSIBLY RIPPLED.
ORNG DOLSTS. REC. WX.
LT GRN-GRY LS, CLEAN MDST. FAINT, ~ HORIZ LAMS, BUT CAN'T SEE GRAINS (O PK/GRST?). CASE A? NOT SURE. LATERALLY HAVE LG (35cm WSDE #30cm NS) W/ SAME FABRIC AS REST, WHICH ALL/MOST ALGAL.
LT GRN-GRY LS W/ A? & . ≤ 10cm WSDE & 4cm NS, IN LWR 15cm OF UNIT. ABOVE ARE LG HEADS, ≤ 50x50cm. HAVE ORNG DOLSTS IN VOIDS. INTERHEAD BEDS ARE LS ≤ 1cm W/ ORNG DOLSTS INTERLAMS ≤ 2mm. SOME COATED? GRNS IN BASAL 15cm, UP TO WAST.
LT GRN, PINK, ORNG SH & LAM'D CO3 MDST ↑ DOLSTS. SH IS CO3-CMTD. SOME OF UNIT GOING TO TALC. WHEN DOLSTS GOES TO TALC, TALC RETAINS SAME COLOR (FRESH & WX) & IS SILTY. ≥ 2 SLICKENSIDED QTZ-CHLORITE VEINS, ≤ 2cm THK, AT ~ 273.5-274m, SUB // TO BDDG.
RED SH ↑ RED MDST
RED MDST GONE TO TALC. UPPR ~20cm GRN & PURPLE-GRY, AT LEAST LOCALLY.
LT GRN LS A W/ . TEXTURE LIKE BELOW
COVER. TALC
LT GRN LS W/ SMALL (≤1mm) . ≤ 10cm ACROSS & ~10cm NS.
NOT SURE OF SYNOPTIC RELIEF
ORNG DOLSTS
RED MDST GONE TO TALC
TAN LS WK/PRST IN INDISTINCT, ≤ 1cm BDS. ORNG DOLSTS INTERLAMS ~1mm THK. OF DK GRN LS LIKE BEDS BELOW BUT NO COATED GRNS. MORE DIFFUSE-LOOKING THAN THOSE ABOVE.
GRN LS PKST W/ SQUARE, ≤ 1x1cm, MOST ONLY A FEW mm. LOTS OF UNID (COATED?) GRNS ≤ 1mm
RED GOING ↑ GREEN SH W/ SOME MDST AT TOP. POSSIBLE IN GREEN, TOP 10-20cm. MAYBE JUST LOADING & JT-FILL.
RED-PURPLE MDST


PINK, SLTY, CO3-CMTD SH.
4: GRN LS GRST W/ @, QTZ GRNS
3: GRN LS PK/GRST MATRIX FOR Ø ≤ 3 cm, MOST < ½ cm. @ & QTZ SAND IN MATRIX
2: YELLOW, PINK & GRN LS W/ST. GRN Ø IN YELLOW & PINK SLT MATRIX. Ø < 5 cm, WX OUT LIKE MARBLES
1: LT GRY-GRN LS O(½-¼ mm) GRST. O ARE RADIAL
GRN LS W/ST ↑ GRADLY LT GRN SH W/ ? OF DK GRN GLAUC SAND/O
SPL90-156
RED SH
GRN LS ARGN W/ @
RED SH
REDSH & MDST ↑ ORNG CO3-CMTD STS. W/IN RED LITHS ARE SOME ORNG STS LAMS THAT LOOK A.
SPL90-155
LT GRY → PINK VF-F QTZ SS
REDSH & MDST
GRN LS GRST W/ POSSIBLE COATED GRNS & @. SMALL @, ~1½ cm WIDE & < 1 cm HT, AT TOP. MAY HAVE GLAUC-COATED GRNS ON TOP ALSO. LAT. ? REDSH → MDST.
LT GRY-BRWN VF-F SS. CLEANER THAN UNIT BELOW. FEW. W/IN UNIT, CLEANS ↑. TOP 5-10 cm IS DK GRN, GLAUC?, SAND EXCEPT WHERE 'OXIDIZED' TO LT GRY-GRN.
LT GRY, MUDDY, F SS W/ LS-CMT. IN PART, BUT VARIES HORIZ & VERT.
TAN-GRY, CO3-CMTD QTZ SS. FEW, IF ANY.
GLAUCO
LT GRN, SLTY MDST W/ DK GRN, GLAUCONITIC FECAL-PELLET-LOOKING CLASTS'. SOME TALC
PINKISH-ORNG-TAN, SLTY, CO3-CMTD MDST. SOME GREEN (GLAUC?) LAMS
MOSTLY RED, MDST W/ POSSIBLE #, ALMOST ∧-STRUC. OCCAS'L 20-40 cm INTERVALS OF SLTY SH, SOMETIMES W/ < 1 cm INTERBDS OF ORNG STS, EITHER DOL-CMTD OR DOLSTS.
SPL90-154
GREEN LS ARGN OF O (⅛-¼ mm) W/ SOME VF & F QTZ GRNS. BDD ≤ 5 cm.
REDDISH-ORANGE ↑ GREENISH GRY, STS & VF SS ↑ SLTY SH. GRAD'L UP FROM 282.5 m. CO3-CMTD, PROBLY THRU-OUT UNIT.
300
295
290
285




REC.WX. ~30-40% REDDISH ORNG DOLSTS

DK GRY LS MDST (OR ⊙ PK/GRST) IN ⊂⊃R. DKR THAN 309m, BUT SIMILAR OTHERWISE. ~15% ↑ 5% DOLSTS, MOSTLY IN V
LWR WXD PART ~50% DOLSTS, REDDISH-ORNG

⊂⊃R LIKE 309 m, DOLSTS 10-15% ↑ ~5%. LWR IN LAMS & V, UPPR IN BLEBS & V.

LWR WXD PART OF ⊂⊃R ABOVE. 3 SUBUNITS EA. ~15-20cm THK. <50% RED DOLSTS IN TOP & BTM. MDL W/ ~15% DOLSTS. MDL LIKE 309 m.

⊂⊃R VERY LIKE 309m. GRY LS WKST W/ ~5% OVERALL ORNG DOLSTS IN V & A FEW DISCONT. LAMS. DOLSTS MOSTLY IN LWR ½.

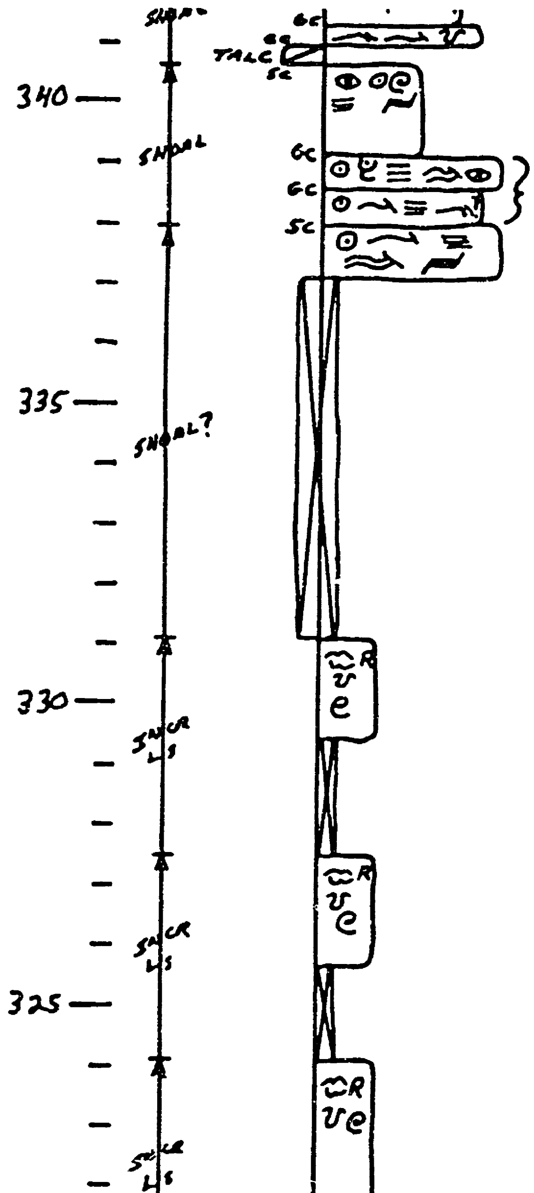
VERY POORLY EXPOSED 311.7 → 314.9m. LT GRY & TAN, LIMY CMTD, STS & VF & F QTZ SS. POSSIBLY 2 CRSN↑ PKGS AS SHOWN. LWR W/ ~10-20 cm OF VF & F LS AREN W/ ~40% QTZ GRNS AT TOP, LT GRN IN COLOR. TOP CNTC W/ ⊂⊃R PROBLY W/IN 20 cm OF WHERE PLOTTED.

LS ⊙ (≤ ¼ mm) GRST W/ ⊙ GOING TO ORNG DOLSTS. <2% DOLSTS LAMS
⊂⊃R LIKE 309 m, BUT ~30% DOLSTS
LT GRY LS ⊙ GRST W/ MANY ⊙ GOING TO DOLSTS. ~5% DOLSTS IN IRREG LAMS IN MDL OF UNIT

⊂⊃R. GRY LS @ WKST, ≤ 1-4cm BEDS. W/ ORNG DOLSTS INTERLAMS ≤ 5mm & V-FILL. ~15%. 1 DOLSTS BED 1-5cm THK (VARIES), W/ ≡ & ~.

LT GRY LS AREN, ~, ~ BEDS ≤ 1cm THK. W/ TAN-GRY DOLSTS, ≡ & RIPPLED, ≤ 5 mm INTERBEDS, ~33% DOLSTS

GRN LS AREN W/ $CO_3$ & QTZ, VF GRNS, & W/ INTERLAMD ORNG DOLSTS
RSNA, SLTY, $CO_3$-CMTD SH.
4: GRN LS GRST W/ ⊙. QTZ GRNS




GRNS LT BRWN, VF, LS ARGN & DOLSTS, ≤ 1 cm ROD. SOME IN IW LWR PART. TALC FROM ?? RARE ☉ ≤ 3 mm
V. LT GRN TALC.
LT GRY LS, VARIABLE LITH. MOST WKST, W/ SOME PKST, GRST. GRNS LIKE 337.5 m. W/ ADDTN OF UNCOMMON @ FRAGS. ⊕ IN ALL LITHS. LIKELY THAT MUCH OF 'MATRIX' IS SMALL, COMPACTED 'O'. ▱ OF GRY LS, ≤ 1½ × 1½ cm.
BOTH UNITS LS ARGN LIKE 337.5 m, BUT MUCH MORE DOLSTS IN LAMS & GRN-REPLACEMENT, ESP. LWR OF 2 UNITS, RODS ≤ 3 cm, MUCH ≤ 1 cm. TOP UNIT W/ ⊕. LWR UNIT ORNG-GRGN. TOP GRY-BRWN.

GRY LS ARGN, VF & F. VF QTZ GRNS. VF & F LS GRNS. ☉ (⅛-¼ mm). OCCASL INTERLAMS & BEDS (≤ 4 cm) OF ORNG & ORNG-BROWN DOLSTS. ALSO GET ▱ OF LS ARGN, ASSO. W/ DOLSTS LAMS; SOME @ DOLTZD.

NOTE: 337.1 → 339.0: IS A LOT OF '≡' ACTUALLY '≡A' IN ORNG DOLSTS?

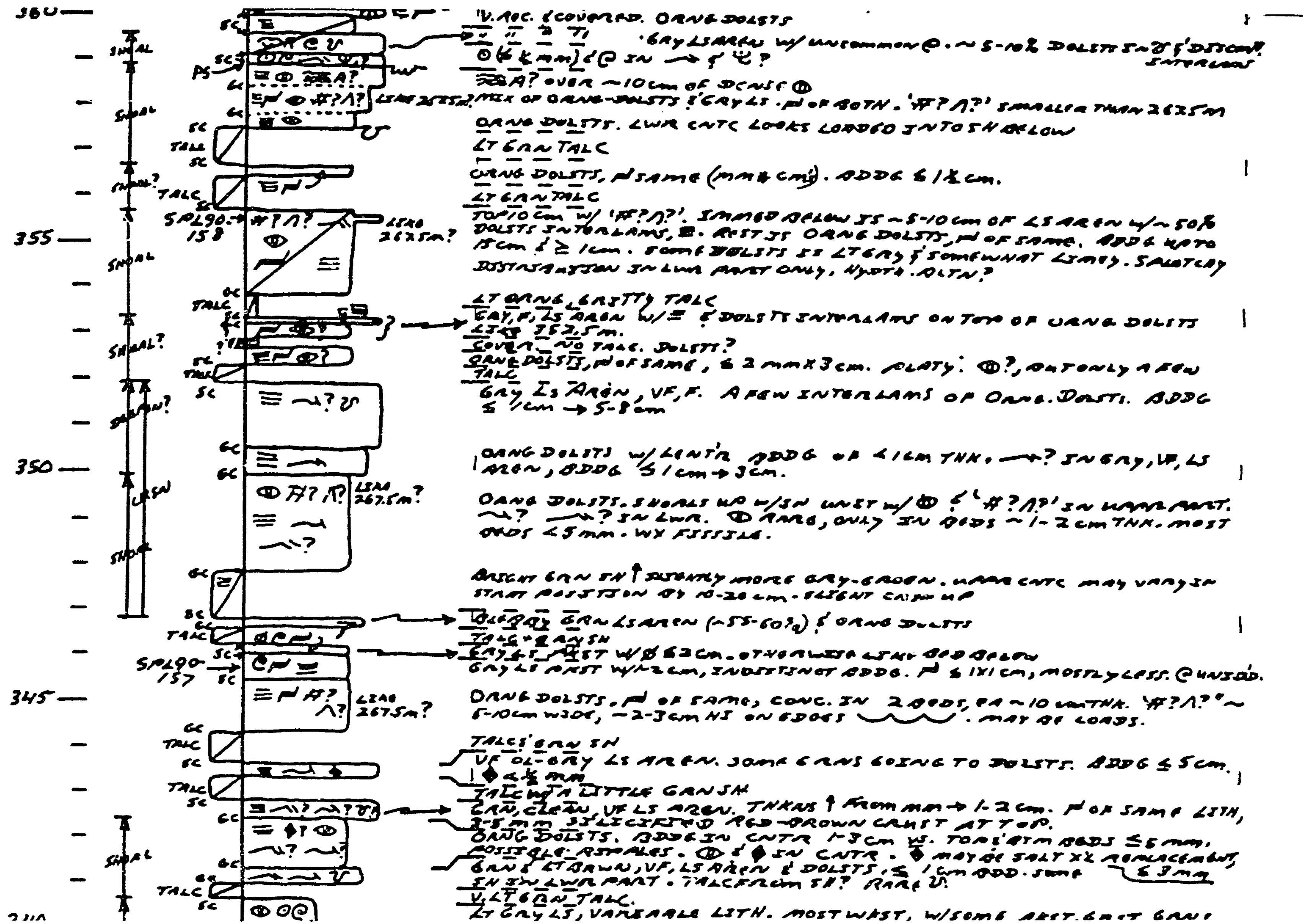
COVER

LIKE 326 m, INCL % DOLSTS, EXCEPT FOR 10 cm WK-PKST EVENT BED IN MDL.

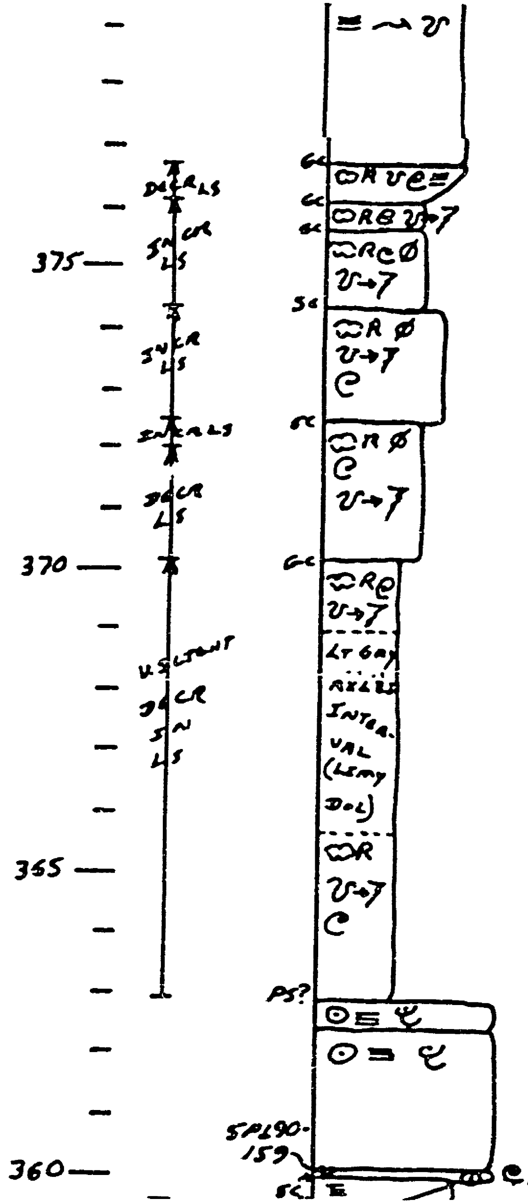
LIKE 320 m. GRY LS MDST W/ ~15% & 10% DOLS'S

COVER.

LIKE 320 m. DOLSTS DECR 10-15% & < 5% IN V. FEW INTERLAMS, BUT IRREG.



360
355
350
345
V. REC. COVERED. ORNG DOLSTS
MIX OF ORNG DOLSTS & GRY LS
ORNG DOLSTS. LWR CNTC LOOKS LOADED INTO SH BELOW
LT GRN TALC
LT GRN TALC
LT ORNG, GRITTY TALC
COVER — NO TALC. DOLSTS?
GRY LS AREN, VF, F. A FEW INTERLAMS OF ORNG. DOLSTS. BDDG ≤ 1cm → 5-8cm
ORNG DOLSTS w/ LENT'R BDDG OF <1cm THK.
TALC & GRN SH
ORNG DOLSTS, CONC. IN 2 BEDS, EA ~10cm THK.
TALC & GRN SH
TALC WITH LITTLE GRN SH
V. LT GRN TALC
TALC
SC
GC
SPL90-158
SPL90-157
SHOAL




GRY LS WKST w/ ~20% DOLSTS IN BTM 10 cm & ~90-95% IN TOP 10 cm. ORNG BRWN DOLSTS IN LAMS ≥ 4 mm, IRREG & ⊟, & IN 𝒱.

GRY LS WKST w/ ~10% DOLSTS IN 𝒱 & 1-3 mm INTERLAMS

WKST w/ Ȼ, Ø. MOSTLY ALTERED TO BRWN DOL w/ INTERLAMS OF BRWN DOLSTS. ~40-50% DOLSTS (~80% DOL). DECR DOLSTS ↑ w/ ~20-30% DOLSTS IN UPPR 40 cm. Ø ≤ 1½ cm.

GRY, LS WK/PKST w/ LOTS OF Ø ≤ 3 cm. OFTEN A LS-LAYER IS A SINGLE ROW OF Ø w/ ORNG-BRWN DOLSTS INTERLAMS ABOVE & BELOW & SOMETIMES IN-BETWEEN. LS BDDG ≤ 1-3 cm. DOLSTS ≤ 1 cm. ~50% DOLSTS EXCEPT FOR TOP ~50 cm WHERE DECR TO ~15% IN TOP 10 cm. SOME OF WK/PK GONE TO DOL

GRY LS WKST w/ SOME ALMOST PKST. BDDG ≈ 2 cm BUT DISRUPTED. ORNG-BRWN DOLSTS ≤ 5-8 mm, BUT IRREG, & IN 𝒱. Ø ≤ 1½ cm IN TOP 30-40 cm

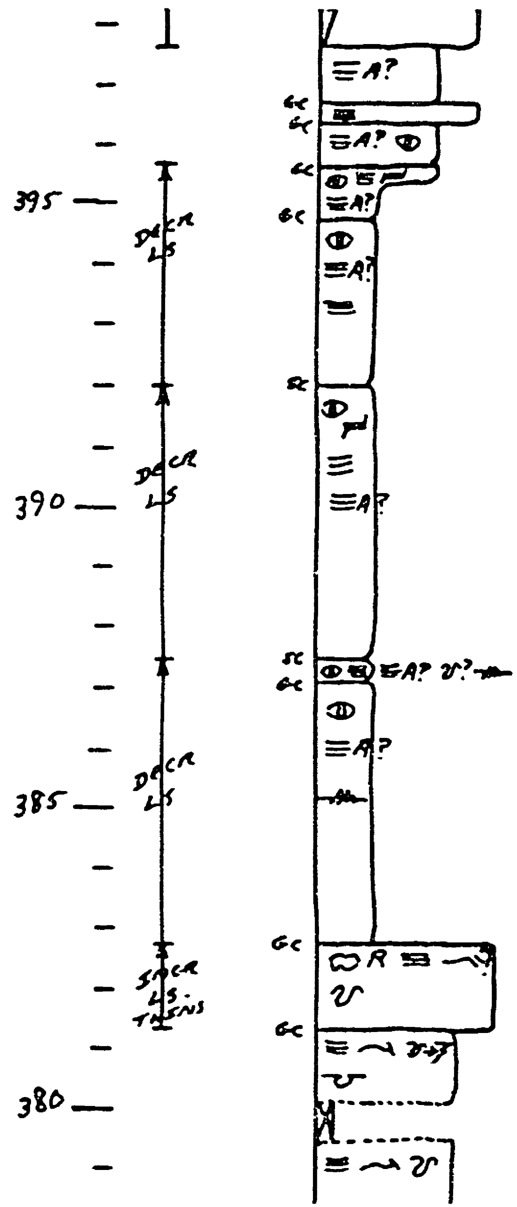
DOL %: TOP 30 cm: ~60→20%
MDL 100 cm: ~20 ↑ 60%
BTM 50 cm: 5-7% ↑ 10-20%

GRY LS MD/WKST w/ ~ ≤5% DOLSTS (GRY-BRWN) IN 𝒱 ↑ ~5-7% ORNG. DOLSTS IN 𝒱-FILLS & A FEW 1-2 mm IRREG LAMS. ALTERED ZONE IRREG IN UNIT & UNDULATORY ALONG OUTCROP. GRADL & DIFFUSE UPPR & LWR CNTK. HYDROTH ALTN? NO Ⓐ MORPHOLOGY

GRY, LS, ⊙ (½-1 mm) GRST. UPPR & LWR CNTX IRREG. PROBABLY PRESS-SOLN

GRY, LS, ⊙ (¼-½ mm) GRST. SOME Ȼ 40-50 cm HS.

GRY LS GRST. P ≤ 1½ x 1 cm. ⊙ (¼-1 mm)
V. REC. & COVERED. ORNG DOLSTS




ORANG DOLSTS LIKE 396m w/o ⦶.

LT GRY LS AREN/O-GRST. LWR 2/3 INTERLAM'D w/ DOLSTS
ORANG DOLSTS. VF, CONT. ▦, POSSIBLY ALGAL. A FEW ⦶ IN LWR PART

STARTS AS LT GRY LS MOST LIKE 385m w/ DOLSTS LAMS LIKE 387.4m & INCR ↑ % DOLSTS, FROM ~10% TO ~ 50-60%. ≁ OF STS.

LT GRY LS MOST LIKE 385m w/ ONLY A FEW DOLSTS INTERLAMS

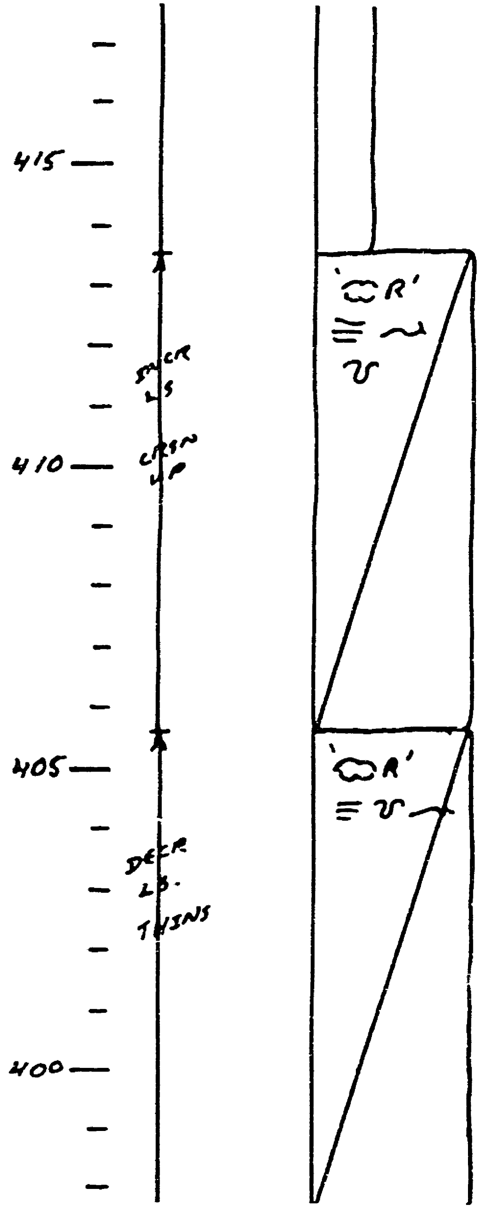
LT GRY LS MOST LIKE 385m w/ INTERLAMS OF DOLSTS LIKE 387.4 UP TO ~15-20% DOLSTS IN TOP 50cm. INTERLAMS ≤1cm. ≁ OF DOLSTS OR ARE DISCONT. INTERLAMS. ORANGISH TINGE TO THIS INTERVAL LACKING IN UNITS ABOVE & BELOW

LT GRY LS MOST LIKE 385m w/ ~5-10% LT ORANG DOLSTS INTERLAMS ≤2mm, USUALLY IN CLUSTERS.

LT GRY LS MOST w/ LOTS OF ~1mm ⦶. POSSIBLE FAINT ▦ A AS WELL. BDDG IN MOST 5-20cm AVE.

GRY LS AREN w/ ≤3mm BROWN DOLSTS INTERLAMS & ʊ-FILL. LS BDDG THINS ↑ 2cm → ≤6mm, DOLSTS THNS ↑ 5mm → <½mm. % DOLSTS DECR ↑ ~50% TO 10%

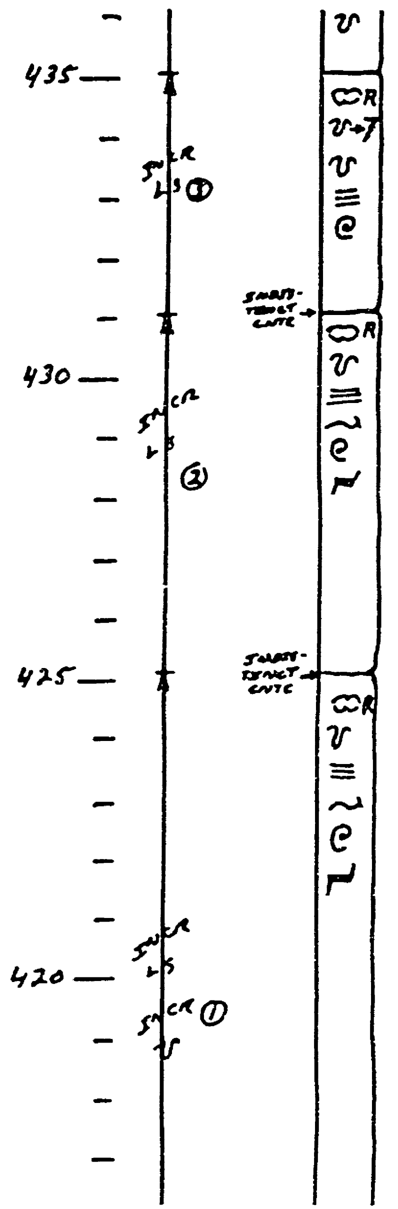
BROWN DOLSTS. COVERED 70cm PROBLY THE SAME. BDDG 1-10cm, MUCH ʊ + T. MOTTLED COLORATION w/ YELLOWISH-BROWN, ORANGISH-BROWN & BROWN, NO VERT. TRENDS NOTED. ~10cm FROM TOP IS A ~10cm THK BED THAT LOOKS LOADED. DE-$N_2O$'ING?




INTERBDD ORNG DOLSTS & GRY LS ARGN. MOSTLY THIN, ≡ LAMD DOLSTS IN LWR PART. INCR NUMBERS & THKNSS OF LS BEDS ↑ 'TIL TOP m ~40% LS. LS BDD ≤ 2cm.
LIKE ωR, BUT ONLY OCCAS'L ʋ. ʋ's INCR ↑. ≡ IN DOLSTS ALMOS EA-LOOKING. NO ⊕. TOP 20cm BED OF DOLSTS W/ WISPS OF LS.

LIKE ωR, BUT ONLY AN OCCAS'L ʋ. INTERBEDDED DOLSTS & VF & F LS ARGN. ~50% DOLSTS OVERALL.

<u>BDDG</u>: 1-2 cm FOR LS    ½-1cm FOR DOLSTS

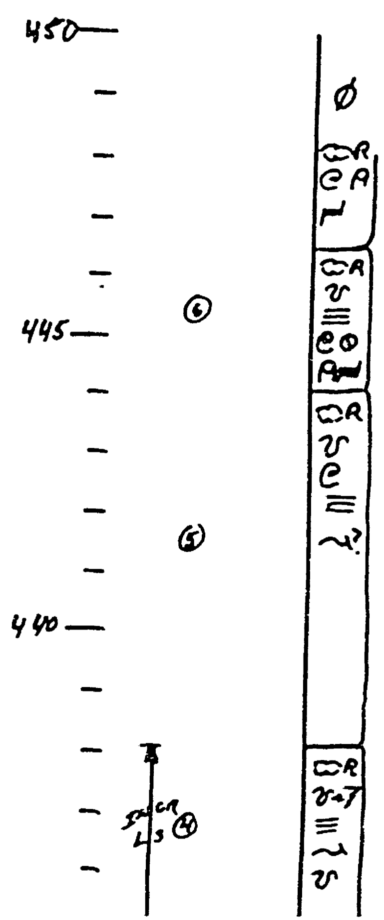



GRY LS LIKE 425m. BDDG 1-5 cm. DOLSTS BROWN & ORNG, BDDG ≤ 5m MOSTLY IN V & DISCONT, LARGE INTERLAMS EXCEPT LWR 30-40 cm W/ ~30% DOLSTS IN LAMS 5-10 mm THK & IN V. REST OF UNIT ~5-10% DOLSTS.

R LIKE 425m. DOLSTS DECR ↑ FROM ~50% IN LWR 50 cm TO ~15-20% OVER ALL THE REST. AT ~427 m, HAVE A 15 cm THK @ BRST EVENT BED, LIKE 419.5m. MOSTLY LS.

GRY LS MOST OR O-PK/GRST W/ UNCOMMON @. AT ~419.5m, HAVE ONE 10-20 cm @ BRST W/ OF LS & DOLSTS. LS BDDG MOSTLY 1-3 cm, SOME ≤ 5cm. DOLSTS IN LAMS ≤ 1cm & V. ~60% DOLSTS ↑ ~30%

Sctn 90-5
Eagle Mtn.



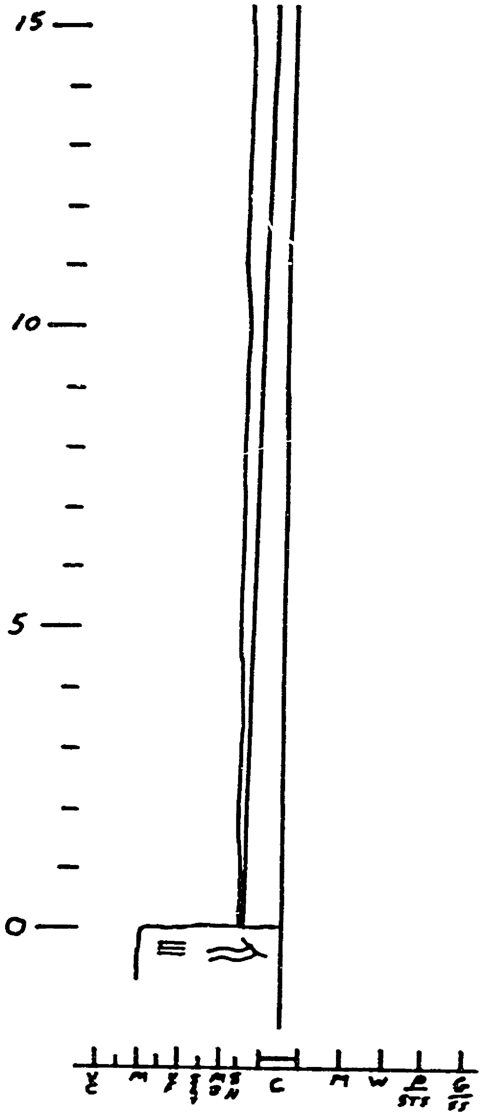

STILL R, BUT DOLSTS NOW OL-GRN w/o REVERTING TO ORNG. Ø AT ~450, (<1cm). SEVERAL PKST W/IN 1ST 3 m. LS A BIT DARKER?

BONANZA KING

R LIKE 433m. ~10-15% DOLSTS IN ≤ 8 mm INTERLAMS & V. DOLSTS ORNG & ORNG-BRWN. LS A GRY MDST (0-PK/GRST) EXCEPT FOR SEVERAL 1-3 cm PKST BEDS NEAR TOP. BDDG 1-3 cm. ASNPKST. ONE (⅛-¼ mm) & STSN GRST, 4 cm THK NEAR TOP. NO VERT TRENDS.

R LIKE 433m. ~10% DOLSTS THRUOUT, NO VERT TRENDS. OL-GRN & ORNG-BROWN & ORNG DOLSTS, IN ≤ 5 mm INTER-LAMS & V. NOT AS Vd AS 433m.

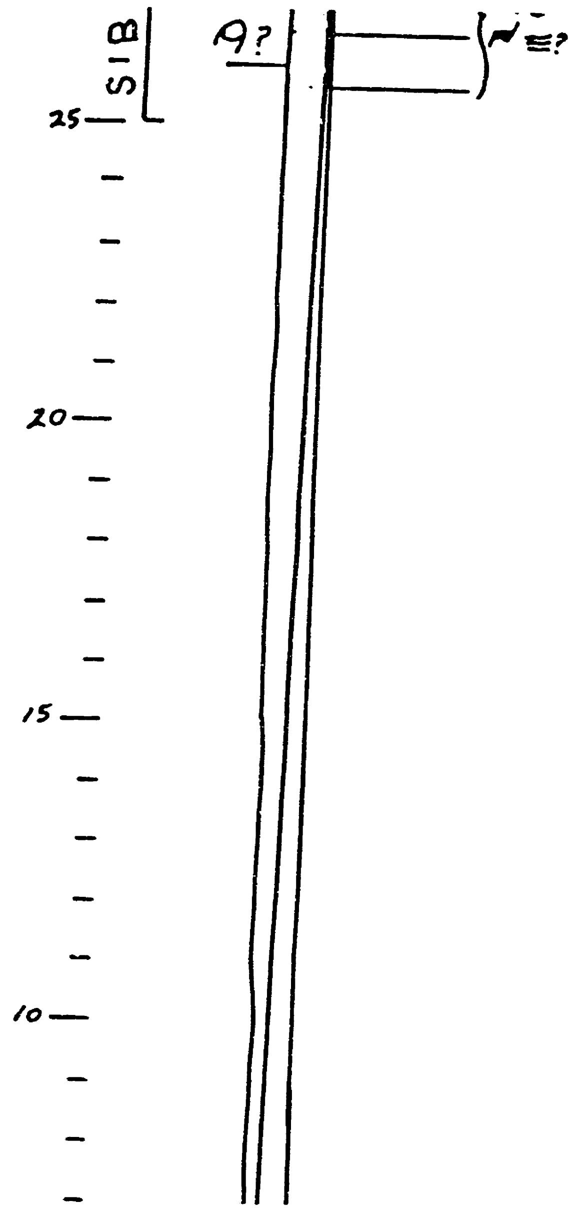
R LIKE 433m. DOLSTS ~25% IN LWR m IN ≤ 1½ cm, = BEDS & LAMS. DECR TO ~5% IN TOP m IN V. LS BDDG 1-5 cm, DOLSTS LAMS ≤ 5 mm. DOLSTS ORNG-BRWN IN UPPER PART, ORNG IN LWR.



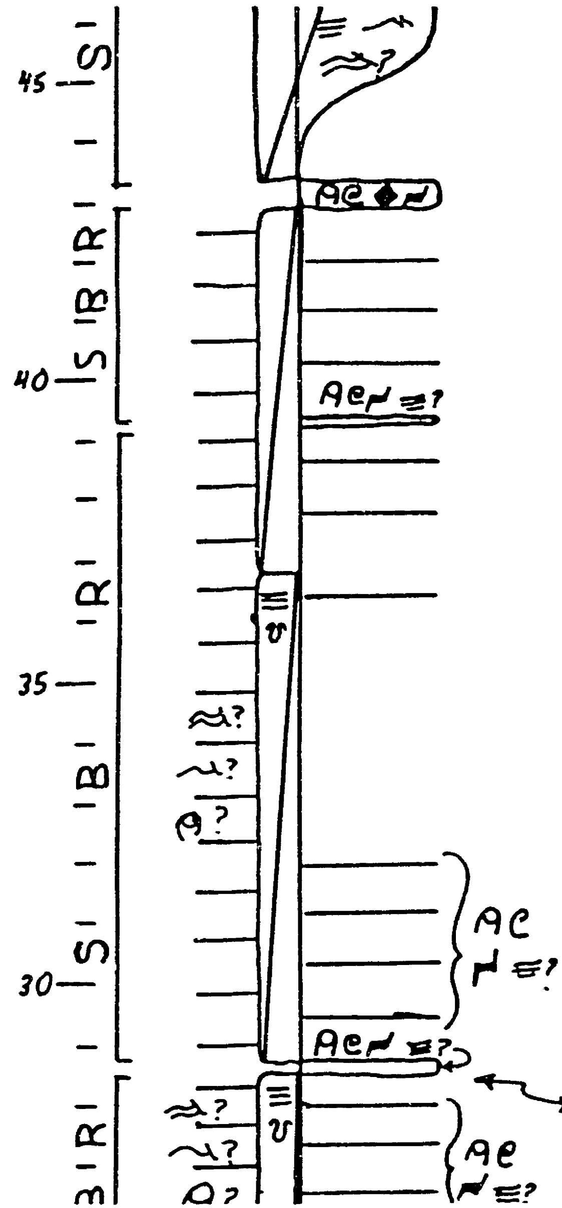

OCCASIONAL SILTY SH BEDS. AT ≈25 m, START TO GET THIN CARBONATE BEDS SIMILAR TO 28.6 m. ALSO START TO GET A FEW THIN, 1→3 cm, ≈?~?, CARBONATE-CEMENTED, VF SS BEDS, w/ RARE VERT B's. POSSIBLE Q-SPINES.

LT GRAY → PINK M-F QTZITE. BADLY FRAC'D. POORLY EXPOSED. LAST QTZITE EXPOSED.

SCTN 90-6
MONTGOMERY HILLS, NV.




MSC. SH W/ VARYING AMTS OF HORIZ ℧'s. BASAL ~5m DK GREEN W/ REDDISH STAIN. BASAL 10-12 m GOES FROM DK GREEN GRADUALLY TO LT GREEN. OCCASSIONAL SILTY SH BEDS. AT ≈25 m, START TO GET THIN CARBONATE BEDS SIMILAR TO 28.6m. ALSO START TO GET A FEW THIN, 1→3cm, ≈?&~?, CARBONATE-CEMENTED, VF SS BEDS, W/ RARE VERT ℧'s. POSSIBLE A-SPINES.




OF LT GREEN, [illegible]
INTERVAL TENDS TO BE PARTLY COVERED W/ FINS
STICKING OUT

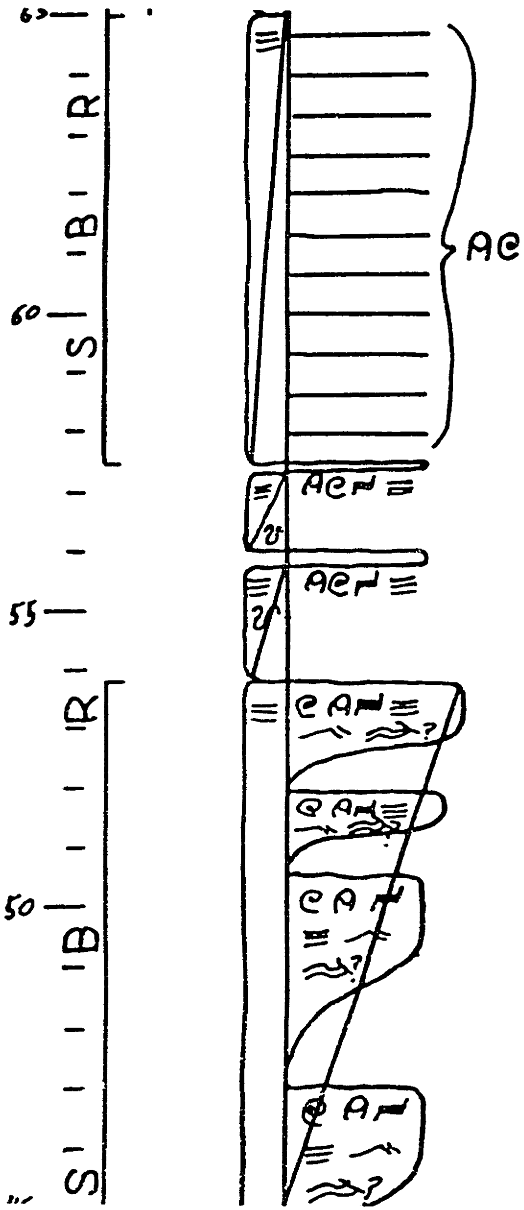
YELLOWISH-GREEN LS PKST W/ SOME WKST. LOTS OF POSSIBLE ECHINOID FRAGS.

LT GREEN, MIC. SH LIKE 20m, W/ OCCASIONAL CARBONATE & SS BEDS. GETTING MORE → IN UPPER COUPLE OF METERS

12 CM THK OL. GREEN LS PKST LIKE 28.6m, TWO W/ LGR (< ½ × 4cm & PLATY) ($\le 1\frac{1}{2}x/\frac{1}{2}$ & EQUANT) MOSTLY OF CALCITE-CMTD MDST

MIC., LT. GREEN SH LIKE 20m. CARBONATE BEDS TO ~32m, THEN NONE TIL ~36½m. CARBONATE BEDS FROM 25 TO 32 m ARE ALL ≤ 8 cm THICK & LENTICULAR.

OL.-GREEN LS PKST W/ QTZ GRAINS (RNDD, ≤ VC) & OCCASIONAL QTZITE PEBBLES ≤ 3-4mm, OF SH & STS ≤ 1cm. POSSIBLY X-BDD (≈ OR ) BUT CAN'T TELL FOR SURE




LT. GREEN CHLORITIC SH W/ ½-2cm THK LS PKST BEDS INTERSPERSED. OL. GREEN W/ SILICIFIED TOPS & BTMS

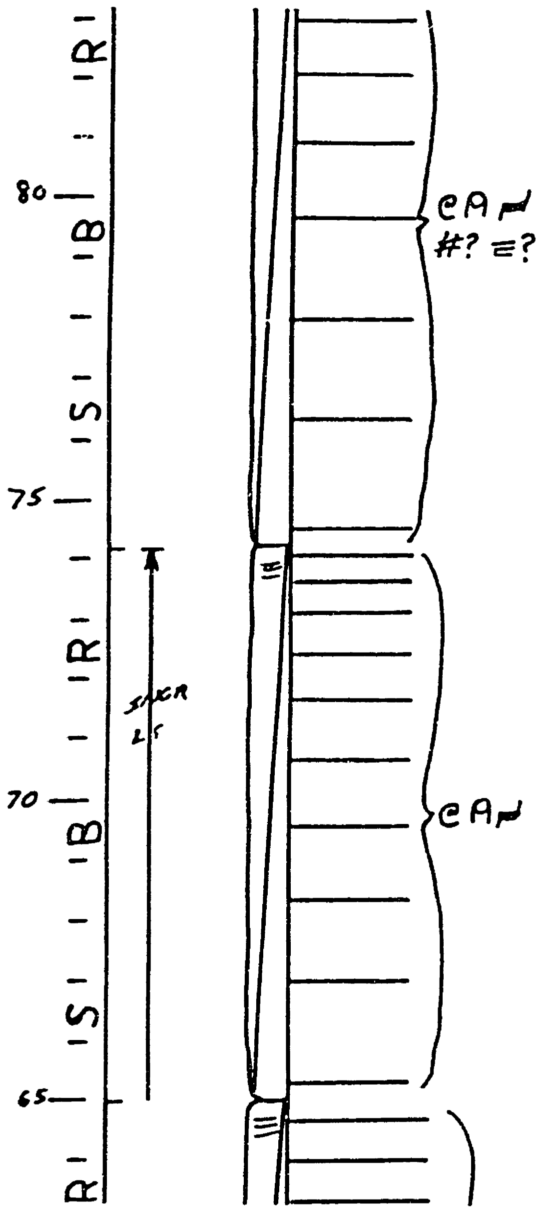
OL. GREEN LS PKST LIKE 28.6m

LT. GREEN CHLORITIC SH?

OL. GREEN LS PKST LIKE 28.6m

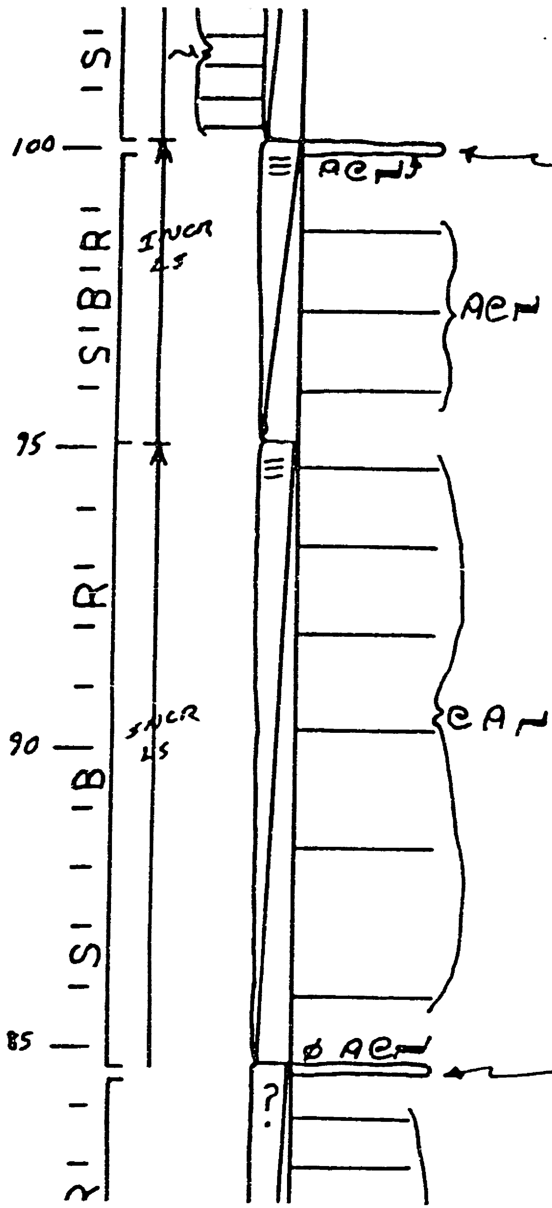
LT. GREEN CHLORITIC SH?

OVERALL AN ORANGE-TAN CARBONATE UNIT SUMMARIZED AS 4 ↑CASN & ↑SNCR LS PACKAGES. LWR 2 PKGS ≈ 3-4m THICK, UPPR 2 ≈ 1½→2 m THK. 3RD PKG IS MINOR. TOP ⅓ OF EA. PKG WEATHERS OUT AS FINS. FINS ARE VF, ≡, ≈? AREN & ▬, ⌒, ≈? GRST OF @ AP. FINS ARE GENLY ≤ 5cm THK. INTERVENING FINES SEEM TO BE PINK STS/DOLSTS W/ ≤ 1cm THK INTERBEDS OF ARENITE? IN LWR PART & INTERBEDS OF LT GREEN, CHLORITIC SH IN LWR PART. ENTIRE INTERVAL TENDS TO BE PARTLY COVERED W/ FINS




NOTE CHANGE IN COLOR OF 'DESERT PAVEMENT'/GROUND-COVER TO OL. GREEN W/ MANY CARBONATE CLASTS. MAY HAVE LOST 'CHLORITIC SH' AS 'BACKGROUND' SEDIMENT. HOWEVER, THERE IS ONLY ONE SMALL (10-15 cm) SET OF LOW FINS ALA 44-57 m. MAYBE 12 PKGS, ~5 m THK EACH, OF 'LS INCR UPWARDS'. LS IS @A WAST LIKE ~67 m IN SCTN 90-5 AT EGL MTN. POSSIBLE MUDCRACKS (#) ≡ IN LS.

GRY TO GRY-GREEN CHLORITIC SH W/ UPWARD INCR. IN NUMBER OF LS BEDS. LS IS OLIVE GREEN WK/PACKST. W/ SILICIFIED UPPER & LOWER SURFACES. LS BEDDED ≤ ½ → 3 cm. OCCASIONAL 1-2 cm, VF SS BEDS W/ ≡. IN LS ARE CARBONATE-CEMENTED MDST < 1x 1½ cm.



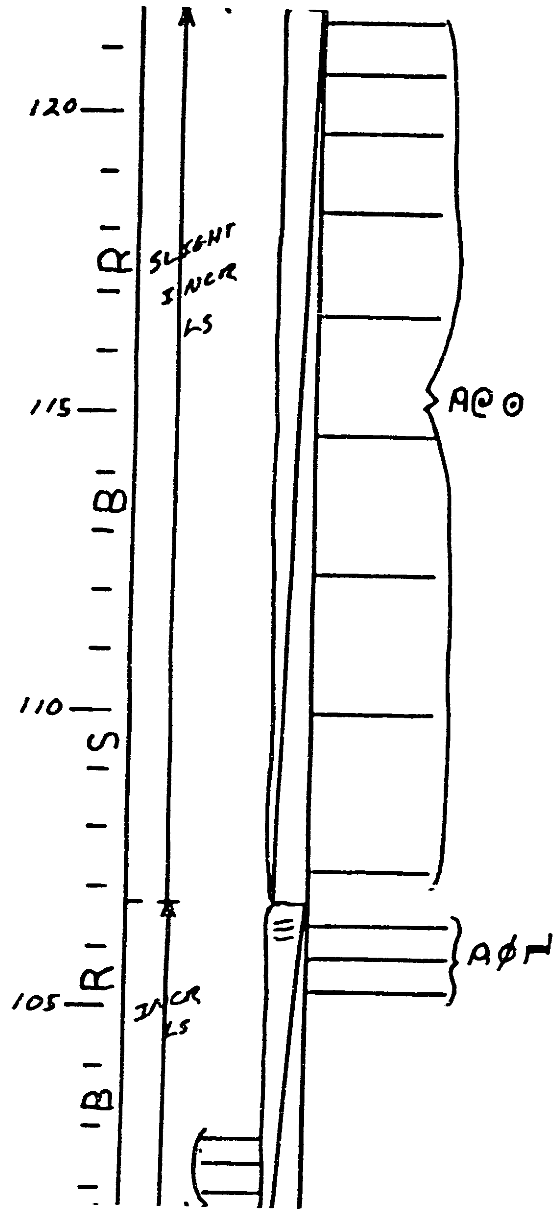

Ø, ≤ 2 cm DIAMETER.

LS AC [illegible] PKST, 10-15 cm THK. [illegible] OF ROUNDED CARBONATE ≤ 1×3 cm

GRAY-GREEN CHLORITIC SH w/ LS PKST BEDS ≤ 2 cm THK

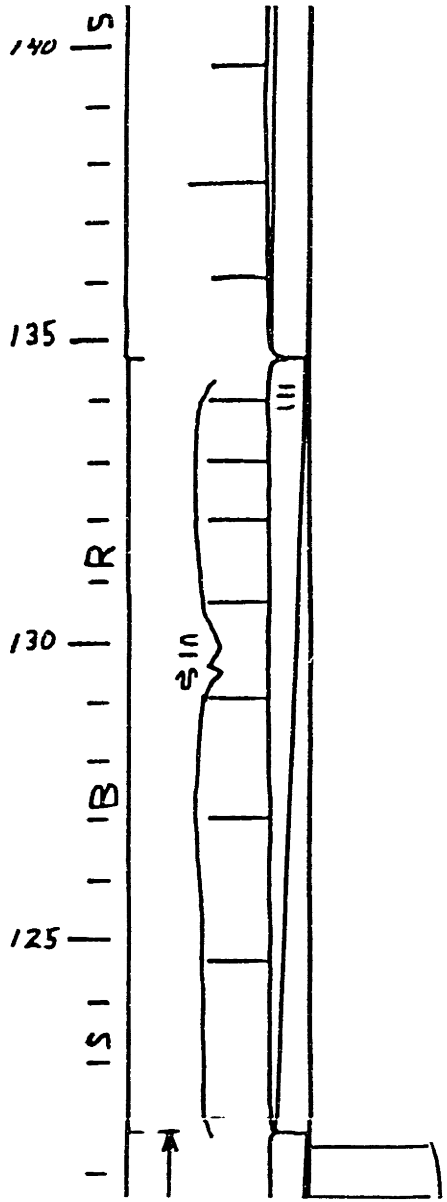
GRAY-GREEN CHLORITIC SH. AS BACKGROUND INTERBEDS OF LS PKST IN LAST 2 m. ~5-20 cm THICK BEDS OF LS w/ [illegible] ≤ 1×1 cm IN THKR BEDS.

OL. GREEN, 15 cm THK Ø PKST w/ AC [illegible]. Ø ≤ 2 cm)

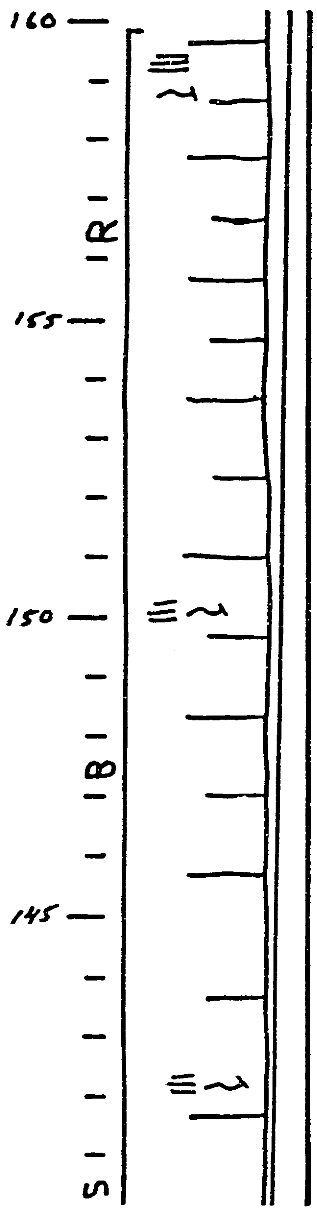



LT GREEN CHLORITIC SH W/ INTERBEDS OF OL-GREEN LS PKST W/ ⊙, ~½mm, IN SOME BEDS

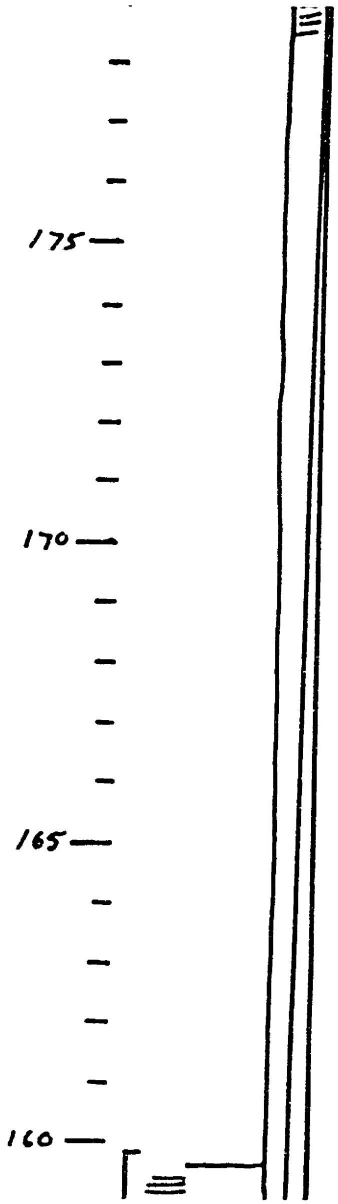
GRAY-GREEN CHLORITIC SH W/ LENTICULAR VF SS BEDS, 1-2cm THK & CARBONATE-CEMENTED, IN LOWER 2½-3 m. TOP 1½ m HAS SEVERAL 1-10cm THK OL-GREEN LS PKST BEDS W/ A@. THICKER LS BEDS ALSO HAVE ⊘ ≤ 2cm DIAMETER




GREEN-GRAY CHLORITIC SH W/ OCCASIONAL ≤ 1cm-3cm THK, VF SS, W/ [illegible] ≡. SOME BEDS CARBONATE-CEMENTED. NO LS BEDS.

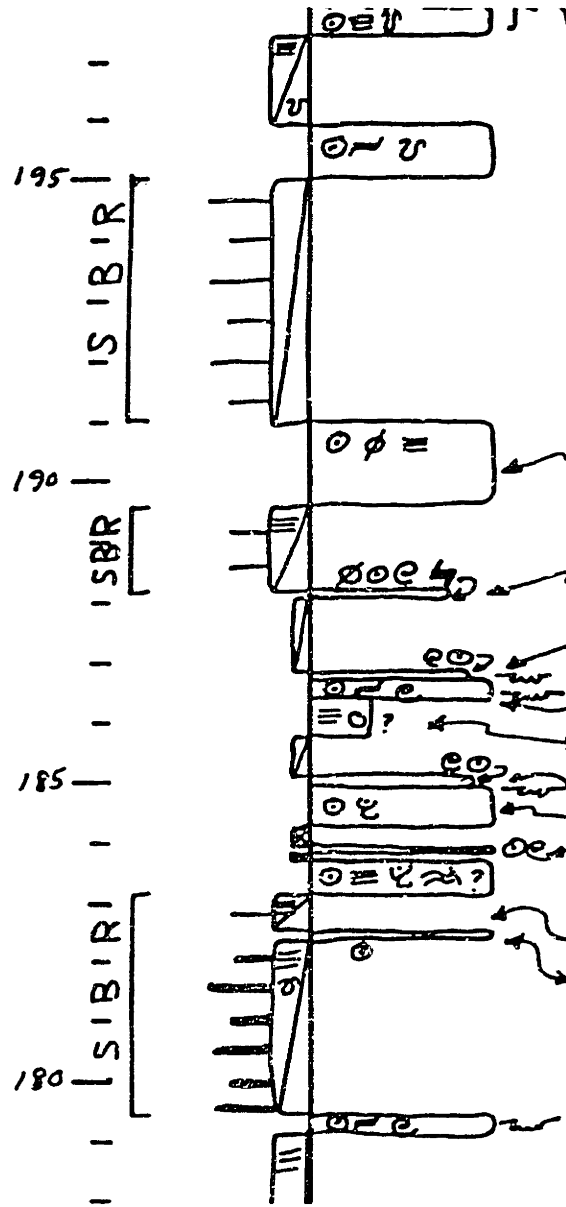



<u>LOWER 1/2</u>: BACKGROUND IS GRAY CHLORITIC SH W/ INTERBEDS OF VF & F SS, BUT NO LS. BEDS HIGH W/ ≡ & ~. SOME SS CARBONATE-CEMENTED




BROWN & GRAY-BROWN LS GRST. AT LEAST 2 BEDS: LWR MOSTLY ECHINOID(?) FRAGS & ᒥ (≤ 1½ * 8 cm) OF STS & MDST. UPPER SS @ & e. PROBABLY SOME SCOUR SURFACES BETWEEN 2 LITHOLOGIES. THICKNESS VARIES ALONG OUTCROP

UPPER ½: COVER SS NOW LIGHTER IN COLOR THAN LOWER ½ – POSSIBLE THAT BACKGROUND SEDS ARE NOW A SILTY, GRAY, CHLORITIC SH. NO SS OR LS BEDS. APPROX 100-150 m TO NORTH THERE ARE SOME INTERBEDDS OF SS.




1-2 mm. TOP w/ 3/4-1 mm ⊙. BTM BDD 3-5 cm w/ some ≤2 mm THK LS AREN (w/ VF QTZ GRAINS) STRINGERS ≡. MDL BDD 3-8 cm. TOP BDD 5 cm. SOME ORNG DOLSTS INTERLAMS

TAN SLTY SH

GRAY & GRAY-GREEN LS ⊙(½-1 mm) GRST w/ ≤ 3 mm × 1½ cm

GREEN MICACEOUS SH w/ INTERBEDS OF VF SS & STS ≤ 3 cm THK

LS ⊙ & ∅ GRST. BDD 5-10 cm. ⊙ IN BTM 20 cm ARE ½-3/4 mm - IN REST OF INTERVAL ARE 1-1¼ mm. ∅ ≤ 1 cm - 2 cm & MOST COMMON & LARGEST IN MDL BEDS (ESSENTIALLY ∅ PKST w/ ⊙ MATRIX). SOME LENTICULAR ORNG. DOLSTS INTERBEDS ≤ 5 cm THK. ALSO SOME ≤ 5 mm INTERLAMS THAT ARE MORE CONTINUOUS THAN INTERBEDS

GREEN SH w/ STS BEDS, ≡ & ≤ 1 cm THK

BROWN & GRAY LS PKST. ∅ ≤ 2 cm. ≤ 1 × 4 cm

COVERED. LIKE 181 m ?

GRAY BROWN LS PK/GRST

AT LEAST 3 BEDS OF ⊙ (3/4-1¼ mm) LS GRST w/ OF LS MDST & ⊙ GRST, ≤ 1 × 5 cm + 1 INTERBED OF DOLSTS ~3-4 cm THK

GREEN-GRAY LS MDST (OR ⊙ PK/GRST w/ VF QTZ GRAINS

COVER. LIKE 181 m ?

GRAY-BROWN LS PK/GRST. ⊙ ECHINOID FRAGS? 1-2 mm, ≤ 5 mm

GRAY ⊙ (½-3/4 mm) LS GRST

COVER. LIKE 181 m ?

GRAY LS GRST. ⊙ 3/4-1 mm & COATED GRAINS. w/ COVER BENEATH.

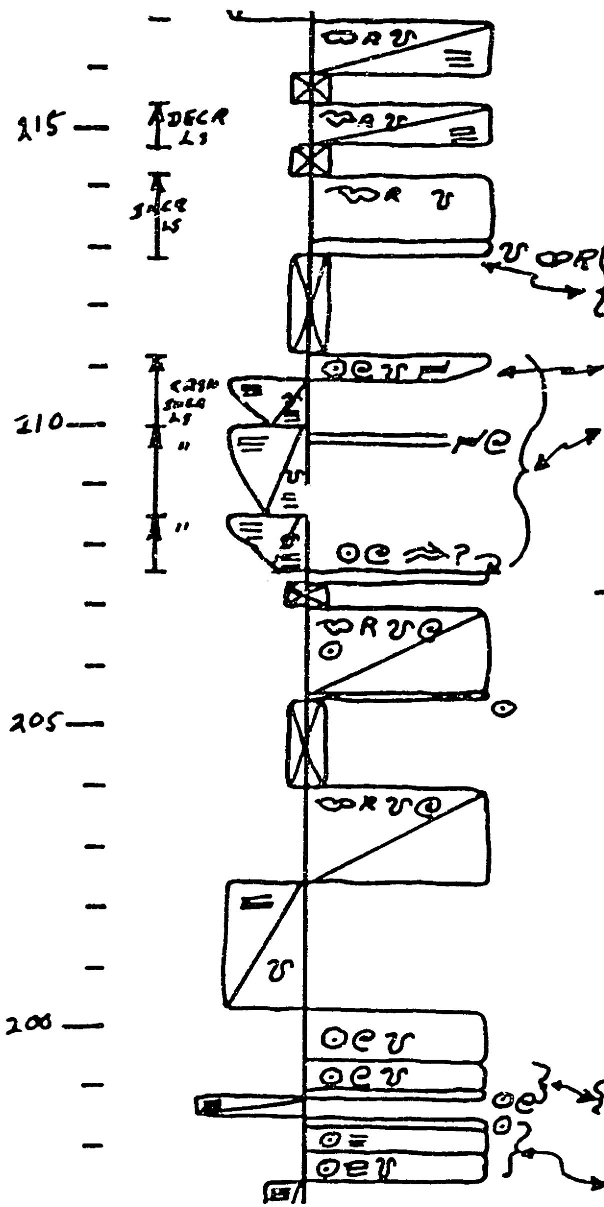
GRAY ⊙ (½-3/4 mm) GRST w/ INTERLAMS & BEDS OF DOLSTS ≡. SOME DOLSTS MAY BE SILT-SIZED ⊙.

STS & SH LIKE 181

GRAY ⊙ (½ mm) LS GRST w/ DISCONTINUOUS INTERLAMS OF DOLSTS ≤ 1 cm THK

GREEN TO KHAKI-GREEN SH, STS & VF SS. STS & VF SS ≤ 10-15 cm BEDS.

BROWN & GRAY-BROWN LS GRST. AT LEAST 2 BEDS: LWR MOSTLY ECHINOID(?) FRAGS & (≤ 1½ × ? cm) OF STS &




~~R LIKE 215m BUT NO OVERALL CHANGE IN % DOL. ≈ 40%

COVER

LS VF-F AREN. GRAY. W/ORNG-BROWN DOLSTS. DOLSTS INCR UPWARDS ~10 ↑ 30% IN INTERLAMS & V. PROBABLY RIPPLED ALSO

COVER

~~R W/AREN. LIKE IMMED BELOW BUT F SAND SIZED ORNG DOLSTS ~10-15% IN INTERLAMS < 3 mm & V. % QTZ GRAINS DECR UP LS BDD ~ 3cm

V ~~R { GRAY-GREEN LS AREN (VF-F) W/ 50-60% QTZ SAND. BDD ~8 cm. INTERLAMS (~40%) OF BROWN DOLSTS, ≤ 5 cm. ARENITE IS NODULAR-WAVY BDD & PROBABLY RIPPLED

COVER

LS PKST LIKE 209.9m. W/ INTERLAMS ≤ 1cm OF DOLSTS. BDD 1-8 cm

3 PKGS OF UPWARD CRSNG & INCR LS. START W/ GREEN, MICACEOUS SH & GO UP TO SLTST W/ V & PROBABLY RIPPLES. MDL PKG W/ 2 @ LS PKST BEDS, 5 cm & 2 cm THK. PKST W/ @, SAND-SIZED LS GRAINS, & [?] OF DOLSTS < ½ × 1 cm

GRAY ⊙ & COATED GRAIN LS GRST. SOME VF LS AREN IN BASAL 5 cm

COVER. LIKE 205 m

GRAY LS VF-F AREN LIKE 203 m. W/ ~10-15% DOLSTS

GRAY LS ⊙ (¾-1 mm) GRST

COVER. EITHER ~~R OR SH/STS/SS

GRAY LS AREN W/ 10-20% VF-F QTZ SAND & < 5% @. BDDG ≤ 1 cm & WAVY/NODULAR. MAY BE RIPPLED BUT CAN'T SEE LAMINAE. ~20% BROWN-ORNG DOLSTS INTERLAMS ≤ 1 cm W/ MOST 2-4 mm

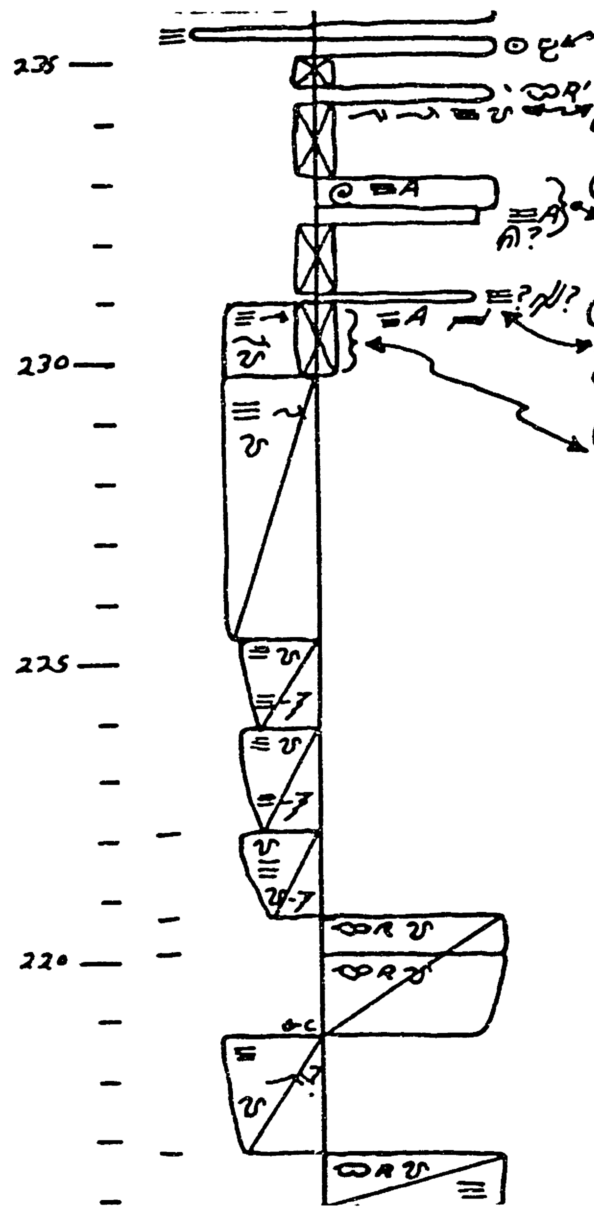
GRAY-GREEN MICACEOUS STS

3 ⊙ LS GRST BEDS (~20 cm THK EA) W/ 2 INTERBEDS OF GREEN LS VF AREN (~10 cm EA). SOME @ IN ⊙ BEDS. TOP ⊙ BED W/ ¼ mm ⊙. ⊙ MOSTLY ½-¾ mm IN OTHER 2 BEDS.

GRAY-GREEN LS ⊙ GRST. LWR UNIT W/ 1-1½ mm ⊙ & UPPER W/ ½-¾ mm ⊙ 3-5 cm BDDG.

TAN VF-F QTZ SS

3 LT GRAY-GREEN LS ⊙ GRST. BTM W/ ⊙ ⅛-¼ mm. MDL W/ ⊙ 1-2 mm. TOP W/ ¾-1 mm ⊙. BTM BDD 3-5 cm W/ SOME 1-2 mm THK LS AREN (W/ VF QTZ GRAINS) STRINGERS [illegible]




GRAY LS ⊙ (¼-½ mm) GRST. ⊙ ≤ 6 cm    [illegible]

COVER. THINNER-BDD CARBONATE LIKE UNIT ABOVE?

GRAY LS VF & F AREN. BDD ≤ 2 cm. INTERLAMS & ~ OR ORNG-BROWN DOLSTS, LAMS ≤ 8 mm. R-LIKE W/ FEWER ~S

COVER. SH?

2 LT GRAY LS UNITS. UPPER IS A @ GRST W/ ≡A IN TOP 10 cm. @ ARE ECHINOID? FRAGS & COATED GRAINS. LOWER UNIT IS FINELY LAMD ≡A, W/ SOME FINELY CLOTTED PARTS. LATERALLY HAVE POSSIBLE A

COVER. LIKE 230.5?

MIX OF ORNG DOLSTS & LS AREN/STS. POSSIBLE PLASTIC DEFORMATION ⊙(?) OF BEDS. ALSO DEFORMED. POSSIBLY ≡A. AMT OF LS VARIES. SOME ARE SED. RX. LATERALLY HAVE DEFINITE ≡A OVER UNIT

COVER. GRAY, NOT REDDISH BROWN, CARBONATE-CEMENTED VF-F SS. LATERALLY IS PINK-ORANGE-TAN STS TO VF SS W/ CARB. CEMENT & ≡ ~ ~ ~

INTERBEDDED VF SS & STS. ⊙ SILICA-CEMENTED. WEATHERS REDDISH-BROWN. FRESH IS PINKISH-GRAY.

SAME AS 221 m, BUT ALMOST NO STS AT TOP

SAME AS 221 m

GRAY-GREEN MICACEOUS MDST. CLEAN UPWARDS TO STS

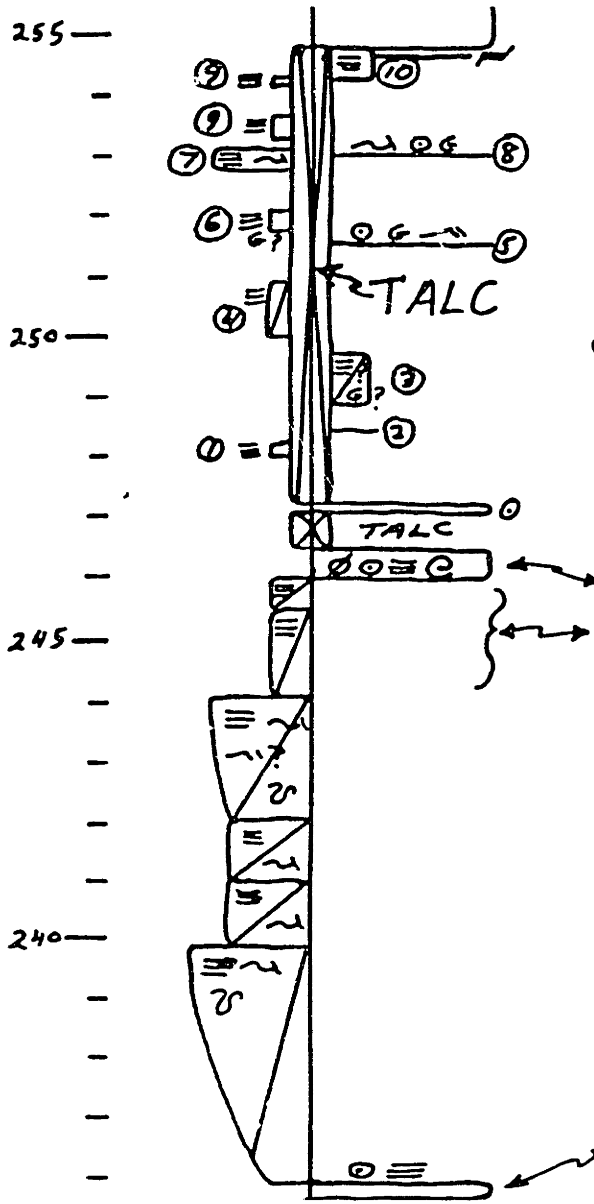
R LIKE 219.5 m. ARENSTS W/ F QTZ-DOLSTS DECR UPWARD ~60% TO 25%

GRAY GREEN LS VF & F AREN W/ SOME MED. QTZ GRAINS; LS ~40-60%. BROWN DOLSTS INTERLAM & ~-FILL, DECR. UPWARD FROM 70% TO ~25% IN TOP 10 cm

BROWN STS GOING UP TO VF SS. SIMILAR TO STS @ 207-210 m. NOTE ALSO INFLUX OF CARBONATE IN UNITS ABOVE.

R'S... F 215 m BUT NO OVERALL CHANGE IN % DOL. ≈ 40%

COVER




(10) LT GRAY LS MOST OR ⊙ PK/GRST. ≡ & POSSIBLY RIPPLED IN ≤1cm → 2 cm BEDS. 1 BED OF LS PK/GRST W/ ~3×8 mm & 3cm THK.

(9) GRAY-GREEN CHLORITIC SH

(8) GREEN LS GRST OF ⊙ & GLAUC. (G) LIKE (5) BUT ~

(7) ORNG-BRWN STS W/ BURST (8) IN IT. PARTS MORE LIKE SILTY SH

(6) GRAY-GREEN CHLORITIC SH W/ OCCASIONAL 2-7 mm LENSES OF VF SAND & POSSIBLE GLAUCONITE.

(5) GREEN LS GRST OF ⊙ (¼ mm, & ⊕) & GLAUC (G) ~¼ mm. MUCH OF RK IS REXLZD TO LS

(4) RED PURPLE MICACEOUS. SILTY SH

(3) PINKISH-ORNG LS MOST, POSSIBLY RIPPLED W/ AT LEAST 2 GREEN LS MOST BEDS < 2 cm THK W/ DK GREEN GLAUC? PELLETS ≤ 2 mm

(2) GREEN GRAY LS MOST 2 cm THK

(1) GREEN, CHLORITIC, SILTY SH

LT GRAY LS ⊙ (¼-1mm) GRST. POORLY SORTED

COVER. TAN, V. GRITTY TALC. ORIGINALLY ORNG DOLSTS?

GRAY-GREEN LS GRST. Ø ≤ 1cm, MOST ~½ cm. ⊙ & COATED GRAINS ~1 mm

LT GREEN CHLORITIC SH

YELLOW-TAN STS W/ SOME STS/VF SAND IN TOP 50 cm

LT GRY-GREEN W/ SOME WEATHERED REDDISH-BRWN STS. BDD ≤ 1cm

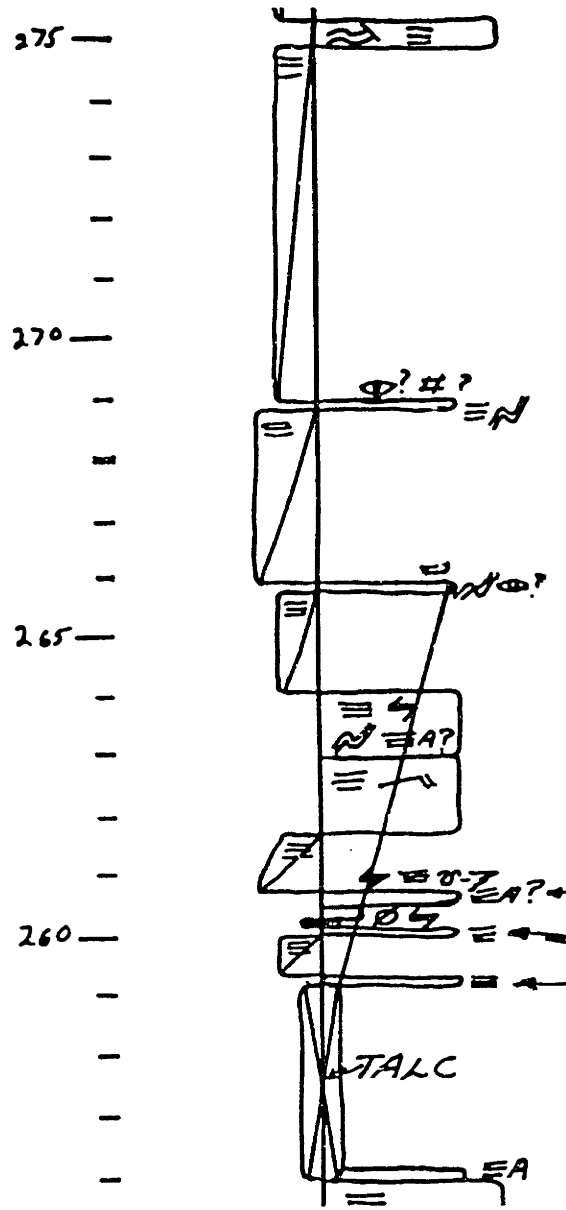
YELLOW-GREEN-TAN MICACEOUS STS. BDD ≤ 1cm

LT GRAY-GREEN VF-F QTZ SS W/ SOME REDDISH-BROWN WEATHERED SURFACES. SEEMS TO CRSEN UP AS BASAL 1m IS MOSTLY GREEN MICACEOUS SH & UPPR 1m MOSTLY SS. BDD ≤ 3cm. SCATTERED PATCHES WEATHER LIKE CARBONATE CEMENTED, BUT MOST IS SILICIOUS CEMENTED.

TAN LS ⊙ (¼ mm) GRST

BROWN F QTZ SS W/ CARBONATE CEMENT } TWO CARBONATE UNITS ARE VERY

[illegible]




LT GRAY, VERY CLEAN LS VF AREN. GRAINS UNIDENTIFIED

RED SH. MUCH GONE TO TALC.

NOTE: ALL RED BEDS COULD BE CLEAVED CHLORITIC MDST W/ CLEAVAGE ≈ PARALLEL TO BEDDING

REDDISH ORNG DOLSTS SIMILAR TO 265.8 m.

CLEAVED RED MDST. LIGHTENS TO BROWNISH GREEN NEAR TOP

BROWNISH ORNG DOLSTS

GREEN, SILTY, MICACEOUS SH

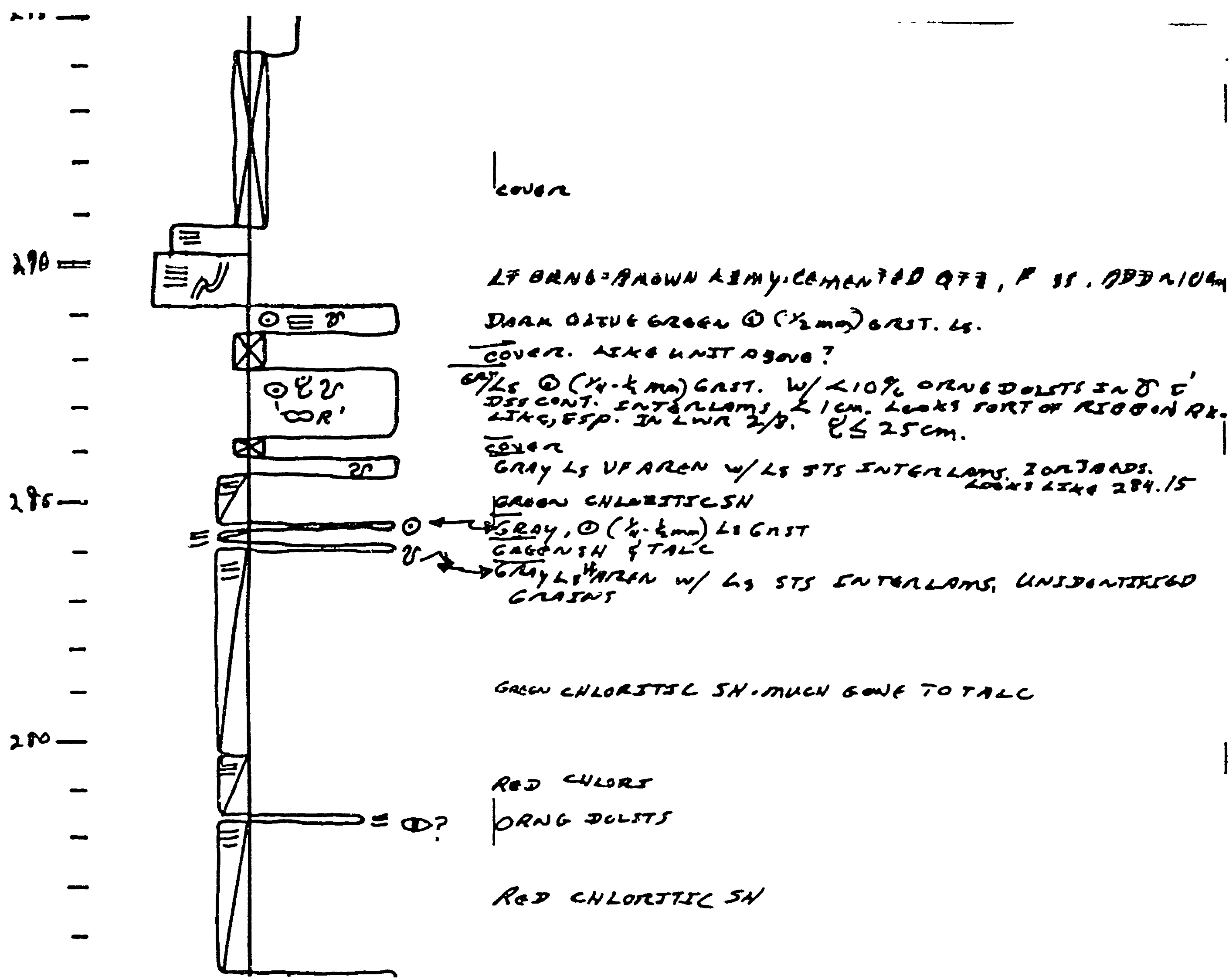
ORNG DOLSTS. MAY BE ≡A, BUT NOT SURE

LT GREENISH-BROWN, LIMY DOL OR DOL'C LS STS. MOST BDDG ≤5 mm. SOME LICN

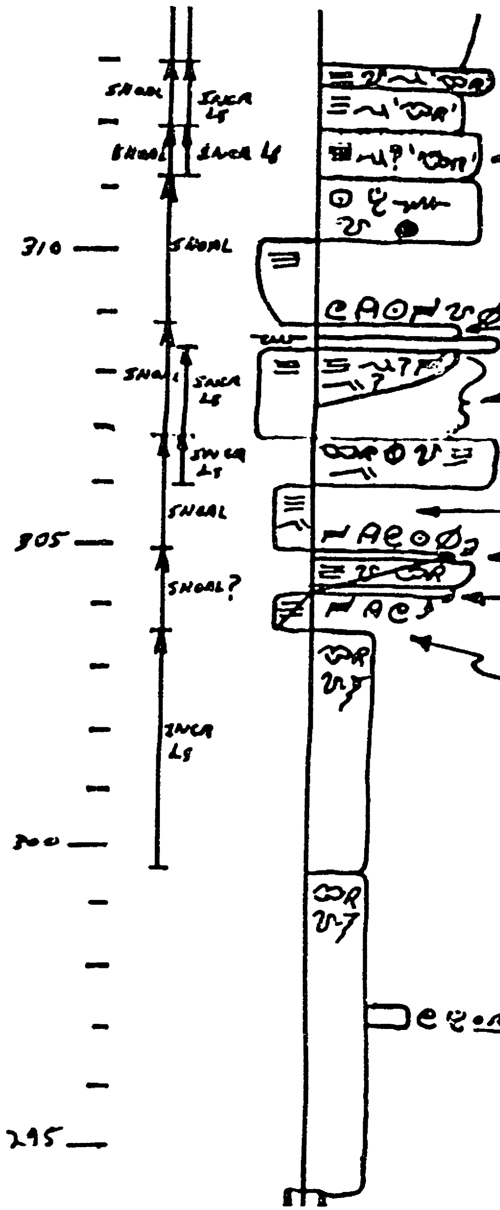
LT GREEN SILTY MDST. CHLORITIC ↑ LT GREEN CHLORITIC SH, MOSTLY TALC.
ORNG DOLSTS. LWR ½ W/ ≡A? 's Nor same. UPPER ½ ...
GREEN LS MOST CLASTS (< ½ x 1 cm) IN ORNG DOLSTS MATRIX? OR ALTERATION OF LS MOST TO DOLSTS? Ø? OR MAY HAVE BEEN ~½ cm Ø BUT ARE NOW PARTIALLY ALTERED
ORNG DOLSTS. LIMY
LT GREEN, CHLORITIC SH
ORNG DOLSTS. LIMY

COVER. PINK, GRITTY TALC. ORIGINALLY SILTY CARBONATE?

ORNG DOLSTS LATERALLY
LT GREY LS AREN W/ UNIDENTIFIED MED-SAND-SIZED GRAIN



290
285
280
COVER
LT BRNG = BROWN LIMY, CEMENTED QTZ, F SS. ODD ~10cm
DARK OLIVE GREEN ⊙ (½ mm) GRST. LS.
COVER. LIKE UNIT ABOVE?
GRY LS ⊙ (¼-½ mm) GRST. W/ <10% ORNG DOLSTS IN ʊ & DISCONT. INTERLAMS, < 1cm. LOOKS SORT OF RIBBON RX. LIKE, ESP. IN LWR 2/3. ʊ ≤ 25cm.
COVER
GRAY LS VF AREN W/ LS STS INTERLAMS, 2 OR 3 BEDS. LOOKS LIKE 284.15
GREEN CHLORITIC SH
GRAY, ⊙ (¼-½ mm) LS GRST
GREENISH & TALC
GRAY LS ¼ AREN W/ LS STS INTERLAMS, UNIDENTIFIED GRAINS
GREEN CHLORITIC SH. MUCH GONE TO TALC
RED CHLORS
ORNG DOLSTS
RED CHLORITIC SH




INTERP. UNIT AS SUB LIMAL

LIKE 311 m, BUT > 60% LS AREN

LIKE 311 m, BUT LESS LS

FINELY INTERLAM'D GRAY LS AREN & LS STS W/ ORNG DOLSTS. BDD ≤ 1cm W/ FEW LS BEDS ≤ 2cm

GRAY LS ⊙ (¼–½ mm) GRST, SOME ⊙ DOL'ZD. BDD 3–15cm, SOMETIMES AMALGAMATED. USUALLY W/ ORNG DOLSTS INTERLAMS ≤ 7cm THK, HOMOG-LOOKING. MAJOR BEDS HAVE RADIAL ⊙

YELLOWISH TAN SH & MDST. CLEAVED CHLORITIC W/ LS STS INTERBEDS. SOMEWHAT LIKE 307, BUT LESS CARBONATE.

GRAY LS PKST W/ ORNG DOLSTS IN ⅋ & DISCONT LAMS. TOP 05cm CLEANER & W/ ½ cm Ø

GRAY & ORNG LS ⊙ (~½ mm) GRST PARTIALLY DOL'ZD. MOSTLY ⅋

LT YELLOWISH-TAN SSL. MOST W/ INCR ≤ 1×2cm SN/BASE IN INTERBEDS OF LS STS RIPPLES (A WAVY-LENTICULAR FABRIC) TOPPED BY A 3–4 CM THK PKST W/ RNDD LS STS ≤ ½×4cm

[illegible]

BDD 1–3cm W/ SOME 8cm. ORNG DOLSTS INTERLAMS ≤ 1cm & IN ⅋.

YELLOWISH-GREEN SH, CLEAVED, CHLORITIC, MICACEOUS, W/ LS STRINGERS OF PKST < 1cm THK, & < 1cm SILT

BROWNISH GRAY PKST (LS). NODORENITE, SUBRNDD, MOSTLY ≤ 1×3cm IN DOLSTS & @ MATRIX. ⊙ & Ø IN TOP 1–2cm. ⊙ ~ ½ mm. Ø ~ 2–3cm

GRAY NODULAR [illegible] OF LS AREN & BRWN DOLSTS. SMALL ⅋ ≤ 2mm. BDD ~1cm. INCR LS UPSECTN

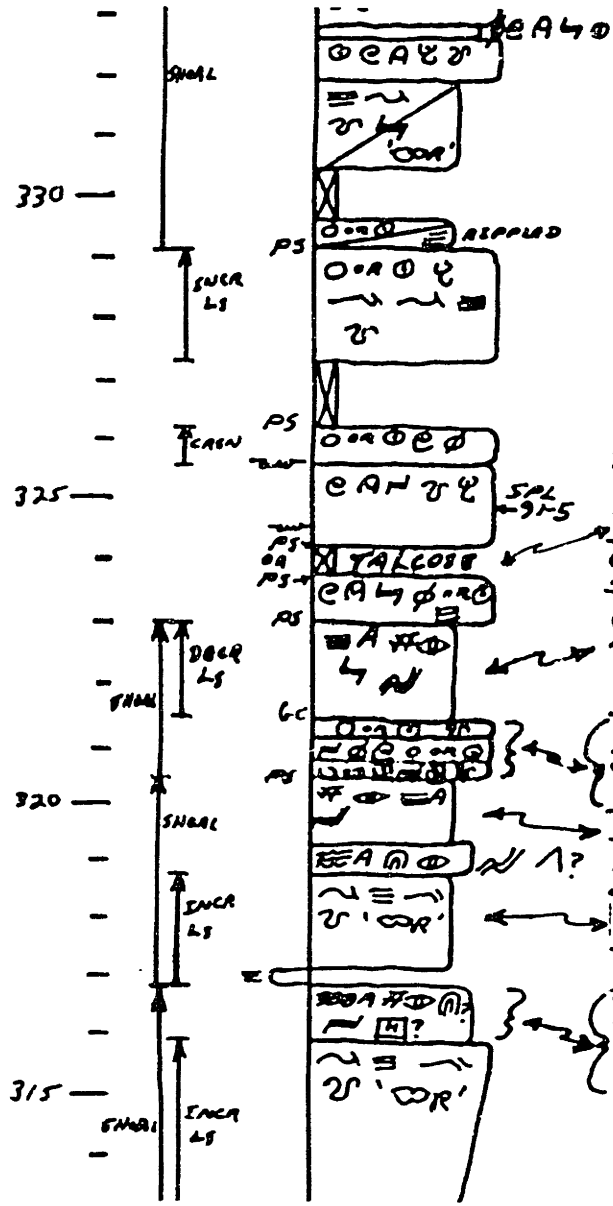
DOLSTS & MOST @ MATRIX W/ RNDD OF LS STS & SH. 2 OR 3 BEDS. ≤ 2×6cm W/ MOST 1×3cm. ORIENTED NORTH

LT YELLOWISH GREEN, MICACEOUS SH. V. POORLY EXPOSED

DK GRAY LS MDST. ORNG-BROWN DOLSTS IN ⅋. A FEW ⅋ FILLED W/ SPAR, ≤ 3mm [illegible]. LS BDD ≤ 5cm. [illegible] DOLSTS LAMINAE THAT ARE WAVY & DISCONT & ≤ ~8mm. DOLSTS DECR FROM ~25% IN BTM 60cm TO ≤ 10%

RIBBON RK LIKE 301 m EXCEPT DOLSTS ≈ 15–20% W/ NO VERTICAL CHANGE

30cm THK ESSENTIALLY UNBURROWED INTERVAL. LS @ WKST, BDD 1–2cm, INTIMATELY INTERLAM'D W/ LS STS BEDS 1–2cm THK. SOME BEDS ALMOST PKST. ON LOW-ANGLE ⅋




GRY LS AN/GRST, C-VC. Ø ≤ ½ cm

GRY LS ⊕ (~½ mm), GRST W/ ORNG DOLSTS INTERLAMS (≤ 5 mm) & [illegible]-FILL. [illegible] ≤ 20 cm. BASAL 20 cm W/ [illegible] & FRAGMENTS

GRY LS (VF) STS, BDD ≥ 3 cm W/ CONT. ORNG DOLSTS INTERLAMS (≤ 5 mm) & [illegible]-FILL. [illegible] MOSTLY LS ≤ ½ x 3 cm IN OCCASIONAL LAYERS.

COVER. PROBABLY LIKE BED IMMED. ABOVE & BELOW. POSSIBLY [illegible] ⊕ (~½ mm) [illegible] WAST ≈ 2 cm THK IN MDL OF COVER

GRY LS STS, FINE ORNG DOLSTS INTERLAMS [illegible]. LS MAY BE RASHED

GRY LS ○/⊕ (VF, MOR. ⊕) GRST, BDD 1-5 cm. TAN & ORNG DOLSTS INTERLAMS ~1 mm → 1 cm THK, W/ A COUPLE 4-6 cm BEDS NEAR BTM. [illegible]. [illegible] UNCOMMON & FILLED W/ DOLSTS. V SLIGHT UPWARD INCR IN GRAIN-SIZE IN LS.

COVER PROBABLY LIKE BASE OF UNIT ABOVE W/ MORE DOLSTS

GRY LS ○/⊕ (LWR VF TO UPPER VF) GRST. @ (ECHIN.?) & Ø (< ½ cm) IN UPPER BEDS. OCCASIONAL DISCONT. ORNG DOLSTS INTERLAMS ≤ 5 mm

GRY LS GRST SIMILAR TO 323.5, C-VC. @ [illegible]. MANY GRAINS DOLZD. ESP [illegible] ≤ 1 x 2 mm. [illegible] ≤ 35 cm. FEW [illegible] SOME ORNG DOLSTS INTERLAMS (& DRAPES?) ≤ 3-5 mm THICK.

COVER. TAN, SLIGHTLY SILTY, TALCOSE. ORIGINALLY ORNG DOLSTS?

GRY LS GRST, MOSTLY VC. BDD 2-15 cm W/ SOME 1-4 cm BEDS, [illegible] & OF VF ○/⊕. @ ARE [illegible]. MANY GRAINS DOLZD.

ORNG DOLSTS W/ THIN (MM THK) [illegible] INTERLAMS OF GRY ⊕ LS. MOST LS THIN [illegible] & IS LEAST ABUNDANT OVER [illegible] 40-50 cm. [illegible] (~2 mm x 1 cm) OF ORNG DOLSTS. MORE ⊕ ABN IN LS THAN IN DOLSTS

3 GRY LS INTERVALS, EA. W/ ORNG DOLSTS INTERLAMS & [illegible]-FILL. MOST LAMS IN MDL UNIT, LEAST IN BTM. BASAL 5 cm W/ [illegible] [illegible] MDL UNIT A MIX OF MOST (OR VF-SLT) & GRST W/ [illegible] OF GRY LS, Ø (< ½ cm), @ & ○/⊕ (~½ mm)

ORNG DOLSTS W/ [illegible] OF SAME

GRY [illegible] A LS W/ ORNG DOLSTS INTERLAMS. MUCH OF [illegible] A GOING TO [illegible] 1-2 cm HI & WIDE. SOME [illegible] A VERY CLEAN. POSSIBLE [illegible]

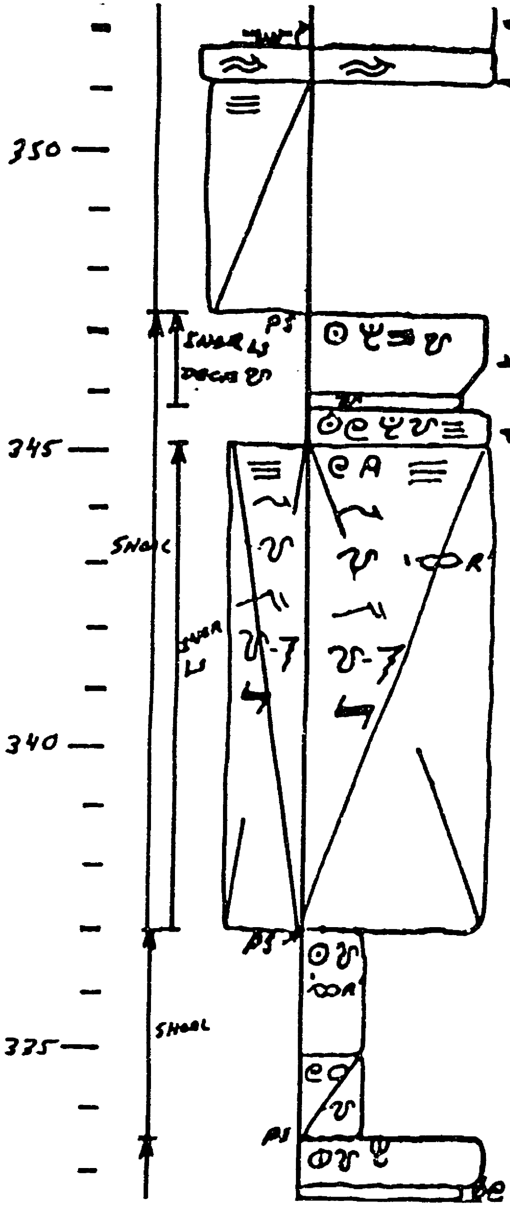
GRY LS AREN W/ ORNG DOLSTS INTERLAMS & [illegible]-FILL. LS BDD 1-5 cm. SIMILAR TO 315 M

YELLOWISH TAN SH W/ NUMEROUS LS STRINGERS

ORNG DOLSTS INTERLAMS IN GRY [illegible] A. BOTH IN MM LAMINAE. SMALL (≤ 5 x 5 mm) [illegible] OF [illegible] A. SOME ⊕ HAVE SQ. TERMINATIONS & MAY BE HALITE MOLDS [illegible] [illegible] TO BE [illegible] ≤ 3 cm ACROSS. [illegible] A MATS ARE MUDCRACKED W/ ~15-20 cm BETWEEN [illegible]. ⊕ IN TOP 15 cm MOSTLY

INTERBEDDED GRY LS AREN & ORNG DOLSTS. MOST [illegible] IN LS. NOT A LOT OF [illegible]. LS BDD ≤ 2 cm, DOLSTS ≤ 5 mm. TOP 60-70 cm OF LS BDD ≤ 5 cm

INTERP. UNIT AS SUBTIDAL




[illegible] ACCENTUATED BY DISSOLN?
GRY LS VF-F ARGN, BDD ~1-8 cm, W/ TAN DOLSTS INTERLAMS, ≤ 1½ cm, MOST ≤ 1 cm. UNCOMMON [illegible]. SOME ~1 mm [illegible] IN UPPER BEDS. ~2 cm RELIEF ON LWR CNTC. SCOUR ACCENTUATED BY DISSOLN?

DOL-CEMENTED VF-F QTZ SS & VF-F LS ARGN W/ QTZ GRAINS IN ≥ 3 SETS OF BROAD LOW ANGLE [illegible] MADE UP OF ~1 CM THK ALTERNATING LAMINA-SETS OF QTZ SS & LS ARGN

REDDISH BROWN DOL-CEMENTED QTZ VF SS. NO [illegible]. NO [illegible]. NO [illegible]. MAY ACTUALLY BE BROAD, LOW-ANGLE [illegible] LIKE OVERLYING UNIT

GRY LS [illegible] GRST & ARGN W/ ↑ DECR. AMTS & THICKNESS OF ORNG DOLSTS INTERLAMS [illegible] ½-1½ mm W/ TOP 10 cm BED ¾-1½ mm. GEN'L CRSN ↑ TREND W/ MORE VF & F ARGN BEDS TOWARD BTM. BDD ≤ 2-20 cm. THKR BEDS ARE [illegible] & [illegible].
ORNG DOLSTS & GRY LS ARGN ≥ 50% DOLSTS

GRY LS [illegible] (≤ ½ mm) GRST & VF LS ARGN. BDD 1-8 cm W/ 1-2 mm INTERLAMS OF REDDISH-ORNG DOLSTS & [illegible]-FILL. SOME [illegible] IN ARGN IN LWR BEDS, [illegible] IN UPPR. SLIGHT CRSN UPWARDS

V. POORLY EXPOSED INTERVAL OF [illegible] FINE INTERBEDDED SILTSTONE & LS ARGN. STS SS TAN, LT BRWN & ORNG & SS A MIX OF DOLSTS & SILICEOUS STS-PROB. SOME SIL. CEMENT. LS SS LT GREEN, VF ARGN W/ SOME DOLZTN. LWR 2/3 OF INTERVAL W/ LESS LS THAN UPPR ⅓. MOST BEDS ≤ 2 cm. [illegible] TRACES IN ALL LITHOLOGIES. SOME LS NEAR TOP W/ [illegible] & [illegible]. LESS [illegible] IN SOME BEDS IN TOP ⅓. OTHERS [illegible]

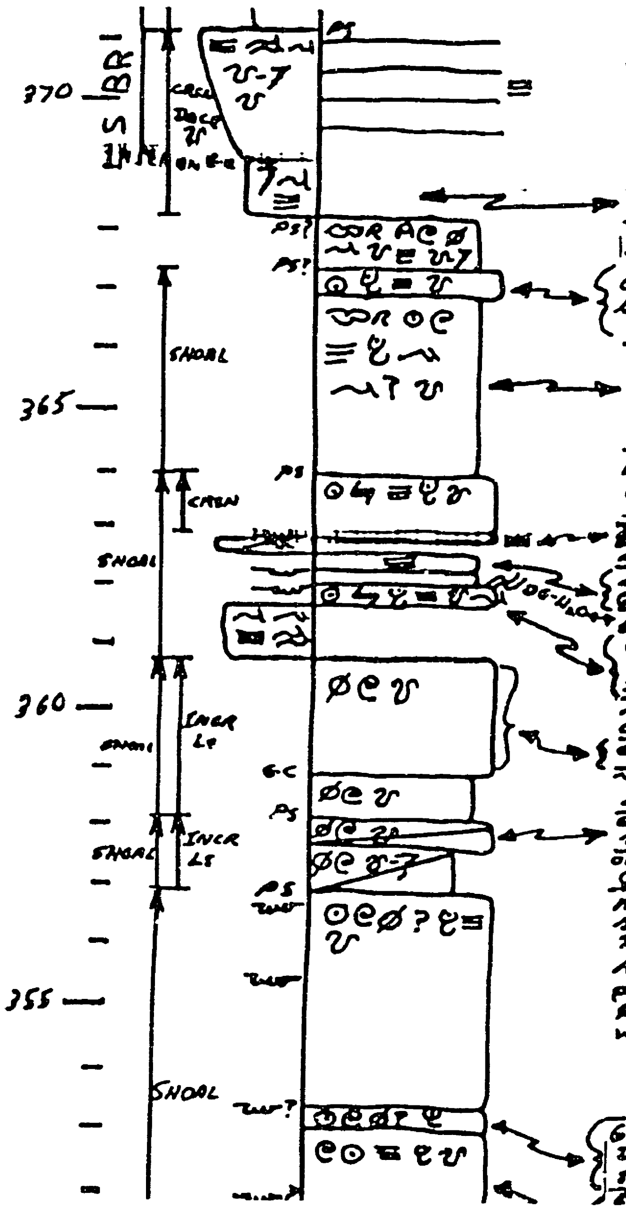
INTERP UNIT AS SUBTIDAL.

GRY LS MDST, BDD ~1-3 cm, W TAN DOLSTS INTERLAMS (1-3 mm) DISCONTINUOUS. OCCASSIONAL [illegible] WK/PKST BEDS NEAR TOP OF UNIT. WEATHERS AS A LEDGE IN COMPARISON TO RECESSIVE WX UNIT BENEATH. [illegible] W/ DOLSTS FILL

GRY LS MDST, BDD ≤ 4 cm W/ OCCASIONAL [illegible] WKST & TAN DOLSTS IN CONT. INTERLAM (≤ 5 mm) & IN [illegible]

GRY LS [illegible] (4-6 mm) GRST. SOME THIN & ORNG DOLSTS DISCONT. INTERLAMS & [illegible]-FILL. SOME [illegible] FILLED W/ [illegible]

GRY LS PK/GRST. C→VC. [illegible] ≤ ½ cm




ADD ≤ 7CM

BRWN VF & F QTZ SS INTERBDD W/ SILTY VF SANDY, MICACEOUS MDST. SS ADD 2-8CM, SOME BEDS [illegible], USUALLY THIN ≤ 1CM. OCCASIONAL CARBONATE-CEMENTED LS AREN BEDS, ≡, ≤ 2CM. OFTEN ALTERNATING [illegible] & PRIMARY SED STRUCTURED BEDS

DRAB, BROWNISH-GREEN SILTY VF SANDY, MICACEOUS SILTSTONE MDST. MOSTLY [illegible], BUT HAVE SOME REMNANT SED. STRUC. ADD MM-1CM

~50-60% ORNG-BRWN DOLSTS W/ GRAY-GREEN LS AREN & PK/GRST. LS ADD ≤ 2CM, DOLSTS ADD ≤ 2CM. SOME BEDS [illegible]. [illegible] ≤ 1CM, UNCOMMON

GRY LS ⊙ (1/4 MM) GRST W/ MANY ⊙ DOL'ZD. LS ADD 2-10CM. BRWN ORNG DOLSTS MOSTLY ≡, ≤ 1CM W/ ONE LENTICULAR ≡ BED ≤ 10CM THK. UNCOMMON [illegible]

[illegible] TEXTURE W/ LS ⊙ (1/2-1/4 MM) GRST & VF-F AREN. OCCASIONAL @ IN LS. ADD ≤ 1-4CM LS, ADD ≤ 2CM DOLSTS. LS GRAYISH GREEN. DOLSTS BROWNISH ORNG. LOTS OF ⊙ DOL'ZD. ~40-50% DOLSTS OVERALL

BROWNISH-GREEN LS ⊙ (1/2-1/4 MM) GRST W/ MANY ⊙ DOL'ZD. ADD 2-10CM. [illegible] UNCOMMON. FEW DOLSTS [illegible]. ⊙ CRSN UPWARD OVERALL. DOLSTS INTERBEDS ≤ 3CM, ≡.

[illegible] VF AREN. MM-LAMD W/ RARE [illegible]

BROWNISH ORNG DOL-CEMENTED VF QTZ SS

LS & DOLSTS – VF AREN. LS ADD ≤ 1-4CM. DOL ADD 3MM-1CM. LS GRAYISH-GREEN. DOL BROWNISH ORNG

LENTICULAR LS & DOL STS – VF AREN. THINS LATERALLY TO ≥ 50CM. FLAT TOP?

GRY LS ⊙ (1/2-1/4 MM) GRST W/ ⊙ PARTLY DOL'ZD. [illegible] ≤ 15CM. ADD 1-35CM. ORNG DOLSTS 1-3CM W/ LENTICULAR BED ≤ 15CM. DOL STS [illegible]. RIPPED-UP DRAPES

MOSTLY LT GRAYISH-GREEN [illegible]. STS & VF SS. SOME ≤ 2CM [illegible]. LT GREEN VF LS AREN INTERBEDS IN LWR FEW 10'S CM. LS INTERBEDS [illegible] GRY ⊘@ PK/GRST ADD 2-8CM W/ ORNG DOLSTS INTERLAMS ≤ 1/2 CM

~50% ORNG & REDDISH ORNG DOLSTS INTERBDD W/ ⊘@ PK/GRST (⊘ ≤ 1CM). LS ADD ≤ 2CM. DOLSTS ≤ 1CM. MORE [illegible] THAN UNIT ABOVE.

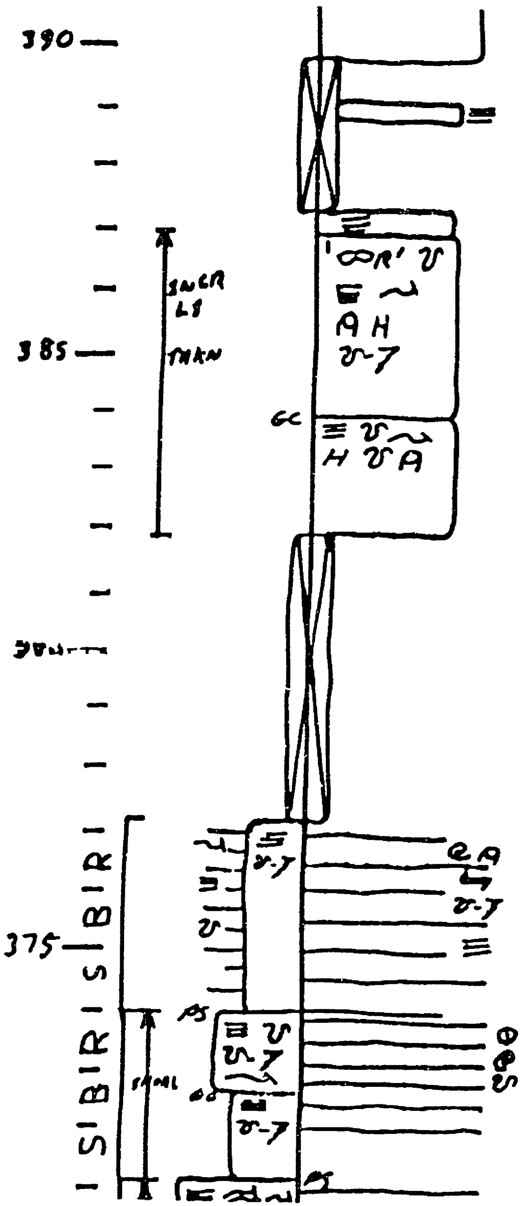
GRY LS ⊘ (≤ 1CM) @ AREN/GRST W/ DISCONT. INTERLAMS OF ORNG DOLSTS. ADD 1-2CM.

ORNG-RED & BRWN DOLSTS W/ BLEBBY INTERBEDS OF LS ⊙⊘ PK/GRST. ⊘ ≤ 1CM. ADDG ≤ 1CM

MOTTLED LT & DK GRY LS GRST & AREN. MOST GRST ARE ⊙ (1/2-1/4 MM) BUT CRSR-GRND BEDS [illegible] HAVE ⊘ (≤ 5MM) & @. SLIGHT CRSN TREND. ADD 1-15CM. TAN DOLSTS INTERLAMS, ≤ 1/2 CM. SCOUR SURFACE AT 355.4M, W/ ≥ 15CM RELIEF, HAS FEW MM-1CM THK DOLSTS BED ON TOP. BELOW SURFACE IS ⊙-@ [illegible] & ABOVE DOLSTS IS ⊙-@-⊘ [illegible]. ⊘ MAY BE LS [illegible] (RNDD). TOP 15-20CM HAS ⊘ ≤ 1/2 CM IN A @ GRST W/ UPWARD FINING & A 2-3CM RELIEF SCOURED BASE.

GRY LS ⊙ (1/2-1/4 MM) GRST W/ @ & ⊘ (≤ 5MM) IN UPPER [illegible]. ADD 5-10CM. DISCONT. TAN DOLSTS INTERLAMS. ~10CM RELIEF ON UPPER CNTC – SCOUR ACCENTUATED BY DISSOLN?

[illegible] LS VF-F AREN ADD [illegible]




COVER EXCEPT FOR 40 cm OF DOLSTS LIKE 387.0 m W/ MORE LS BEDS < 1 mm. DIAGENETIC? ▬ A? ▬ @?

ORNG DOLSTS W/ BDDG < 5 mm. INTERLAMS OF LS STS ≤ 3 mm. BEDS OF GREEN LS < 1 mm. DIAGENETIC?

LIKE UNIT IMMED BELOW, ALTERNATING LS & DOLSTS. LS HOMOG. VF STS OR MDST. LS STS ALSO W/ ▬, ~, SOME V-7. LS BDD ≤ 4 cm, MOST ~ 1 cm. ~ 50-60% LS. DOLSTS ≤ 1-2 cm, MOST < 1 cm. '▬'-LIKE EXCEPT FOR SMALLER V

MOSTLY ORNG DOLSTS, SUB-mm LAM'D & IN BEDS ≤ 1 cm, W/ INTERBEDS OF LT GREEN LS STS. BOTH ▬. V (1-2 mm), ~, NO #, NO ⦶, NO ^, NO ▬A, NO A. SOME LS BEDS HOMOGENOUS(?). LS MOSTLY ≤ 1 cm, A FEW ≤ 2 cm. ~ 20-30% LS. RARE TO UNCOMMON A FRAGMENTS IN LS

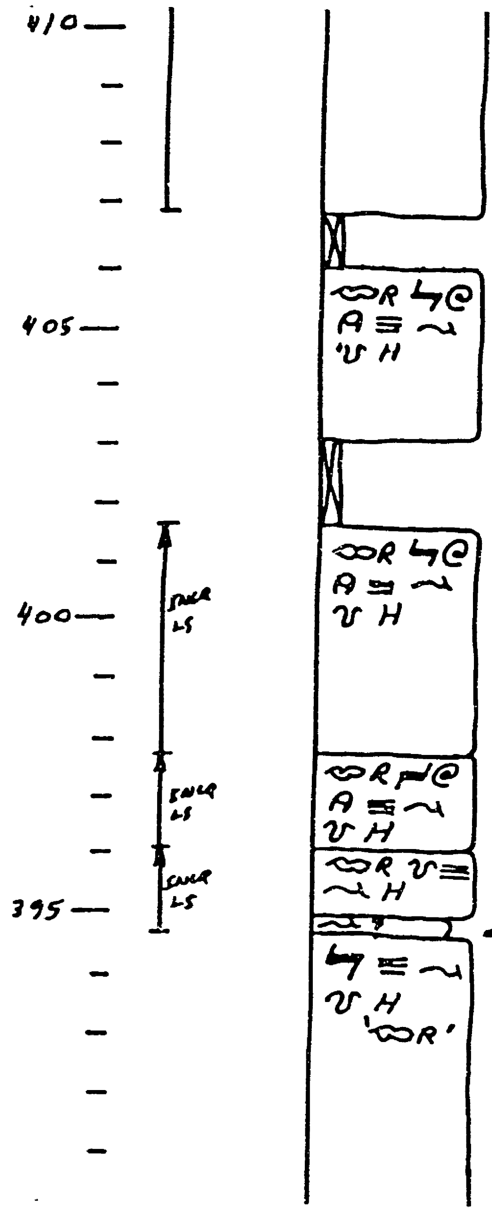
[illegible] [illegible]. [illegible] [illegible] [illegible] BROWNISH-[illegible], SILTY, MICACEOUS MDST W/ V-7 & ≡ PEEKING OUT THRU THE COVER.

BACKGROUND SEDS: DARK BROWNISH-GREEN TO REDDISH-BROWN, SILTY, MICACEOUS MDST. REDDISH-BROWN QTZ STS & VF SS INTERBEDS ≤ 4 cm. LS PART W/ ▬ OF STS & V FILLED W/ STS, MOSTLY V-7. OCCASIONAL VF LS AREN W/ ▬

~ 60% ORNGSH-BROWN STS & VF QTZ SS CMTD BY DOL. W/ THIN (≤ 4 cm) INTERBEDS OF LS VF AREN & ⊙·@ AN/EAST. MOST LS BDD ≤ 1-2 mm. FEW ~

DRAB, BROWNISH-GREEN, SILTY, MICACEOUS MDST W/ ▬ LS-CMTD/LS VF AREN INTERBEDS ≤ 2 cm. LESS Vb THAN 368.5 m. STS & SS BDD ≤ 8 cm

[illegible]




LAMS ≤1cm & V.
TOP BED SS 5cm THK [illegible] A PK/CAST OF LS.

COVER

LITHS AS 395.5m FOR LS, BDD ~8cm, ≥ 3 BEDS 3-8 cm of -@-A PK/CAST. ≤5-8% LIMY, GREEN, BROWN, RED DOLSTS, MOSTLY IN ZA & A FEW ≤5mm INTERLAMS. [illegible] ≤1x1cm CF W/ IN 395→401.65m W/ ≤1x5cm.

COVER

SAME LITH AS 395.5m. LS BDD ~10cm. ≥ 5 BEDS OF LS -@-A CAST 5-10cm THK SCATTERED IN UNIT, MOSTLY IN LWR ⅔. DOLSTS BDD ≤5mm EXCEPT FOR BASAL 35-40cm WHERE BDD 2-10cm & ≡, ~. ABV 35-40cm ~30-40% DOLSTS. QUICKLY DROPS TO ≤5-8%, MOSTLY IN V. IN UPPER PART OF UNIT DOLSTS GOES TO GREEN LIMY STS.

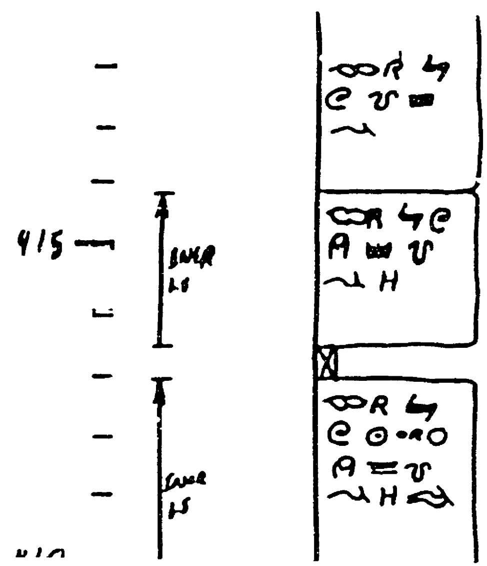
SAME LITH AS 395.5m. LS BDD ≤12cm. ~15→20% DOLSTS UP TO ~5-10%. HAVE A 12cm THK (LS)-@-A CAST W/ 3-4cm OF LS STS ON TOP, AT THE TOP OF THE UNIT.

GRY LS VF ARGN STS & MDST (O PK/CAST?), BDD ~5cm. ARGN STS W/ ≡, ~. MDST H. ~15% TAN DOLSTS IN V & ≤2cm INTERLAMS.
{~80% ORNG DOLSTS W/ ~1x4cm CLASTS OF LS STS & SOME LAMS ≤1cm IN BASAL 10cm. ~?

GRY LS VF ARGN & STS. BDD ≤1cm→5cm, ≡, ~, H. SOME LS MDST/O PK/CAST H. A FEW BEDS W/ OF SOME & OF ORNG DOLSTS. DOLSTS ALSO INTERLAMD, ≤1½cm & FEWER THAN LS STS. ≡. ~60% LS W/ LITTLE VERT. CHANGE. FEW V.

SECTION 90-6

MONTGOMERY HILLS, NV.




FEW STS INTERLAMS. MOSTLY GREEN OR RED & LSMY. LS SS GRAY GRY THAN BELOW, COARSER W/ MORE [illegible] ANGAST [illegible]. A FEW SPAR-FILLED V. [illegible] OCCUR ~10-15m ABOV & THIS UNIT, MOSTLY ≤ ½-1cm.

BONANZA KING. CONTACT SOMEWHAT GRADATIONAL COULD PROBABLY MOVE UP 1→5m

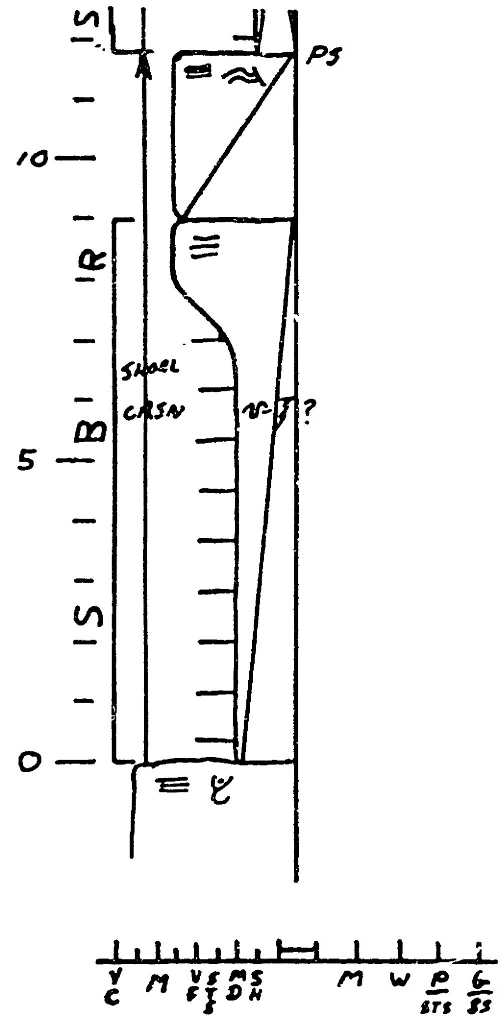
LITHS LIKE 405m. LS [illegible] ~10 cm W/ [illegible] BEDS OF [illegible] 5-10 cm THK (INCL TOP BED). DOLSTS [illegible] TAN, RED, GREEN [illegible] [illegible], MOSTLY IN [illegible] [illegible], [illegible] IN LOWER [illegible] HALF. [illegible]

COVER

LITHS LIKE 405m. LS BDD ~10 cm W/ ≥5 BEDS OF [illegible] GRST 3-10cm THK & 1 BED OF ⊙/O (~1mm) [illegible] (~1-2mm) GRST 5cm THK. DOLSTS ST TAN, GREEN, RED & LSMY. 5-10% OVER MOST OF UNIT, USUALLY IN [illegible].

ABOUT 20-30 cm W/ ~15-20% ORNG & RED DOLSTS IN INTER-

[illegible]




WHITE, CLEAN, F QTZITE

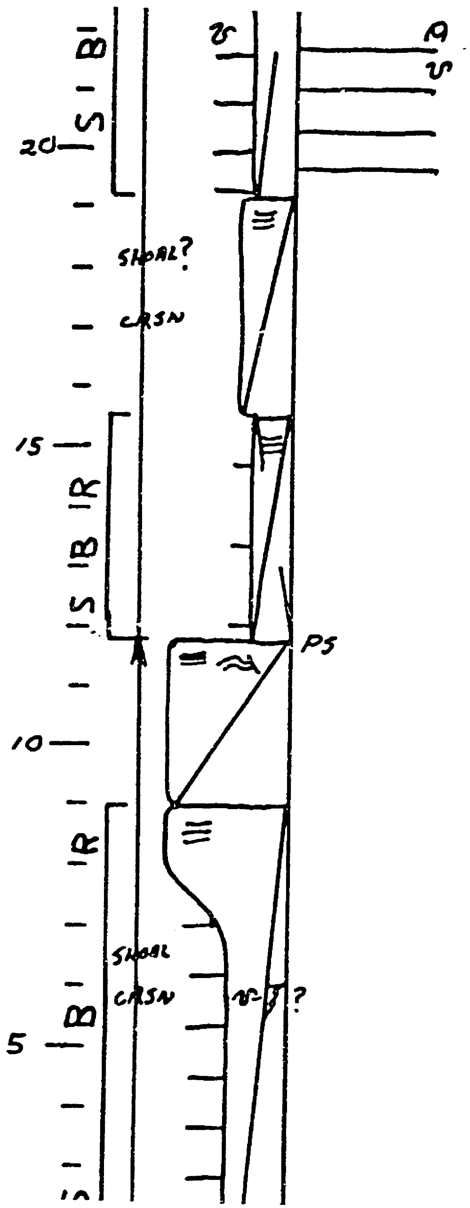
REDDISH-PURPLE, SILTY, VERY MICACEOUS SILICIOUS MOST W/OCCASSIONAL SILICIOUS VF SS, ≡, INTERBEDS ≤5 CM THK. MOSTLY COVERED. TOP ½M IS A MUDDY MICACEOUS F QTZ SS, REDDISH GRAY

CARARRA FM.

ZABRISKIE QTZITE.

WHITE TO CREAMY TAN, M-C QTZITE. V. BADLY FRACTURED & SLICKENSIDED

SMITH, BAXTER MINE, NO. RESTING SPG RNG




- REDDISH-BROWN LS-CEMENTED VF [illegible]
POSSIBLY MUDDY MATRIX
③ GRAYISH-BRWN VF QTZ-CEMENTED QTZ SS, BDD ≤ 3 cm.

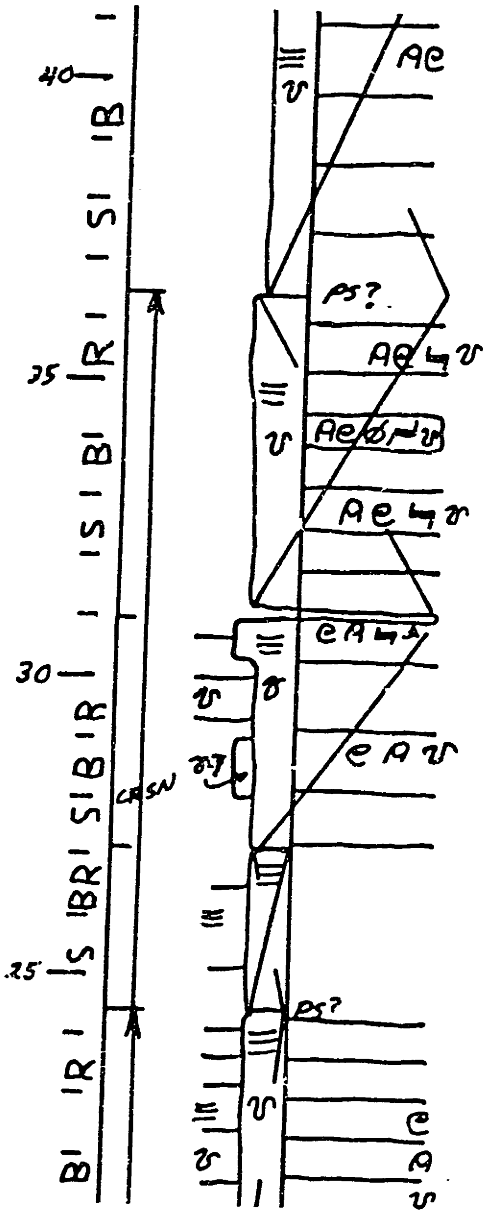
ALL LITHS w/ V. MOST SS IN UPPR 1 m. OVERALL UPWARD INCR IN EVENT BEDS

MOTTLED RED, REDDISH-PURPLE, GREEN, GREENISH-YELLOW, SH → MDST. MICACEOUS, SILTY TO VARYING EXTENT. OVERALL A BIT CRSR & THKR LAMD THAN 14 m

GREEN, CHLORITIC, MICACEOUS, SLIGHTLY SILTY SH. OCCASIONAL: A MDST BED A FEW cm THK.

WHITE, CLEAN, F QTZITE

REDDISH-PURPLE, SILTY, VERY MICACEOUS SILICEOUS MDST W/ OCCASSIONAL SILICEOUS VF SS, ≡, INTERBEDS ≤ 5 cm THK. MOSTLY COVERED. TOP 1-2 m IS A MUDDY MICACEOUS F QTZ SS, REDDISH GRAY




BACKGROUND: GREEN TO PURPLISH-GRAY, MICACEOUS, CHLORITIC, SLIGHTLY SILTY SH. W/EVENT BEDS OF AC LS WK/PKST, BDD 1-3 cm.

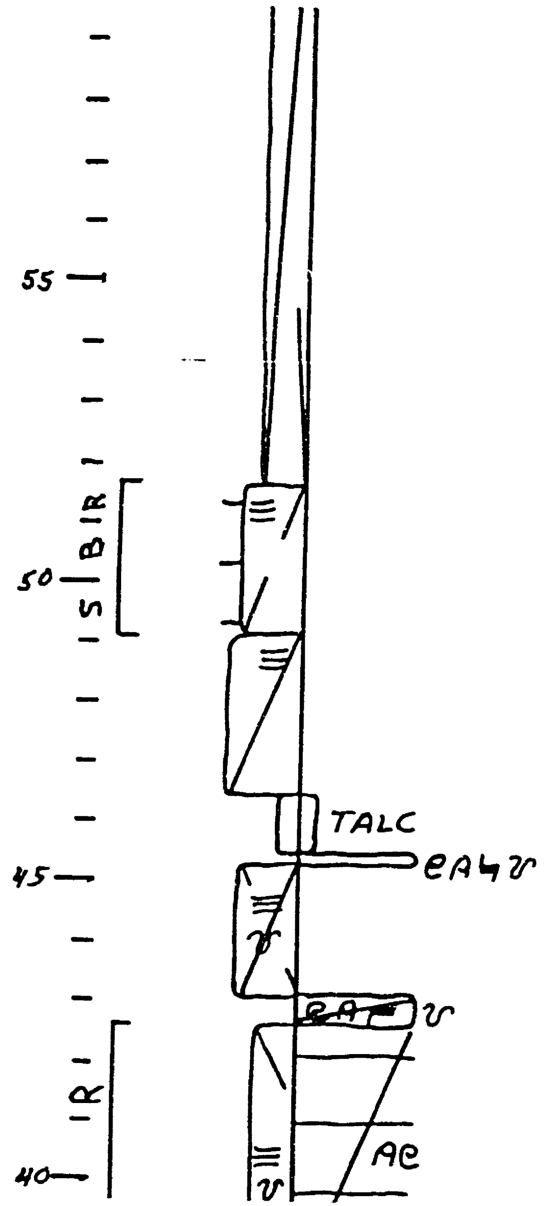
BACKGRND BEDS ARE A MIX OF GREEN, MICACEOUS, CHLORITIC, SLIGHTLY SILTY SH & PURPLISH-GRAY, MICACEOUS, SLIGHTLY SILTY SILICEOUS MDST.
EVENT BEDS OF LS Ae bg WK/PKST, KHAKI GREEN → YELLOWISH GREEN, BDD 2-5 cm. AT ~ 34 m, HAVE ONE 30-40 cm THK Aeø bg WK/PKST, BDD 2-5 cm. ø ≤ 5 mm, OFTEN W/ A FRAG. AS A CORE.
ALL LITHS W/ ϑ

KHAKI-BROWN LS PKST W/ ITS bg ≤ 1x8 cm, MOST ≤ 1x2 cm

4 LITHS: BACKGRND: ① GREEN, MICACEOUS, CHLORITIC, SLIGHTLY SILTY SH. DOMINANT IN LWR 1 m & UPPR 2 m
② PURPLISH-GRAY, MICACEOUS, SILTY MDST. ϑ-7 IN 38-39 m.
EVENT BEDS: ③ KHAKI-GREEN LS eA PKST. IRREG & LENTICULAR ≤ 1 cm x ~10-40 cm
④ LS-CEMENTED VF QTZ SS, BEDD ≤ 2 cm, ≡
ALL LITHS W/ ϑ

GREEN, REDDISH-PURPLE CHLORITIC, MICACEOUS, SLIGHTLY SILTY SH W/ OCCASIONAL 1-2 cm THK, VF, MUDDY, ≡, MICACEOUS QTZ SS

4 LITHS: BACKGRND IS REDDISH-PURPLE UP TO GREEN, (50/50) CHLORITIC, MICACEOUS, SILTY SH.
EVENT BEDS: ① REDDISH-BROWN LS eA, PKST, BDD ≤ 1-5 cm
② REDDISH-BROWN LS-CEMENTED VF QTZ SS, BDD ≤ 2 cm. POSSIBLY MUDDY MATRIX
③ [illegible]




PURPLISH-GRY, MICACEOUS, CHLORITIC, SLIGHTLY SILTY SH
MOSTLY COVERED

LT YELLOWISH-GREEN TO MOTTLED REDDISH GRY, MICACEOUS, CHLORITIC, SILTY MDST. BLOCKY WEATHERING. OCCASIONAL VF STS BEDS, ≤5cm, ≡

BROWNISH-GRY, V. SLIGHTLY SILTY, MDST TO MUDDY STS. MICACEOUS TO CHLORITIC IN PARTS. BLOCKY WEATHERING

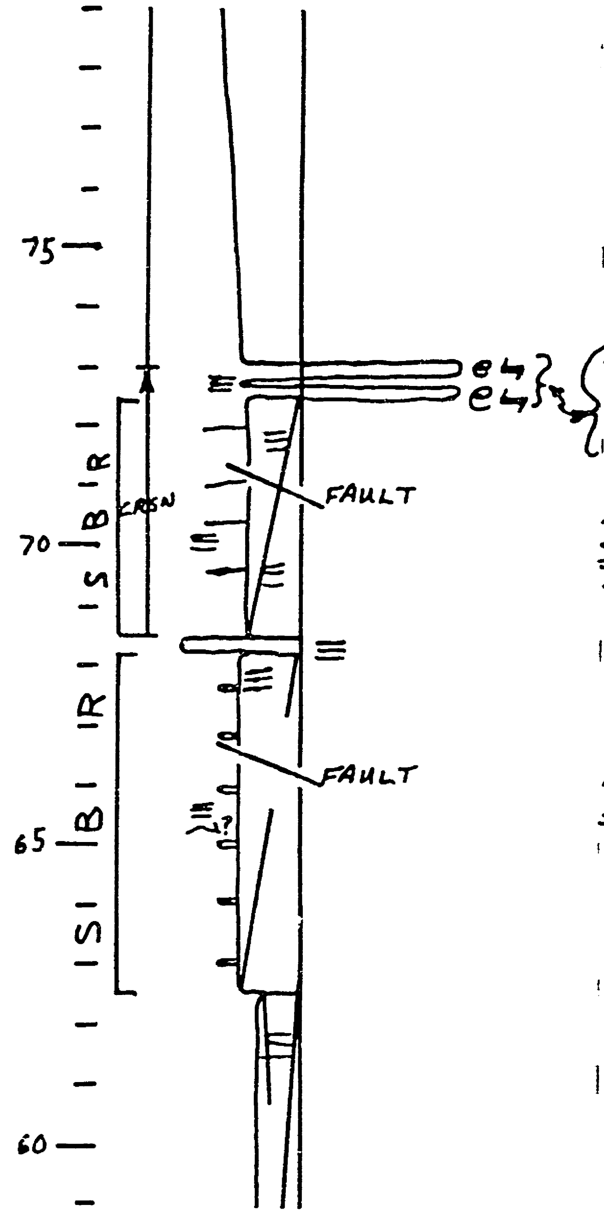
TAN, SLIGHTLY SILTY TALC

LIKE 43m

REDDISH-GRY, SILTY, MICACEOUS MDST W/ SOME PARTS ALMOST MUDDY STS

LT GREEN LS WA/PKST. LOTS OF BROWN DOLSTS IN V, & BLEBS. SORT OF OOR-LIKE.

BACKGROUND: GREEN TO PURPLISH-GRY, MICACEOUS, CHLORITIC, SLIGHTLY SILTY SH. W/EVENT BEDS OF AC



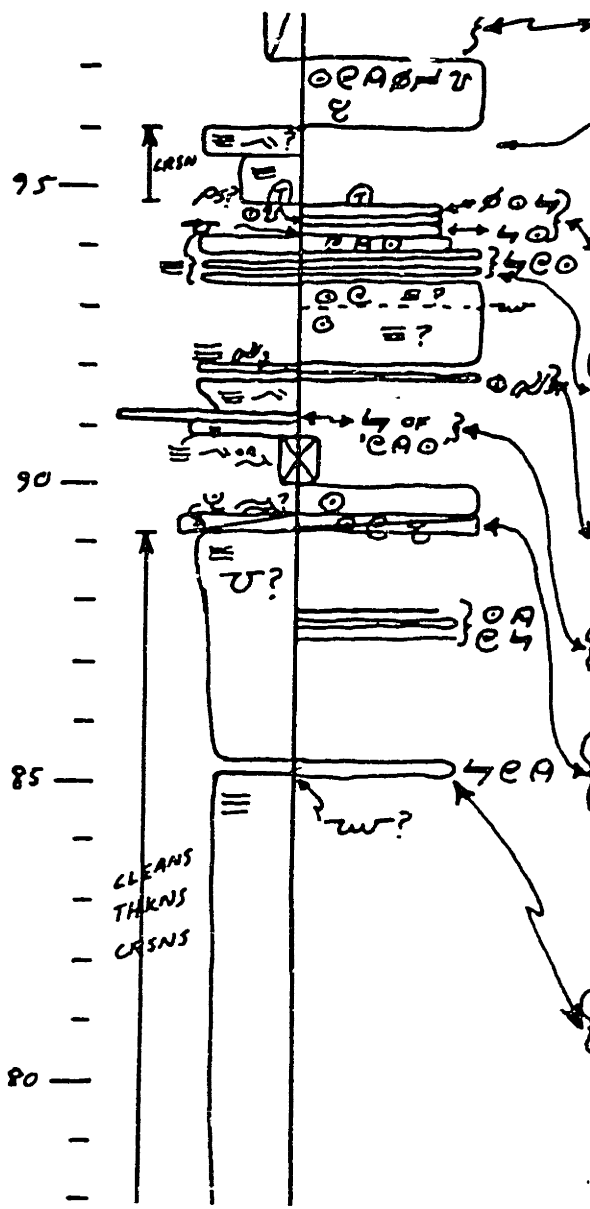

MOST BDDG ≤ 2cm TO A GRAYISH-GREEN ...
MOST BDDG 8-10cm

3 BEDS OF GREY & BROWN LS PKGRST W/ 1 BED OF TAN, SILTY SILICEOUS MDST. 2 LS BEDS ON TOP & ONE ON BTM W/ (≤ 1X1 mm) & (< 1 x 3 mm) IN ALL. BTM LS BED ~8-10 cm THK. MDST BED ~12 cm THK & ATOP BTM LS BED. TOP 2 LS BEDS EACH ~15 cm THK

MIX OF GREEN SH & PURPLISH-GRAY, SILTY, MICACEOUS, CHLORITIC MDST W/ OCCASIONAL STS TO VF SS INTERBEDS ≤ 5cm & ≡. BASAL ~125 cm MOSTLY GREEN, MICACEOUS, CHLORITIC SH

PURPLISH-GRAY, SOMEWHAT MUDDY F. QTZ SS

PURPLISH-GRAY & IN PLACES GREEN, MICACEOUS, CHLORITIC, SILTY MDST W/ OCCASIONAL VF STS BEDS ≤ 7cm THK, ≡ ~?




GRAY LS ⊙ (½ mm) GRST w/ SOME A, @, ø (≤ 1½ cm) & (≤ ½ x 2 cm), BDD ~2-10 cm. SOME DISCONT. & DRAPES ≤ 20 x 2 cm. TOP ~15 cm, ⊙ ~ ¾ mm w/ LESS OF REST & ≤ 5 cm NS. TOP BED HAS DOLZD BRIGHT ORNG ⊙ IN PLACES 2-4 cm THK

BRWN, F QTZ SS. SLIGHT UPWARD CLEANING

GREENISH-BRWN, MICACEOUS, SLIGHTLY SILTY MDST, LAM'D ≤ 1 cm w/ A ~10 x 20 (HxW) cm GROWING UP FROM LWR CNTC. A OCCUR DISCONTINUOUSLY ALONG CONTACT

3 GRY LS PKST. BASAL CNTC w/ MXT SIL/CO3 UNIT IS LOADED. BTM PKST: HAS BRWN DOLSTS ≤ ½ x 2½ cm, MOST THINNER, PLATY & ANGULAR. TOP 5 cm MOSTLY GRY & SUBRNDD ≤ 1 x 4½ cm. ⊙ IN MATRIX. MDL PKST: ⊙ (¼-½ mm) w/ ʊ. TOP PKST: ø ≤ 2½ cm w/ ⊙ IN MATRIX. SOME DOLSTS IN UPPR 3 cm

RECESSIVE WEATHERING MIX OF STS & VF SS & A @ ⊙ LS PKST (GRY) ALL BDD ≤ 1½ cm

2 UNITS OF BROWN & GRAY-BRAWN VF QTZ SS, 2-5 mm LAM'D, ~10 cm THK EACH. EACH OVERLAIN BY GAY LS GRST w/ @ ⊙ ≤ ½ mm. ARE OF ⊙ GRST, SUBRNDD. LWR GRST w/ ≤ 1 x 5 cm IN 2 BEDS 7-8 cm THK. UPPR GRST w/ ≤ 4 x 12 cm IN ONE BED ~10 cm THK.

GRY LS ⊙ (½-¾ mm) GRST. TOP ~30 cm A CRSE @-⊙ GRST, SCOURED INTO LWR CLEAN ⊙ GRST. ALL BDD 2-4 cm. SED STRUCS UNCLEAR. ≡?

GRY LS GRST OF ⊙ (F & VF) w/ VF QTZ SAND 10 cm THK OVERLAIN BY ~15 cm THK VF QTZ SS. BOTH w/ ∕∕, POSSIBLE LOADING

GRY-GREEN & BRWN, MICACEOUS, MUDDY STS CRSNS UP TO VF, CLEAN QTZ SS. LAM'D ≤ 1 cm

DK GRY CLASTS OF '@ A ⊙' ≤ ~5 x 10 cm w/ MATRIX OF F. QTZ SS. A SMALL DEBRIS FLOW? (LS PK/GRST). UNDERLAIN BY BRWN VF-F QTZ SS BDD 1-5 cm.

COVER. PROBABLY SH/MDST/STS

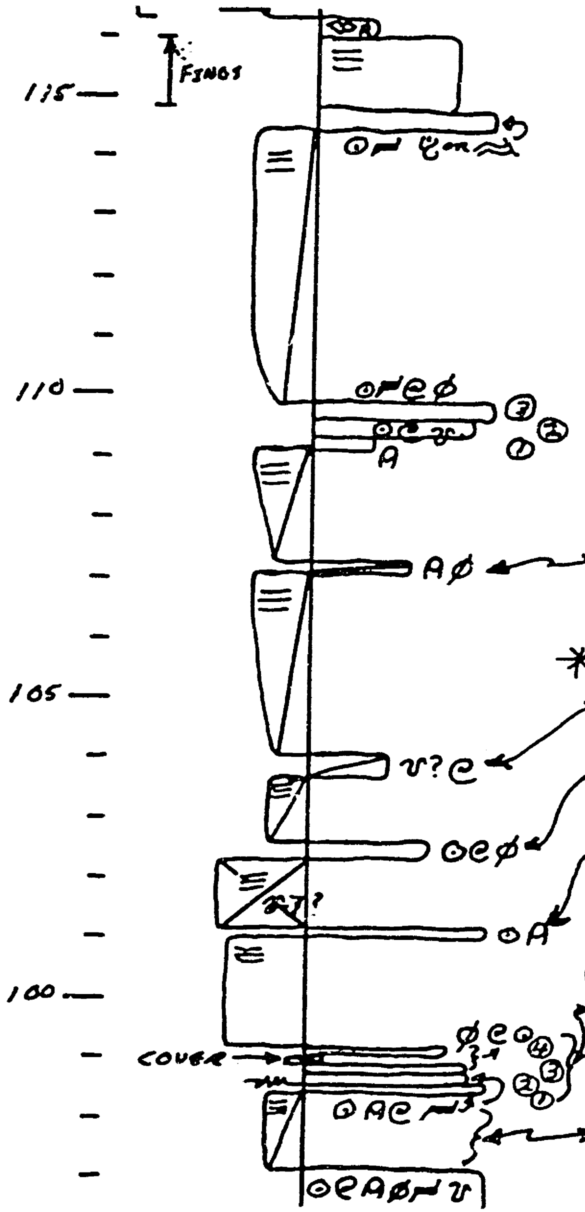
GRY LS ⊙ (½-1 mm) GRST. BDD 3-6 cm

RECESSIVE WEATHERING GRY ⊙ (½-¾ mm) & @ LS GRST, BDD 2-6 cm, INTERBDD w/ VF & F BRWN QTZ SS w/ LS-CEMENT. BDD 3-5 cm. POSSIBLY SOME SH OR SIL. STS BEDS IN MORE WEATHERED PARTS.

CRSNS FROM CLEAN STS UP TO A GRAY VF SS, BDD ~3-6 cm, ≡ AT ~87½ m, HAVE 3 LS PK/GRST BEDS, 5, 10 & 5 cm THK w/ ⊙ (≤ ½ mm) A @ (≤ 1 x 4 cm) - ⊙ DOMINANT GRAIN. LATERALLY LS BEDS THIN & COALESCE TO ~20-35 cm OF ⊙, ETC + SAND. IN SS HAVE A POSSIBLE ~20 x 20 cm LOAD STRUC IN ONE LOCATION, BUT MUCH OF UNIT LATERALLY IS COVERED.

CARBONATE PK/GRST, 25 cm THK, w/ OF BRWN STS ≤ 1 x 1 cm TO ≤ 1½ x 4 cm & @ A FRAGMENTS ~1 x 1 mm. SOME INVERSE GRADING.

UNIT CHANGES UPSECTION FROM A GRAYISH-BROWN MUDDY STS w/ MOST BDDG ≤ 2 cm TO A GRAYISH-GREEN CLEAN STS w/ MOST BDDG 3-6 cm




DOLSTS DECR UP, 10% ↑ 6 90.

ORNG-BRWN, LSMY DOLSTS W/ ~25%? QTZ GRAINS & SOME INTERBDD LS STS ≤ 1cm. BDD ≤ 2 cm FOR DOLSTS. SIMILAR TO 100 m, BUT LESS QTZ. FINES UP TO MORE OF A "SILTY SH"

GRAYSH-GREEN LS ⊙ (<⅛-½ mm, MOST ≤ ¼ mm) GRST, BDD 5-10 cm RND-SHARND OF DOLSTS & LS MD/STS CONCENTRATED IN TOP & BTM BEDS. CENTER 1-2 BEDS W/ FEW. ~½ x 1 cm → 1 x 5 cm. TOP SURFACE IS WAVY & TOP BED HAS INCLINED. MAY BE OK

GREEN, SLIGHTLY SILTY, MICACEOUS LAM'D SH CHANGES UP TO BRWNSH-GRAY & YELLOWISH-GRAY, SILTY MDST W/ MORE CARBONATE CEMENT IN UPPER ½.

③ GREENISH-GRAY LS GRST, MOSTLY ⊙ (~½ mm), W/ RNDD (2-5 mm), COATED GRNS (2-3 mm), ∅ (<1 cm) NEAR TOP. YELLOW SPAR CEMENT

② GRAY LS ⊙ (⅛-½ mm) PK/GRST W/ SOME @ & BRWN DOLSTS IN ②. BDD 2-5 cm

① LT GREEN-GRY LS MD/WKST W/ DOLSTS DECR UP SCTN. SORT OF A GRADATIONAL ZONE TWEEN SILICEOUS BEDS BELOW & CLEAN CARBS. ABOVE

GREEN, SLIGHTLY SILTY, MICACEOUS SH CHANGES UP TO REDDISH-BROWN SILTY MDST, BDD ≤ 1-2 cm. SH LAM'D ≤ 1 cm.

LT BRWN LS WKST W/ LAMS & BEDS OF DOLSTS ≤ 1 cm. ∅ ≤ 1 cm

YELLOWISH-GREEN, SLIGHTLY SILTY, MICACEOUS SH CHANGES UP TO BROWN, SILTY, MICACEOUS MDST, BDD ≤ 1-2 cm. SH LAM'D ≤ 1 cm.

* NOTE: FAULTING 97-109 m. SOME BEDS ARE DISCONTINUOUS &/OR CUT OFF. LATERAL CONTINUITY HARD TO TRACE DUE TO COVER.

YELLOWISH-GRY LS MD/WKST, BDD ≤ 5 cm

YELLOWISH-GREEN, SLIGHTLY SILTY, MICACEOUS SH

YELLOWISH-GREEN LS WK/PKST W/ ⊙ (½-1 mm) & ∅ (≤ 1 cm)

GRY-BROWN VF SS TO CRS STS, QTZ, NON-CARB CEMENTED. POSSIBLY MUDDY & V-T IN PLACES. MAY HAVE SH LIKE 103 m

LT GREEN LS ⊙ (½ mm) GRST W/ SOME A FRAGS., BDD 2-5 cm

BRWN → ORNG-BRWN LSMY & DOL-CEMENTED QTZ STS, BDD ≤ 3 cm, MOST ≤ 1 cm. LOOKS VERY CARBONATE-ISH, ALMOST A DOLSTS W/ QTZ GRAINS

④ ORNG & GRY LS & DOL PKST W/ 1-6 cm OF ∅ (≤ 1 cm) AT BASE IN PKST. REST ⊙ (½ mm) IS DOM. GRAIN. DOLSTS INTERLAMS MORE CONT. THAN BELOW. COVERED 10 cm TWEEN ③ & ④

③ GRY LS PK/GRST W/O ∅ DOMINANT. MOSTLY ⊙ LIKE ① BUT ALSO IRREG, DISCONT INTERLAMS OF ORNG DOLSTS

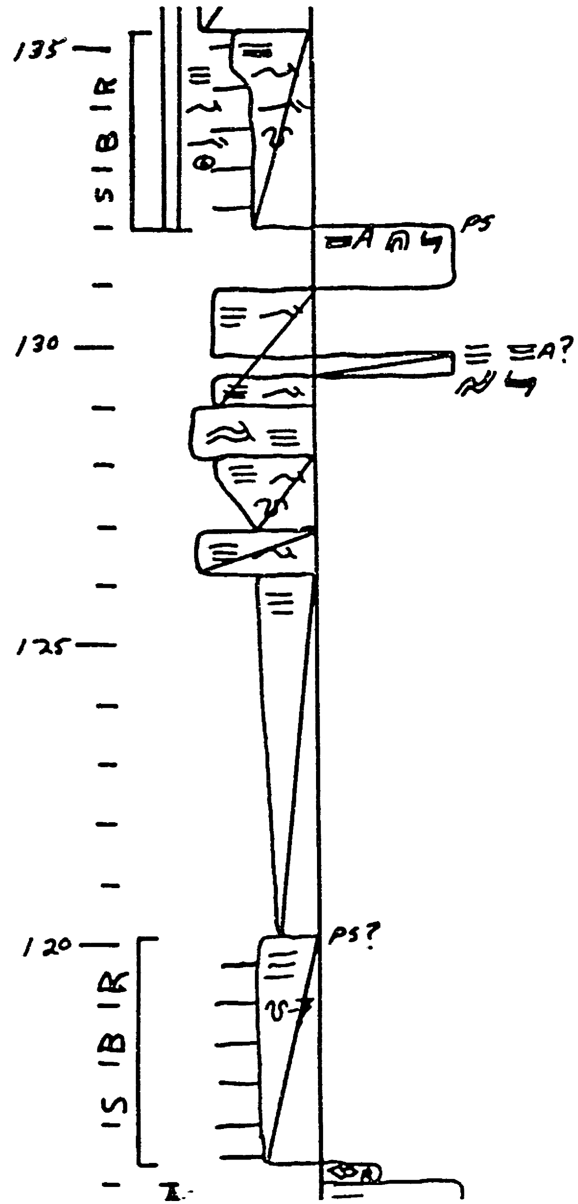
② GRY LS PK/GRST W/ ∅ ≤ 2 cm & 'MATRIX' LIKE ①. DOLSTS IN PLACES. LWR CNTC STYLOLITIC W/ ≥ 3 cm RELIEF. ∅ DOMINATE

① GREEN LS ⊙ (¼-¾ mm) GRST W/ MOD-HI % OF A @ COATED GRNS & FEW DOLSTS 1-2 x 5-10 mm

YELLOWISH-GREEN, SLIGHTLY SILTY, MIC & CHLRTC SH

GRAY LS ⊙ (½ mm) GRST W/ SOME A, @, ∅ (≤ 1½ cm) & (≤ ½ x 2 cm), BDD ~2-10 cm. SOME DISCONT, & DRAPES ≤ 20 x 2 cm. TOP ~15 cm, ⊙ ~¾ mm W/ LESS OF REST & ≤ 5 cm HI. TOP BED HAS DOLTD BRIGHT ORNG ⊙

[illegible]




BACKGROUND: GREEN TO GRAY-GREEN, SILTY, MICACEOUS MDST. BDD ≤ 1 cm. TOP ~50 cm THK, MOSTLY CLEAN, SILICA-CEMENTED STS W/ MICA. ≡, ~.
EVENT BEDS: OCCASIONAL VF QTZ SS. GREEN, GRAY SILICA-CEMENTED. LT BROWN LIMY-DOLOMITIC-CEMENTED. BOTH BDD 1-3 cm. ⊙(¼-½ mm) SCATTERED THRU-OUT. ⊙ ARE RADIAL ⊕.

ORNG, SOME GRAY, DOLSTS. BROAD LOW-RELIEF Ⓐ; SOME 9 cm W × 7 cm H. 15 cm COVERED IN MDL W/ MORE ≡ & ≡A ABOVE & MORE ≡A & Ⓐ BELOW. ↳ OF ORNG DOLSTS.

LT GREEN, VF QTZ-CMTD SS. BDD ≤ 1 cm. RECESSIVE WEATHERING

ORNG DOLSTS W/ MORE ≡A THAN ≡, SOME SOFT-SED DEFORMATION, MOD. AMT OF ORNG DOLSTS ↳, PLATY, ANGULAR. RECESSIVE WEATHERING. HYDROTH. ALTERATION GOES TO LS LIKE 130½ m.

ORNGSH-BRWN, LS-CMTD F QTZ SS. BROAD, LOW-AMPLITUDE Ⓐ

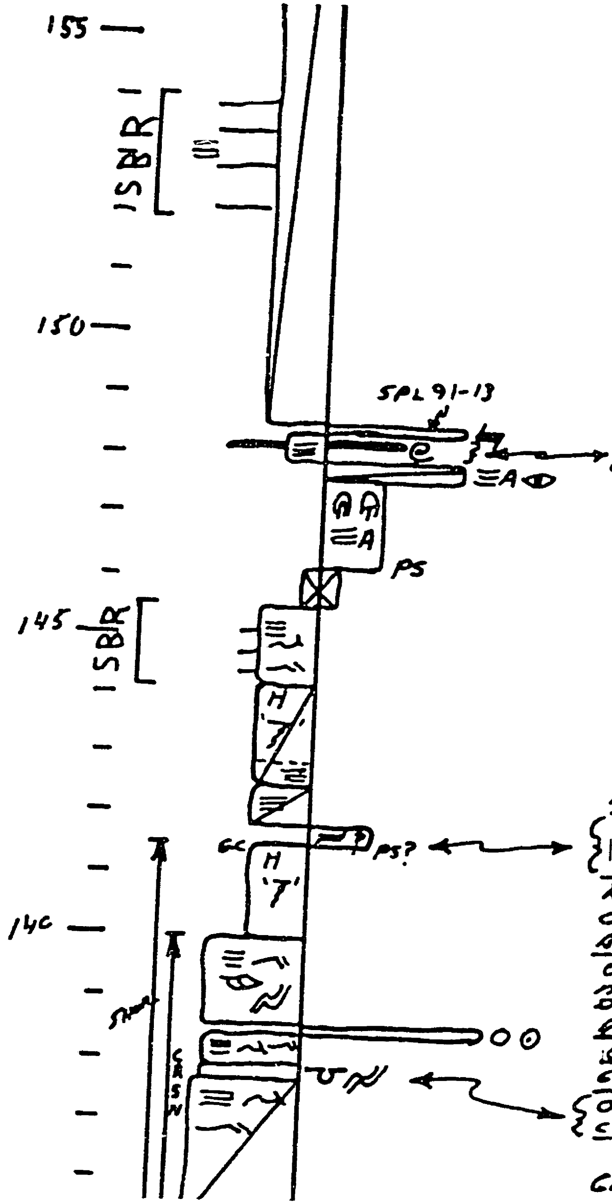
GREENISH-BROWN QTZ-CMTD MDST GOING UP TO VF SS. BDD ≤ 3 cm

MIX OF ORNG-BRWN DOL-CEMENTED SS & SS & BROWNISH-GRAY QTZ-CEMENTED FINE SS. DOL-CMTD SS BDD ≤ 2 cm
QTZ-CMTD SS BDD 6.5 cm

GREEN MICACEOUS SILTY SH UP TO GREENISH-BROWN, MICACEOUS SILTY MDST. BDD ≤ 2 cm

GREENISH & YELLOWISH-BROWN, MICACEOUS, SILTY MDST W/ OCCASIONAL VF SS INTERBEDS 1-2 cm THK. MDST BDD ≤ 1-2 cm.

GRY LS MDST, BDD ≤ 2 cm W/ INTERLAM ≤ 3 mm OF ORNG DOLSTS. DOLSTS DECR UP, 10% → 5%.
ORNG-BRWN, LIMY DOLSTS W/ ~25%? QTZ GRAINS & SOME




SS BOTH AS KNOBS ~5 cm HI & 10-15 cm WIDE & BROAD GENTLE CHANGE OVER METERS LATERALLY.

GREEN LS (≤2x4 cm) PKST W/ DOLSTS MATRIX. SUBANG. & OF ≡ LS MDST

GREEN & TAN, MICACEOUS SH W/ 1 BED OR MXT. CARBONATE-CEMENTED VF QTZ SAND & Q LS WKST

ORNG DOLSTS. FINE LAMS. BDD ≤3 cm

GREENISH-GRAY 'ALGAL' MDST. HEADS ≤25 cm HX 40 cm W. ORNG DOLSTS IN VOIDS & IN INTERLAMS ≤3 mm IN LWR 1/3. W/ SOME COARSE CONCENTRIC LAMINAE.

COVER

MOSTLY REDDISH-PURPLE, MICACEOUS MDST, ≡. TOP 30 cm GREENISH-BROWN. BASAL 5-8 cm ORNG, < mm-LAM'D & DOL'C. INTERBDD ≤1 cm BEDS OF STS, ≡.

REDDISH-PURPLE MDST LIKE 141 m, EXCEPT LWR 40 cm WHICH IS GREEN, CHLORITIC MDST

LT. ORNGISH-TAN, DOLOMITIC, TALCOSE MDST. PARTIALLY ALTERED.

YELLOWISH-GREEN LS MDST (OR O PKST). POSSIBLY MADE OF IRREG., SUBRND, ≤1 cm MDST. OCCASIONAL SPAR-FILLED VOIDS ~½x½ cm

REDDISH-PURPLE MDST W/GREEN 2NDARY CLAY: CHLORITE?. TOTALLY CHURNED, BUT MAY BE DUE TO SOIL PROCESSES RATHER THAN BURROWING. TOP 15 cm SS GREEN W/ GRAD'L BNDRY. BLOCKY WX

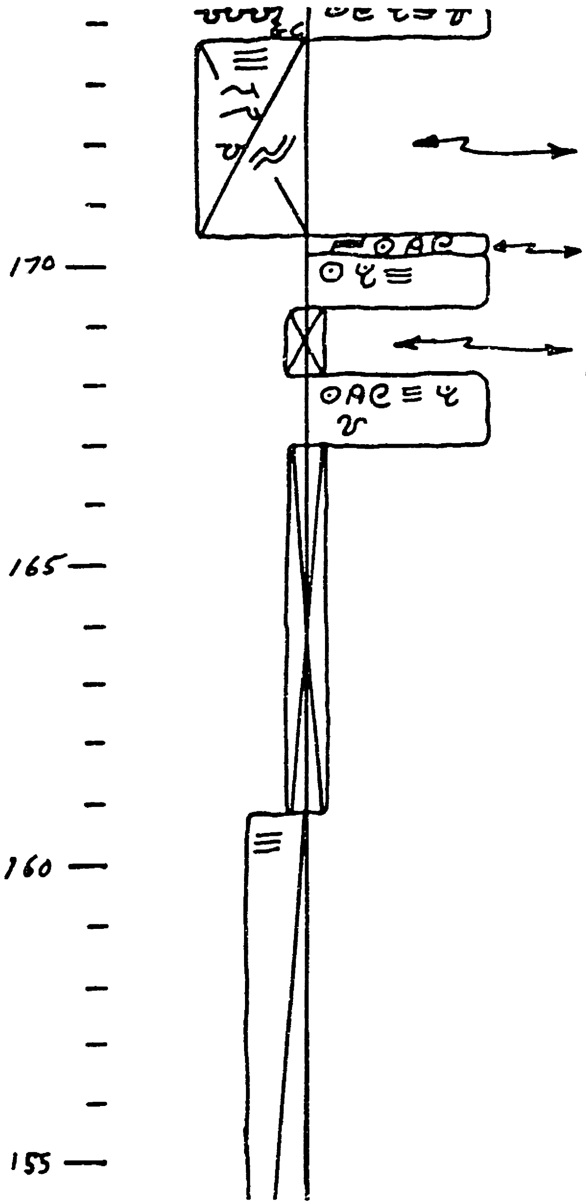
ORNG, LIMY & DOL'C CEMENTED, VF, MICACEOUS QTZ SS. BDD MOSTLY ≤1 cm, SOME ≤4 cm. IS A CLIMBING WAVE RIPPLE. DEPOSITION OF THIS UNIT MAY HAVE CAUSED LOADS AT 137.8 m DE-H₂O STRUC AT 138.8 m.

GREEN LS O & Q (¼-½ mm) GRST. BDD 2-4 cm. NO STRUC. RECOG'D

GREEN, MICACEOUS, VF QTZ SS, SILICA CEMENTED. BDD ≤1½ cm

ORNG & BROWNISH-GREEN VF QTZ SS. MICACEOUS, SILICA-CEMENTED, BDD ≤1 cm. LOADED & SOFT-SED DEFORMATION

GREEN VF-F QTZ SS, SILICA CEMENTED. BDD <1 cm.




BROWNISH-GRAY LS ⊙(1/4-1/4MM) GRST W/ ... ...
BASAL 25-35 cm W/ ⊙ 1/2 mm. SOME DISCRETE ORNG DOLSTS
INTERLAMS ≤ 1-2 cm IN LWR 1/2. BASAL 25-35 cm W/ 5-7 cm
BEDS OF DOLSTS, LENTICULAR & ≡. MAIN PART OF UNIT W ≤ 35 cm

{ MIX OF GREEN SH, VF & F LS-CMTD SS & STS, BDD ≤ 5 cm.
POSSIBLY 2 CRSN-UP PKGS (SNTSS) W/ A 3 m SH/STS INTERVAL
AT TOP. V. POORLY EXPOSED. ≈171-171 1/2 m HAVE LOADING/
DO $H_2O$ STRUCT ≈25×25 cm TO 25×50 cm }

{ BROWNISH-GRAY GRST W/ MANY DOLZ'D ⊙. ⊙(1/2-3/4 mm). 1/4 OF ⊙(1/4 mm) GRST,
LS VF-FARGN & LS STS, ≤ 8 1/2 × 11 cm, SUB ANG. TO SUB RND, FLOATING
IN A 'MATRIX' OF ⊙AC GRST. SHELTER POROSITY NOW FILLED W/
CEMENT. TOP 7 cm A SEPARATE BED }

BROWNISH-GRAY LS ⊙(~1/2 mm) GRST, BDD 10-20 cm. MOST ⊙ DOLZD

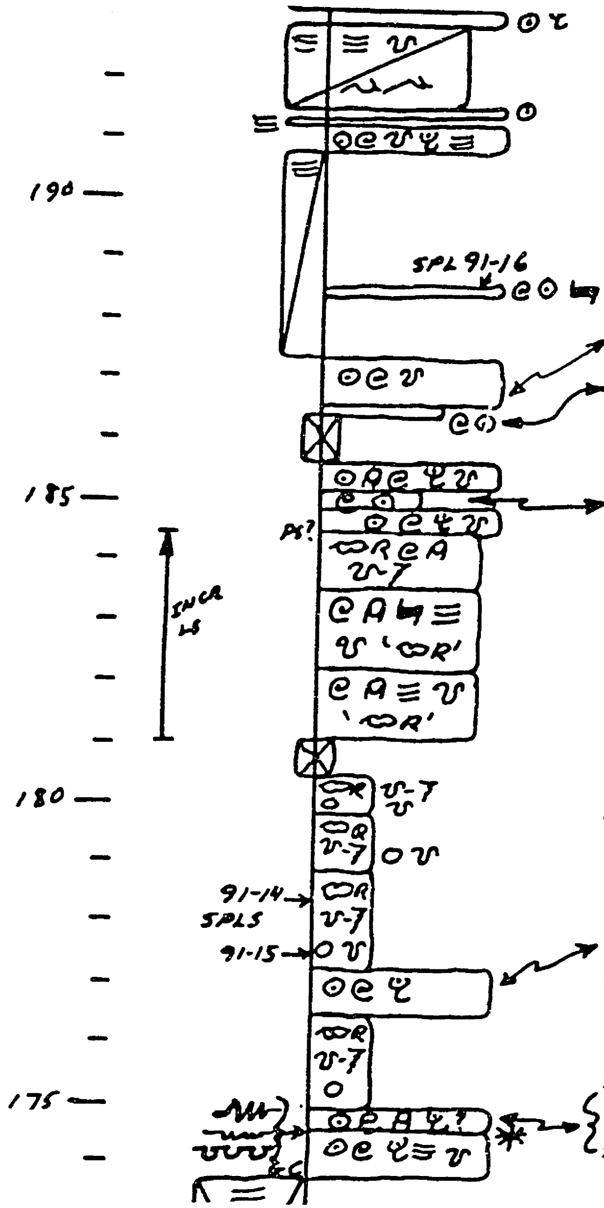
{ COVER EXCEPT FOR TOP 25 cm WHICH IS VF SAND → CRSE SILT-
SIZED LS GRAINS. POSSIBLY ⊙. VERY RECESSIVE. LIMY DOL OR DOL'C
LS }

BROWNISH-GRAY LS ⊙(~1/4 mm) GRST BDD 4-12 cm. SOME @, SOME
DISCONTINUOUS ORNG DOLSTS LAMS < 1 cm THK. MANY ⊙
DOLZD.

COVER

REDDISH-PURPLE SH. CRUDELY LAM'D. OCCASIONAL LT. BROWN
CARBONATE-CEMENTED F-VF SS LAYERS IN ≈ 152-154 m. ALSO ≡

* SURFACE AT 174.6 m: ≳ 12 cm OF RELIEF. VERT. ≤ 3 cm LONG FILLED W/ DOLSTS OR
CRSR GRAINS FROM BED ABOVE CUT DOWN INTO LOWER
UNIT. ALSO GET SOME DISSOLN (—) OF GRAINS BOTH
ABOVE & BELOW SURFACE, IE, & IN PLACES HAVE
≤ 2 cm THK LAYER OF ORNG DOLSTS ALONG CONTACT—
AT LEAST PARTIALLY INSOLUBLE RESIDUE?. RELIEF
IS BOTH AS KNOBS ~5 cm HI & 10-15 cm WIDE & BROAD
GENTLE CHANGE OVER METERS LATERALLY.




LT BROWNISH-GRAY LS ⊙(~⅛ mm) GRST. ∪ 5-15 cm
MIX OF GREENISH SH LIKE 190 m & GREEN LS STS BDD ≤ 2 cm w/ INTERBEDS/LAMS OF ORNG-BROWN DOLSTS ≤ 5 mm. LS MOSTLY ~, w/ ≡, —. DOLSTS ≡. WEATHERS VERY RECESSIVE.
LT GRAY ⊙(~¼ mm) LS GRST. ⊙ RADIAL.
GREEN SH LIKE 190 m
LT BROWNISH-GRAY LS ⊙ (≤ ⅛ ↑ ¼ mm) GRST. ∪ ≤ 10 cm, OFTEN IN 'BAR-RING-BONE' SETS, ∪ w/ ORNG DOLSTS. DOLSTS ALSO IN INTERLAMS ≤ 1½ cm IN LWR ⅓, ≡.

SLIGHTLY GREEN, SILTY, CHLORITIC SH ABOVE & BELOW THE GREEN LS @ PKST

GREEN LS @ PKST ~2 cm THK OVERLAIN BY GRAY LS ⊙@ GRST w/ [illegible] OF GREEN PKST(?), SUBRNDRND, ≤ 1 x 2 cm.

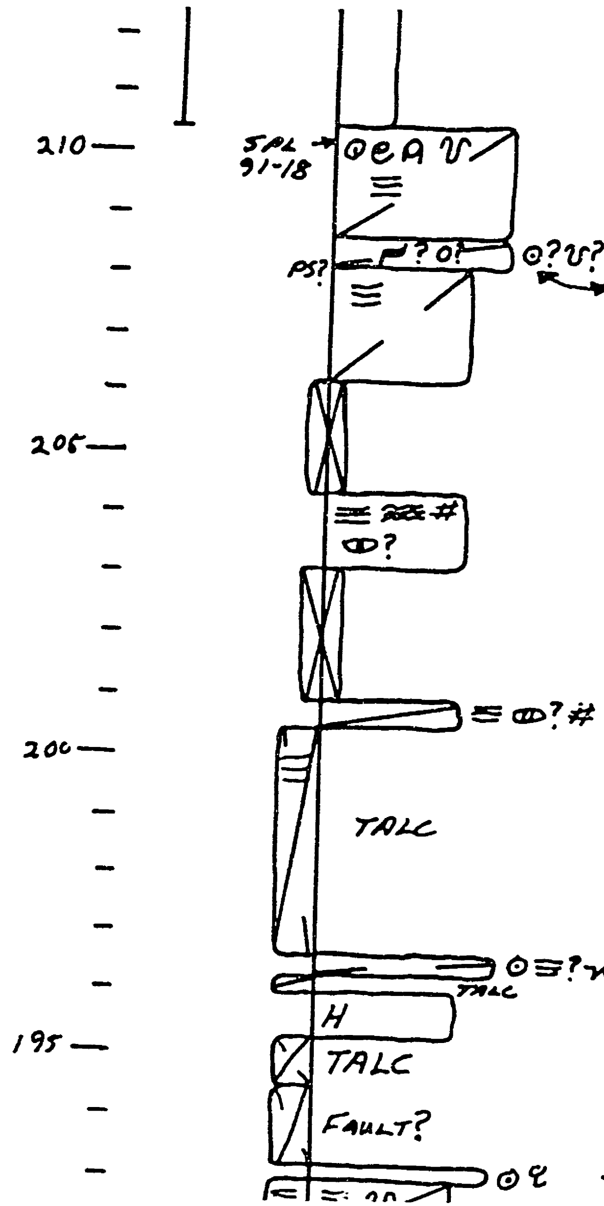
BROWNISH-GRAY LS ⊙ (≤ ¼ mm) GRST w/ OCCASIONAL @. ∪ FILLED w/ ORNG DOLSTS. DOLSTS ALSO IN DISCONTS IRREG INTERLAMS ≤ 5 mm.
GREEN LS WK/PKST. BDD ≤ 1 cm. LENTICULAR, ORNG DOLSTS INTERBEDS ≤ 5 mm. ⊙ VF + SAND-SIZE. RECESSIVE WEATHERING.
COVER. LIKE BEDS IMMEDIATELY ABOVE?
BROWNISH-GRAY LS ⊙ (≤ ¼ mm) GRST w/ SMALL POCKETS ENRICHED IN @ (~30-40%), LENTICULAR ≤ 2 x 20 cm. SOME ORNG DOLSTS BLEBS ≤ 1 x ½ cm

BLEBBY GRAY LS WKST w/ BLEBBY ORNG DOLSTS (50%). BOTH UPPER & LWR CONTACTS ARE WAVY, PROBABLY DISSOLUTION
BROWNISH-GRAY LS ⊙ (½-1 mm, AVE ¼ mm) GRST w/ FEW ORNG DOLST BLEBS & ≤ 5 cm, IRREG, CONT. INTERLAMS
LS VF AREN & VC STS LIKE 181 TO 183 m. ~10% DOLSTS IN ∪ LS BLEBBY. < 10% @ & A
ALTERNATING LS (~60%) & DOL VF AREN → VC STS. LS BDD ~3 cm. DOL BDD ≤ 1-2 cm. IRREG BDDG BUT SOME LS ≡. TOP 20-30 cm w/ ≥ 3 BEDS OF RNDD [illegible] OF SAME LITHS, ≤ ½ x ¾ cm. SHELTER POROSITY w/ EQUANT? CEMENT.
ALTERNATING DOL & LS VF AREN → VC STS w/ < 10% @. ~55% DOL. IRREG BDDG 1-3 cm, POSSIBLY DUE TO ∪ OR RIPPLES.

COVER, LIKE 181½ m?
LIKE 179 m, BUT 5-10% DOLSTS IN ∪. STILL A FEW SPAR-FILLED ∪ & DOL'ZD ⊙(< ⅛ mm)
GRY LS MDST w/ OCCASIONAL DOLZD ⊙(< ¼ mm). A FEW SPAR-FILLED ∪. ~35-40% KHAKI GREEN DOLSTS IN BLEBS & ∪. LS ALSO BLEBBY LOOKING.
GRAY LS MDST & VF ⊙ PK/GRST LIKE 176 m, BUT ~5-10% ORNG DOLSTS IN ∪. SPAR-FILLED ∪ ALSO

BROWNISH-GRAY LS ⊙ (≤ ¼ mm) GRST w/ MANY ⊙ DOLZD. TOP 10 cm IS GRAY LS ⊙ (½-1 mm) GRST w/ COATED @. ∪ ≤ 15 cm.

GRAY LS MDST & VF ⊙ PK/GRST. BOUNDARIES UNCLEAR BETWEEN 2 LITHS DUE TO SIMILAR ∪-7 TEXTURE & COLOR. ~30-35% KHAKI-GREEN LIMY DOLSTS IN ∪ & IRREG BLEBS. LS ALSO BLEBBY. SOME ⊙ DOLZD. MOST PROBABLY A VF ⊙ PKST
GRY LS ⊙ (¾-1 mm up to ¼-½ mm) GRST w/ @, A FRAGS. 5-10 cm ∪ MAYBE. IRREG. INTERNAL DISCONT. FINING UP DOLSTS LAMS < 5 mm THK. DISSOLN FEATURE?
BROWNISH-GRAY LS ⊙(¼-¾ mm) GRST w/ MOST ⊙ DOLZD. BASAL 25-35 cm w/ ⊙ ⅛ mm. SOME DISCRETE ORNG DOLSTS
... BASAL 25-35 cm w/ 5-7 cm




HAVE LATERAL VARIATION IN TOP OF ⊙ GRST & CNTC W/ OOR. HAVE A 70-85 cm THK ... W/ ⊙ & @ GRST W/ SPAR CEMENT AROUND GRAINS. TOP CONTACT W/ OOR IRREG, POSSIBLY DUE TO SOFT SED DEFORMATION. GRAY → BROWNISH GRAY LS ⊙ (¼-½ mm) GRST W/ SOME INTERVALS MORE A @ GRST. BDD < 1 → 10-15 cm. SOMEWHAT CRSNR THAN UPWARDS. ORNG DOLSTS IN U & 1-3 mm INTERLAMS, NUMEROUS IN LWR ¼, FEWER & THKR AS GO UP. NO OOLITES

GRAY LS GRST W/ GRAINS ≤ ¼ mm. A FEW GRAINS DOLZD & SUB RND. CAN'T REALLY TELL COMPOSITION. U? W/ ORNG DOLSTS, BUT MAY BE ... ≤ 1x1 cm. ALSO HAVE ORNG DOLSTS DISCONT INTERLAMS ≤ 2 mm IN LOWER ½

ORNG DOLSTS INTERBDD/LAMD W/ GREEN LS STS. MOST BDD ≤ 1-3 mm, ESPECIALLY IN LOWER ½; UPPR ½ W/ BDD ≤ 1 cm, TOO COARSE TO BE ≡A. NO U RECOGNIZED.

COVER. LIKE 207 m?

ORNG DOLSTS LIKE 200.5 m. SOME ... LS STS BEDS IN LOWER ¼.

COVERED EXCEPT FOR A BIT OF GREEN SH.

ORNG DOLSTS. GOOD #. VERY QUESTIONABLE ⊕ < 1 mm.

TALC W/ GREEN SH & ORNG DOL/QTZ VEINS. MAY HAVE SOME TAN DOLSTS, ≡, 1-5 mm ALSO.

2 BEDS OF LT BROWNISH-GRAY LS ⊙ GRST. LWR BED ~13 cm THK W/ ⊙ ≤ ½ mm. UPPR ~17 cm THK W/ ~½ mm ⊙ W/ RADIAL STRUC. SMALL STYLOLITES (...)

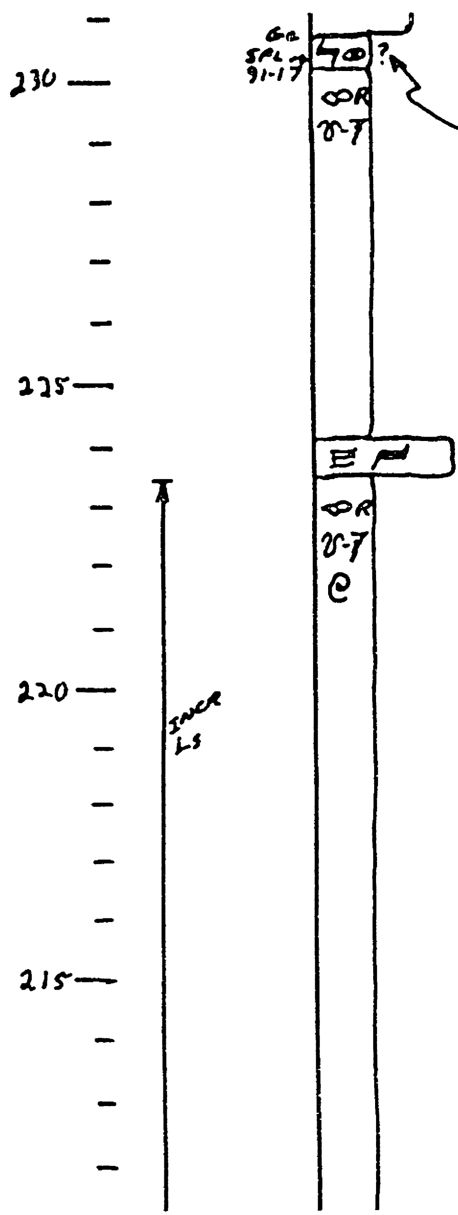
TALC W/ BITS OF SH & GREEN LS STS.

ORNG, F DOLSTS, BDD ~1-10 cm. QUITE LIKELY DUE TO HYDROTHERMAL ALTERATION AS THERE ARE NUMEROUS QTZ VEINS.

MOSTLY WHITE/TAN TALC W/ A LITTLE SH ALSO.

BRECCIA LIKE 190 m, BUT MORE CHLORITIC. 50 cm THK QTZ VEIN/BRECCIA IN TOP 60 cm.

LT BROWNISH-GRAY LS ⊙ (~¼ mm) GRST. ⊕ 5-15 cm




GRAY LS WKST W/ [illegible] OF GRAY LS MOST ≤ 1X1 cm, SUBRND [illegible], LS BDD ≤ 1.5 cm, AVG 2-3 cm. REDDISH-ORANGE DOLSTS IN [illegible] & INTERLAMS ≤ 5 mm. POSSIBLY A PART. MATRIX IS VF SPECKLED WHITE & BLACK & MAY BE SMALL GRAINS IN MATRIX/CEMENT. ~10% DOLSTS.

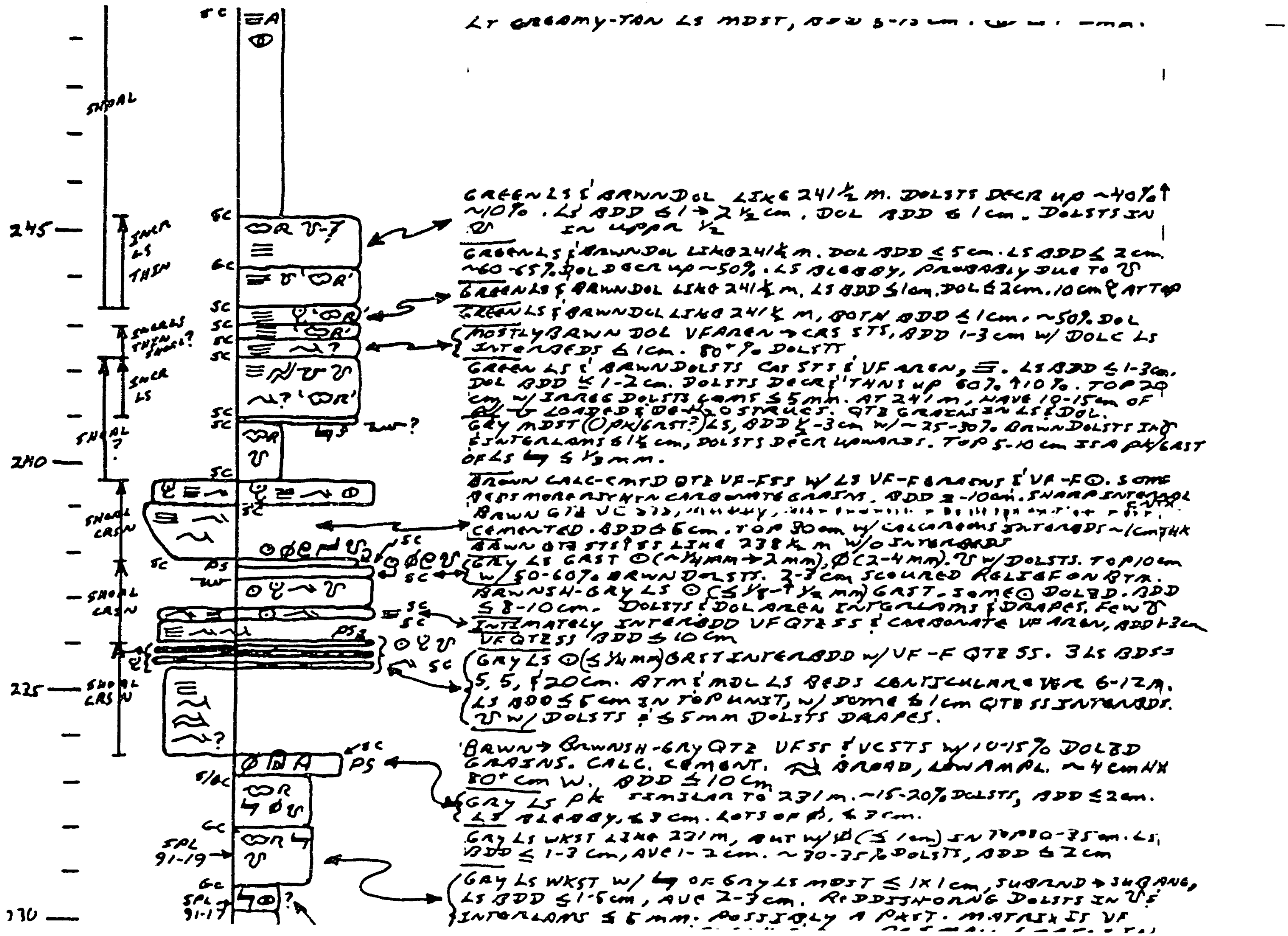
GRAY LS MOST W/ SOME SUBRND [illegible] (1-2 mm) OF SAME, ALSO IRREG BLEBS OF SPAR CEMENT ≤ 1X1 cm ([illegible]?).

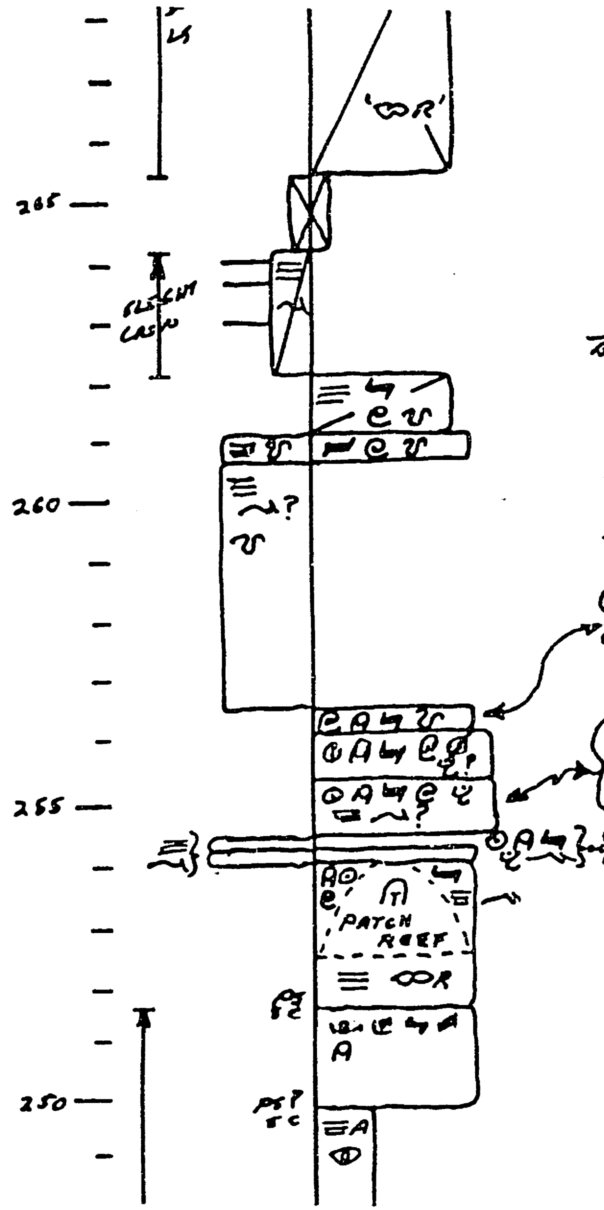
GRAY LS MOST (O PK/GRST?) W/ ≤ 10% KHAKI-GREEN TO TAN DOLSTS, MOSTLY IN [illegible], SOME IN 1-2 mm INTERLAMS, IRREG.

TAN DOLSTS, BDD ≤ 2 cm, [illegible]. ANG. [illegible] OF GRAY LS MOST ≤ 1X1 cm FLOATING IN DOLSTS. LATERALLY VARIABLE % DOLSTS, W/ GRAY LS MOST THAT CAN GET UP TO 15-20 cm THK. SOMETIMES HAVE DOLSTS INTERLAMS IN LS.

GRAY LS MOST (O PK/GRST?) W/ KHAKI-GREEN LIMY DOL. IN [illegible] & BLEBS. ~35-50% DECR UP TO <10% DOL. RARE @ BUT DID SEE POSSIBLE BRACH VALVE, CONVEX UP ~1 cm ACROSS. % DOLSTS ~ CONSTANT UNTIL LAST FEW METERS. NO SPAR-FILLED [illegible] SEEN. SOME INTERVALS A LS VF GRST W/ UNIDENTIFIED GRAINS.

HAVE LATERAL VARIATION IN TOP OF A GRST & CNTC W/ [illegible]. HAVE


LT CREAMY-TAN LS MDST
SHOAL
245
240
225
230
SHOAL CRSN
GREEN LS & BRWN DOL LIKE 241½ m. DOLSTS DECR UP ~40% → ~10%. LS BDD ≤1 → 2½ cm. DOL BDD ≤ 1 cm. DOLSTS IN
IN UPPER ½
GREEN LS & BRWN DOL LIKE 241½ m. DOL BDD ≤ 5 cm. LS BDD ≤ 2 cm.
~60-65% DOL DECR UP ~50%. LS BLEBBY, PROBABLY DUE TO
GREEN LS & BRWN DOL LIKE 241½ m, LS BDD ≤1 cm. DOL ≤ 2 cm. 10 cm AT TOP
GREEN LS & BRWN DOL LIKE 241½ m, BOTH BDD ≤ 1 cm. ~50% DOL
MOSTLY BRWN DOL VF AREN → CRS STS, BDD 1-3 cm W/ DOLC LS INTERBEDS ≤ 1 cm. 80+% DOLSTS
GREEN LS & BRWN DOLSTS CRS STS & VF AREN. LS BDD ≤ 1-3 cm. DOL BDD ≤ 1-2 cm. DOLSTS DECR & THNS UP 60% → 10%.
GRY MDST (PK/GRST?) LS, BDD ½-3 cm W/ ~25-30% BRWN DOLSTS
& INTERLAMS ≤ 1½ cm, DOLSTS DECR UPWARDS.
BROWN CALC-CMTD QTZ VF-F SS W/ LS VF-F GRAINS & VF-F
CEMENTED. BDD ≤ 5 cm.
GRY LS GRST
W/ 50-60% BRWN DOLSTS. 2-3 cm SCOURED RELIEF ON BTM.
BRWNSH-GRY LS
≤ 8-10 cm. DOLSTS & DOL AREN INTERLAMS & DRAPES.
INTIMATELY INTERBDD VF QTZ SS & CARBONATE VF AREN,
VF QTZ SS BDD ≤ 10 cm
GRY LS
5, 5, & 20 cm.
LS BDD ≤ 5 cm IN TOP UNIT, W/ SOME ≤ 1 cm QTZ SS INTERBDS.
W/ DOLSTS & ≤ 5 mm DOLSTS DRAPES.
BRWN → BRWNSH-GRY QTZ VF SS & VC STS W/ 10-15% DOL BD GRAINS. CALC. CEMENT.
80+ cm W. BDD ≤ 10 cm
GRY LS PK SIMILAR TO 231 m. ~15-20% DOLSTS, BDD ≤ 2 cm.
GRY LS WKST LIKE 231 m,
BDD ≤ 1-3 cm, AVE 1-2 cm. ~30-35% DOLSTS, BDD ≤ 2 cm
GRY LS WKST W/ OF GRY LS MDST ≤ 1x1 cm,
LS BDD ≤ 1-5 cm, AVE 2-3 cm.
INTERLAMS ≤ 5 mm. POSSIBLY A PKST. MATRIX IS VF
SPL 91-19
SPL 91-17




BEDD. TOP CONTACT SOMEWHAT ARBITRARY.

COVER

GREEN, SILTY, MICACEOUS SH W/ OCCASIONAL BEDS OF VC STS, [symbol], [symbol], BDD ≤ 1-2 cm. CRSNS UP TO VF QTZ SS BEDS ELSENT THICKENS UP

BRWN
DOL & GREEN LS STS & VF AREN. DOL ~60%, BDD ≤ 2 cm. LS [symbol] (≤ ½ x ½ cm) [symbol] WK/PKST, BDD ≤ 2 cm. QTZ GRAINS MIXED W/ CARBONATE BEDS

MIXED QTZ SS & STS LIKE BELOW, BDD ≤ 1 cm, W/ LS [symbol] (≤ 1 x ½ cm) GRST, BDD 1-5 cm THK. W/ SPAR-FILLED SHLTR POROS. & LS STS BEDS

BROWN, ORANGISH-BROWN, REDDISH-BROWN VF QTZ SS & VC STS, CALC-CEMENTED. BDD ≤ 1-5 cm. UNCOMMON INTERBEDS OF LS [symbol] [symbol] WK/PKST. [symbol] VARIABLE. MICACEOUS W/ SOME SILT → VF SAND CARBONATE GRAINS

INTERBDD BRWN DOLSTS & GREEN LS PK/GRST ([symbol], [symbol] ≤ 5 x 5 mm). BDD ≤ 1 cm EXCEPT FOR A COUPLE OF LS BEDS 1-3 cm THK AT TOP
LS LIKE 2.55 m W/ Ø (≤ 1 cm) MOSTLY DOLBDD SN / BDD 2 cm THK W/ DOLSTS & DISCONT. LS BDD ~3-15 cm, MDL 25 cm FINER-GRAINED W/ ≤ ½ mm [symbol], NO Ø, FEW [symbol] & SOME [symbol].

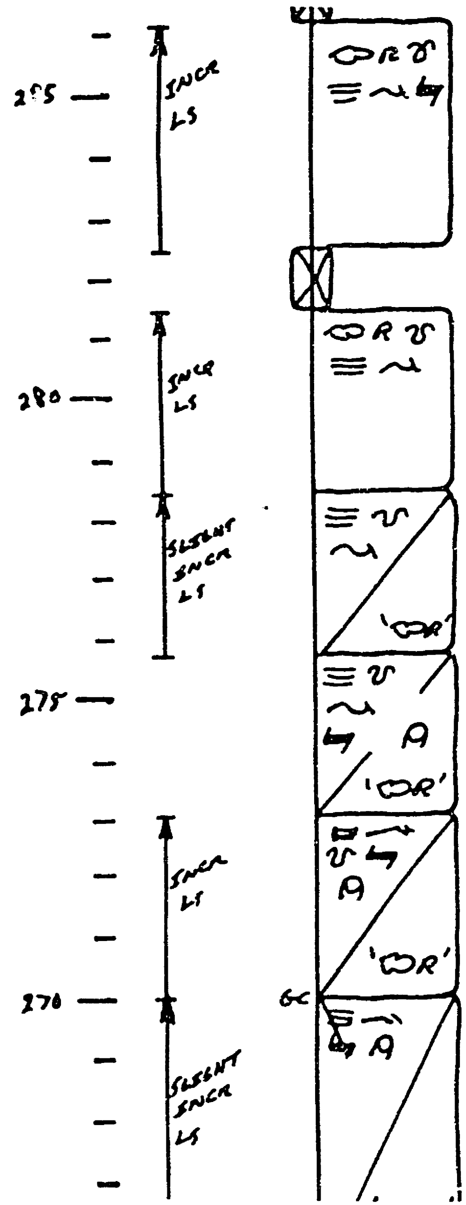
BROWNISH-GRY LS GRST W/ [symbol] (¼-½ mm), A & [symbol], [symbol] (MOSTLY DOLSTS, ≤ 1x1 cm, AND. SUBRND). SOMETIMES [symbol] DRIFT. SOMETIMES [symbol] GRST. BDD 2-15 cm W/ INTERBEDS OF DOLSTS & QTZ STS & VF SS, [symbol], [symbol]?, BDD 1-3 cm. INTERBDS CONCENTRATED IN MDL & TOP 10 cm. SOME BEDS OF LS [symbol] LOOK TO HAVE [symbol] ≤ 5 cm

MIX OF VF QTZ SS, [symbol] W/ LS [symbol] (≤ ½ mm) GRST W/ A, [symbol] OF DOLSTS & LS. BDD 1-5 cm W/ [symbol] ≤ 5 cm & [symbol]. SOME DISCONT ORNG DOLSTS ≤ 5 cm THK.

A PATCH REEF ~1.95 m HI X 2.65 m W. SMALLER [symbol] LATERALLY. SURROUNDED BY MIXED SEDS. MOSTLY INTERBDD DOLSTS & VF DOL AREN W/ VF LS AREN, & PATCHES OF [symbol] [symbol] GRST. [symbol] ≤ ½ mm. [symbol] MOSTLY OF DOLSTS ≤ 1 X 1 cm. OCCASIONAL [symbol] ≤ 20 X 20 cm. ALL LSTNS BDD 1-10 cm. THINNR BDD BELOW [symbol] < 1-3 cm & MORE [symbol] R-LIKE. % DOLSTS ~50% OVERALL BUT VARIES THRUOUT. NOTICEABLE COMPACTION OF SEDS AROUND [symbol]. PART OF A OVER-[illegible]

GRY LS PK/GRST W/ 1-2 mm [symbol], MUCH [symbol] [symbol] (LS & DOLSTS ≤ 1X1 cm) Ø ≤ 2 cm BUT SPARSE. INTERP: STORM DEPOSIT?.

LT CREAMY-TAN LS MDST, BDD 5-15 cm. [symbol] ≤ 1-2 mm.




LS LIKE BELOW, BDD 1-8 cm. A COUPLE OF 1-6 cm THK [~] BEDS, W/ [~] (LS STS) IN HORIZONTAL CLAST-CONGL. W/ SPAR-FILLED SHELTER POROSITY. LS INCR UP ~70% ↑ 90%. ORNG DOLSTS BDD ≤ 2 cm W/ MOST ≤ 1 cm & IN [Ø].

COVER

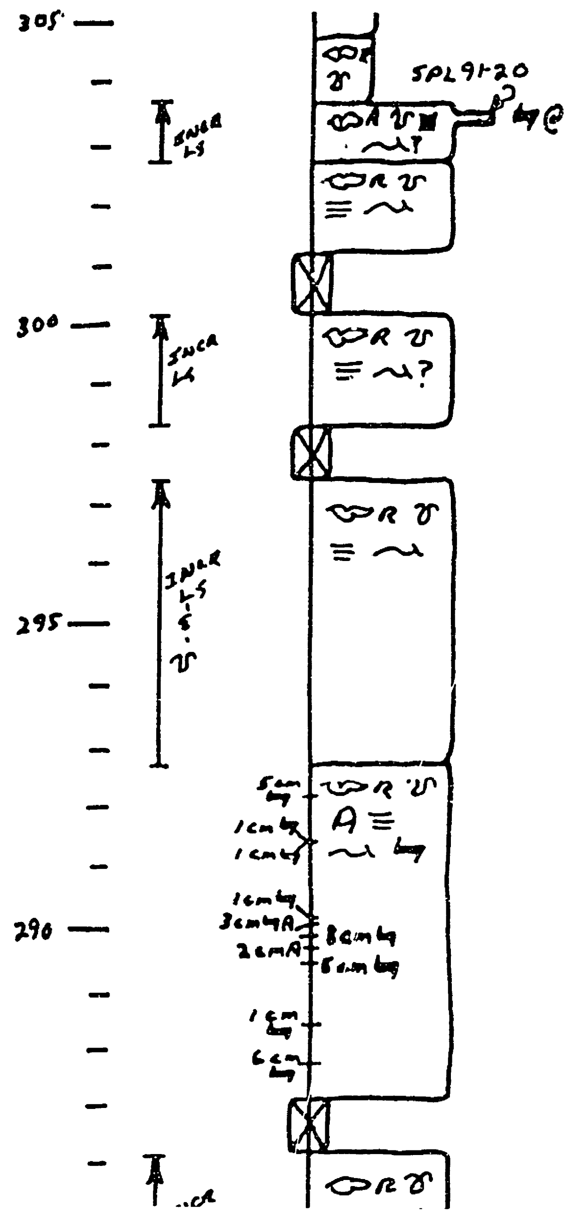
GRY LS VF STS W/ ≡, [~], BDD ≤ 1→5 cm. ORNG DOLSTS BDD ≤ 2 cm, MOST < 1 cm & IN [Ø]. LS INCR UP ~65% ↑ 80-85%

GRY & GRY-GREEN LS VF STS, BDD ≤ 1-4 cm, W/ ≡, [~] & 2 BEDS OF [~] A 4-5 cm THK. [~] OF LS. DOLSTS MOSTLY ≤ 1 cm, SOME 2-4 cm & IN [Ø]. LS INCR UP ~50% ↑ ~70%. ALMOST [Ø]R, NEEDS MORE [Ø]

GRY & GRY-GREEN LS VF STS BDD ≤ 1→3 cm, ≡ [~] [~] A, LIKE BELOW BUT ~60% LS W/ LITTLE VERT. CHANGE. ORNG DOLSTS, MOSTLY IN INTERLAMS & [Ø], E. FEW [~]-BEDS, BUT NOT AS MANY AS BELOW. ALMOST [Ø]R, BUT NEED A BIT MORE [Ø]

INTERBDD ORNG DOLSTS & GREEN LS STS, BDD ≤ 1→3 cm LS INCR TO ~75-80%. DOLSTS OFTEN ≤ ½ cm. THKEST [~] A BED ~8 cm W/ [~] ≤ 1X5 cm. [Ø]R-LIKE BUT FEW [Ø]

MOSTLY ORNG DOLSTS, CRSLY LAM'D → THINLY (≤ 2 cm) BDD. (NOT [~] A) W/ SOME GREEN LS STS W/ SAME LAMS & BDDS. OCCASIONAL BEDS OF LS [~] (≤ 1X3 cm MOST < 1X1 cm), BDD 1-3 cm, W/ MORE BEDS IN UPPER ½. A IN [~] BEDS. LS INCR UP ≤ 10% ↑ 20-25% A FEW [~] IN LS. [Ø]R-LIKE, BUT LESS [Ø] & V. THINLY BEDD. TOP CONTACT SOMEWHAT ARBITRARY.




LS PROBABLY A VF STS LIKE PREVIOUS BEDS BUT TOO HACKLY-WEATHERED TO TELL. LS BDD 1-5cm w/ONE 5-8cm BED. DOLSTS ≤ 1cm LAMS & ⊽, DECR. UP FROM ~60% TO ~10%.

LIKE 299m, EXCEPT LS INCR UP ~45% ↑ ~90%. A 13cm-THK FLAT [illegible] CAST w/ [illegible] ≤ 8mm x 12cm w/ ECHINOID? FRAGMNT & SPAR-FILLED SHELTER POROSITY.

LIKE 299m, EXCEPT ~75-80% LS THRU-OUT.

COVER

GRY LS VF STS, ALMOST LOOKS LIKE A MDST. BDD ≤ 1→4cm. DRNG DOLSTS BDD ≤ 2cm & IND⊽. LS INCR UP ~60 ↑ 70-75%

COVER

GRY LS VF STS w/ ≡, ~. BDD ≤ 1-3cm. LS INCR UP 60-85% ↑ 90%. ORNG DOLSTS IN ⊽ & ≡, BDD ≤ 1cm. A FEW SPAR-FILLED ⊽.

LS [illegible] BELOW, [illegible] 1 [illegible]. 7 [illegible] [illegible] < 1→8cm THK w/ LS STS [illegible] (INDICATED w/ THICKNESSES). SOME [illegible] IMBRICATED ~45°, MANY HORIZ OR JUMBLED. SOME A HASH BEDS, INCL. SOME w/ SiS MATRIX. DOLSTS BDD ≤ 2cm, MOST < 1cm, ~20-25% OVERALL.

[illegible] BEDS: SOME TRUNCATE LATERALLY, INCL. THE 8cm THK BED. SOME OF THINNER BEDS PINCH & SWELL OVER 2.5m LATERALLY, AS DO THKR BEDS. THESE BEDS PROBABLY NOT CONTINUOUS OVER 100'S m.

COVER

LS LIKE BELOW, BDD 1-8cm. A COUPLE OF 1-6cm THK [illegible] BEDS w/ [illegible] HORIZONTAL CLAST-[illegible] w/

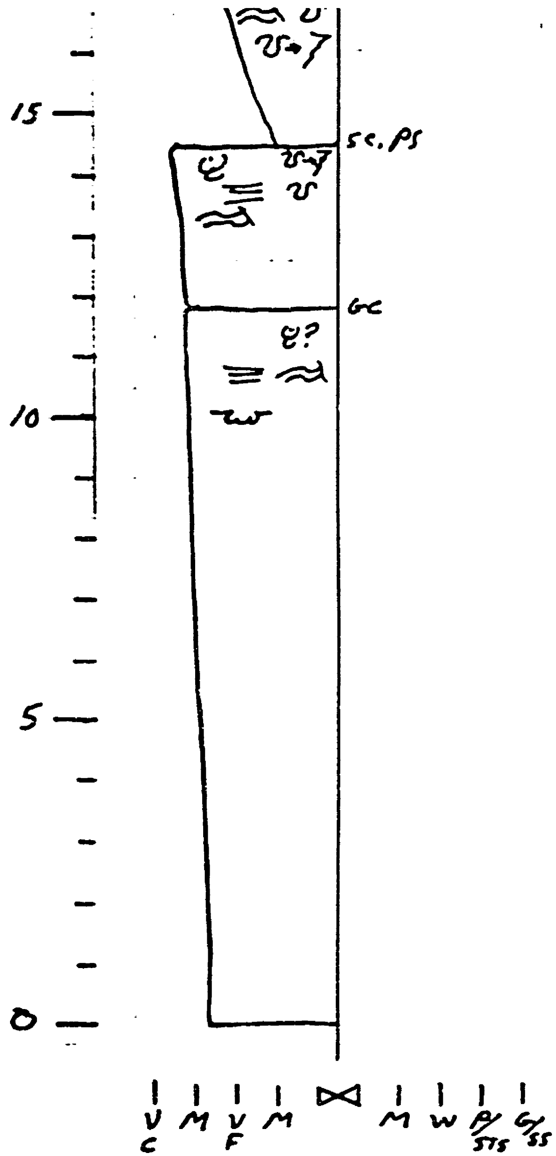
SECTION 91-1

BAXTER MINE, NO. RESTING SPG. RNG.

LS A GRY MDST (THO MAY BE A STS OR ⊙PKST, BUT SEE GRAINS)
DOLSTS LIMY, KHAKI BROWN. SPAR-FILLED ℧. ∅ AT 307.5M,
≤ 1½ cm. NO WK/PKST. LS BDD 1→7 cm. DOLSTS ≤ 1 cm.
~20% DOLSTS.

BONANZA KING Fm

305

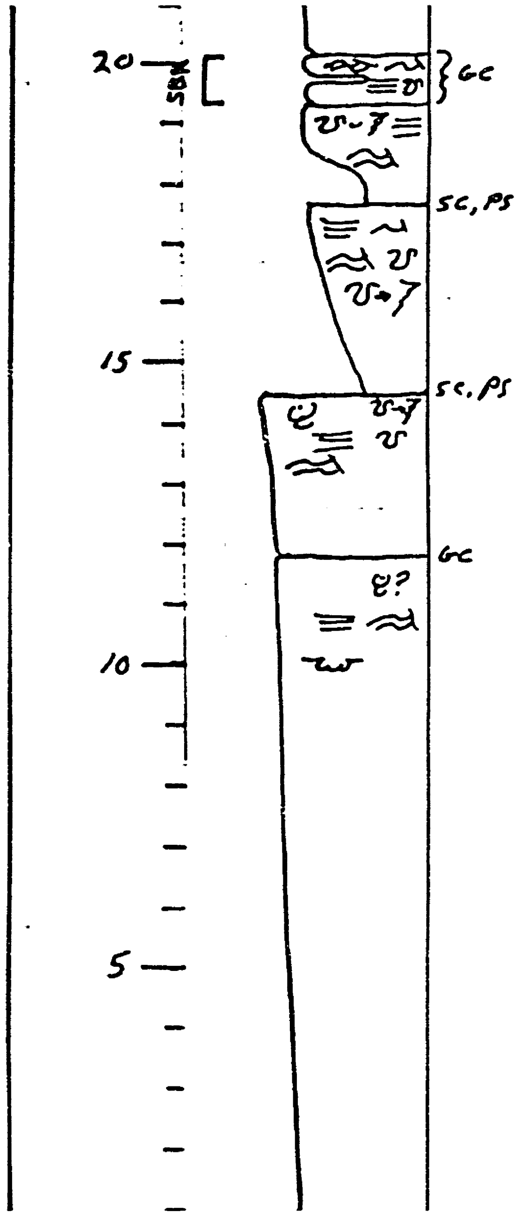



DK REDDISH-PURPLE, CRSN-UP MOST TO VF SS TO F SS QTZITE. ≈ 2-10cm. ∪ NOT SKOLITHOS. BDD 2-10cm. MICACEOUS CHLORITIC

PINK-BROWN, CRSN-UP C-M TO C W/ VC,M,F QTZITE ⌣ 5-15cm. ∪ IN TOP ~20cm ANY NOT SKOLITHOS. TOP 5cm ∪-7, BEDSETS 5-35cm

WHITE-TAN-PINK-PURPLE, CRSN-UP F-M TO M-C QTZITE. POSSIBLE ≤10cm ⌣ IN TOP METER. INTERNAL SCOURS ≤1m WIDE X 10cm HI. BEDSETS 5-45cm

SECTION 92-1 ECHO CYN
SO. FUNERAL RNG



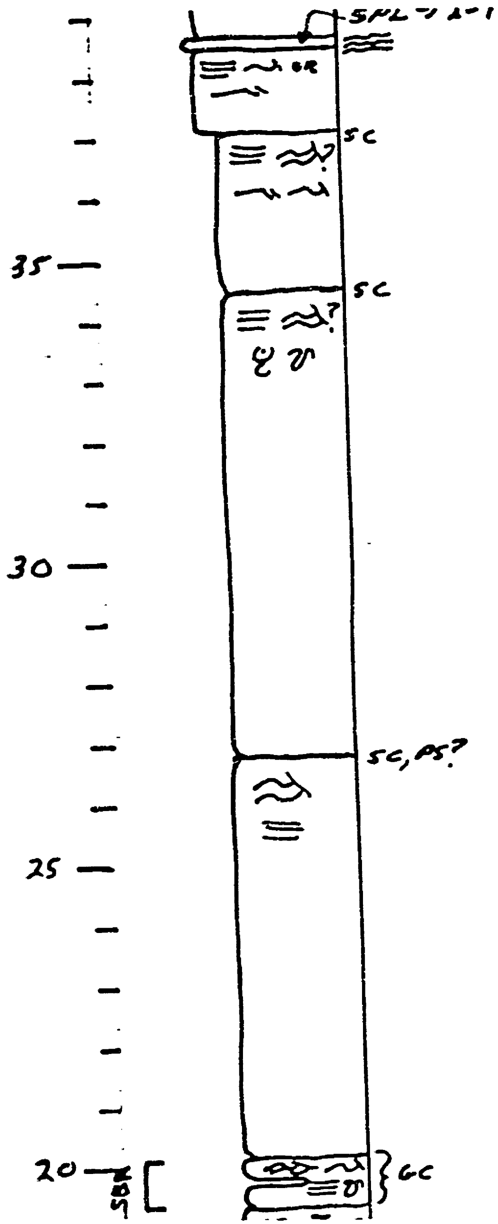

PINK SS & RED-PURPLE MDST. SS IS FINE, ≈. MDST IS ≡ & ʊ. SS BDD 5-30cm. MDST BDD ≤10 cm. MDST DECR UP, IS MICACEOUS, CHLORITIC. ~5-10 BEDS TOTAL.

DK REDDISH-PURPLE W/ GREENISH-TAN CRSN-UP MDST TO VF TO F QTZITE. ≈ ≤10cm. ʊ NOT SKOLITHOS. MDST MORE ʊ THAN SS. BDD ≤ 5-70 cm. MICACEOUS. CHLORITIC.

DK REDDISH-PURPLE, CRSN-UP MDST TO VF SS TO F SS QTZITE. ≈ 2-10cm. ʊ NOT SKOLITHOS. BDD 2-10cm. MICACEOUS CHLORITIC

PINK-BROWN, CRSN-UP C-M TO C W/ VC, M, F QTZITE. ϱ 5-15cm. ʊ IN TOP ~20 cm BUT NOT SKOLITHOS. TOP 5 cm ʊ-7. BEDSETS 5-35cm

WHITE-TAN-PINK-PURPLE, CRSN-UP F-M TO M-C QTZITE. POSSIBLE ≤10 cm ϱ IN TOP METER. INTERNAL STRUCTS S/M WIDEX 10cm NS. BEDSETS 5-45cm




BRWN M W/F'C, SS, DOL-CEMENTED, BDD ≤ 1 cm. NOT QTZITE.

LT PINKISH-GRY MED QTZITE, BEDSETS ≤ 20 cm

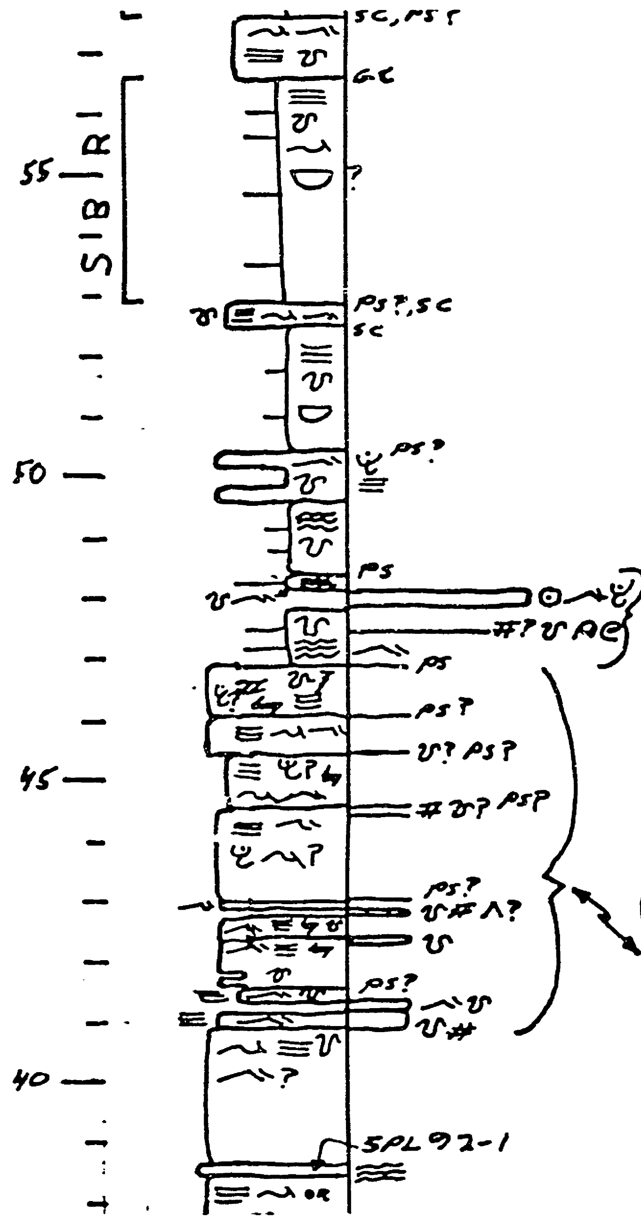
REDDISH PURPLE F QTZITE, BDD ≤ 20 cm W/ ≡ INTERVALS OF MUDDY SS, BDD ≤ 5 cm W/ ʋ.

LT PINK, GRY, TAN F QTZITE. DOMINANTLY ≡. ʋ UNCOMMON. ʋ ON BEDSET SURFACES & IN MUDDY SS. BDD 5-15 cm. BEDSETS ~10-30 cm. MUDDY SS BEDS ALSO MICACEOUS, CHLOR. STIC IN OCCASIONAL ≤ 10 cm THK INTERBEDS. SEVERAL 1-2 m THK PKGS OF CRSN-UP/THKN-UP W/IN UNIT.

PINK TO LT GRY F QTZITE. BDD 5-25 cm. BEDSETS ~ 25-60 cm. BEDS THKN UP

PINK SS & RED-PURPLE MDST. SS IS FINE, ≈. MDST IS ≡ & ʋ. SS BDD 5-30 cm. MDST BDD ≤ 10 cm. MDST DECR UP, IS MICACEOUS, CHLORITIC. ~5-10 BEDS TOTAL.

... UNIT TO




DARK BROWN VF-F SS, BDD 1-10 cm, HORIZ. . MOST INTERLAMS. SILICA CEMENT. SS MORE LATERALLY CONTINUOUS THAN PREVIOUS CARRARA SS.

DK GREEN, SILTY MDST & ALMOST PURPLISH W/ OCCASIONAL VF, DISCONTINUOUS LENTICULAR VF SS, ≤ 2 cm THK. IN SOME SS. ≡ IN MDST, BDD ≤ 1 cm.

ORANGISH-BROWN F SS, BDD 2-6 cm W/ MDST INTERLAMS. ON SURFACES HORIZONTAL.

DK GREEN SILTY MDST W/ A COUPLE OF DISCONTINUOUS, LENTICULAR VF SS ( ) ≤ 4 x 80 cm & ≤ 10 x 30 cm. HORIZ.

3 UNITS: 2 REDDISH-BROWN F-M SS W/ DARK GREEN SHALEY MDST BETWEEN SS. BDD 3-10 cm, , , , CARB-CMTD?. MDST BDD ≤ 1 cm, ≡, . NUMBERS, THKNSS OF SS BEDS VARIES LATERALLY.
GREEN, SILICEOUS MDST, MICACEOUS, CHLORITIC, BDD ≤ 1 cm W/ A COUPLE OF VF QTZ SS INTERBEDS ≤ 1 cm THK.

MIX OF ORANGISH-BROWN SILICEOUS MDST, F QTZ SS, A C LS PKST, & ⊙ LS BRST. ALL BDD ≤ 1-3 cm EXCEPT THE PKST ≈ 5 cm. SS BOTH SILICA- & CARBONATE-CEMENTED. ⊙ ¼-½ mm.

CARRARA Fm

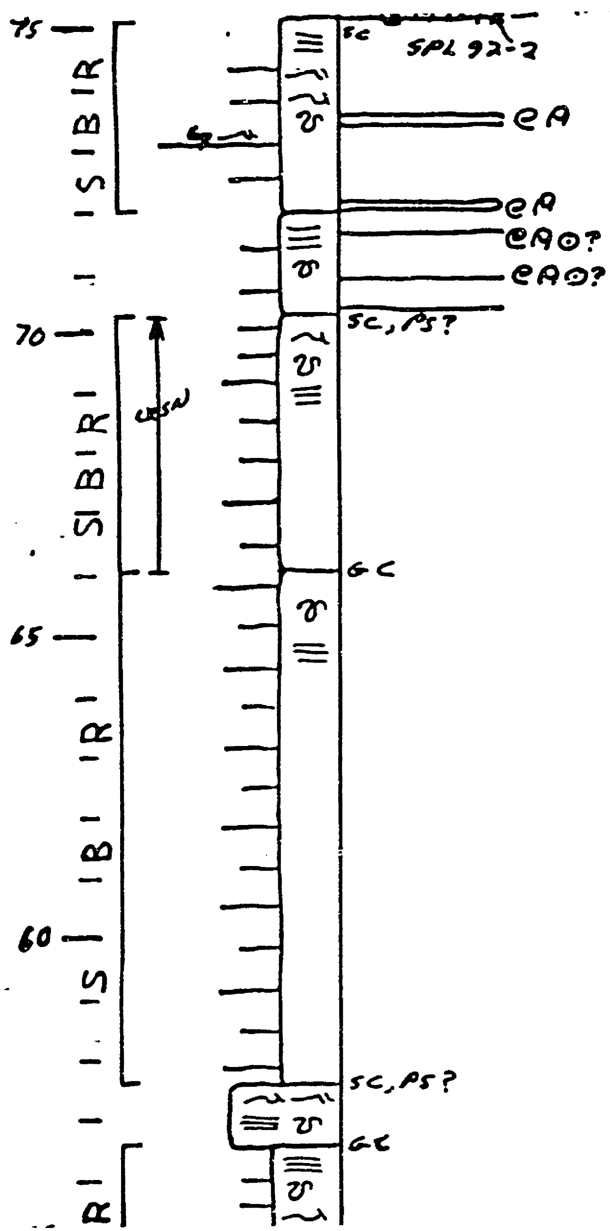
ZABRISKIE QTZITE

NOTE: FROM 37 m TO 46.9 m, HAVE NUMEROUS DOL. MDST & DOL-CEMENTED SS INTERBEDS IN QTZ SS, ON ALMOST A 1-2 m THK 'CYCLE'. INTERPRETATION: POSSIBLE TIDAL FLAT.

MOSTLY PINK MED & F SS, MOSTLY SILICA-CEMENTED, BDD ≤ 1-3 cm, W/ A FEW ≤ 4 cm. INTERBEDS OF BROWN DOL MDST ≤ 1-2 cm THK W/ A FEW ≤ 3 cm, COMMONLY AT TOPS OF SS UNITS. ALSO HAVE SOME DOL-CEMENTED SS, USUALLY AT TOPS OF SS UNITS. OF DOL MDST, ≤ ½ x 2 cm MOSTLY W/ SOME ≤ 8 x 4 x 2 cm AT TOP (46 m). SOME DOL MDST BEDS DISCONTINUOUS. MUCH, BUT NOT ALL OF IN MDST.

LT GRAY, M SILICA- & DOLOMITE-CEMENTED SS. BDD 1-2 cm. SEVERAL ≤ 1 cm DISCONTINUOUS DOL-CMTD INTERBEDS OF SS.

BRWN M W/ F & C, SS, DOL-CEMENTED, BDD ≤ 1 cm. NOT QTZITE.




ENTIRE UNIT MAY BE LATERALLY DISCONTINUOUS.

GREEN MDST, BDD ≤5mm, ≡, MICACEOUS, CHLORITIC W/ LS PK/GAST BEDS (WHERE LOCATED), @A, ≤½ mm ECHINOID?, HOMOGENOUS, BDD ≤5cm, 4 BEDS AT BASE & 2 IN MIDDLE. ALSO ~10-15 INTERBEDS/m OF VF-F SS, BDD ≤6cm, SHOWN SCHEMATICALLY ≡, ~, ~, CARB. CEMENT. Ʊ IN ALL LITHS

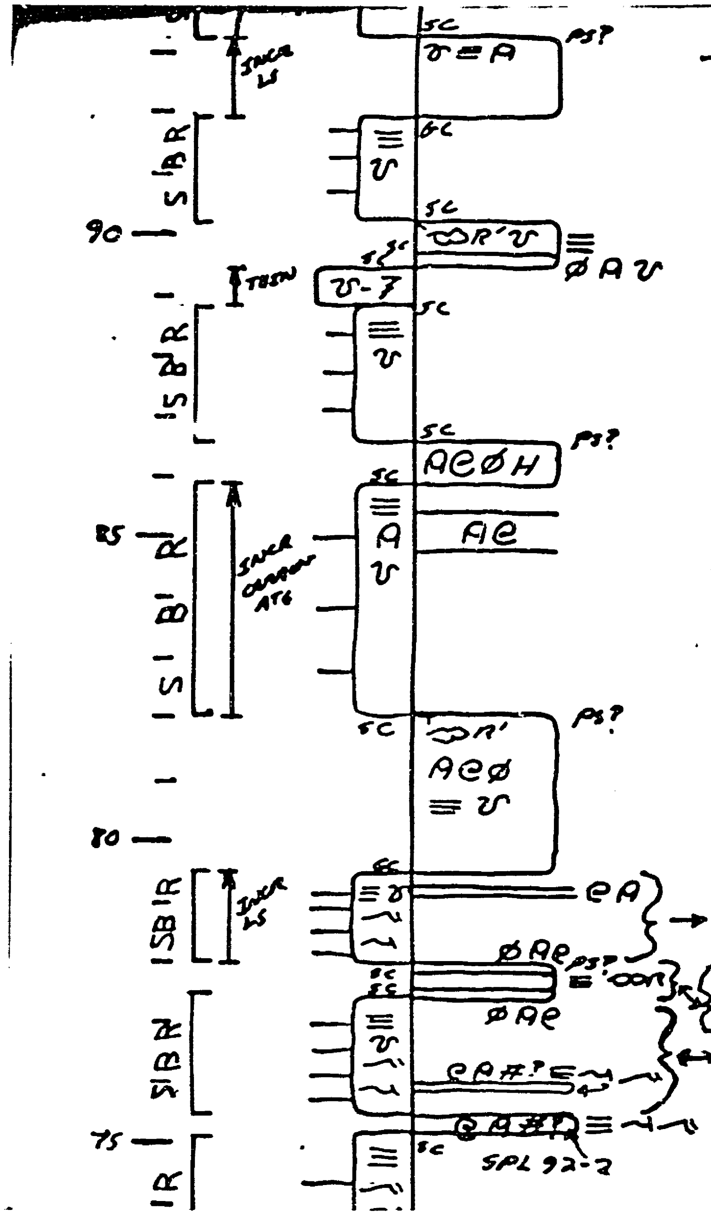
GREEN MDST, BDD <5mm, ≡, MICACEOUS, CHLORITIC W/ A COUPLE OF VF SS INTERBEDS, ≤1cm, ≡ & 3 LS PK/GAST, @A, O(<½mm)?, BDD ≤2cm. Ʊ IN ALL LITHS.

GREEN TO DK GREEN SILTY MDST, BDD <5mm, ≡, Ʊ, MICACEOUS, CHLORITIC W/ INTERBEDS OF VF & F SS, BDD ≤ 3cm, ~, ≡, Ʊ. Ʊ HORIZONTAL & VERTICAL. FREQUENCY OF SS BEDS INCR. UP TO ~10/METER.

DK GREEN MDST, BDD ≤1cm, ≡, Ʊ W/ 1-2 INTERBEDS/METER OF F & VF DK GREEN SS, BDD 2-8cm, ~, ≡, Ʊ. SS BEDS PROBABLY DISCONTINUOUS.

DARK BROWN VF-F SS, BDD 1-10cm, HORIZ. Ʊ. MDST INTERLAMS, SILICA CEMENT. SS MORE LATERALLY CONTINUOUS THAN PREVIOUS CARRARA SS.

DK GREEN. SILTY MDST & ALMOST RUBBLE W/ OCCASIONAL




Interbeds of sts & vf ss, bdd ≤ 3 cm, ≡, carbonate-cemented, w/ slight incr upwards, few ♂ in lwr part w/ upward incr to ♂ in top ~70 cm. Interbd: [illegible] orangish-brown dolsts, bdd ~5-15 cm, indistinct, w/ occasional interbeds of ls A pkst, ~2 cm thk, w/ more pkst in lwr ½

Lt green-gray mdst, bdd ≤ ½ cm, w/ interbeds of sts & vf ss, bdd ≤ 1 cm, carbonate-cemented, w/ upward incr in interbeds.

Orangish-brown carbonate sts & pkst, ♂ in both, ≡ in [illegible]. Ø ≤ 2 cm in pkst. Some A in sts.

Reddish brown vf ss bdd 15-45 cm, thinning up, carbonate cemented

Lt (green gray) mdst, bdd ≤ ½ cm w/ chloritic & [illegible]. Interbedded sts & vf ss, ≤ 1-2 cm, lenticular, carbonate cemented.

Brown ls pkst, w/ 3-4 beds in 70 cm of thknss. [illegible] rare, 1 x 3 cm. Ø ≤ 1 cm. @ incl. Echinoid? fragments

Lt green, mdst. somewhat punky & talcy, bdd ≤ ½ cm. Interbeds of vf qtz ss, bdd ≤ 1-2 cm, & of foss. pkst, w/ @, A, bdd ≤ 3 cm, upward incr in CO3 beds (ls) w/ few if any in lwr ½. A in both mdst & in ls pkst. Few ♂ in lsts.

Green ls? w/ orng dolsts, both bdd ≤ 1-5 cm, ♂. Also ls @ pkst w/ Aristolsa, Peachella?, O. Gilberti. Ø ≤ 1 cm. Echinoid? fragments ≤ ½ mm.

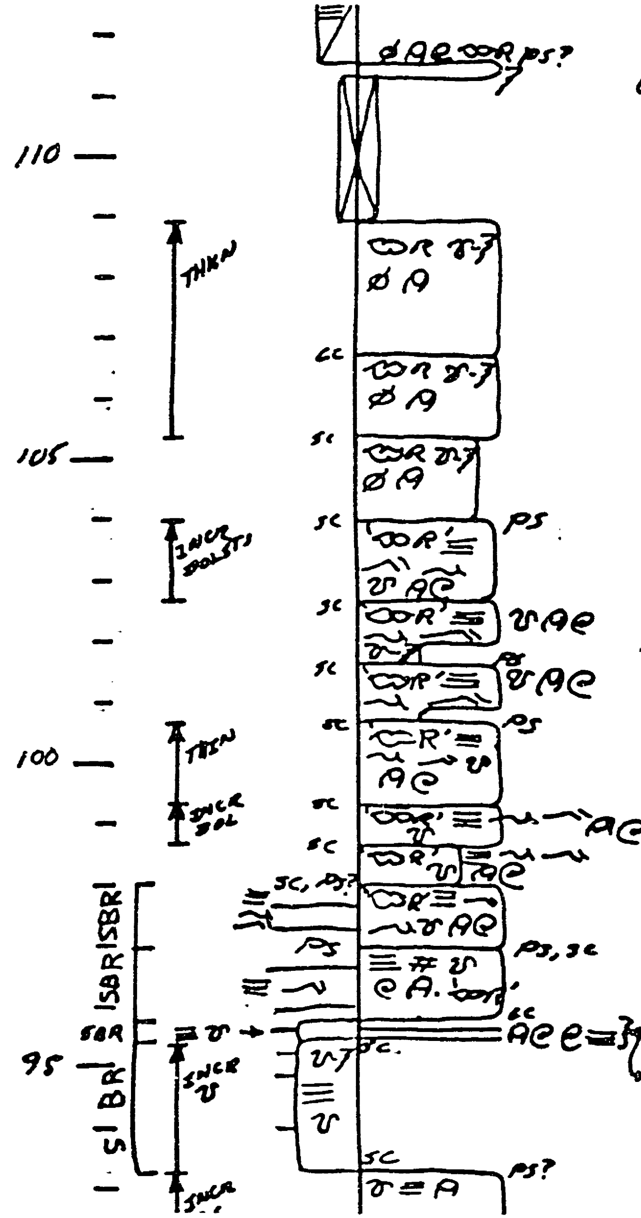
→ Most like 74 m. Ls pk/grst like 75.3 m. Ls incr upward

[illegible] w/ both ls & dol ≡ & sts to vf aren, bdd 1-2 cm, ~50/50 ls/dol ~25 cm thk for unit, above & below [illegible] and ls pkst w/ 15 cm top ≤ 10 cm thk, btm, both homogeneous Ø ≤ 3½ cm, biggest Ø in top bed.

← Most like 74 m. Pk/grst like 75.3 m

Khaki-green, fossiliferous ls pk/grst, bdd ≤ 7 cm, possible echinoid fragments, w/ some siliceous mdst interlamina. Entire unit may be laterally discontinuous.

Green mdst. bdd ≤ 5 mm, ≡, micaceous, chloritic w/ ls




LIKE 115m? MOSTLY COVER.

GRY LS PKST IN ⊂⊃R. 10R = BEDS IN 20cm. Ø ≤ ½ cm.

COVER

LITHS LIKE 105½ 106 m, W/ SOME LS A WK/PKST. BEDS 5-15 cm. DOLSTS <20% IN ϑ-FILL. AGAIN POSSIBLE ARCHEOCYATHIDS? BEDS THKN UP WHEN 105-109 m TAKEN AS A WHOLE. Ø ≤ 3 cm.

GRY ⊂⊃R W/ LS A PKST & ORNG DOLSTS IN ϑ & DISCONT LAMS. PKST BDD 3-6 cm, DOLSTS ≤ 5 mm, < 20%. Ø ≤ 1½ cm. POSSIBLE ARCHEOCYATHIDS?

GRY ⊂⊃R W/ LS A WK/PKST & ORNG DOLSTS INTERLAMS & ϑ. WK/PKST ≤ 6 cm → 1-2 cm. DOLSTS ≤ 1 cm, < 20% DOLSTS. Ø ≤ 4 cm. POSSIBLE ARCHEOCYATHIDS?

GREEN LS STS W/ ORNG DOLSTS & OCCASIONAL A PKST, ALL BDD ≤ 2 cm, MOST ≤ 1 cm. INCR DOLSTS UPWARDS, < 20% OVER MOST OF UNIT, INCR TO ~40% TOP ½ m. PKST ALSO INCR UP.

SAME LITHS AS 101 m, BUT BASAL 40 cm IS GREENISH. ∴ LS MOST. ALL BDD ≤ 2 cm, MOST ≤ 1 cm. < 50% DOLSTS. A COUPLE OF A PKST, ≤ 1 cm THK. OVERALL GREEN

LITHS SAME AS 100 m, BDD ≤ 3 cm, MOST ≤ 1 cm. ≥ 50% DOLSTS. BASAL ~10 cm IS GREENISH, RECESSIVE, SILTY LS MDST. TOP 2 cm A A PKST. OVERALL ORNG

GREEN & ORNG LS & DOL STS BEDS W/ OCCASIONAL A@ WKST. ALL BDD ≤ 3 cm THIN UP TO ≤ 1 cm. ≥ 90% DOLSTS BRISTOLIA A OVERALL ORNG. @ INCL. ECH? FRAGS. OVERALL ORNG

MIXED GREEN A@ WK & PKST & ORNG DOLSTS. WK & PKST BDD ≤ 2 cm DOLSTS BDD ≤ 3 cm, INCR UP. @ INCL. ECH? FRAGS. OVERALL GREEN

GREEN A@ WKST W/ DOLSTS INTERLAMS. WKST BDD ≤ 1-3 cm, DOLSTS BDD ≤ 1 cm, ~35% DOLSTS. @ INCL. ECH.? FRAGS. OVERALL GREEN

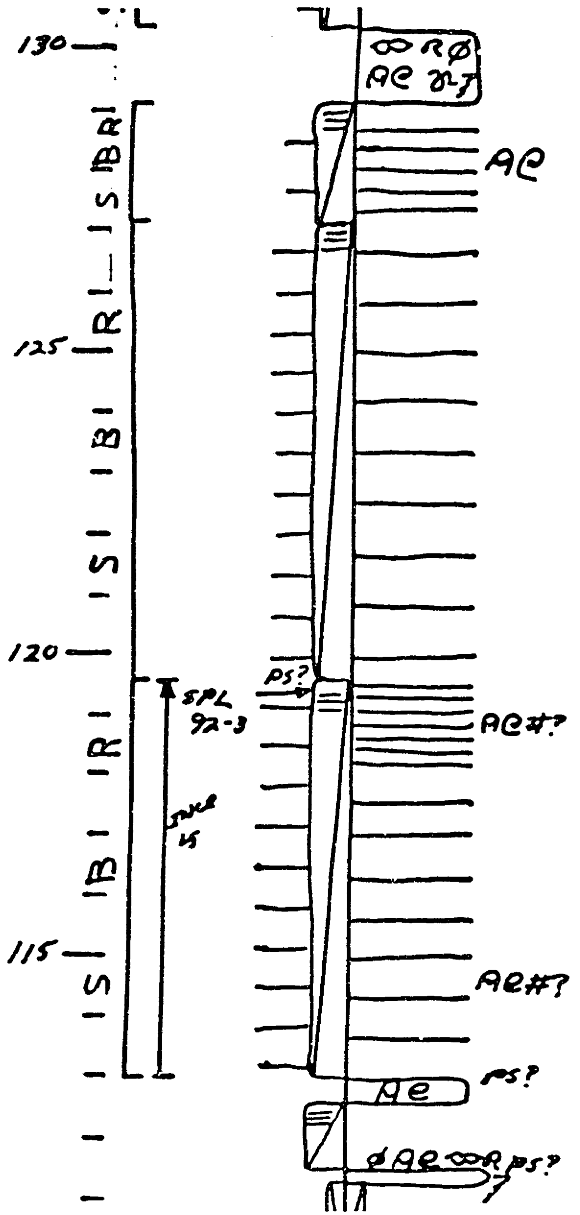
REDDISH ORNG DOLST & W/ A@ AS PKST & A FEW INTERBEDS OF QTZ SS/VFSS. ALL BDD ≤ 3 cm. @ INCL ECHINOID? FRAGS. CARBONATE CEMENT

REDDISH-ORNG DOLST W/ INTERBEDS OF QTZ STS & VFSS, ALL BDD ≤ 3 cm.

LT GREENISH-GRY MDST W/ INTERBEDS OF QTZ STS/SS, BDD ≤ 1 cm & @ PKST. BEDD ≤ 1 cm, A & @. QTZ SS/STS CARB-CMTD. SMALL ϑ. LS INCR UP.

LT GRAYISH-GREEN GREENISH MDST, BDD ≤ ½ cm, ≡, CHLORITIC, INTERBEDS OF STS & VFSS, BDD ≤ 2 cm, ≡, CARBONATE-CEMENTED, W/ SLIGHT INCR UPWARDS. FEW ϑ IN LWR PART W/ UPWARD INCR TO ϑ IN TOP ~70 cm. INTERP: CHANGE FROM SHORE TO INTERTIDAL?

ORANGISH-BROWN DOLSTS, BDD ~5-15 cm, INDISTINCT, W/ OCCASIONAL




GREENISH-GRAY ⊘R w/ LS ∅ @ WK/PKST, ∅ ≤ 2cm. ≤ 20% ORANG DOLSTS IN ∅ & DISCONT INTERLAMS & ∅ REPLACE-MENT

LIKE 118.7-119.6 m. SILTY SH w/ WK/PKST INTERBEDS

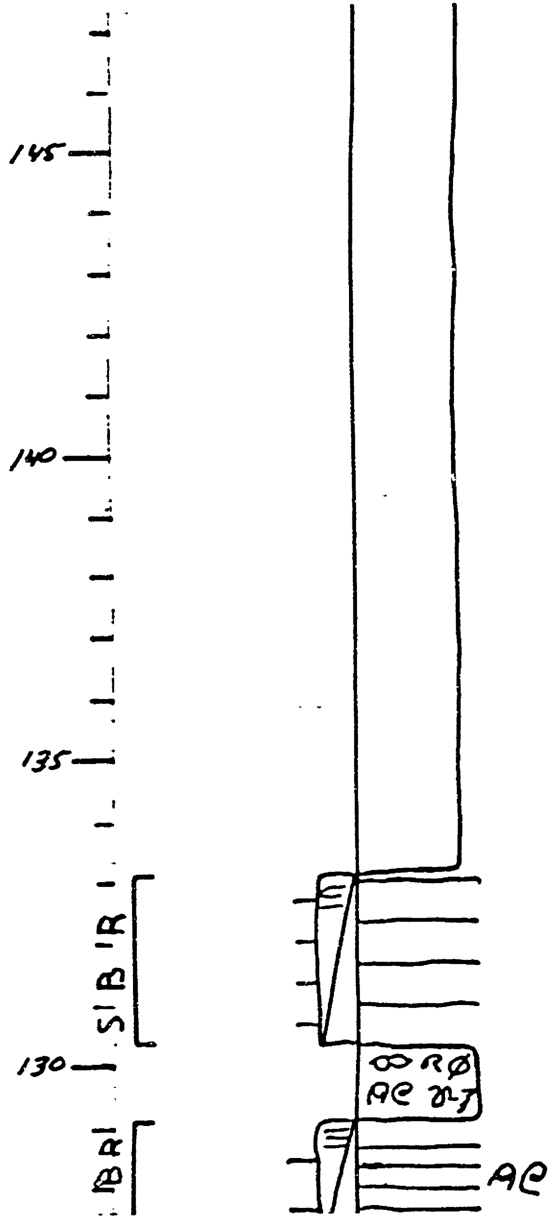
GREEN SILTY SH LIKE 115 m

LT GREEN, SILTY SH BDD ≤ 5 mm, w/ INTERBEDS OF GRY AE w/PKST BDD 1-4cm & INTERBEDS OF SLTST & VF SS BDD ≤ 1-3cm, CARBONATE CEMENTED. INCR UP SN NUMBER OF WK/PKST BEDS w/ N15 IN TOP 1½ m.

GREEN @ WK/PKST, BDD ≤ 2cm.

LIKE 115 m? MOSTLY COVER.

GRY LS PKST IN ⊘R. 10 OR 2 BEDS IN 20cm ...

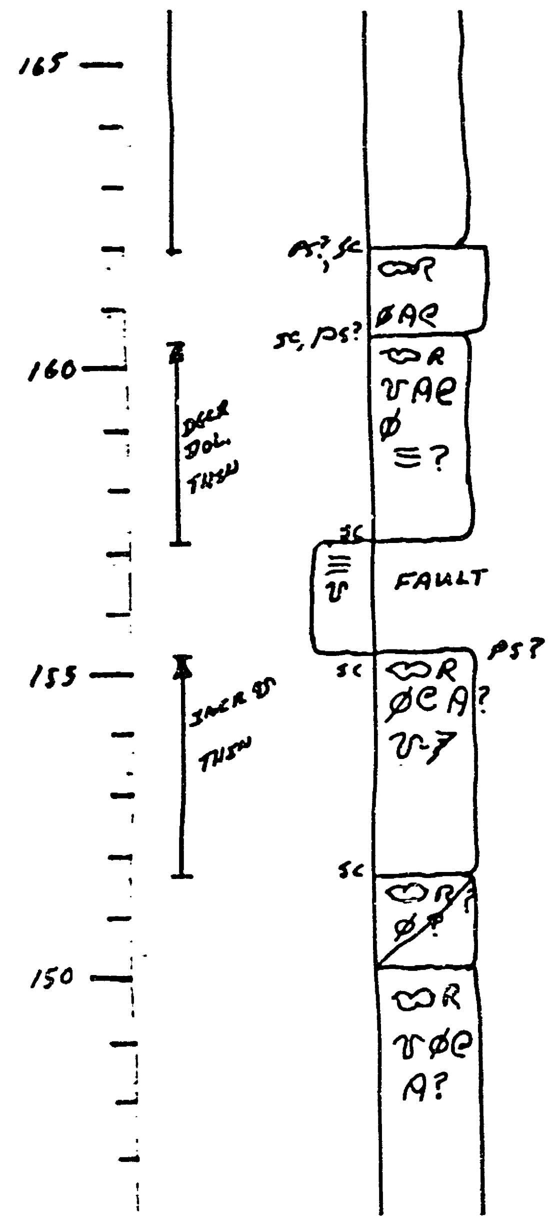



GRY @ WKST w/ ≤10% BRWN DOLSTSIN [illegible]-FILL. BDD (LS) ≤1-6 cm. MAY BE ±2m BEDSETS. Ø ≤ 2½ cm. POSSIBLE ARCHEO-CYATHIDS? WEATHERS AS A LARGE WALL OF ROCK.

LSME 115 m: MAY BE FAULTING IN THIS INTERVAL

GREENISH-GRAY [illegible] w/ LS Ø @ WK/PKST, Ø ≤ 2cm. ≤ 20% ORANG DOLSTS IN [illegible] & DISCONT INTERLAMS & Ø REPLACEMENT

LSME 118.7-119.6 m. SILTY SH w/ WK/PKST INTERBEDS



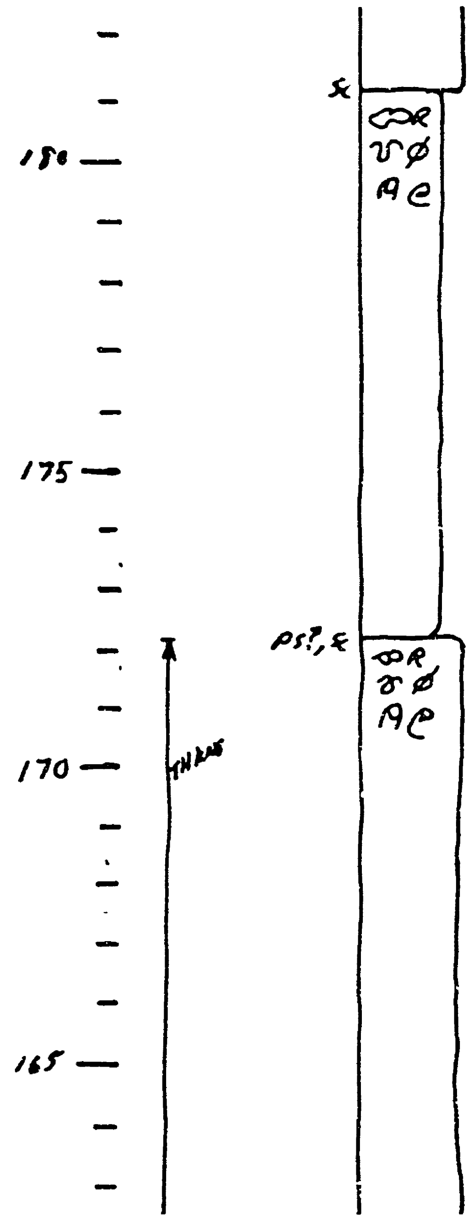

GRAY @ WK/PKST, BDD ≤ 1-4 cm, MOST 2-3 cm, W/ ORNG DOLSTS IN Ɣ & DISCONT INTERLAMS. Ø ≤ 2½ cm, GRNSNOID? FRAGS, POSSIBLE ARCHEOCYATHIDS? OVERALL ORNG TINT.

ⓞR W/ GRAY @ WKST, BDD 2-8 cm, AVG 4-5 cm, W/ ORNG/OCCASIONAL BRWN DOLSTS INTERLAMS & INTERBEDS ≤ 2 cm. OCCASIONAL @ LS/PKST BEDS ALSO. DOLSTS DECR UP FROM ~40% IN BTM 1 m TO ≤ 5-10% IN TOP 1 m, W/ THINNING OF INTERBEDS FROM ≤ 2 cm TO INTERLAMS ≤ 5 mm. ≡? IN THKR DOLSTS BEDS. POSSIBLE GRNSNOID? FRAGMENTS & ARCHEOCYATHIDS? WEATHERS AS A WALL

LT GRYSH-GREEN MOST, CHLORITIC. CALCITE VEINS & GOUGE NEAR TOP & BTM OF UNIT

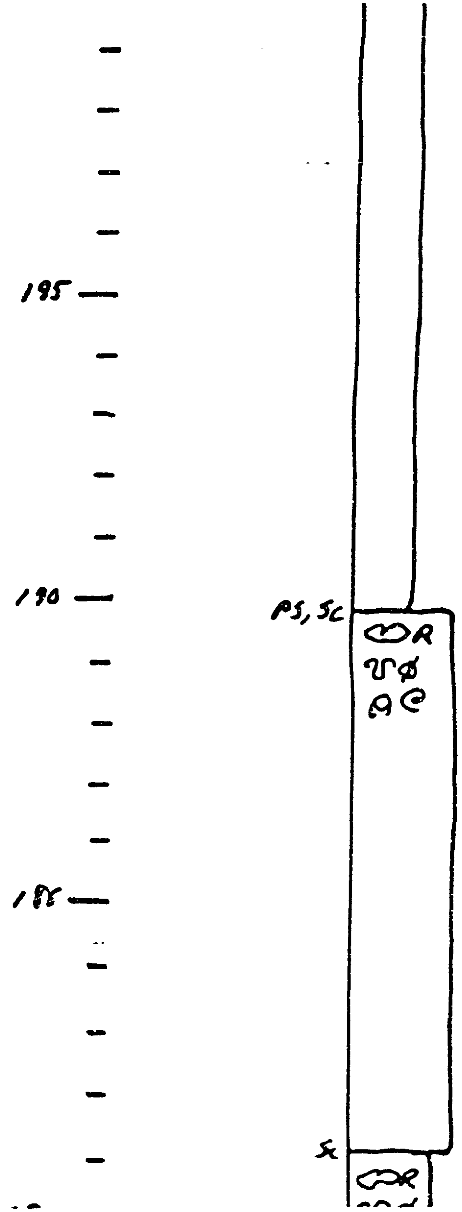
GRY WKST ⓞR, BDD ≤ 1-10 cm W/ ~15-20% ORNG & BRWN DOLSTS INTERLAMS (≤ 1 cm) & IN Ɣ, LAMS BOTH CONTINUOUS & DISCONT. Ø ≤ 2 cm. A FEW @ PKST BEDS INCLS ALSO. POSSIBLE UPWARD INCR. IN Ɣ & UPWARD THINNING OF WKST

SHEARED & PARTIALLY COVERED ⓞR?.




DK GRY AS MOST TO Ø @ WAST, ADD 5-25cm NEAR BL. W/ 3-7% GREEN-BROWN DOLSTS IN Ʊ. Ø @ WAST BEDS SCATTERED THRU-OUT, OFTEN 20+cm THK. Ø ≤3cm. BEDDING INDISTINCT, MASSIVE-LOOKING.

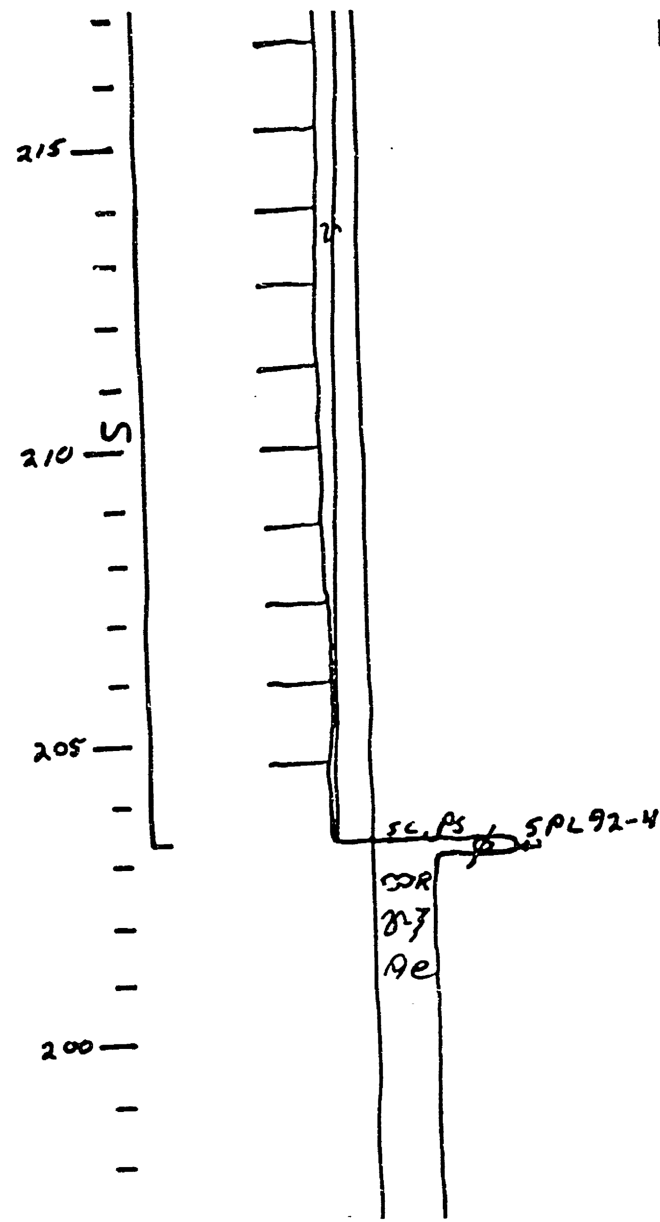
GRY Ø, @ WAST, ADD ~1-8cm, W/ INTER ADD BROWN DOLSTS (~5-10%) IN Ʊ & INTERLAMS ≤1 cm TO 3-5 mm. WAST BED-THKNSS INCR UP, AVE 2-3cm & 6-8cm, THEN DECR TO AVE 3-4cm IN TOP 2-3 m. ALSO SOME DECR UP IN INTERLAM THKNSS Ø ≤3cm, BEDDING DISTINCT.




DOLSTS, ~10-15%, ALSO IN ZT, NO CONTINUOUS INTERLAMS.
TOP ~20 cm GOES TO Ø WAST, THEN Ø PAST AT TOP
BEDDING INDISTINCT AGAIN, RATHER MASSIVE-LOOKING

NOTE: From 157.2 m TO 203.3 m, ROCK WEATHERS AS A LARGE WALL.

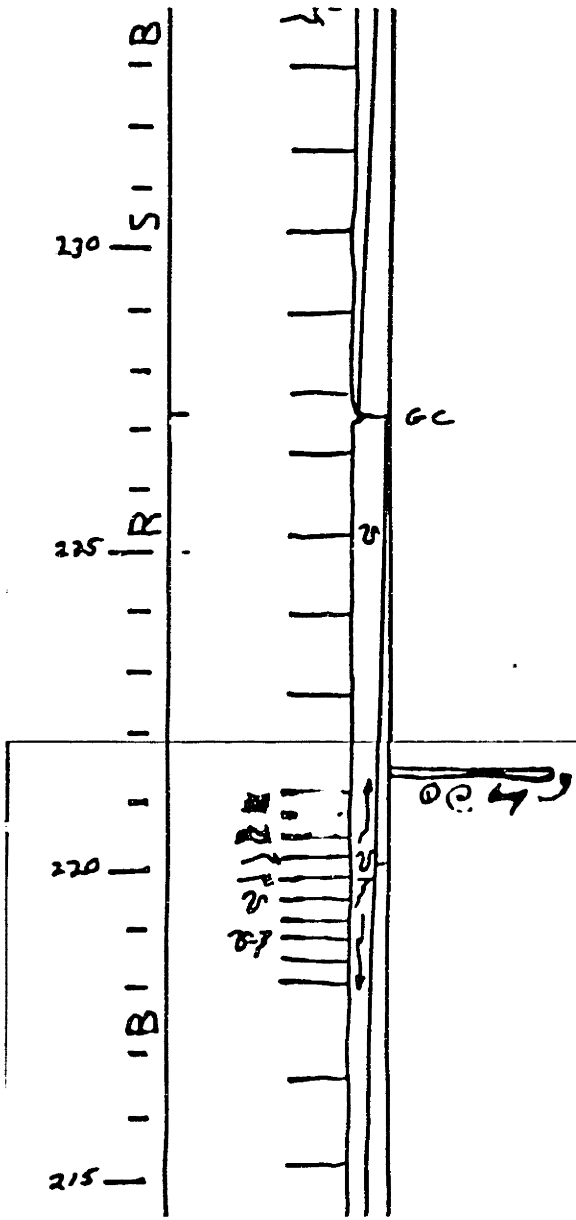
GRAY ØQ WAST, BDD 5-10 cm, W/ BRWN DOLSTS IN ZT & ≤1 cm INTERLAMS, CONT, ~ 5-10%. AMT OF Ø IN BEDS VARIES. BEDDING DISTINCT




⊙, ECHINOID? FRAGS & ≤10 cm, OCCURS OUT INTERMITTANTLY & MAY BE CONTINUOUS. SH BELOW THE PK/GRST TO ≈219m IS [illegible] & ALMOST A MDST. POSSIBLE PS BNDRY IN INTERVAL ~220-223m
A NOT SEEN THRU-OUT UNIT (203.3→227.3m)

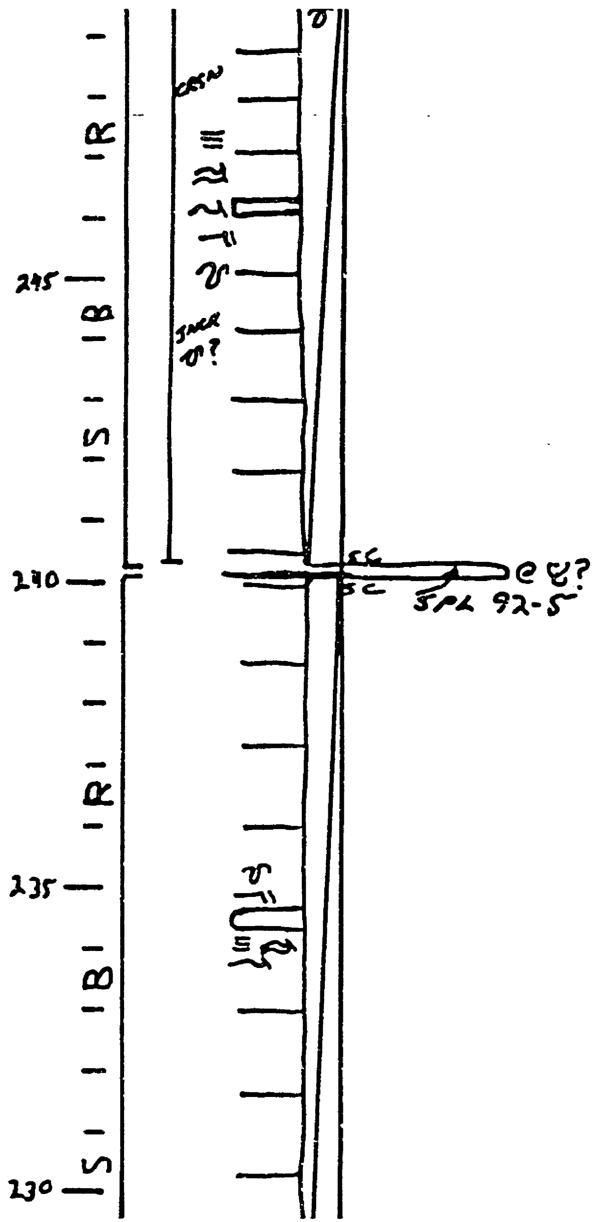
NOTE: A NOT SEEN 203.3m → 250.1m

Dx gry ø @ MDST; BDD ~5-10cm, W/ BLEBS OF BRWN DOLSTS, ~10-15%, ALSO IN [illegible], NO CONTINUOUS INTERCLASTS. TOP ~20 cm GOES TO ø WKST, THEN ø PKST AT TOP BEDDING INDISTINCT AGAIN, RATHER MASSIVE-LOOKING




GRAY-PURPLE SILTY [CHLORITIC] SH, CLEAVED [WAVY]. OCCASIONAL VF QTZ SS INTERBEDS ≤ 1-8 cm THK w/ ≡ ≈ ~ ~ ʊ. AT ~233.4m, IS A 35 cm-THK AMALGAMATED SS UNIT. POSSIBLE PS BNDRY AT 233.4m

GREENISH-GRAY SH, CLEAVED. 1/2" UTP SS INTERBEDS ≤ ~8 cm, MOST SILICA-CEMENTED, A FEW CARBONATE-CEMENTED. SS w/ ≡, ≈, ~, ~, ʊ, ʊ-ℱ w/ A FEW ʊ IN SH (POSSIBLY OBSCURED BY CLEAVAGE). AT 218-221 m, HAVE SEVERAL SS BEDS THAT CRSN UP, THEN FINE UP [ABUNDANT]; AT ~222-223 m, A 10 cm THK PK/GRST w/ ⊙, CRINOID? FRAGS & ≤10 cm, OCCURS OUT INTERMITTANTLY & MAY BE CONTINUOUS. SH BELOW THE PK/GRST TO ≈219m IS ʊ-ℱ & ALMOST A MDST. POSSIBLE PS BNDRY IN INTERVAL ~220-223m




@ = ECHINOID? FRAGMENTS. ≤ 5-25 cm.

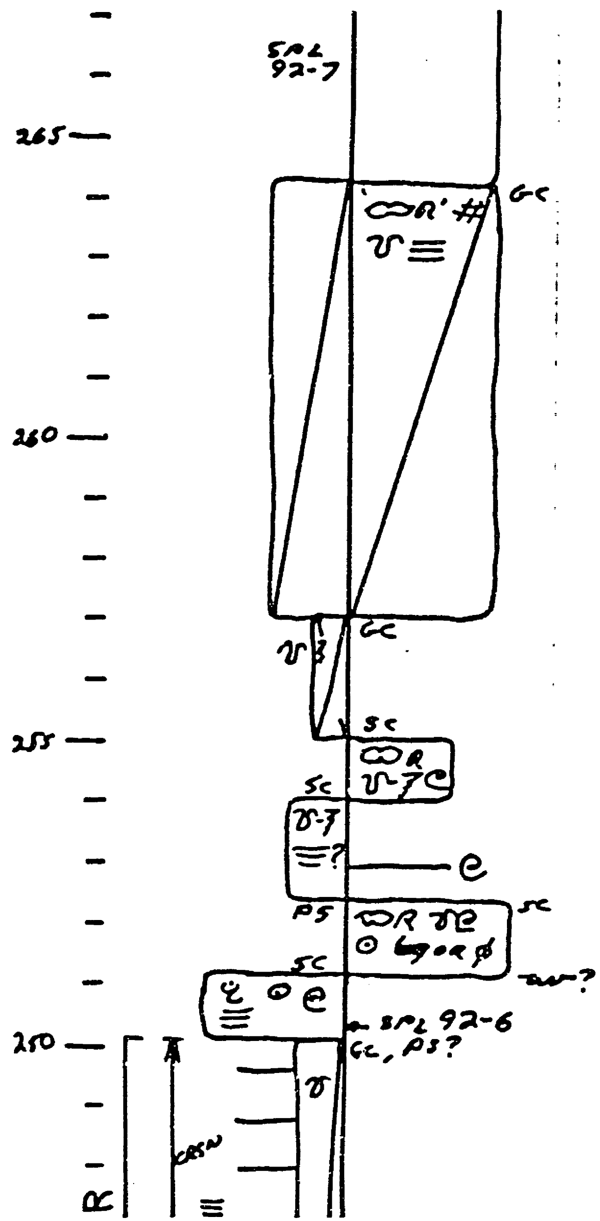
NOTES: PROBABLE PS BNDRY AT 237.45 m, BUT NOT SURE OF ONE AT 250.1 m; POSSIBLY NOT.

GRAY-PURPLE SILTY SH VERY LIKE 230 m W/ AN OVERALL CRSN UP, TOP ~1 m MORE A MOST. INTERBEDS OF VF-F SS, W/ ≡, ≈, ~, ~, BDD ~1-7 cm. NUMBER OF SS BEDS INCR UP. AT ~246 m SS A ~30 cm THK AMALGAMATED SS UNIT. IN BOTH LITHS, INCR UP? SH CLEAVED.

BRWN PK/GRST W/ @ & M-VC QTZ GRNS, BDD ~4, 7, & 6 cm. @ OR ECHINOID FRAGS & VC-SAND-SIZED. F QTZ SS BEDS, ≥ 5 cm THK BENEATH. LATERAL VARIATION IN SS, PK/GRST THKNS & NUMBER OF BEDS.

GRAY-PURPLE SILTY CHLORITIC SH, CLEAVED W/ MICA. OCCASIONAL VF QTZ SS INTERBEDS ≤ 1-8 cm THK W/ ≡ ≈ ~ ~. AT ~233-4 m, SS A 35 cm THK AMALGAMATED SS UNIT. POSSIBLE PS BNDRY AT 233-4 m

... TO ... cm THK. THERE ARE # JUST ABOVE THE ...




GREEN & TAN, NON-DOLOMITIC & POSSIBLY CALCITIC NON-NODULAR RIBBON ROCK. VERY HARD TO PICK OUT BEDS & STRUCTURES IN NON-DOL'C ROCK. RECESSIVE WEATHERING & CLEAVAGE. SOME MAY BE SILICICLASTIC.

ASSUME TO BE LIKE 265-270 m, OR CLOSE TO IT. UPPER CNTC SOMEWHAT ARBITRARY BECAUSE THE DOL. CONTACT VARIES STRATIGRAPHICALLY AS YOU MOVE LATERALLY.

GREEN, SILTY, CLEAVED SH, PROBABLY CARBONATE CEMENTED

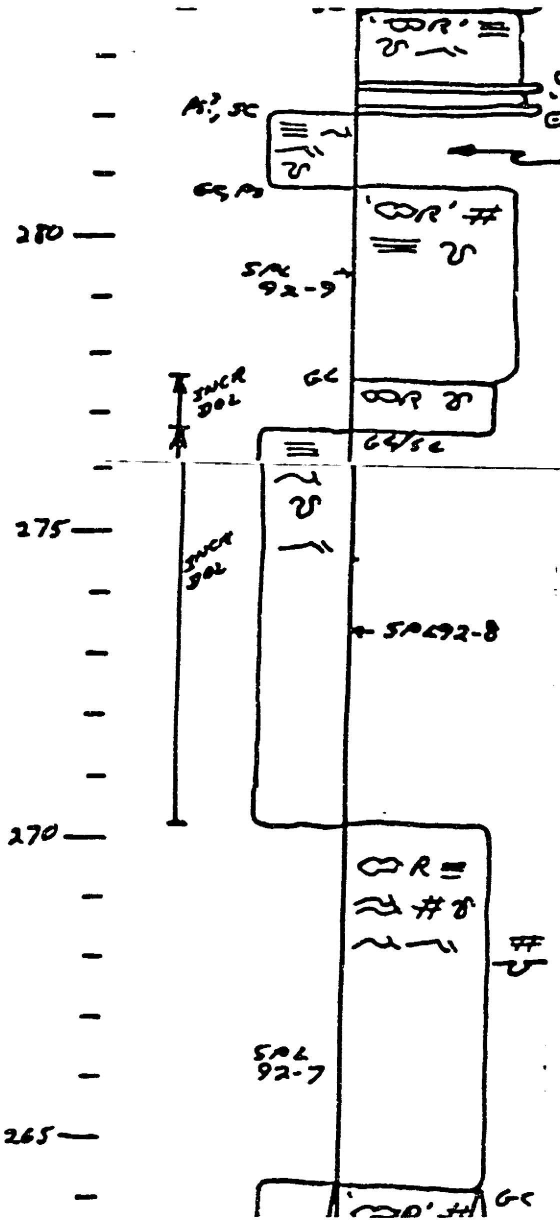
GRY-GREEN LS WKST, BDD ≤ 1 cm, W/ ~50% GRY-GREEN LSTS INTERLAMINATED. WEATHERS MORE PUNKY & RECESSIVE THAN 252 m, WHICH IT IS SIMILAR TO.

GRY-GREEN SILTY, MICACEOUS MDST, BDD < 1 cm. ≡? MAY BE CLEAVAGE. ONE @ LS WKST, GREEN-BRWN, ≤ 3-5 cm THK AT ~253 m.

GREENISH-BRWN, PUNKY WEATHERING @ PK/GRST BDD ~1-3 cm W/ SOME DOLSTS IN ... & INTERLAMS < 5 mm. ... < ... cm. EITHER ∅ OR ... CAN'T TELL FOR SURE DUE TO PUNKY, RECESSIVE WEATHERING.

MED. SS W/ SOME CRSE QTZ GRNS, BDD ~3-25 cm, W/ ... IN THKR BEDS, ≡ IN THNNR. CARBONATE-CEMENTED IN UPR, SILICA-CEMENTED IN LWR. ⊙ ≤ ½ mm, @ = ECHINOID? FRAGMENTS. ... 5-25 cm.

NOTE: PROBABLE PS BNDRY AT 252.45 m, BUT NOT SURE IF ONE AT 250.1 m; POSSIBLY NOT.




(@ AT TOP

2 LITHS: ORNG DOLSTS & VF ARKN 'ØR' LIKE 280m & GREENY LS ⊙ (3 H-Km) GRST. GRST BDD ≤1-5 cm. LATERALLY THE LOWER GRST BED THKNS TO 50 cm ⊙ GRST, THEN SPLITS INTO SEVERAL ≤10-15 cm GRST BEDS W/ SILICICLASTIC BEDS BETWEEN, THEN GOES BACK TO 2-3 THIN ⊙ GRST BEDS

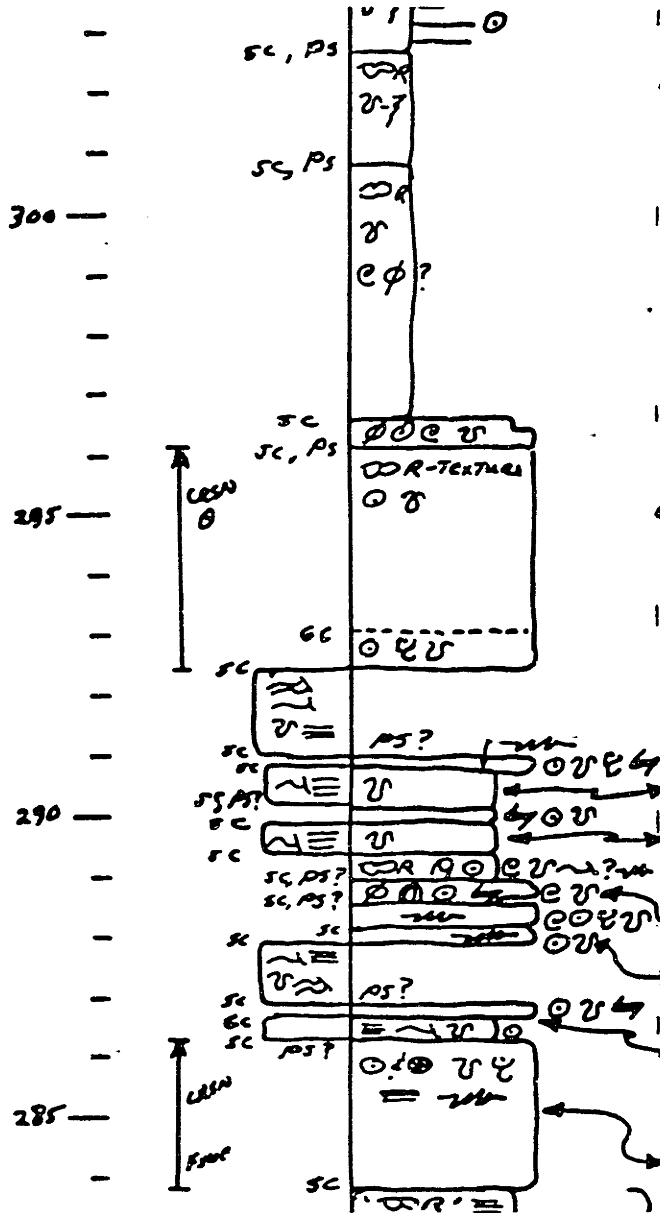
LIKE 275m, BUT NO MUD CRACKS (#)

ORNG DOLSTS & VF ARKN & SILICA-CEMENTED STS & VF SS. ʊ uncommon. # SLIGHTLY MORE COMMON
~35-40% DOL'C CEMENTED, REST SILICA-CEMENTED ?

GREEN LS & ORNG DOL STS., BDD ~2 cm. OVERALL ~50% DOL, & INCR UP DOLSTS %

GRY-BRN QTZ STS & VF SS, MOSTLY BDD ≤ 1-2 cm, SOME ≤ 2-3 cm. ʊ uncommon. BROAD, LOW-ANGLE, SWALEY LAMS ≤ 1 cm THK, ~. OCCASIONAL DOL'C STS BEDS 1-2 cm THK. TOP 1½ m MORE DOL'C & LESS DISTINCT BDDG. TOP 30 cm W/ INCR AMOUNT OF DOLSTS INTERBEDS

LS & DOL STS. MOSTLY BDD ≤1 cm, SOME 2-8 cm. ~50-60% DOLSTS. MOSTLY ≡, #, ʊ, W/ FEWER ≈, ~, ⌒. GOOD ʊ AT 268 m W/ GREEN LS LOADED DOWN INTO DOLSTS (~5-10 cm THK & ~50 cm WIDE) BED ~45 cm THK. THERE ARE # JUST ABOVE THE ʊ




~30-35% IN BTM 40 cm UP TO ~15-20%. (TAN UP TO GREEN). SOME ⊙ WK/PART BEDS.

GREEN-GRAY LS MDST (OR ARENITE), BDD 2-3 cm W/ ORNG-DOLSTS IN ℧ & INTERLAMS. BTM 20-30 cm W/ ~35-40% UP TO ~15-20% DOLSTS IN TOP.

GRAY LS MDST (OR ARENITE). Ø? ≤ 5 mm & ≤ 10%. BDD 2-3 cm W/ ORNG-BRWN DOLSTS IN ℧-FILL, ≤ 5-10% UP TO ~25% UP TO ~15-20%

Ø (≤1-2 cm) ⊙ (~¼ mm) LS GRST, W/ DISCONT ORNG-DOLSTS IN ℧ & INTERLAMS ≤ ½ cm. Ø CYLINDRICAL. LS BDD ~10 cm. TOP 10 cm IS PK/GRST.

GRAY LS ⊙ (~½ UP TO ~1 mm) GRST, BDD 2-4 cm. W/ ORNG DOLSTS IN ℧ & DISCONT. INTERLAMS ≤ 1 cm, ≤ 5-10%. ⊙ CRS UP. TOP 15-20 cm IS ℧7, REST IS ℧. BTM 60 cm W/ 10-15 cm BEDS & NON-OR TEXTURE

GREEN & TAN QTZ VF SS, BDD ≤ 1-10 cm, PROBABLY CARBONATE & SILICA CEMENT. SOME BEDS W/ MICA

GREEN ⊙ (½-1 mm) LS GRST, BDD 3-10 cm, W/ DISCONT. DOLSTS & INTERLAMS

ORNG-TAN DOL & LS (CMTD) STS/VF SS W/ CARB. & QTZ GRNS, BDD 1-4 CM, MOSTLY DOL

GREEN & ORNG PAST, 1X15 cm BED., STS ↳. INTERP AS

SAME AS 290.5 m: MIXT CEMENT/MIXT GRAINS, GRAVITY PROCESS FLOW

GRAY & ORNG LS & DOLSTS BED ~1-4 cm. ⊙ (~1 mm), DOLSTS INTERLAMS ≤ 5 mm

GRAY LS ⊙ (≤ ¼-¾ mm) (GRST) ↳ OF CO3, Ø ≤ 2 cm. BASAL 4 cm W/ Ø ⊙ ↳ & ⊙ (≤ ½ cm HxW) PKST.

GRAY ⊙ LS GRST. BDD ≤ 1-4 cm, ≤ 15 cm. ⊙ (≤ ½ mm),

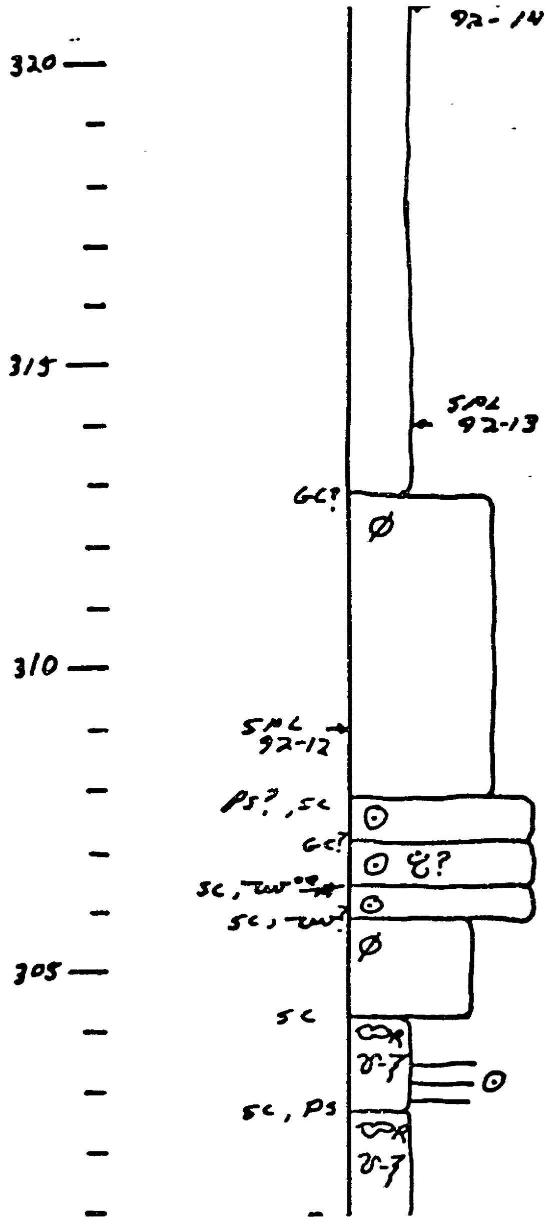
GREEN LS ⊙ GRST, BDD ≤ 1-4 cm, ⊙ (½-¾ mm)

TAN & GREEN QTZ STS & VF SS, BDD MOST ≤ 1 cm, SOME 1-4 cm % CLAY IN MATRIX VARIABLE, CARB-CEMENTED

GRAY LS ⊙ GRST, INDISTINCT BDDG. ⊙ (½-¾ mm), ↳ DOLSTS ORNG

ORNG DOLSTS & SILICEOUS STS & DOLOMITIC VF QTZ SS, BDD ≤ 2 cm. DOL & CALCITIC CEMENT. SEVERAL LS ⊙ BEDS IN TOP 5-5 cm

BRWN, GREEN, GRAY LS ⊙ (≤ ¼-1 mm) GRST, BDD ~5 to 20 cm (℧). DOLSTS INTERLAMS ≤ 10 cm THK, DISCONT. ⊙ FINE UP, MANY DOLZD, BUT THEN INCR UP W/ LGST ⊙ AT TOP




HAVE A CAUD & [illegible]-TEXTURE W/ [illegible], BUT LOSE IT UPSECTION.

NOTE: INTERVAL OF 292.5m → 331.55m WEATHERS AS A LARGE WALL.

MED LT GRAY LS Ø(≤1½ cm) PKST. UNLIKE 305m, THESE Ø W/O DISTINCT LAMS, & W/ SPAR IN CENTERS.
NOTE: ARE Ø PKST AT ~308-313m & ~304-306m SOME OF HALLEY'S [illegible] BEDS?

GRAY LS ⊙(~1mm) GRST

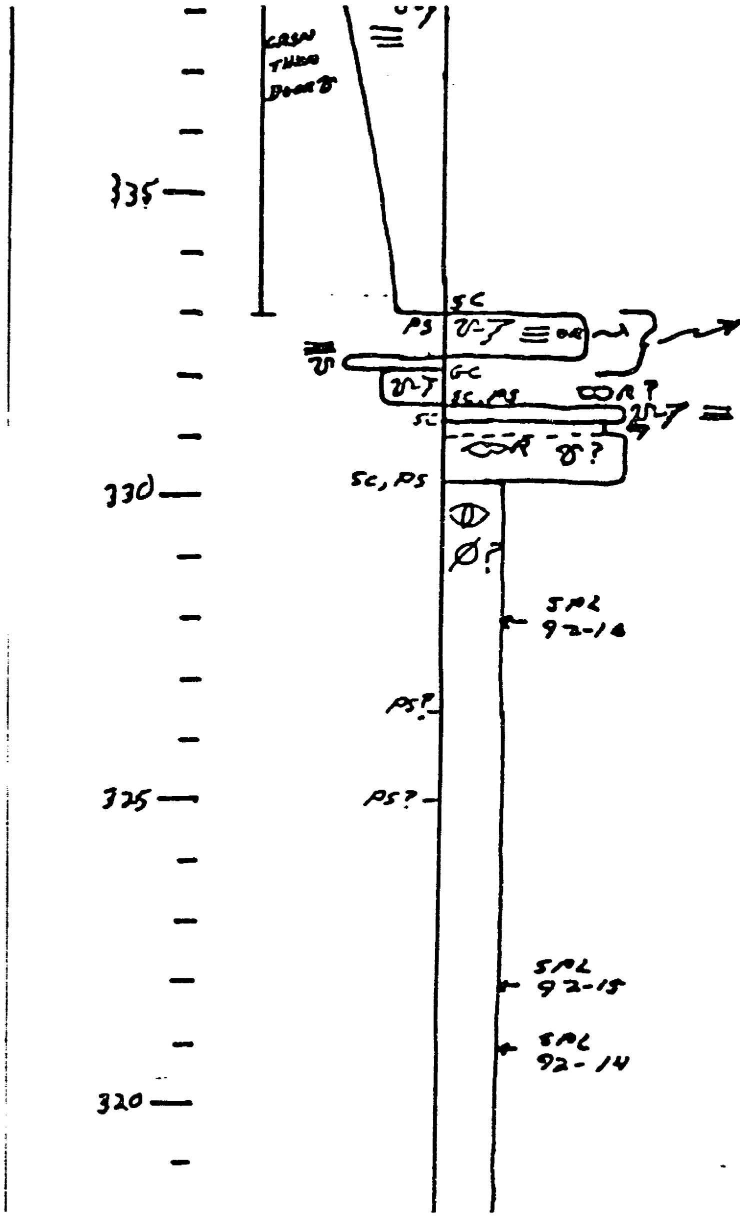
BROWNISH-GRAY LS ⊙(~1mm), 1-2 BEDS? INDISTINCT. MANY ⊙ SILICA-REPLACED

GRAY ⊙(~1mm) LS GRST. TOP CONTACT W/ ~3 cm RELIEF

DK GRAY Ø(≤1 cm) WK/PKST

GRAY LS MDST (OR ARENITE), BDD 2-3cm. W/ TAN & GREEN DOLSTS, ~30-35% IN BTM 40 cm, UP TO ~15-20%. (TAN UP TO GREEN). SOME ⊙ WK/PKST BEDS.

GREEN-GRAY LS MDST (OR ARENITE), BEDD 2-3cm W/ ORNG-DOLSTS IN [illegible] & INTERLAMS. BTM 20-30cm W/ ~35-40% UP TO ~15-20% DOLSTS IN TOP.




GREEN MDST CRSNS UP TO F-VF QTZ SS, MOSTLY BDD 1-2 cm, MAX OF ~8 cm. VERTICAL CHANGE IN SED. STRUCS OF RIPPLES & ≡ ON UP TO ≈, RIPPLES & ≡ & OF ℧-7 IN BASAL ~2 m GOES UP TO ℧. TOP 10 cm W/ ≈. UPWARD CRSN, THKN, DECR ℧. BASAL ~2½ m MORE MDST THAN SS. ABOVE ~2½ m, MORE SS THAN MDST.

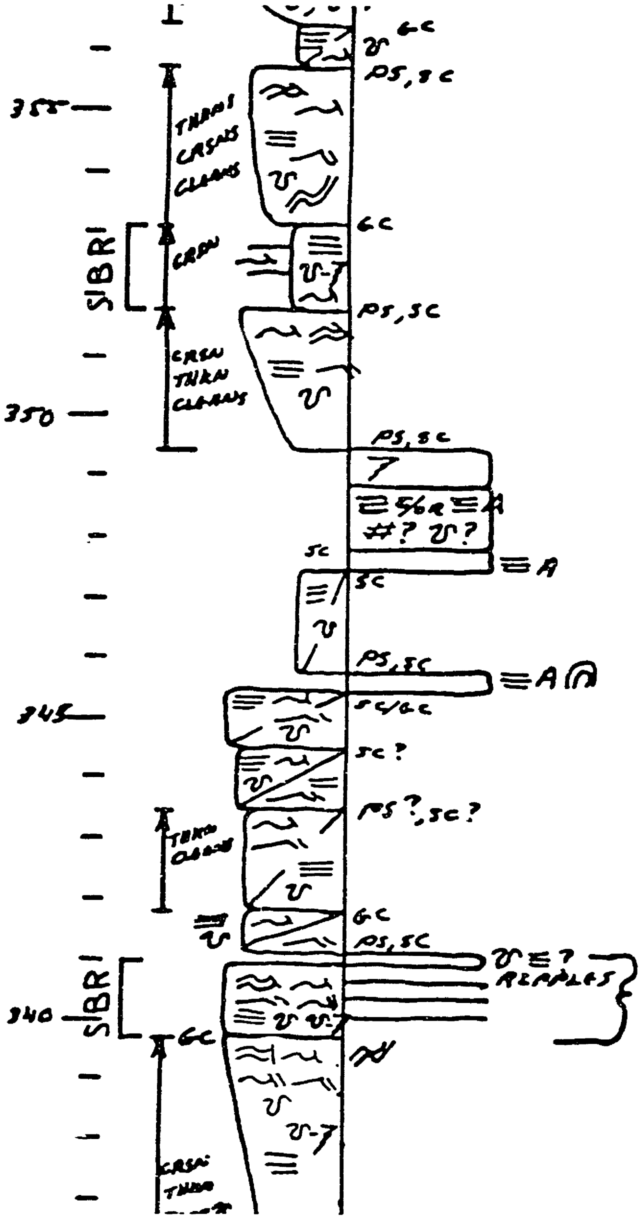
ORNG-BRWN DOLSTS, BDD ~2-5 cm W/ INDISTINCT SED. STRUCS. BTM 30 cm A MUDDY, VF QTZ SS

YELLOWISH-TAN SILTY MDST, BDD ≤ 1-3 cm

REDDISH-BROWN DOL. VF GRN/STS W/ ≡ IN BTM 3-4 cm, ℧-7 IN REST

GRY TO BRWN DOL. VF GREN/STS, EXCEPT FOR TOP 10 cm OF LS PK/GRST (GRAINS ~1 mm, NOT IDENTIFIED), W/ SOME OF DOL STS/GREN ≤ 5 mm.

LS MDST. ~315 TO 322 m, SS LT GRY. ABOVE & BELOW IS MED LT GRY. COLOR CHANGES ARE GRADUAL. START TO GET CRSE, CRUDE LAMINAE AT ~314 m. Ø ~1 cm, MAY NOT BE Ø TNO. ⊕ OFTEN NOT IN CRUDE LAMS, BUT ARE RANDOMLY ARRANGED. AT BASE, HAVE A CRUDE ℧R-TEXTURE W/ ⊕, BUT LOSE IT UPSECTION.



SS TAN, MAY BE CARBONATE CEMENTED

TAN, SILTY SH/MDST, BDD ≤ 5mm W/ SOME VF SS ⅛"STS BEDS, ~.

BRWN VF QTZ SS W/SILTY MDST/SH INTERBEDS. MOSTLY BDD ≤ 1½ cm, MANY ~6 cm. MICACEOUS. SOME ~ SH BEDS ≤ 5cm.

TAN-GREEN, SILTY, MICACEOUS MDST BDD ≤ 2cm W/ DISCONT VF QTZ SS INTERBEDS, ~, INCR UP IN SS. ≤ 10 cm THK QTZ & CALCITE VEINS IS THERE A FAULT?

DESERT VARNISHED VF TO F QTZ SS, BDD MOSTLY ≤ 1½ cm, SOME ≤ 8cm, MICACEOUS, CRSNS UP. W/ SILTY, MICACEOUS SH INTERBEDS IN LWR PART

ORNG MUDDY DOLSTS. SATORP: MAY HAVE BEEN BURROWED AT PS BNDRY

ORNG DOLSTS, BDD < 5mm. '#?' SMALL, NEAR TOP. ~ UNCOMMON

ORNG DOLSTS. BROAD, V. LOW AMPLITUDE MOUNDED BUNDLES. TRYING TO BE ∩

GREEN, PINK & TAN SILTY SH TO MDST, BDD < 5mm, IN PART MICACEOUS

ORNG DOLSTS. ∩ ARE BROAD, LOW AMPLITUDE. NO MUDCRACKS

BRWN VF-F QTZ SS, BDD ≤ ½ 1cm. CARBONATE CEMENTED

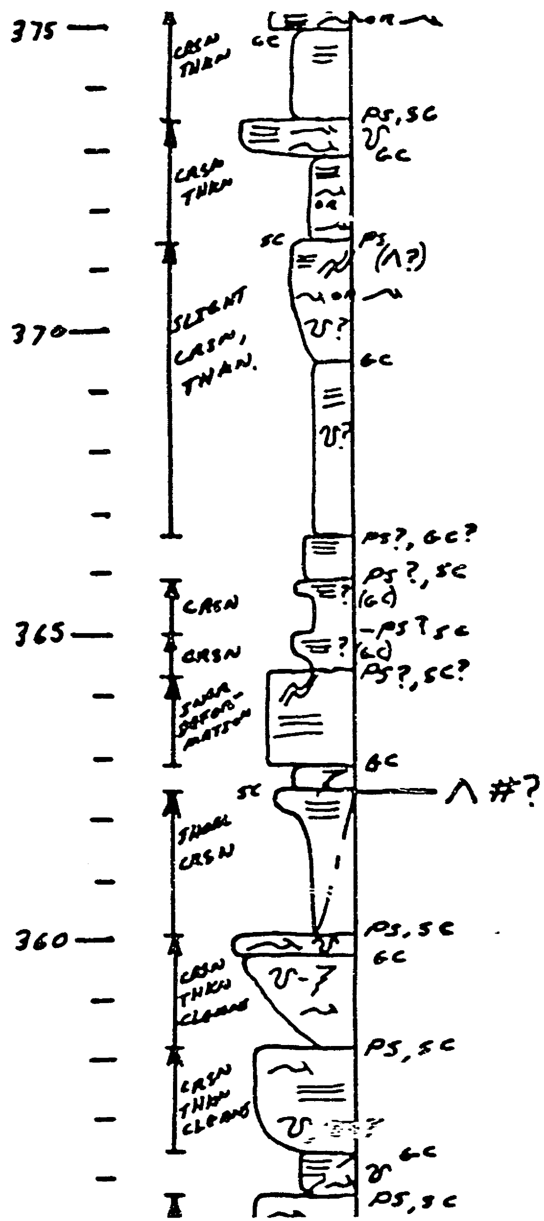
LT GREEN VF QTZ SS W/ SHLY MICACEOUS INTERBEDS, BDD ≤ 1½ cm. CARBONATE CEMENTED

PURPLISH-BROWN, VF QTZ SS, BDD ≤ 1½ cm. CLEANER THAN UNIT IMMEDIATELY BELOW. TOP 10 cm CARBONATE CEMENTED & TAN THKNS, CLEANS UP

GREEN & TAN, MUDDY, VF QTZ SS, BDD ≤ 5mm, MICACEOUS

GREEN VF-F QTZ SS, BDD 1-4cm, W/ ORNG DOLSTS DISCONT INTERLAMS ≤ 1-2cm THK & ONE 10cm THK DOLSTS BED AT TOP. FEW ~, MOSTLY RIPPLES & ≡.

GREEN MOST CRSNS UP TO F-VF QTZ SS, MOSTLY BDD 1-2 cm, MAX OF ~8 cm. VERTICAL CHANGE IN SED. STRUCS OF RIPPLES ...




DK PINK, SILTY & VF-SANDY MDST, ≤ 1cm & LAM'D

GREEN & DK PINK SILTY SH/MDST, CLEAVED, MICACEOUS

PINK QTZ SS & VF-F SS ABOVE PINK SILTY MDST, ALL BDD ≤ 1cm

PINK SILTY SH/MDST, LAM'D ≤ 5mm

PINK & TAN SILTY MDST, MOST LAM'D ≤ 5mm. SOME MDST BEDS ≤ 1½ cm. MICACEOUS. ~ MAY ALSO INCL. TEPEES (∧), SEVERAL cm HI. NO # SEEN

GREEN, PINK, REDDISH-ORNG, SILTY SH < ½-1cm, CLEAVED W/ INTERBEDS OF STS (≤ 1cm) & SOME VF SS/STS STRINGERS ≤ 2-3mm

RED-PURPLE, SILTY MDST, CLEAVED, BDD < 5mm?, MICACEOUS STRINGERS OF VF SS - MICRORIPPLED? 2-3 mm HI.

2 SETS: PINKISH-ORNG SILTY MDST (≡?) OVER GREEN SILTY SH/MDST. BOTH LITHS CLEAVED. BOTH MICACEOUS. MDST ~ 20cm THK EACH. LWR SH/MDST ~ 50cm, TOP SH/MDST ~ 100 cm THK.

QTZ STS, BDD < 5mm GROUPED IN ¼ TO ½ cm SETS. BTM ½ ≡, W/ TOP ½ ~ & ≡

GREEN, CLEAVED MDST. ATHERS TO PENCIL-SHAPED PIECES

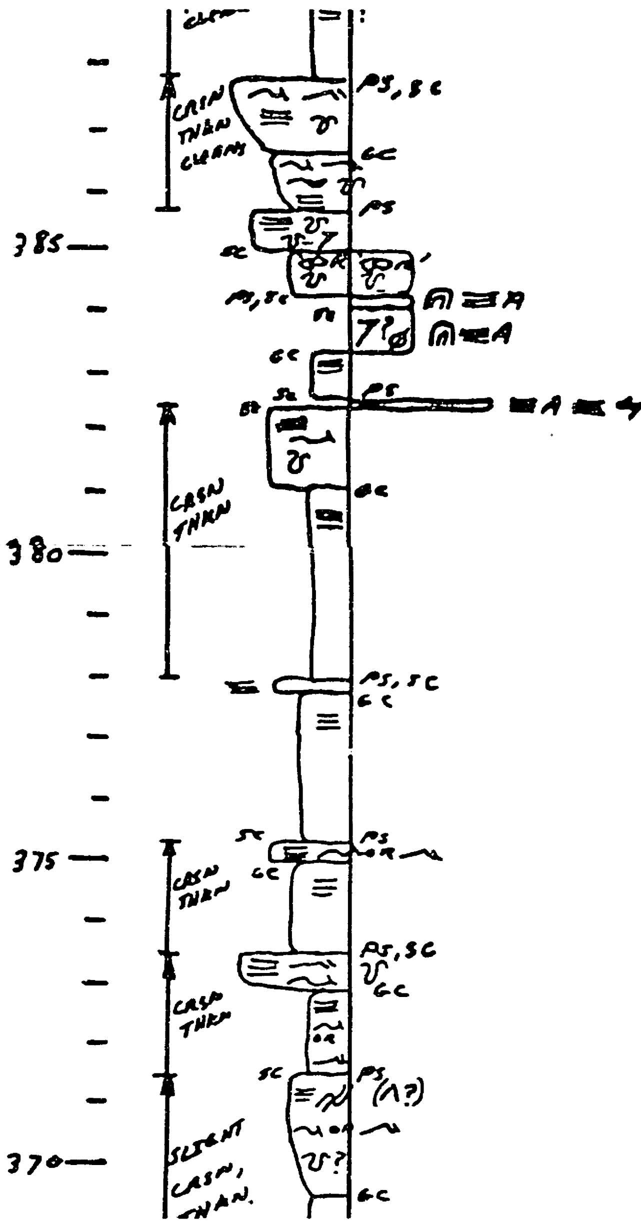
ORNG-PINK + TAN SILTY SH CHANGES UP TO GREEN SILTY SH CHANGES UP TO TAN, PINK DOL. CEMENTED QTZ STS W/ ∧ # IN TOP 45 cm. ALL LITHS BDD < 5mm. MICACEOUS. TOP 40 cm WEATHERS MORE BLOCKY.

ORNG-PINK, TAN F QTZ SS, BDD ≤ 1-2cm, MICACEOUS, CARBONATE-CEMENTED

GREEN & TAN VF-F QTZ SS, MOSTLY BDD ≤ 1cm, MAX ~4cm. W/ INTERBEDS OF MDST/SILTY SH.

DK BRWN, TAN, GREEN VF QTZ SS, MOSTLY BDD ≤ 1cm W/ SOME ≤ 4cm. INTERBEDS OF SILTY SH/MDST. MICACEOUS. TOP 10cm IS TAN, MAY BE CARBONATE CEMENTED

TAN, SILTY SH/MDST, BDD ≤ 5mm W/ SOME VF SS & STS BEDS, ~.




GREEN, HP TO RED-PURPLE, SILTY SH, MM-LAM'D, CLEAVED, CHLORITIC

VF-F QTZ SS, TAN, MOSTLY BDD ~1-2 cm, MAX ~7 cm, MICACEOUS, ~≤ 10-15% SH, ʊ SPARSE

INTERBDD TAN SILTY SH & VF SS, BOTH BDD ≤ 1 cm, MICACEOUS ~40% SH, ʊ SPARSE

TAN VF QTZ SS, MOSTLY ʊ? W/ ≡ IN TOP 5 cm

PINK & ORNG SIL. MDST W/ ~30-35% GREEN LS MDST, SIL BDD ≤ 2 cm, LS BDD ≤ 1 cm. BOTH CLEAVED. ʊ SPARSE

GREEN LS SILTY MDST LIKE UNIT IMMEDIATELY BELOW.

GREEN/PINK SILTY LS MDST, POSSIBLY CLEAVED, ∅ ~1 cm IN BASAL 3-4 cm. INTERLAM'D ORNG DOLSTS. ≡A, ⋒ APPEAR LATERALLY.

GREEN, SILTY SH

ORNG DOLST, MM LAM'D. NO MUDCRACKS (#)

DK PINK SS & SILTY MDST, BDD ≤ 1 cm, INTERBDD SILTY SH LIKE BELOW (380 m). 3 COUPLETS OF (SH/SS), EACH ≈ 40-60 cm. NO MUDCRACKS.

DK PINK, PURPLE, GREEN SILTY SH, ≤ 5 mm BDD/LAM'D, W/ SOME CARBONATE CEMENT

PINK SILTY, SANDY MDST, BDD ≤ 1 cm

GREEN & PINK SILTY SH/MDST, MM LAM'D TO ≤ 5 mm

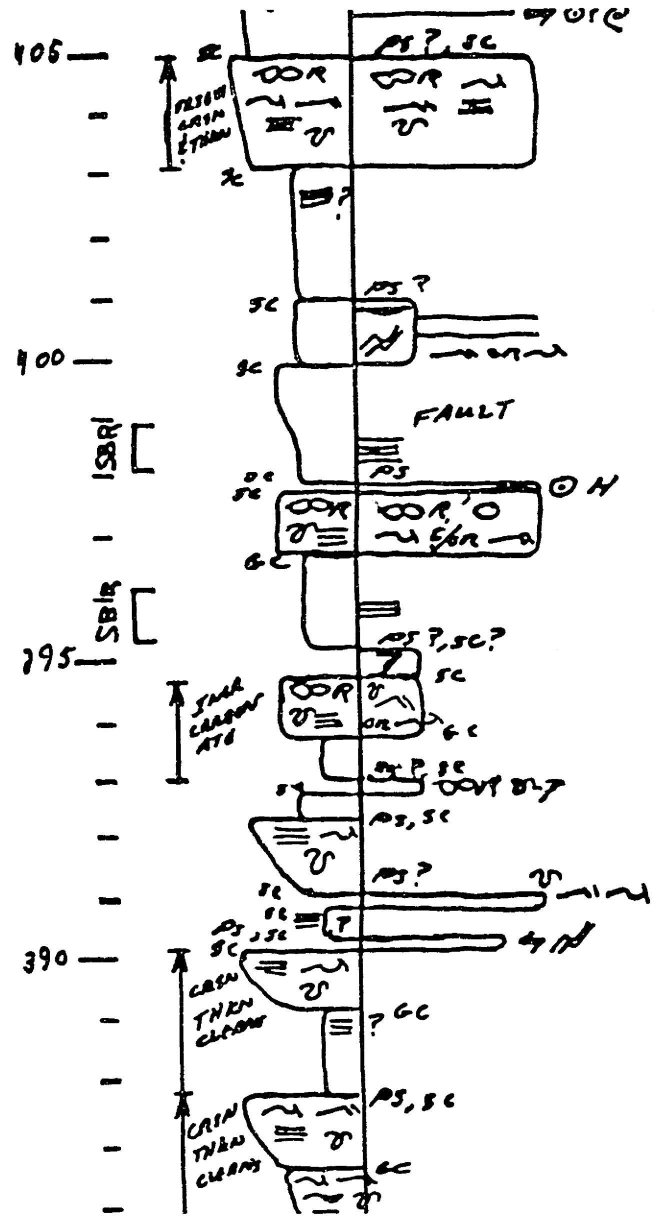
DK PINK, SILTY & VF-SANDY MDST, ≤ 1 cm & LAM'D

GREEN & DK PINK SILTY SH/MDST, CLEAVED, MICACEOUS

PINK QTZ SS & VF-F SS ABOVE PINK SILTY MDST, ALL BDD ≤ 1 cm

PINK SILTY SH/MDST, LAM'D ≤ 5 mm

PINK & TAN SILTY MDST, MOST LAM'D ≤ 5 mm. SOME MDST BDS ≤ 1½ cm. MICACEOUS. ≈ MAY ALSO INCL. TEPEES (∧), SEVERAL cm HT. NO # SEEN




OVERALL BROWN. A MIX OF SILICEOUS VF & F QTZ SS W/ VF-F CARBONATE ARENITE, W/ BROWNS & ORNG STS, BOTH SIL. & CARB. ALL LITHS BDD ≤ 1-3 cm.

PINK, GREEN, GRY MDST, CLEAVED

INTIMATELY INTERBDD GREEN LS MOST ⊙(VF-F)GRST W/ PINK SILICEOUS SILTY MDST. OOR-LIKE TEXTURE. LS BDD ≤3 cm, SIL. MDST BDD ≤ 6 cm. BOTH MOSTLY BDD ≤1 cm. GRST IN CHANNEL-FORMS

GREEN CHANGE UP TO PINK CHANGE UP TO ORNG SILTY MDST CHANGE UP TO MUDDY STS, MM-LAM'D?. AT ~398 m, HAVE 70 cm INTERVAL W/ GREEN LS MOST (⊙ PK/GRST?) & INTERBDDS ≤1 cm THK. ~5-8 cm OF FAULT GOUGE

⊙ (½-¼ mm) LS GRST

DK PINK SIL STS & VF-F GREEN LS ⊙ GRST

GREENS & PINK SILTY SH, MM-LAMD?. AT ~395.8 HAVE SEVERAL DK GREEN DISCONT INTERBEDS OF CARBONATE, ≤1 cm THK LIKE 390-391 m.

GREEN MDST? INTERBDD W/ PINK SH?

PINK SILICEOUS SH W/ GREEN LS MOST OOR TEXTURE, BDD ≤1 cm. ≡ IN BOTH. RIPPLES IN STS AT TOP 5 cm (ORNG DOLSTS)

RED SH, SILTY, MM LAM'D W/ INTERBEDS OF CARBONATE ≤1 cm

GREEN LS MOST W/ ORNG & PINK STS. GRNS UP. PUNKY WEATHERING

PINK & GREEN MDST & SILTY SH, CLEAVED, CHLORITIC

PINK VF-F QTZ SS ABOVE SILTY MDST, ∇ SPARSE

GREEN LS VF-F AREN, BDD ~1 cm, W/ INTERBDD SH

RED SILTY SH, MM-LAMD

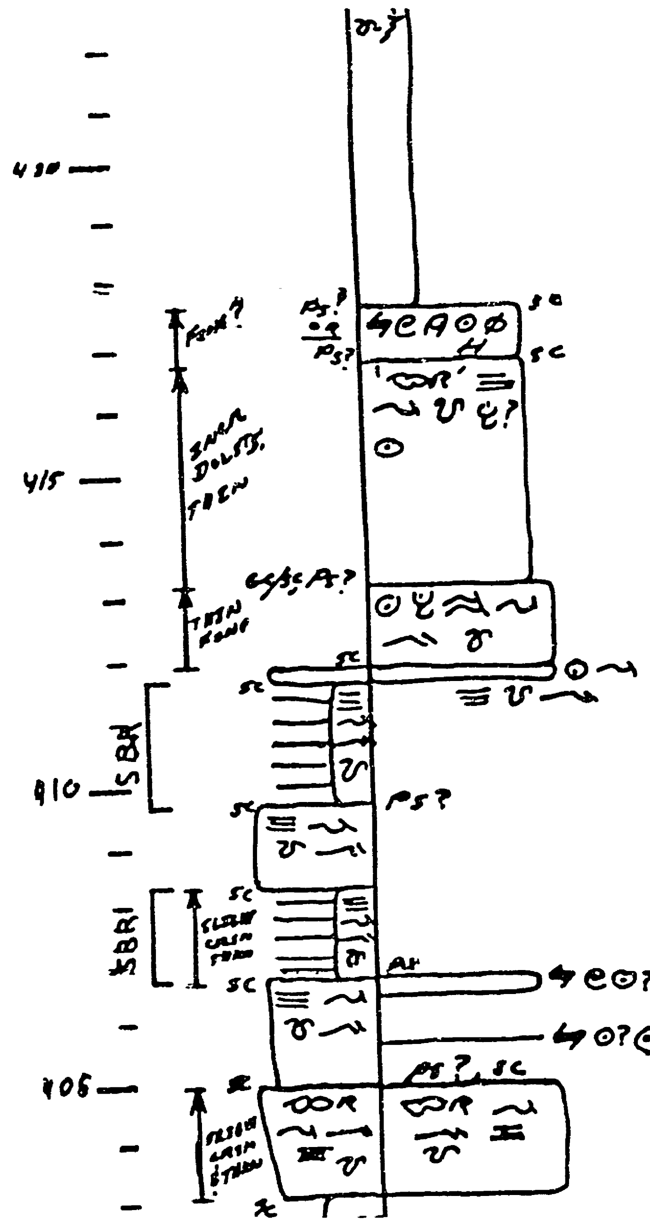
ORNG DOLST

PINK & TAN VF F QTZ SS, BDD ≤1→3 cm, CARBONATE-CEMENTED SPARSE ∇

GREEN, UP TO RED-PURPLE, SILTY SH, MM-LAM'D, CLEAVED, CHLORITIC

VF-F QTZ SS, TAN, MOSTLY BDD ~1-2 cm, MAX ~7 cm, MICACEOUS, ~≤ 0-15% SH, ∇ SPARSE

INTERBDD TAN SILTY SH & VF SS, BOTH BDD ≤1 cm, MICACEOUS AND/OR SH. ∇ SPARSE




DK GRY LS MOST W/ BRWN DOLSTS IN ?, BDD ~1-2cm ≤5%

GRY & PK/GRST. ⊙(≤½mm) (≤½ x 4cm) ø (≤1cm). MAY FINE UP.

GRY LS STS/VF AREN W/ ORNG DOLSTS, BDD ≤3cm MOSTLY, W/ A FEW ≤10cm (POSSIBLE ?). ? COMMON. NO ?. DOLSTS INCR UP ~25% TO 50%. ~35-40% OVERALL. LS THNS UP SOME ⊙(≤¼mm) IN LWR 20-30cm ONLY

GREEN LS GRST W/ ORNG-BRWN STS INTERBEDS. LS BDD 10-15cm W/ BEDSETS ~30-50cm. STS BDD ≤4cm, BDSETS ≤12cm. THNS & FINS UP. FEW ?. GREEN ⊙(VF-F) GRST & TAN VF QTZ SS, BOTH BDD ≤1-3cm FEW ?.

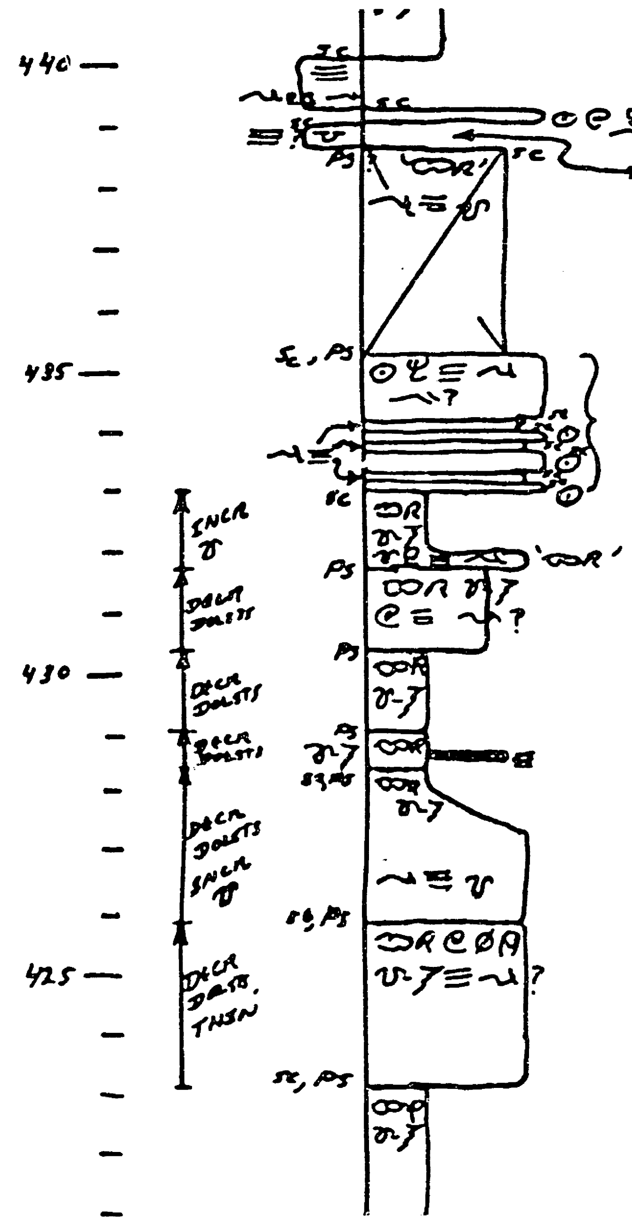
ABVE 407m, SS BDD ≤2cm, SH BDD ≤ ? cm

GREEN & DK BRWN SILTY SH, BDD ≤5mm, TAN F & VF SS. FSS BDD ≤2-7cm, MOST 4-7cm. VFSS BDD ≤1-3cm IN RIPPLES.

GREEN & DK BRWN SILTY SH, BDD ≤5mm W/ INTERBEDS OF VF SS BDD ≤1½ cm. SLIGHT CRSN THKN UP

BRWN VF-F QTZ SS W/ SILTY SH INTERBEDS, MOSTLY BDD ≤1-3cm, MAX VF ~6cm. 2 CARBONATE PK/GRST BEDS, LWR SS 5cm THK, UPPER SS 10cm THK (MAY BE GRAVITY/DEBRIS FLOWS).

OVERALL BROWN. A MIX OF SILICEOUS VF & F QTZ SS W/ VF-F CARBONATE & ARENITE, W/ BROWN & ORNG STS, BOTH ?. ? CARB. ALL LITHS BDD ≤1-4cm.




. . . . . . CLEAVED.

ORNG, PINK, TAN STS LIKE 439m, NO ... . CLEAVED

GRAY LS GRST, ⊙(¼-½mm), FEW

GREEN & PURPLE, SILICEOUS STS W/ A FEW RIPPLES & ... AT TOP? . BDD ≤ 1cm . CLEAVED.

GREEN-GRAY LS STS W/ TAN DOLSTS, BOTH BDD ≤ 1cm, ~50/50%

GRAY LS ⊙ (VF-F) GRST, BDD ~1-15cm, W/ INTERBDD DK GRAY LS VF AREN/STS W/ ~50% DOLSTS. ⊙ GRST ..., ≡, ~, FEW ... AREN/STS W/ ~, ≡, ... MORE THAN GRST. ONLY TOP ⊙ GRST W/ DOLSTS, OTHER ⊙ GRST W/O.

GRAY LS MDST (STS/AREN?) W/ INTERBEDS OF ORNG DOLSTS. BTM ~30cm IS VF SS/STS (LS) W/ DOLSTS, ~ ≡ @. ALL BDD ≤ 1-2 cm. ~20-25% DOLSTS BTM 30cm ..., TOP 1m ...

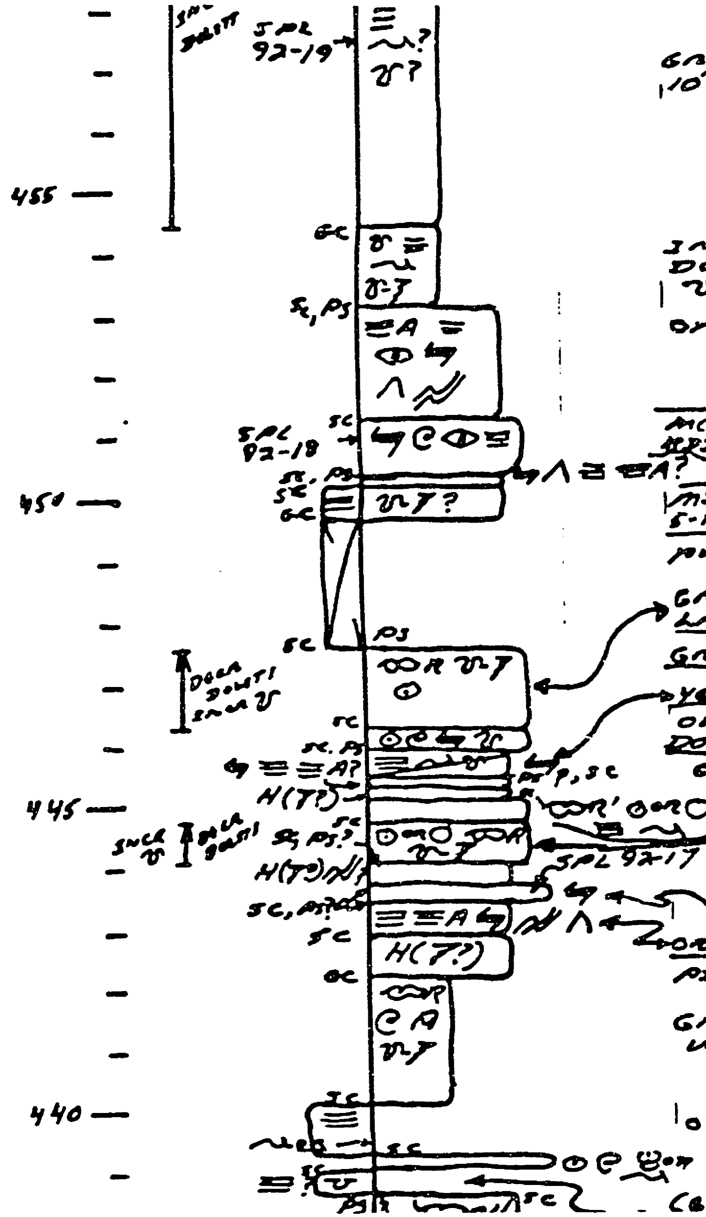
GRAY LS WK/PKST, BDD ≤ 1-2cm, W/ BRWN DOLSTS, BDD ≤ 5mm. LS ≡, ~? . DOLSTS DECR UP > 50% TO ~20% . ... MAY INCR UP

GRAY LS MDST BDD ~2-5cm W/ ORNG-BRWN DOLSTS INTERLAMS ≤ 5mm IN BASAL 35cm & IN ... THE REST OF THE UNIT. DOLSTS DECR UP ~35% TO ≤ 5%

GRAY LS MDST, BDD ≤ 2cm W/ BRWN-ORNG DOLSTS IN ... . A 10cm THK LS ... IN MIDDLE . DOLSTS DECR UP ~35% TO ≤ 5%

BRWN DOLSTS W/ GREEN-GRAY LS STS/VF AREN W/ TOP 25cm A LS MDST (...). ... IN REST OF UNIT. ONE 5cm THK LS WK/PKST. DOLSTS DECR UP ~50-60% TO ≤ 10-15%

BRWN DOLSTS & GREEN-GRAY LS STS/VF AREN LS BDD ≤ 3cm DOLSTS THINS UP ≤ 3cm TO ≤ 1cm IN TOP 60cm. ≡, ~? IN BOTH LITHS IN LWR PART OF UNIT. TOP 60 cm W/ WKST OF @ Ø A IN MATRIX OF STS/AREN. DOLSTS DECR UP ~50-65% UP TO ~10% IN TOP 60cm. Ø ≤ 1cm




GRY LS MDST, BDD ~1-10 cm, W/ ORNG DOLSTS, BDD ≤1-10 cm. LOTS OF ⊕, DOLSTS INCR UP ~10-15% TO ~40%

INTERBDD MED GRY LS MDST, BDD ~1-10 cm, & ORNG DOLSTS, BDD ≤1 cm. ~35-40% DOLSTS. LS Ʋ-7. DOL Ʋ, ≡, ~?

ORNG, TAN & BRWN DOLSTS, LAM'D ≤1 cm

MED GRY LS PK/GRST W/ ORNG DOLSTS INTERBEDS, ALL BDD ≤1 cm-10 cm. POSSIBLE SMELTER POROSITY

ORNG DOLSTS, ⊂ OF SAME LITH.

MIXED SILICEOUS SILTY SH & ORNGISH-BRWN DOLSTS, BDD ≤5-15 cm.

PURPLE-RED & GREEN SILTY SH

GRY LS PK/GRST, BDD ≤1-3 cm W/ REDDISH DOLSTS INTERLAMS. DOLSTS DECR UP ~15-20% TO ≤5-10%. Ʋ INCR UP ⊙ ≤ ¼ mm

GRY LS PK/GRST ⊙(≤¼ mm) ⊂(≤⅛ mm). DOLSTS IN Ʋ & INTERLAMS

YELLOW, TAN, GREEN DOLSTS

ORNG DOLSTS LIKE 443.3 m

DOLSTS LIKE 442.5 m.

GRY LS PK/GRST & TAN DOLSTS LIKE 449.9 m, FEW Ʋ

GRY LS PK/GRST & TAN DOLSTS, ⊙ & ○ (VF-F), BDD ≤1½ cm. UPPER ⅓ Ʋ-7. DOLSTS DECR UP ~60% TO ~25%

TAN, PINK, YELLOW DOLSTS LIKE 442.5 m

GRY LS BRECCIA, ⊂ ≤1 cm

ORNG DOLSTS, BDD ≤5-7 mm, ⊂ OF SAME. ∧(≤3-4 cm Ht)

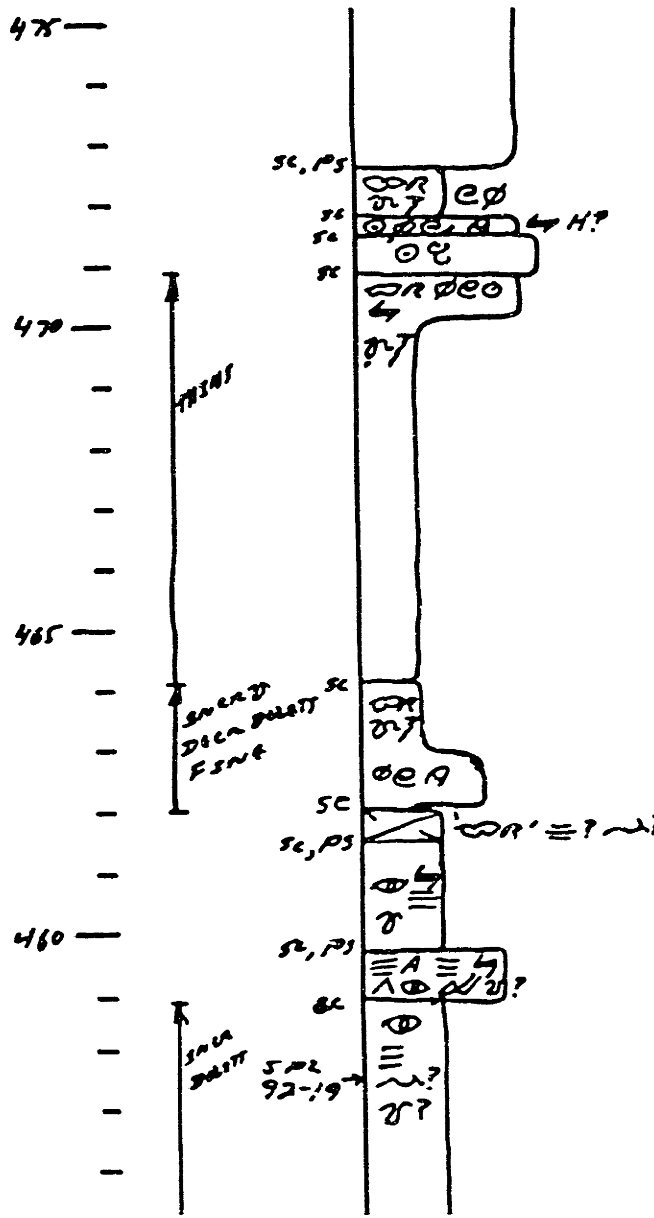
PINK, ORNG, TAN, PINK-WEATHERING DOLSTS.

GRY LS MD/WKST, BDD ½ cm IN BTM ⅓ & ≤½ cm IN UPPER ⅔. W/ ~10% GREEN DOLSTS. UPPER ⅓ CLEAVED.

ORNG, PINK, TAN STS LIKE 439 m, NO Ʋ. CLEAVED

GRY LS GRST, ⊙(¼-½ mm), FEW Ʋ

(GREEN & PURPLE, SILICEOUS STS W/ A FEW RIPPLES




DISCONT.

GRY LS WKST, BDD ~2-4 cm, W/½ INTERLAMS OF REDDISH-ORNG DOLSTS ≤ 5 mm & IN ϑ, ~10-15%. Ø ≤ 3 cm

GRY LS PK/GRST, BDD ~5-25 cm, ⊙(½-3/4 mm), (≤½ cm) Ø ≤ 1 cm

GRY LS ⊙ (½-3/4 mm) GRST, BDD ~5-25 cm

GRY TO DK GRY LS MDST, BDD ≤20-30 cm IN LWR PART & ~2-3 cm IN UPPR. ORNG-RED DOLSTS IN ϑ, ≤5-10%. TOP ~60 cm IS LS PK/GRST ⊙(≤½ mm), OF GRY LS (≤1 cm), Ø ≤ 2 cm.

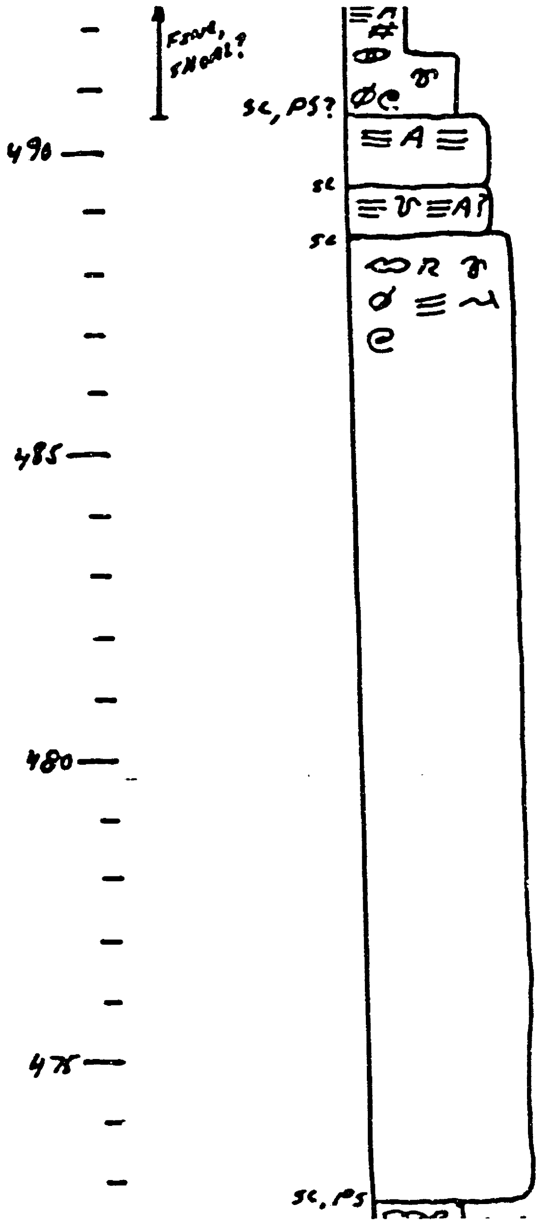
GRY LS MDST, BDD ≤10 cm W/ REDDISH ORNG DOLSTS, BDD ≤1 cm. ⊙ LS WK/PKST, BDD ≤ 2 cm IN LWR ½, Ø ≤ ½ cm. DOLSTS IN INTERLAMS & ϑ, DECRNG FROM ~25-30% TO ~10%? ONLY IN ϑ

LS MDST (AREN?) & ORNG DOLSTS, BOTH BDD ≤ 1 cm

GRY LS MDST & ORNG DOLSTS W/ OF ORNG DOLSTS, LIKE 455 m.

ORNG DOLSTS, LAM'D ≤1 cm, OF SAME. AT ~459½ m, IS A 10 cm THK GRY LS STS/VF AREN, BDD ≤ 2 cm W/ ϑ?

GRY LS MDST, BDD ~1-10 cm, W/ ORNG DOLSTS, BDD ≤1-10 cm. LOTS OF ⊕, DOLSTS INCR UP ~10-15% TO ~40%




MOSTLY GRAY LS WK/PKST ... INTERLAMS & V-FILL. W/ SOME ORNG-REDDISH DOLSTS INTERLAMS. Ф THRU-OUT EXCEPT BASAL 20-30 cm. # IN TOP 10 cm. ≡A MOSTLY IN TOP 20 cm. Ø ≤ 1 cm.

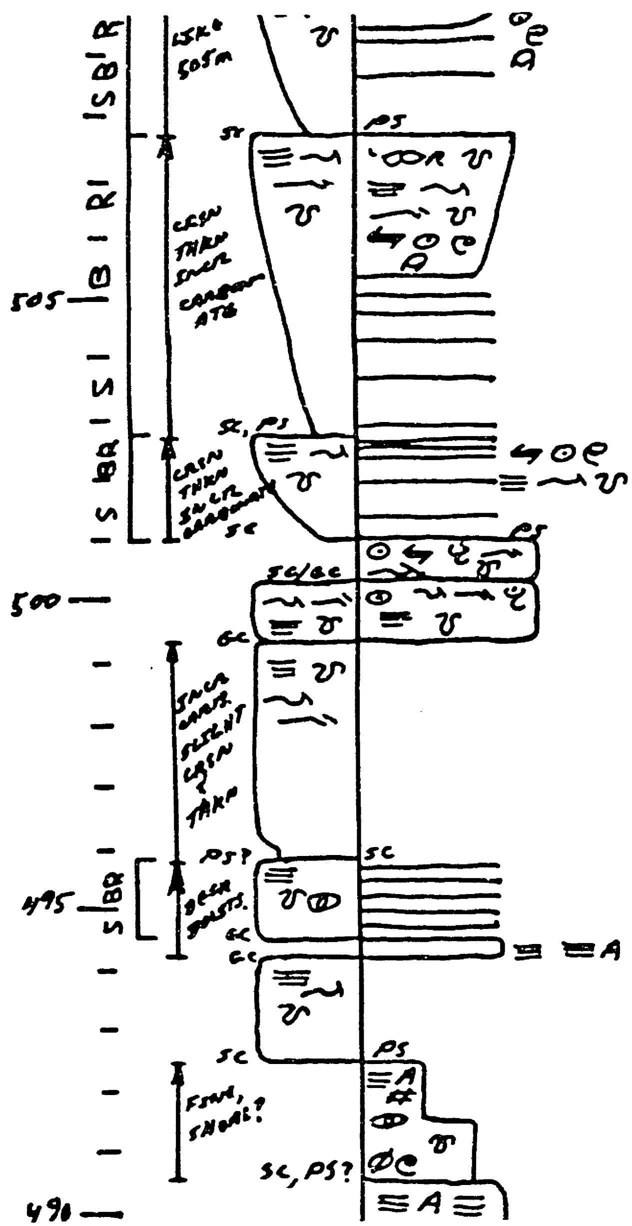
ORNG DOLSTS, LAM'D ≤ 5 mm. NO #, Λ, Ф SEE

GRAY LS STS(?) (COULD BE MDST), LAM'D ≤ 5 mm W/ SOME REDDISH DOLSTS IN ≤ 2-3 mm INTERLAMS & V

MOSTLY BRWN DOLSTS (~60-65%) W/ LS AREN? INTERLAMS, BOTH BDD ~1-3 cm. BASAL 1-2 m W/ Ø(≤2 cm), @ WK/PKST

DISCONT.

GRAY LS WKST, BDD ~2-4 cm, W/ INTERLAMS OF REDDISH-ORNG DOLSTS ≤ 5 mm & IN V, ~10-15%. Ø ≤ 3 cm




SAME MIX OF LITHOLOGIES AS 505 m. ⊙ (≤ ½ mm) & ≤ 1 cm.

BROWN & GREEN SILTY SH, QTZ STS & VF SS w/ GREEN LS PKST BEDS & SOME LS STS/VF AREN. SH MM-LAM'D. QTZ STS & SS BDD ≤ 1-2 cm. LS BDD ≤ 1-3 cm. ⊙ (≤ ½ mm) & ≤ ½ mm. LIKE 502 m

BRWN, SILTY SH, MM-LAM'D, W/ QTZ STS & VF SS, BDD ≤ 1-2 cm, & SOME PKST BEDS ≤ 1-2 cm, ⊙ (≤ ½ mm), & of CARBONATE (≤ ½ mm). LS IS GREEN.

ORANGISH-BRWN ⊙ (½-1 mm) GRST, BDD ~2-7 cm, w/ DOLSTS & (≤ 6 cm). ⊙ DOLZD. A ~5 cm THK SS BED AT TOP w/ ≡ ~
LS ⊙ (≤ ½ mm) GRST & TAN VF QTZ SS, BOTH MOSTLY BDD 1-3 cm w/ SOME LS BEDS 5-6 cm (⊽).

RED-BROWN, CHANGES UP TO ORNG-BROWN, VF QTZ SS, BDD ≈ ≤ 1-3 cm, LWR ½ SILICA-CEMENT, UPPR CARBONATE CEMENT

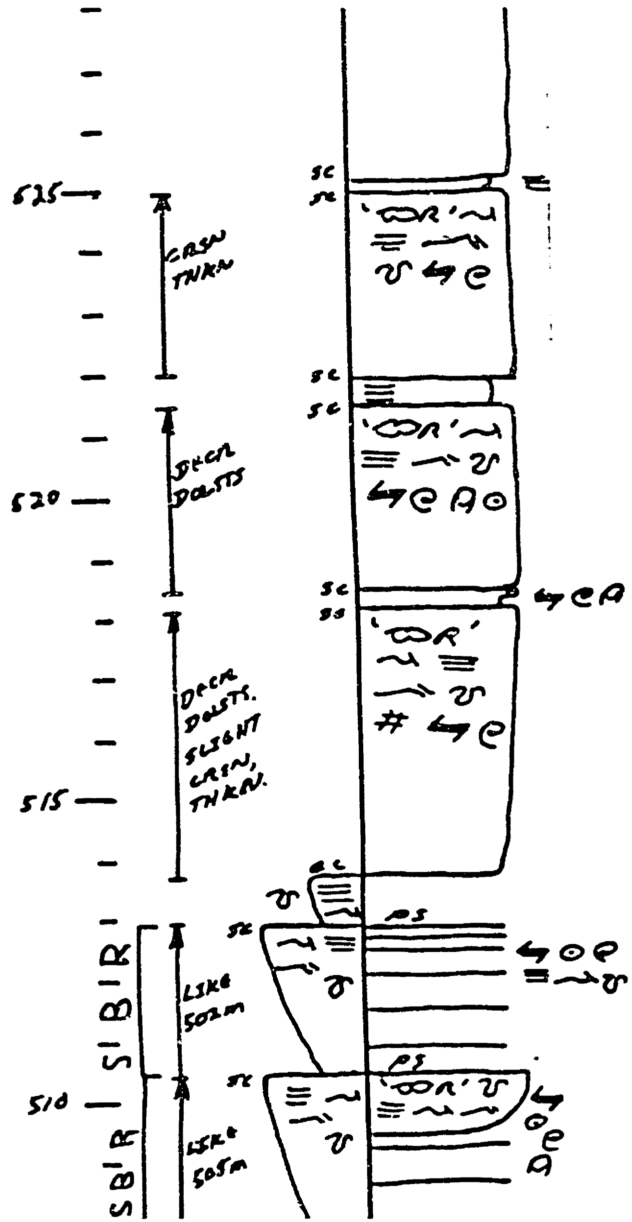
TAN VF, SILTY QTZ SS w/ SOME ORNG DOLSTS INTERBEDS, ALL BDD ≤ 1 cm. ⊕ POSSIBLE IN UPPR 30 cm ALONG DOLOMITIC HORIZONS (< ½ mm)

ORNG DOLSTS, NO #, ∧, ⊕. LIKE 490 m

RED-BRWN VF, SILTY QTZ SS, BDD ≤ 1-2 cm w/ OCCASIONAL PODS (RIPPLES) OF CARBONATE CEMENTED SS OR CARB LITHOLOGY

MED LT GRY LS WK/PKST IN LWR ½ & LS MDST IN UPPR ½. w/ SOME ORNG-REDDISH DOLSTS INTERLAMS & ⊽-FILL. ⊕ THRU-OUT EXCEPT BASAL 20-30 cm. # IN TYP 10 cm. ≡A MOSTLY IN TOP 20 cm. Ø ≤ 1 cm.

ORNG DOLSTS, LAM'D ≤ 5 mm. NO #, ∧, ⊕ SEE




TOP CONTACT GRADATIONAL OVER 10'S OF cm. NO #

SAME LITHS AS 515 m, 520 m. DOLSTS BDD ≤ 1 cm, LS STS/ADD ~1-4 cm, LS PK/CAST BDD ~2-4 cm. ONLY A COUPLE OF PK/CAST. ~30% DOLSTS. NO #

ORNG DOLSTS, POORLY LAM'D W/≤10% LS STS.

GREEN LS STS/AREN W/OCCASIONAL LS PK/CAST BEDS & ORNG DOLSTS. LS STS/AREN BDD ≤ 1-4 cm, PK/CAST BDD ≤ 4-8 cm, DOLSTS BDD ≤ 1 cm w/ A 5 cm BED & A 12 cm BED. PK/CAST ARE LENTICULAR W/SCOURED BTM & SIDES. OF GREEN LS AREN/STS, ≤ 15 cm, PLATY & IMBRICATED. DOLSTS DECR UP ~40% TO ~25-30%. NO #

ORNG DOLSTS, BDD < 1 cm, W/~25% LS STS & A 6 cm THK CAP OF GREEN LS PK/CAST THAT IS LATERALLY DISCONT.

ORNG DOLSTS, BDD < 3 cm, MOST ≤ 1 mm & GREEN LS PK/CAST & STS/VF AREN, BDD ≤ 1-3 cm. ≤ ½ cm. # UNCOMMON & NEAR THE TOP. THRU-OUT. LS STS/AREN MORE COMMON THAN PK/CAST. DOLSTS DECR UP FROM ~95% TO ~50%.

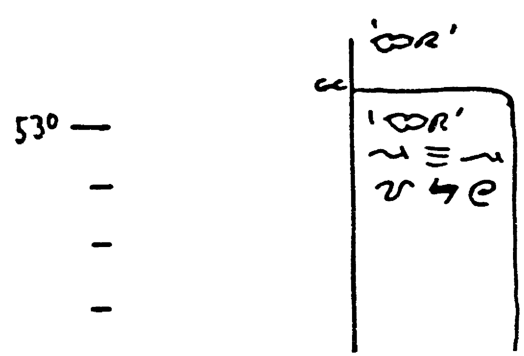
REDDISH, SILTY SH & SILICEOUS STS, BOTH BDD ≤ 1 cm, POSSIBLY CARBONATE CEMENTED

SAME AS 502 m

SAME MIX OF LITHOLOGIES AS 505 m. ⊙ (≤ ½ mm) ≤ 1 cm.

SECTION 92-1

ECHO CANYON, SO FUNERAL RANGE, CALIF.



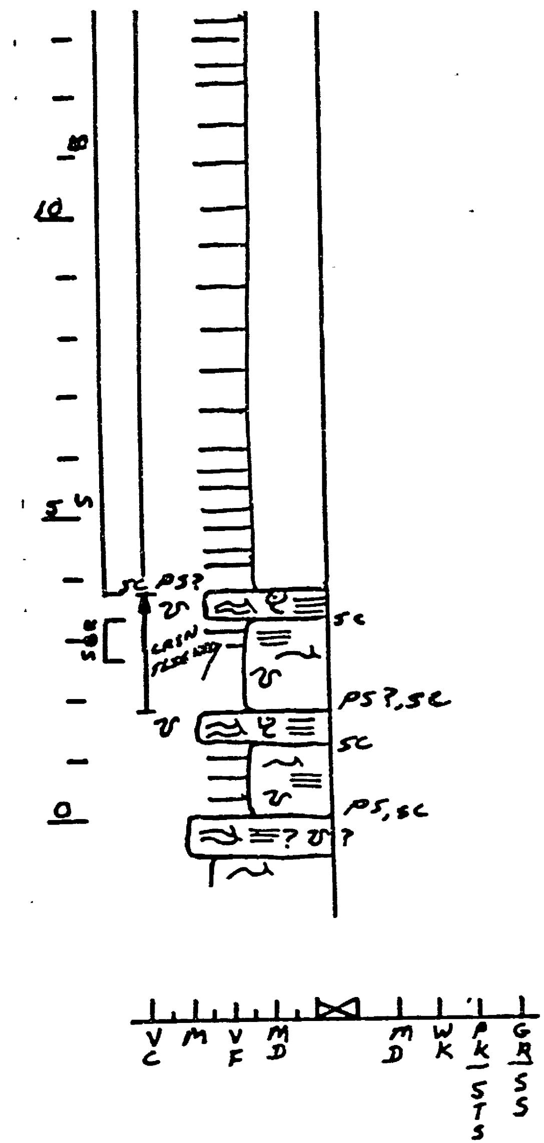

KHAKI-GREEN & BROWN DOLSTS INTERLAMS, THIN. INSTEAD OF ORNG DOLSTS

BONANZA KING FM.

CARRARA FM.

SAME LSTHS AS 515m, 520m. LS STS/ARGN ADD ≃ 1-4cm, LS OX/CAST ADD ≤ 1-4 cm. DOLSTS ADD ≤ 1cm, ~25-30%

TOP CONTACT GRADATIONAL OVER 10'S OR cm. NO #




MOSTLY GREEN MUDDY QTZ STS TO SILTY MDST. MICACEOUS.
INTERBEDS OF: ① VF-M QTZ SS, BDD ≤1-3cm, ≡, ~, ʊ. MOSTLY FU BTM 1-2m & AGAIN ≈12m TO TOP, SILICA & CARBONATE CEMENTS. ② AC LS PCKST, BDD ≤1-4cm, ~, ≡, ʊ

GRY-BRWN VF-F QTZ SS, BDD ≤1-8cm. SOME INTERBEDS MUDDY STS TO SILTY MDST, BDD ≤1cm

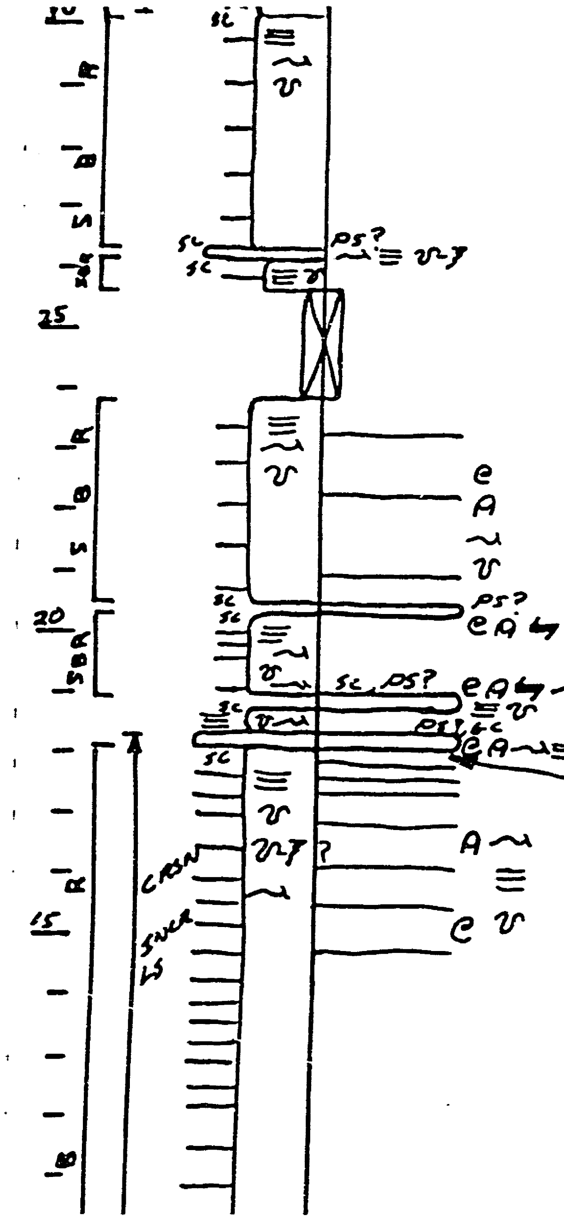
GREEN MUDDY QTZ STS, BDD ≤1cm. MICACEOUS W/ A FEW VF-F SS BEDS, ≤1-3cm, ~, ≡, NEAR TOP OF UNIT

BRWN F-M QTZ SS, BDD 1-10cm W/ 2/3 BEDS MUDDY STS, 1-3 cm THK.

GREEN MUDDY QTZ STS, BDD ≤1cm, MICACEOUS. W/ 3 BEDS F QTZ SS, MICACEOUS, 7cm, 2cm & 2cm THK

BRWN M & F QTZ SS, MED BDD ~15-35cm, F BDD ≤1-2cm

SECTION 92-2
So. RESTING SPGS RNG




GREEN MUDDY STS TO SILTY MDST, BDD ≤ 1cm, MICACEOUS W/ INTERBEDS OF VF–F SS, BDD ≤ 1-2cm.

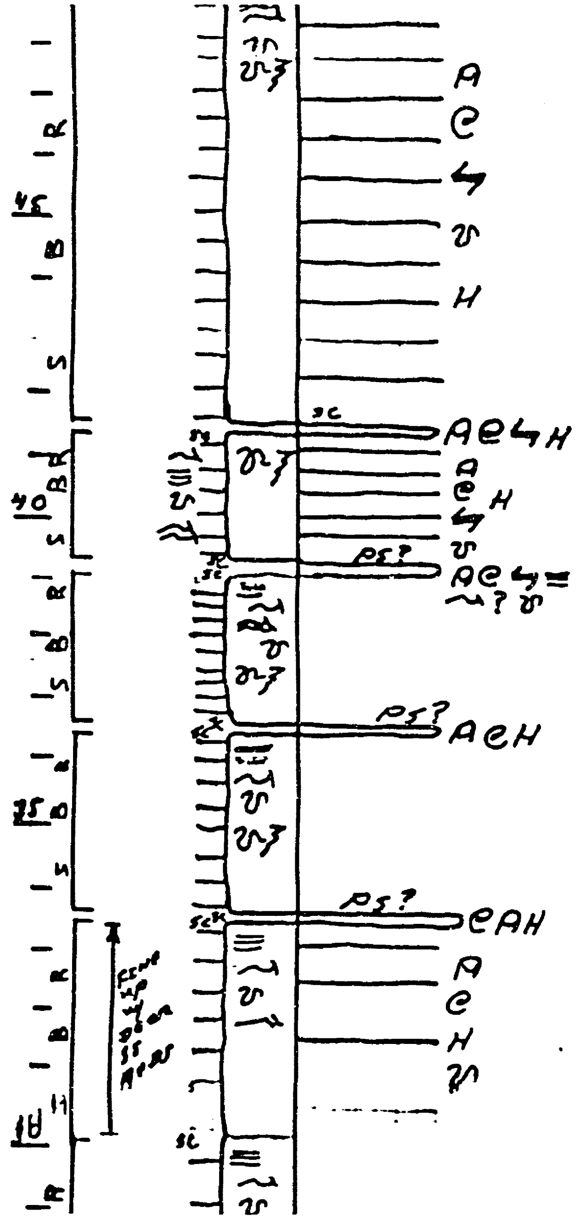
GRAY-BRWN F QTZ SS, 2 BEDS TO ≤ 5cm W/ ADJ CONTINUOUS MDST INTERBED ≤ 1½ cm BETWEEN. Ʋ? ONLY IN PART.
GREEN, SILTY MDST W/ INTERBEDS OF VF & QTZ SS, ALL BDD ≤ 1cm

COVER

GREEN, MUDDY STS TO SILTY MDST, BDD ≤ 1cm, W/ INTERBEDS OF VF–F QTZ SS, BDD ≤ 1-3cm, SILICA- & CARBONATED CEMENTED & OCCASIONAL PKST (LS) BEDS, ≤ 1-3cm. STS/MDST IS MICACEOUS

BRWN LS WK/PKST. 15 cm BED. OF SAME, ≤ 1x2 cm.
GREEN MUDDY STS TO SILTY MDST W/ VF & QTZ, SILICA-CEMENTED SS. MICACEOUS
WK/PKST (LS), BDD ≤ 1-5cm
GREEN, MUDDY, MICACEOUS. MUDDY STS TO SILTY MDST, BDD ≤ 1cm W/ SS & CARBONATE INTERBEDS, BDD ≤ 1-5cm
BRWN LS PK/WKST W/ SOME VF–F SS INTERBEDS, BDD ≤ 1-5cm.
SS CARBONATE – CEMENTED, BROWN

MOSTLY GREEN MUDDY QTZ STS TO SILTY MDST. MICACEOUS.
INTERBEDS OF: VF–M QTZ SS BDD ≤ 1-2...




GREEN MUDDY STS TO SILTY MDST W/ INTERBEDS OF GREEN-BROWN VF-F QTZ SS & LS PKST (BROWN). STS BEDD ≤ 1cm. SS & PKST BDD ≤ 1-5cm. MICACEOUS. ≤ 1cm

BROWN LS PKST BED 10 cm THK. ≤ 1x2 cm SOME QTZ M SAND.

GREEN, PINK SILTY MDST TO MUDDY STS IN BEDSETS ≤ 10-15cm. INTERBEDS OF VF-F SS, ≤ 1-3cm & OF LS PKST ≤ 1-5cm. MDST IS . INTERBEDS ARE , . ≤ ½ cm. MDST MICACEOUS.

BRWN LS PKST, BDD ≤ 1-7cm W/ SOME SILTY MDST INTERBEDS ≤ 1-2cm. ≤ 1cm

GREEN & PINK MUDDY STS TO SILTY MDST, BDD ≤ 1cm W/ INTERBEDS OF VF-F SS, BDD 1-3cm. MORE SS BEDS THAN 35m.

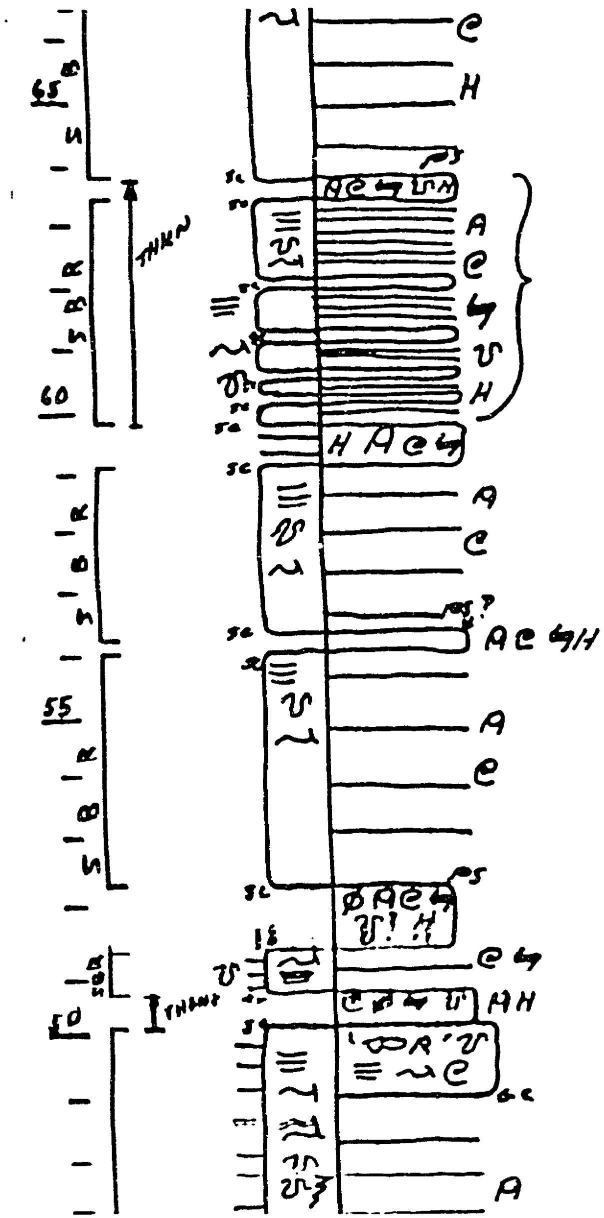
NOTE: 2-4 PKST BEDS IMMEDIATELY ABOVE & BELOW 20 cm BED AT 35.5 m. MAY NOT BE CONTINUOUS

BROWN LS PKST, 20 cm BED. ECHINOID? FRAGMENTS

GREEN MUDDY STS TO SILTY MDST, BDD ≤ 1cm W/ INTERBEDS OF VF-F SS, BDD ≤ 1-2cm, STW CA-CEMENTED. STS SS MICACEOUS

BROWN LS PKST W/ QTZ SAND. SGL. BED 10 cm THK

GREEN MUDDY STS TO SILTY MDST, BDD ≤ 1cm. W/ INTERBEDS OF VF-F SS, BDD ~ 3cm & OCCASIONAL, BROWN LS PKST W/ VF-M QTZ SAND, BDD 3-7cm. STS SS MICACEOUS




GREEN-BRWN @ PKST LS, BDDS 3 cm

TAN SILTY MDST W/ GREEN-BRWN @ LS PKST. MDST UNITS ARE 15 IN NUMBER, 30 TO 130 cm THK. MAIN PKST BEDS ARE 5 IN NUMBER, 5 TO 30 cm THK. ALSO ≈ 25 PKST BEDS ≤ 1-3 cm THK. ≤ 1/2 X 10 cm THK OF @ WKST

GREEN-BRWN @ LS PKST. 3 15 cm BEDS W/ 1-3 cm THK CARBONATE & MDST/STS BEDS BETWEEN. A 1/2 TAN

SAME LITHS, ETC AS 55 m.

GREEN-BROWN @ LS PKST. 2 MAIN BEDS ~25 cm AT TOP & ~12 cm AT BTM W/ SEVERAL ~2 cm BEDS BETWEEN. ≤ 1/2 X 8 cm.

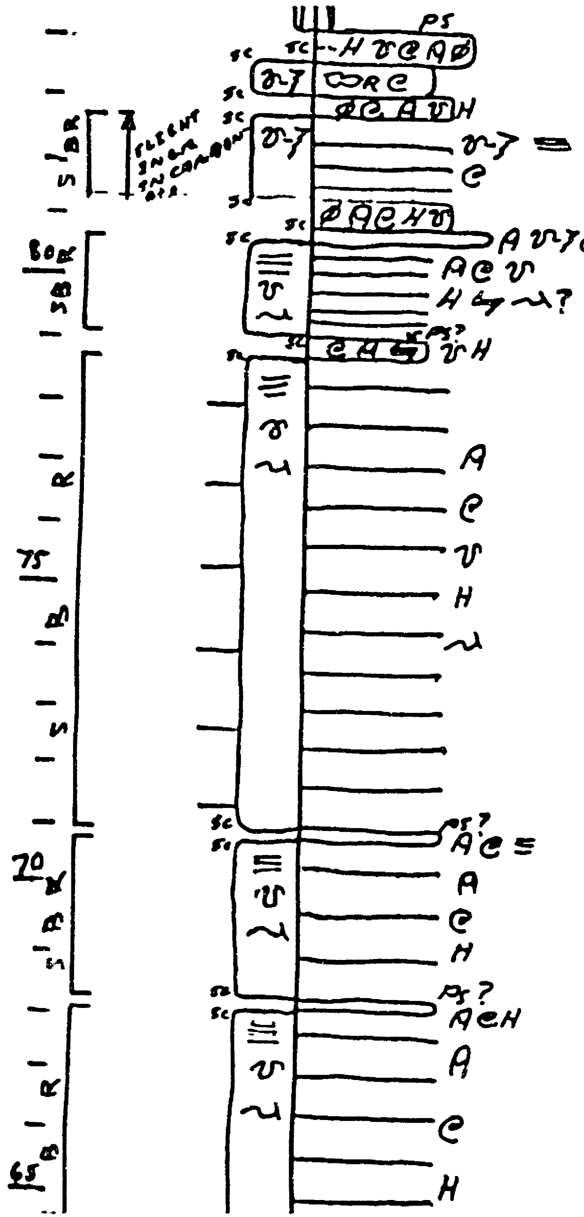
GREEN SILTY MDST, BDD ≤ 1 cm W/ A FEW TAN & GREEN-BRWN LS PKST BEDS ≤ 1 cm THK. ASCNELLA & O. GILBERTI ? TRILOBITES.

GREEN @ Ø WK/PKST. Ø ≤ 3 cm. 1-2 cm. @ INCLUDE ECHINO

LITHS LIKE BELOW. STS BDD ≤ 1 cm. SS & PKST ≤ 1/2 cm

GREEN @/Ø PKST. BTM BDD ~25-30 cm, UPPER BDD 3-5 cm: INTERBEDS OF RED SIL. STS, ~1-8 cm, & BEDRNE DOLSTS, DISCONT. MIXED SILICLCS STS & RED LS AREN/STS W/OCCASIONAL LS PK/GRST, ALL BDD ≤ 1-3 cm. ~50% SIL. STS. UPWARD INCR IN CARBONATE & BED THICKNESS

GREEN MUDDY STS TO SILTY MDST W/ INTERBEDS OF GREEN-BRWN VF-F QTZ SS & LS PKST (BROWN). STS BEDD ≤ 1 cm. SS & PKST BDD ≤ 1-5 cm. MICACEOUS.




@ LS @ PKST, IN 25 cm BEDS. Ø ≤ 1 cm IN UPPR BED

GRY & PURPLE ... R W/ LEWK/PKST & SILICEOUS SILTY MDST

GRY-GREEN @ Ø (≤ 2 cm) PKST (LS) W/ RED DOL? STS IN ... & DISCONT INTERLAMS ≤ 1 cm

TAN & PURPLE SILTY MDST W/ GRY-PURPLE CARBONATE STS, BOTH BDD ≤ 2-3 cm. FAINT ≡ IN STS.

GREEN Ø (≤ 2 cm) @ PKST, 45 cm THK BED.

GREEN LS FAREN, 25 cm BED. SPARSE A@

GREEN & TAN SILTY MDST, ≤ 1 cm BEDS, W/ LOTS OF BRWN LS PK/WKST INTERBEDS ≤ 1-4 cm W/ TOP 2 7-8 cm EACH. ... IN TOP 2 PKST ONLY, ≤ 1X5 cm.

GREEN-BRWN @ ... WK/PKST IN 2 BEDS 20-25 cm & ~10 cm W/ A 10 cm SILICEOUS MDST BED INBETWEEN.

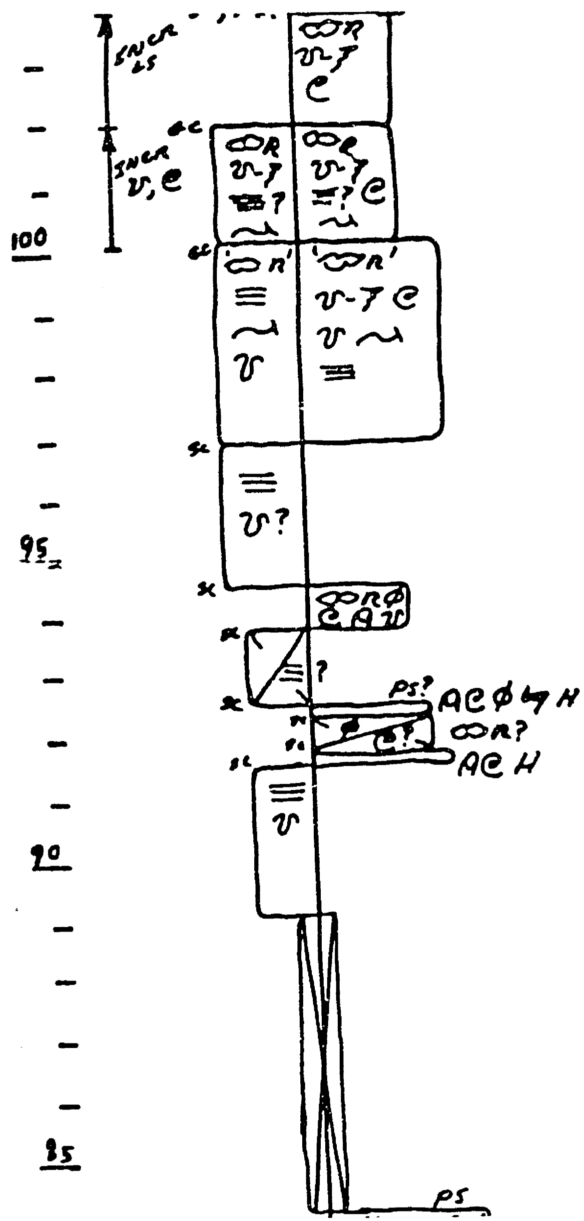
GREEN SILTY MDST, BDD ≤ 1 cm W/ MOSTLY BRWN LS PKST INTERBEDS & SOME VF-F QTZ SS INTERBEDS. BOTH BDD ≤ 1-4 cm.

GREEN-BRWN LS PKST, BDD ≤ 1½-4 cm W/ SILICEOUS MDST INTERBEDS ≤ 2 cm

LS THIS LIKE 65 cm

GREEN-BRWN @ PKST, 10 cm

GREEN SILTY MDST, BDD ≤ 1 cm W/ INTERBEDS OF GREEN-BRWN @ PKST LS, BDDS 3 cm




GRAY LS WKST, BDD ~2-6 cm w/ INTERBDD REDSTS, BDD ≤ 1/2 cm & IN ʊ. DOLSTS DECR UP ~30-35% TO ~5-10%

PINKISH-RED MUDDY STS, BDD ≤ 1-2 cm, MIXED WITH GRAY LS @ WKST, BDD ≥ 4 cm. STS CARBONATE-CEMENTED, MAY HAVE CARBONATE GRAINS. ~30-35% STS

REDDISH PINK & TAN SILICEOUS STS & GRAY LS STS w/ @, BOTH BDD ≤ 1-3 cm. LS MORE ʊ-7. SIL. STS MORE ~, ≡, ʊ.

PINK & TAN, BLOCKY, MUDDY STS, BDD ≤ 1→3 cm.

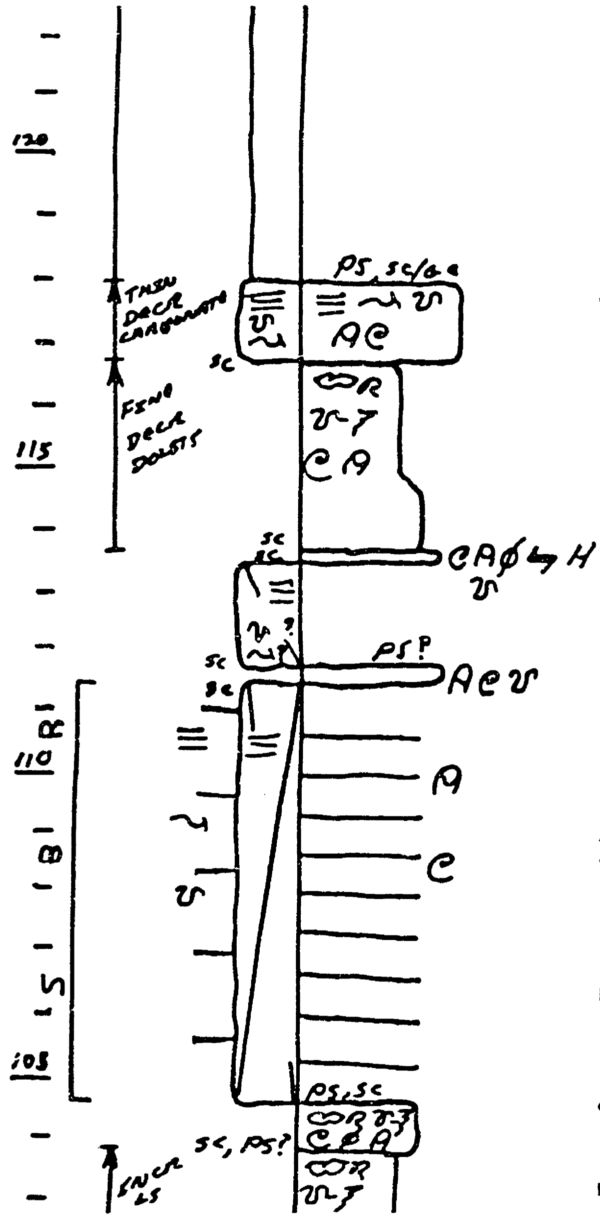
GRY-ORNG @ WKST, BDD 2-5 cm w/ INTERLAMS OF ORNG & REDDISH-PINK STS INTERBEDS. Ø ≤ 2 cm

RED, SILTY SH, RECESSIVE WEATHERING

2 GREEN LS WK/PKST & PKST BEDS 10 cm THK ON EITHER SIDE OF 70 cm THK RED & GREEN WK/PKST. Ø ≤ 1/2 cm

REDDISH & ORNGSH-PINK SILTY MDST, PROBABLY CLEAVED.

@ LS @ PKST IN 25 cm BEDS. Ø ≤ 1 cm IN UPPER BED




INTIMATELY INTERBDD TAN SILTY MDST, GRY-BRWNLS ARGN/STS W/ C, & LS AC PKST. ALL BDD ≤1½ cm.

GRY LS WKST, BDD ≤2-4cm, W/ REDDISH-ORNG DOLSTS IN IRREG INTERLAMS ≤1cm THK, & ?

GRY LS WK/PKST , 15 cm BED. ≤1x10cm. Ø ≤2cm

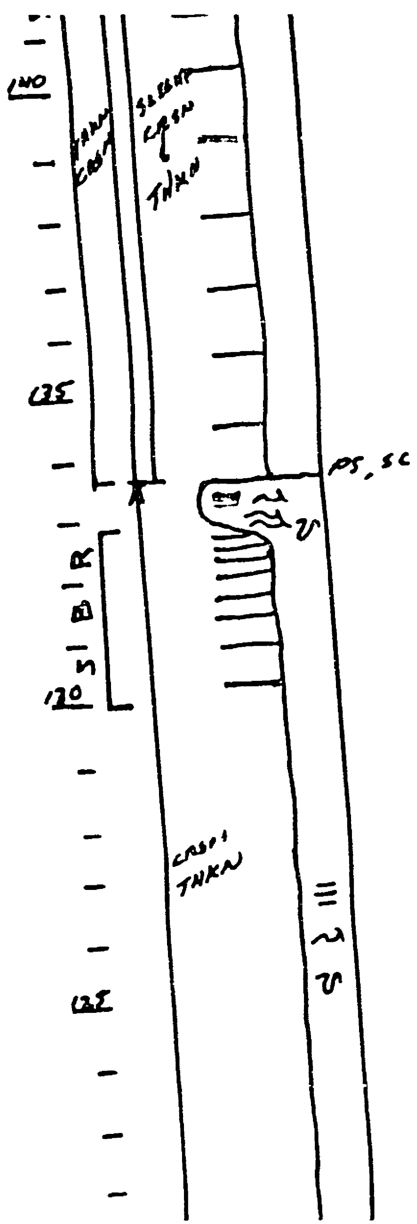
GREEN, GRY, ORNG, SILTY, MICACEOUS MDST, BDDS 1cm

YELLOWISH-GREEN C PKST, BDD ~2-3cm

MOSTLY COVERED, REDDISH PINK SILTY MDST W/ INTERBEDS OF C LS WK/PKST & VF QTZ SS. INTERBDS ≤ 1cm.

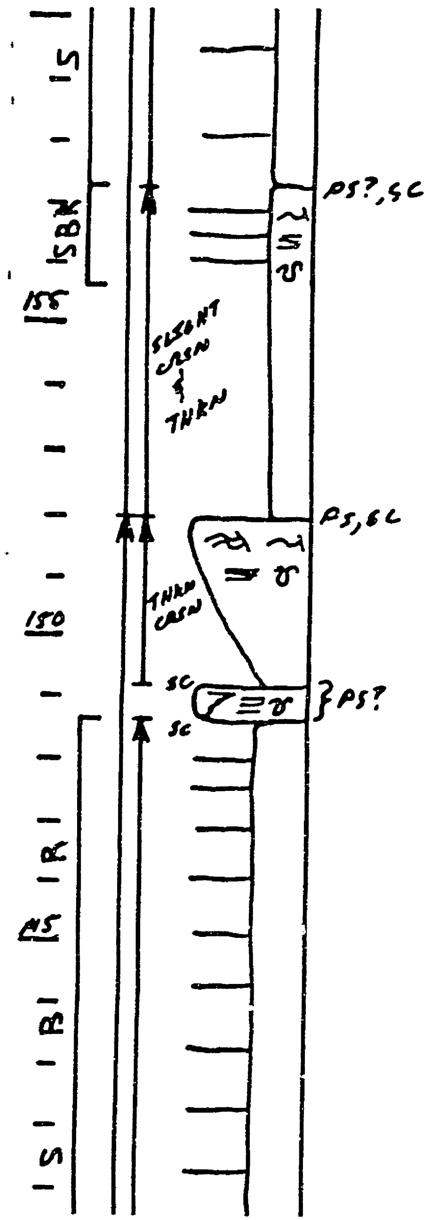
GRY LS WK/PKST, BDD ~1-3cm W/ REDDISH-ORNG STS, BDD ≤1cm & IN ?, ~10-15% STS. Ø ≤1½ cm

GRY LS WKST BDD ~2-6 cm w/ INTERBDD ...




~140 m, MOST SS BEDS 1-3 cm w/ some ≤10 cm

GREEN SILTY, MICACEOUS SH & ODD S 1/2 cm, w/ VF-F QTZ SS INTERBEDS STARTING @ AT ≈ 130 m; ODD ~3cm (mostly) w/ some ≤10 cm. IN TOP 1-2 m, STILL HAVE ~40-50% SH.

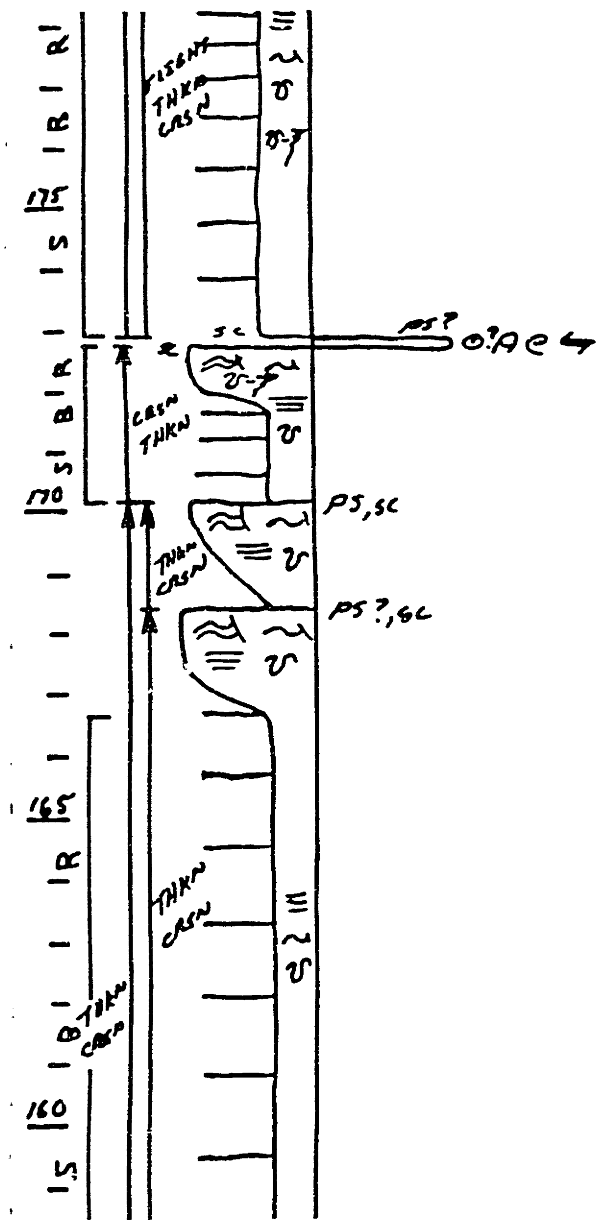



GREEN, SILTY, MICACEOUS SH, BDDS ≤ ½cm w/ A FEW VF-F SS BEDS, ≤ 1-5cm AT TOP.

GREEN, SILTY, MICACEOUS SH w/ BRWN VF-F SS. SH BDDS ≤ ½cm. ≈ 5-11cm, IN SETS ≤ 17cm. OTHER SS ≤ 4cm.

BRWN, VF-F SS, MOSTLY w/ 2 INTERVALS ≤ 7cm THK EACH w/ =, ~, SF. ≈ 35cm TOPPED BY ~7cm OF = & ~ & THEN REPEAT THE TOPPED BY =, ~.

GREEN & SILTY MICACEOUS SH/MOST w/ INTERBEDS OF VF-F QTZ SS LIKE 131m. BELOW ~140m. BEDS ≤ 1cm. ABOVE



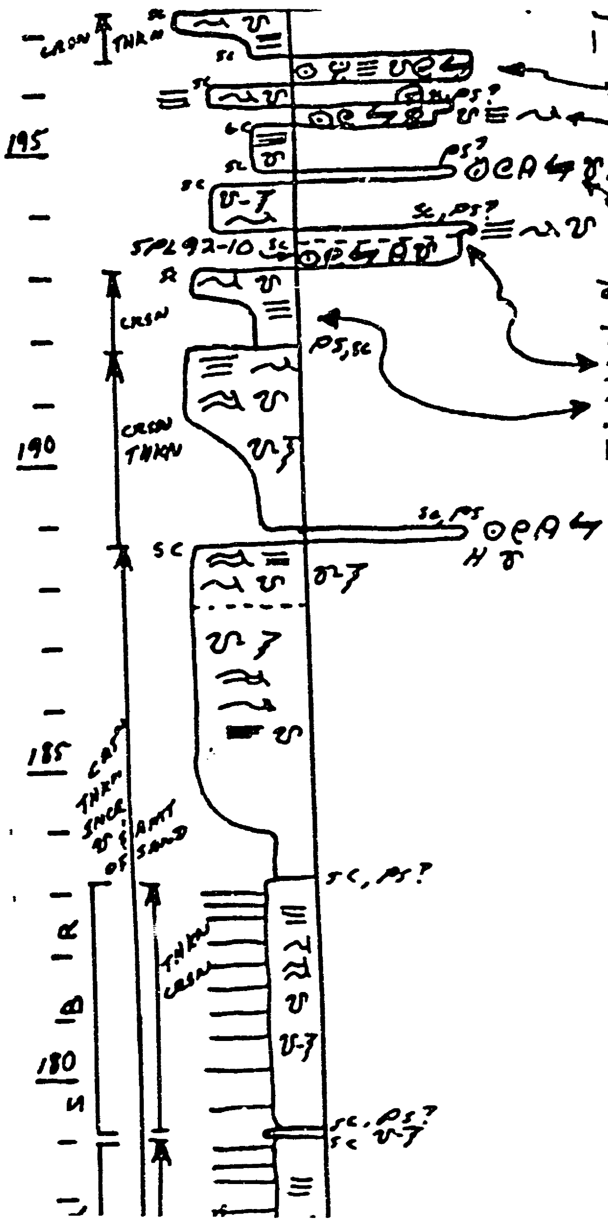

GREEN SILTY SH, BDD ≤ 5MM W/ INTERBEDS OF VF-F SS, BDD ≤ 3 cm.

BROWN PKST, M-F GRAINED, POSSIBLY OOLITIC. ↳ ≤ 1.5 cm & M-F ROUNDED CARBONATE. SGL 15 cm BED

GREEN SILTY SH W/ INTERBEDS OF VF-F SS, ≈ 50% SS IN TOP ~70-80 cm. ≈ & V-? ≤ 8 cm. REST OF SS BEDS ARE ≤ 4 cm.

GREEN, SILTY, MICACEOUS SH W/ VF & F SS INTERBEDS. ≈ 5-13 cm. REST OF BEDS LIKE 165 m.

GREEN, SILTY, MICACEOUS SH, BDD ≤ ½ cm W/ SCATTERED INTERBEDS OF VF-F SS. AT ≈ 167 m, THICKER SS BEDS COME IN W/ LOTS OF GREEN, SILTY SH INTERBEDS. SOME SS CRSNS UP VF TO F. ≈ BDD 5 → 20 cm. OTHER SS BEDS ≤ 1 → 5 cm.




SAND
SILTY, MICACEOUS SH, BDD ≤ 5mm, UP TO VF-F QTZ SS, BDD ≤ 3 cm

GREEN ⊙ GRST, BDD 2-20cm. ⊙ ½-1mm. ≤ 2x20mm. 1ST GOOD OOLITE

PINK VF-SANDY STS, BDD ≤ 1cm

GREEN LS STS, BDD ≤ 1cm, TOTAL THKNESS 8cm, OVERLAIN BY

BROWN PK/GRST (LS), 20 cm BED, w/ STITCHING ~10cm HS INTO NEXT UNIT. ⊙ ~ ¼ mm. ≤ ½x10cm. ≤ 1cm

PINK, GRY, SILTY, MICACEOUS SH, BDD ≤ 5mm

BRWN LS PK/GRST, 10cm BED. ⊙(½-¾mm) ≤ ½x2cm. SOME VF-M QTZ SAND

GRY-BRWN VF SANDY, MDST, BDD ≤ 1cm

GREEN & BRWN VF-F LS ARGN & PK/GRST. TOP ~20cm ARE IN BDD ~2cm, 2 PK/GRST BEDS, ~20cm EA. SOME BRWN DOLST INTERCALATED ≤ 1cm. ⊙ ½-1mm. ≤ ½x8cm

LITHS LIKE 176m, BUT SS ONLY VF. SH ≤ 5mm. SS ≤ 2cm

SAME LITHS AS 176m. SH ≤ 5mm. SS ≤ 1-10cm

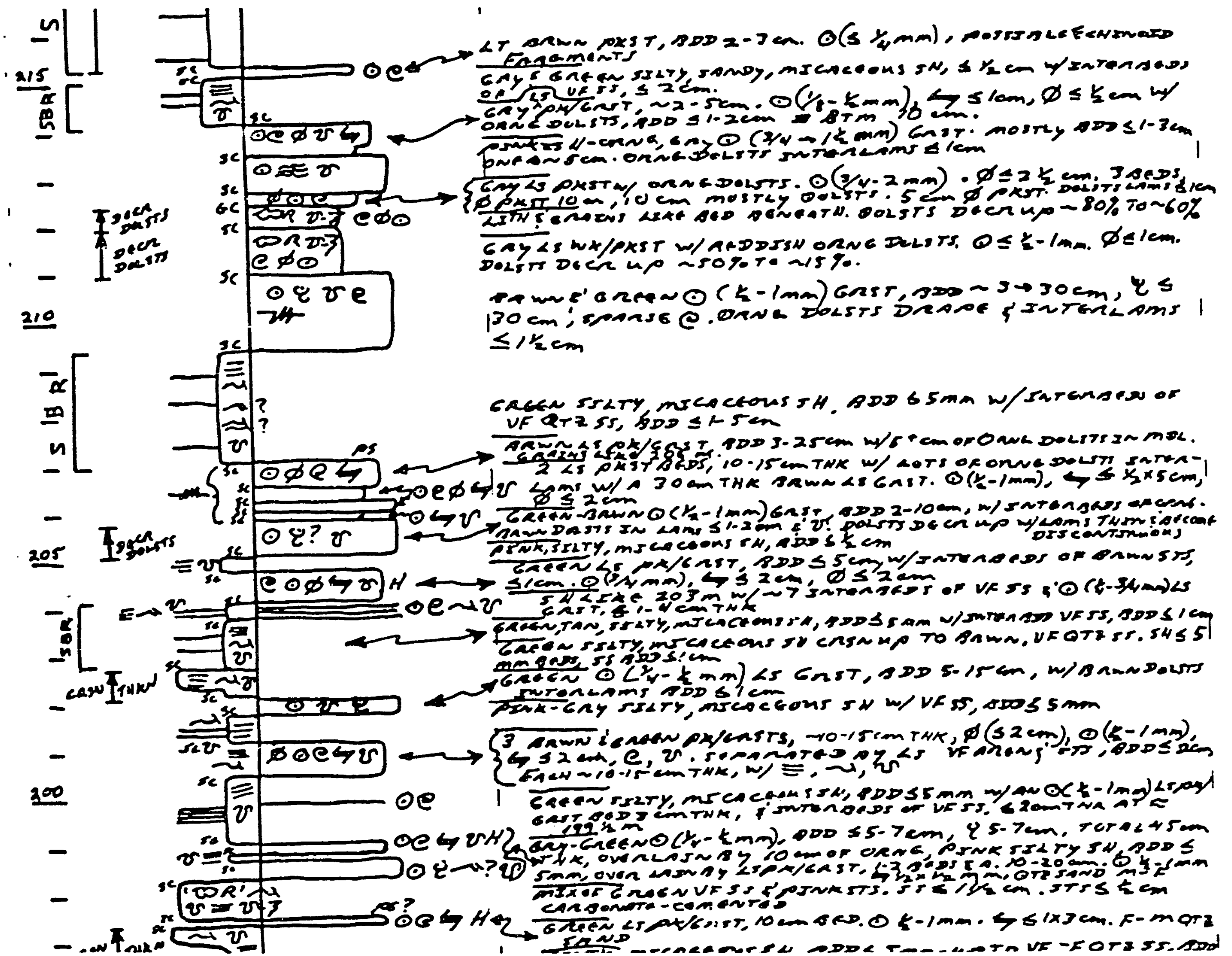
BRWN PK/GRST, ~10cm THK w/ ~2cm OF VF QTZ SS AT BASE ⊙(¼-½mm). M-F ½x7cm. LG ARE OF VF QTZ SS

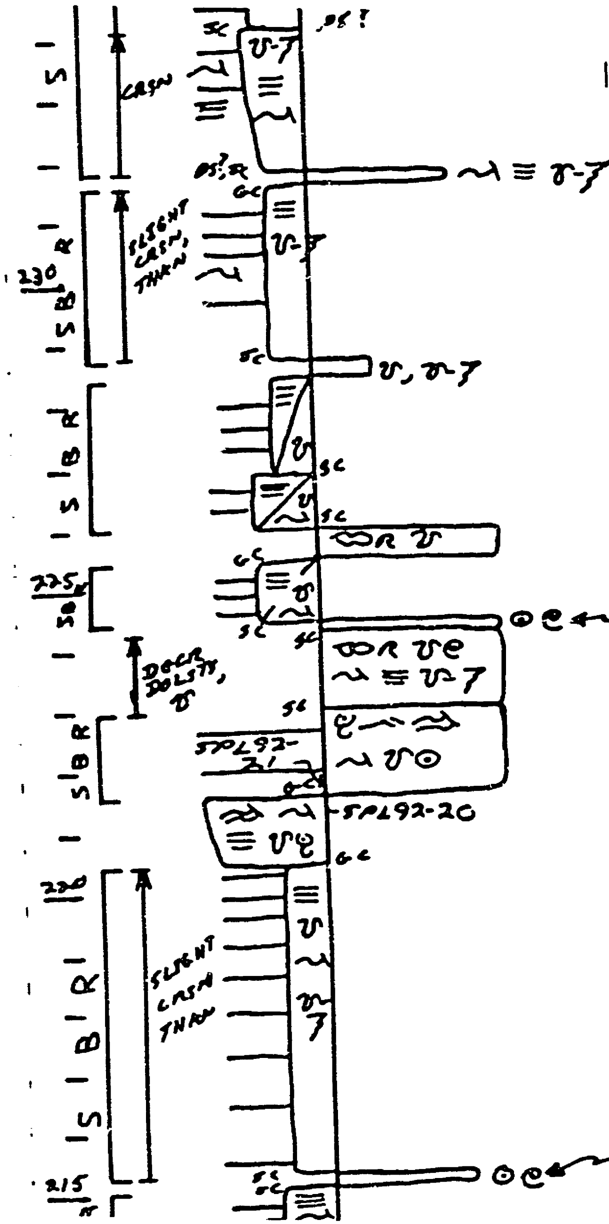
LITHS LIKE 176m. SH BDD ≤ 5cm. SS BDD ≤ 10cm. TOP 1m w/ POSSIBLE CARBONATE CEMENT. BTM 60-80cm ARE SH.

LITHS LIKE 176m. & V-? SS BDD ≤ 6cm, OTHER SS BDD ≤ 3cm.

YELLOWISH-GREEN, CARBONATE-CEMENTED SILTY, SANDY MDST, BDD ≤ 1cm,

GREEN. SILTY SH, BDD ≤ 5MM w/ INTERBEDS OF


215
210
205
200
S
SBR
S
B
R
SBR
DECR DOLSTS
DECR DOLSTS
DECR DOLSTS
CRSN THKN
SC
LT BRWN PKST, BDD 2-3 cm. ⊙(≤ ¼ mm), POSSIBLE ECHINOID FRAGMENTS
GRAY & GREEN SILTY, SANDY, MICACEOUS SH, ≤ ½ cm W/ INTERBEDS OF LS VF SS, ≤ 2 cm.
GRAY PK/GRST, ~2-5 cm. ⊙(⅛-¼ mm), ≤ 1 cm, Ø ≤ ½ cm W/ ORNG DOLSTS, BDD ≤ 1-2 cm BTM 10 cm.
PINKISH-ORNG, GRAY ⊙ (¾ ~ 1½ mm) GRST. MOSTLY BDD ≤ 1-3 cm ON FAN 5 cm. ORNG DOLSTS INTERLAMS ≤ 1 cm
GRAY LS PKST W/ ORNG DOLSTS. ⊙(¾-2 mm). Ø ≤ 2½ cm. 3 BEDS, Ø PKST 10 cm, 10 cm MOSTLY DOLSTS. 5 cm Ø PKST. DOLSTS LAMS ≤ 1 cm
LITH & GRAINS LIKE BED BENEATH. DOLSTS DECR UP ~80% TO ~60%
GRAY LS WK/PKST W/ REDDISH ORNG DOLSTS. ⊙ ≤ ½-1 mm. Ø ≤ 1 cm. DOLSTS DECR UP ~50% TO ~15%.
BRWN & GREEN ⊙ (½-1 mm) GRST, BDD ~3→30 cm, ≤ 30 cm; SPARSE ⊙. ORNG DOLSTS DRAPE & INTERLAMS ≤ 1½ cm
GREEN SILTY, MICACEOUS SH, BDD ≤ 5 mm W/ INTERBEDS OF VF QTZ SS, BDD ≤ 1-5 cm
BRWN LS PK/GRST, BDD 3-25 cm W/ 5 cm OF ORNG DOLSTS IN MDL. GREEN LS ≤ 2 cm. 2 LS PKST BEDS, 10-15 cm THK W/ LOTS OF ORNG DOLSTS INTERLAMS W/ A 30 cm THK BRWN LS GRST. ⊙(½-1 mm), ≤ ½ x 5 cm, Ø ≤ 2 cm
GREEN-BRWN ⊙(½-1 mm) GRST, BDD 2-10 cm, W/ INTERBEDS OF ORNG-BRWN DOLSTS IN LAMS ≤ 1-2 cm. DOLSTS DECR UP W/ LAMS THIN & BECOME DISCONTINUOUS
PINK, SILTY, MICACEOUS SH, BDD ≤ ½ cm
GREEN LS PK/GRST, BDD ≤ 5 cm W/ INTERBEDS OF BRWN STS, ≤ 1 cm. ⊙(¼ mm), ≤ 2 cm, Ø ≤ 2 cm
SH LIKE 203 m W/ ~7 INTERBEDS OF VF SS & ⊙ (½-¾ mm) LS GRST, ≤ 1-4 cm THK
GREEN, TAN, SILTY, MICACEOUS SH, BDD ≤ 5 mm W/ INTERBEDDED VF SS, BDD ≤ 1 cm
GREEN SILTY, MICACEOUS SH CRSN UP TO BRWN, VF QTZ SS. SH ≤ 5 mm BEDS, SS BDD ≤ 1 cm
GREEN ⊙ (¼-½ mm) LS GRST, BDD 5-15 cm, W/ BRWN DOLSTS INTERLAMS BDD ≤ 1 cm
PINK-GRAY SILTY, MICACEOUS SH W/ VF SS, BDD ≤ 5 mm
3 BRWN & GREEN PK/GRSTS, ~10-15 cm THK, Ø(≤ 2 cm), ⊙(½-1 mm), ≤ 2 cm, ⊙, SEPARATED BY LS VF GRAINS STS, BDD ≤ 2 cm EACH ~10-15 cm THK, W/ ≡, ~,
GREEN SILTY, MICACEOUS SH, BDD ≤ 5 mm W/ AN ⊙(½-1 mm) LS PK/GRST BDD 3 cm THK, & INTERBEDS OF VF SS, 6 cm THK AT ≈ 199½ m
GRAY-GREEN ⊙(¼-½ mm), BDD ≤ 5-7 cm, ≤ 5-7 cm, TOTAL 45 cm THK, OVERLAIN BY 10 cm OF ORNG, PINK SILTY SH, BDD ≤ 5 mm, OVERLAIN BY LS PK/GRST, 1-2 BEDS EA. 10-20 cm. ⊙ ½-1 mm, ½ x ½ mm, QTZ SAND MIX
MIX OF GREEN VF SS & PINK STS. SS ≤ 1½ cm. STS ≤ ½ cm CARBONATE-CEMENTED
GREEN LS PK/GRST, 10 cm BED. ⊙ ½-1 mm. ≤ 1 x 3 cm. F-M QTZ SAND




GREEN SILTY SH, BDD ≤ 5mm, CRSN UP TO GREEN SILTY MDST BDD ≤ 2cm. BOTH MICACEOUS. W/ OCCASIONAL VF SS INTERBEDS ≤ 1½ cm THK

ORNG DOLSTS W/ SOME GREEN LS STS, BOTH BDD ≤ 1½ cm, MAY HAVE SILICA GRAINS ALSO.

GREEN, SILTY, MICACEOUS, SH, BDD ≤ 5mm. W/ VF SS BDD ≤ 1½ cm

BRWN-GREEN LS MOST, BDD ≤ 1cm. LESS IN CENTER.

GREEN & PINK SILTY SH, BDD ≤ ½ cm.

LITHS LIKE 225m.

GRY LS F. AREN & TAN DOLSTS, W/ LOTS OF QTZ GRAINS, BOTH BDD ≤ 1cm. ~35% DOLSTS

PINK, GREEN, GRY, SILTY, MICACEOUS MDST, BDD ≤ 5mm W/ INTERBEDS OF VF SS, ≤ 1½ cm. CARBONATE CEMENT

YELLOW-GREEN GRST, 10cm BED. ⊙ (¾ mm). ECHINOID FRAGMENTS?

LT GRY LS F AREN, BDD ≤ 2-4cm. W/ REDS & ORNG QTZ & DOLSTS BDD ≤ 1-3 cm, INTERBEDS & . DOLSTS DECR UP ~40-50% TO ~10-15%.

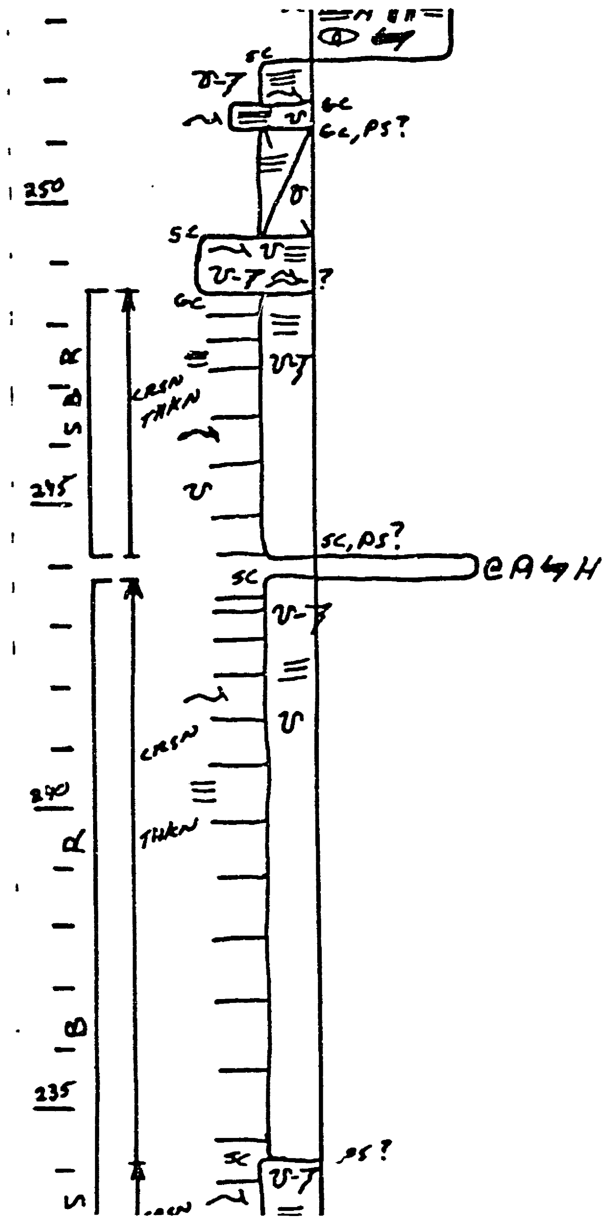
TAN ⊙ (¼-½ mm) GRST, ≤ 25cm, W/ INTERBEDS OF F QTZ SS, ≤ 10cm & STRINGERS ≤ 1cm, CARBONATE & SILICA CEMENTS

VF-F QTZ SS, BDD ≤ 10cm, W/ SH INTERLAMS ≤ 5mm. & ≤ 5cm. CARBONATE CEMENT

GREEN SILTY SH, BDD ≤ 5mm W/ VF SS INTERBEDS, MOSTLY ≤ 1cm, SOME ≤ 2cm.

LT BRWN PKST, BDD 2-3cm. ⊙ (≤ ¼ mm), POSSIBLE ECHINOID FRAGMENTS

GRY & GREEN SILTY SANDY, MICACEOUS SH, ≤ ½ cm W/ INTERBEDS OF LS VF SS, ≤ 2cm.
[illegible] GRST, ~2-5cm. ⊙ (⅛-½ mm), ≤ 1cm, Ø ≤ ½ cm W/ [illegible] BTM 10 cm.




ORNG DOLSTS, ADD ≈ 2cm. ... OF SAME.

GREEN, GRAY, SILTY, MICACEOUS SH, ADD ≤5mm

PINK, GRAY, ORNG MICACEOUS STS, ADD ≤1cm, CARBONATE CEMENT.

GREEN, SILTY, MICACEOUS SH, ADD ≤5mm

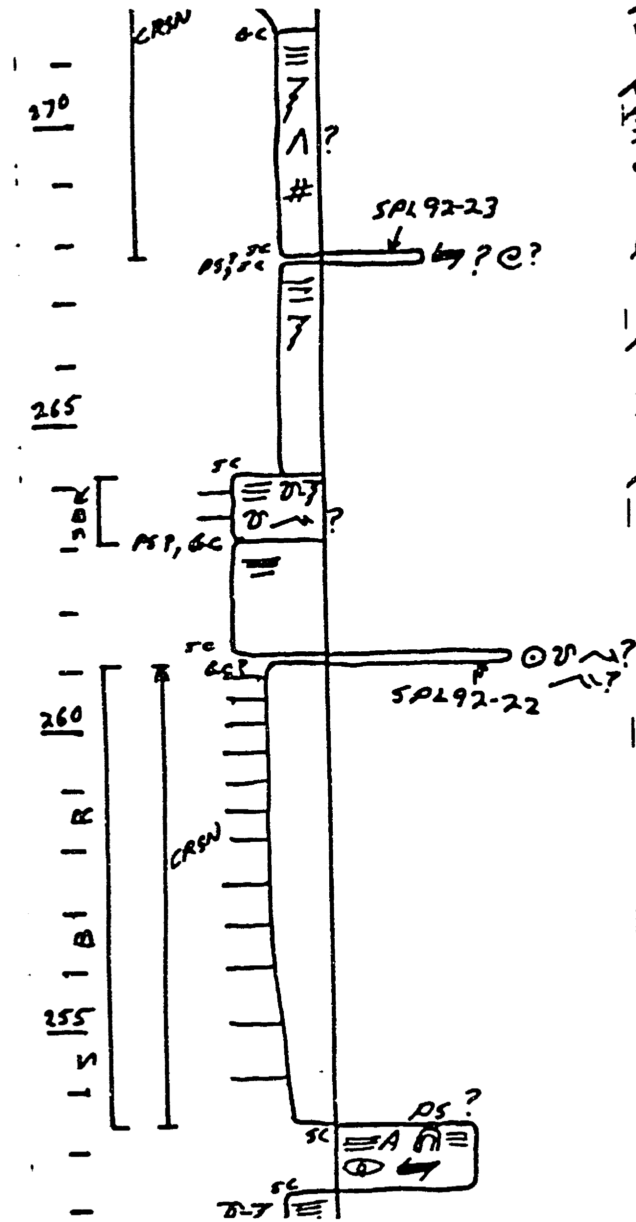
TAN VF-F SS, ADD ≤4cm. CARBONATE CEMENT; AREA

GREEN SILTY SH, ADD ≤5mm W/INTERBEDS OF VF SS, ADD 1→4 cm. SH IS MICACEOUS

ORNG DOLSTS WK/PKST, ≈30cm THK. ≤1x1½ cm.

GREEN, SILTY, MICACEOUS SH, ALMOST MDST, ≤5mm BEDS, W/A FEW VF SS BEDS, MOSTLY ≤1½cm THK, EXCEPT IN TOP 1½ m, WHERE THEY ARE ≤ 3cm THK.

GREEN SILTY SH, ADD ≤5mm, CRSN UP TO GREEN SILTY MDST




[illegible] VERTICAL, PROBABLY SKOLITHOS

RED, PURPLE SILTY MICACEOUS SH LIKE 265m. Λ ≤5cm HI. BDD ≤5mm. TOP OF INTERVALS A SHARP CONTACT (SC), BUT BASE OF INTERVALS MORE A GRADATIONAL CNTC (GC) I.E. . ʋ ARE LIKE 272 m.

YELLOW-GREEN MARLY, WKST?, 10cm BED. POSSIBLE ≤ ~ 1×½ mm OR ECHINOID? FRAGMENTS.

RED-PURPLE SILTY, MICACEOUS SH, BDD ≤ 5mm. ALTERNATING BLOCKY & FISSILE WEATHERING ON ~1m INTERVALS, ALTERNATING ≡ & . NO # OR Λ SEEN. 1ST GOOD REDBED. ʋ LIKE 272 m

PINK, GRAY & TAN STS & VFSS W/SOME F SS INTERBEDS, ALL ≤ 1cm. MICACEOUS. SOME CARBONATE CEMENT

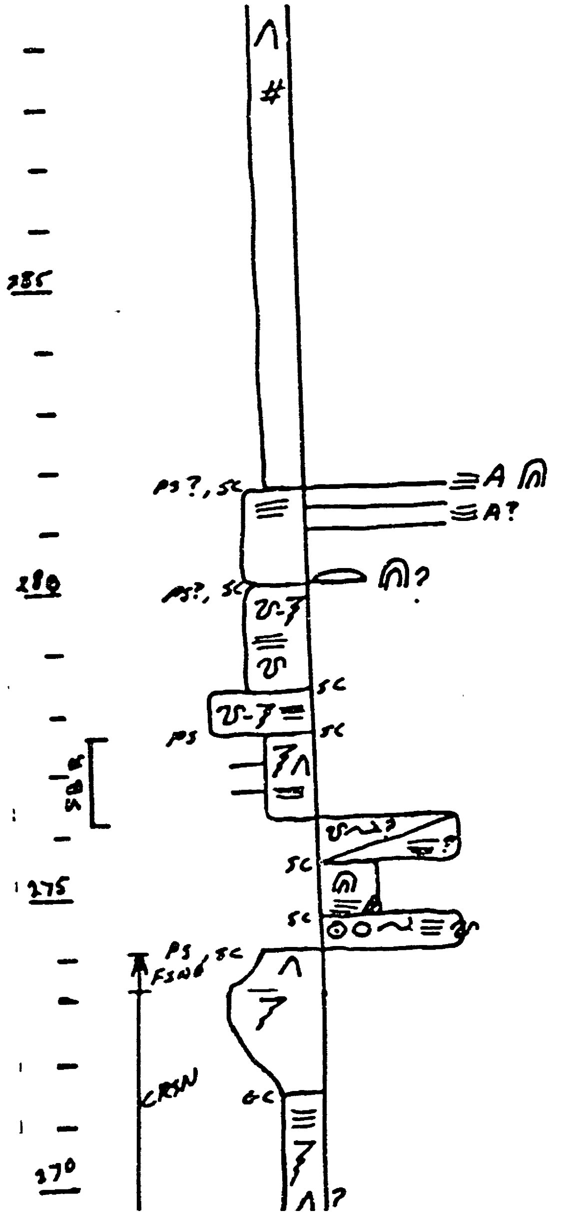
TAN & GRAY STS TO VF SS, BDD ≤ 5mm. MICACEOUS, MUDDY. NO ʋ OR # SEEN.

ORNG, PINK, GRAY ⊙ (≤ ½mm) GRST/STS/VF ARGN, BDD ≤ 2cm. SILICIFIED ⊙. STS/ARENMAY INCL. QTZ GRAINS

SILTY, MICACEOUS SH CRSN UP TO SILTY, SANDY MDST, POOR BDD ≤ 1cm. W/INTERBEDS OF VF SS, BEDD ≤ 4cm

ORNG DOLSTS, BDD ≲ 2cm. OF SAME.

GREEN, GRAY, SILTY, MICACEOUS SH, BDD ≤5mm




RED-PURPLE SILTY SH LIKE 265 m, 270 m. TOP & BTM ~1 m W/ MORE PINK & GRAY. ʊ ARE LIKE 272 m, IE. VERTICAL & PROBABLY SKOLITHOS

GREEN, PINK, ORNG SILTY MDST W/ ORNG DOLSTS STRINGERS. TOP 5 cm ARE ORNG-GREEN DOLSTS W/ STROMATOLITES

GREEN-BRWN DOLSTS INDISCONT. BUMPS ≤ 10 cm HI x 30 cm WIDE

GREEN, GRAY, SILTY, MICACEOUS, SANDY MDST. BDD ≤ 1 cm

TAN, VF SS, BDD ≤ 1 cm. CARBONATE CEMENT

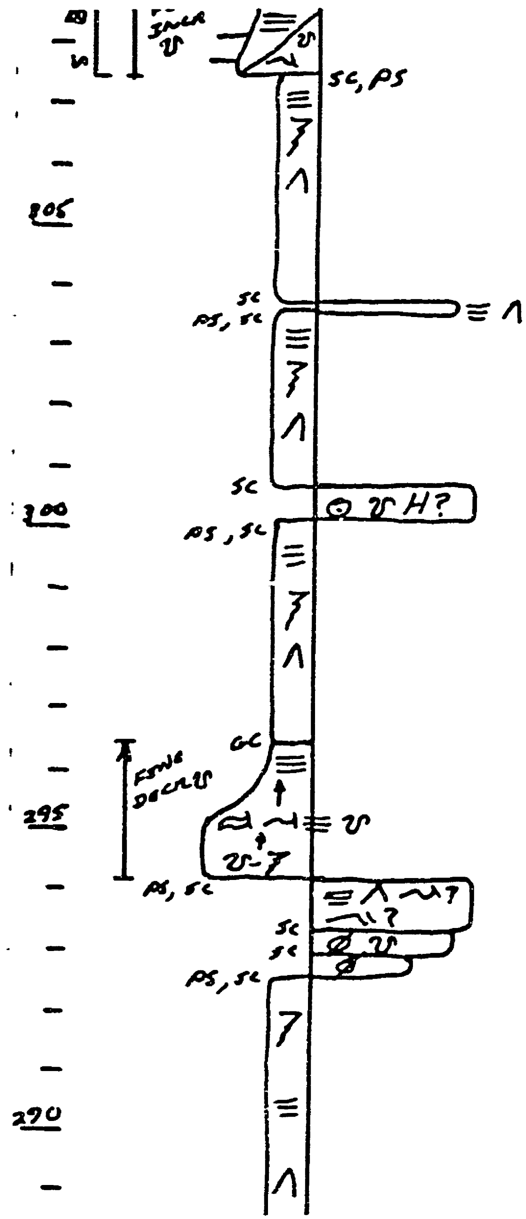
GREEN, TAN, PINK SILTY, MICACEOUS SH/MDST W/ A FEW STRINGERS OF STS. ALL BDD ≤ 5-10 mm. ʊ LIKE 272 m

ORNG DOLSTS, BDD ≤ 1/2 cm

LT GRAY LS MDST. ⋒ ≤ 20 cm WIDE x 15 cm HI W/ ~5-7 cm OF SYNOPTIC RELIEF
MIXED LS PKST, LS STS & DOLSTS. PKST BDD ≤ 2 cm, STS ≤ 1/2-1 cm. 3 INTERVALS, EA. ≈ 15-20 cm OF MOSTLY PKST TOPPED W/ STS. ⊙ & O 1/4 - 1/2 mm

PINK, GRAY, TAN SILTY SH CRSNING TO MDST TO MUDDY STS/VF SS & FINE TO MDST. ALL BDDS 1/2-1 cm, MICACEOUS. ALTERNATING ≡ & ⁊ OVER ≈ 1 m INTERVALS. MUDDY STS/VF SS (≡) VERY LIKE 262 m. ʊ ARE VERTICAL, PROBABLY SKOLITHOS

RED, PURPLE SILTY MICACEOUS SH LIKE 265 m. Λ ≤ 5 cm HI. BDD ≤ 5 mm. TOP OF ⁊ INTERVALS A SHARP CONTACT (SC), BUT BASE OF ⁊ INTERVALS MORE A




[illegible] SILTY, SANDY, MICACEOUS MDST, BDD ≤ 1cm(?) W/ INTERBEDS OF VF SS, MOSTLY BDD ≤ 1cm, SOME ≤ 3cm. V VERTICAL, EITHER SKOLITHUS OR OPHIOMORPHA

RED, PURPLE, SILTY, MICACEOUS SH, BAND ≤ 1mm. V LIKE 285m

RED, PURPLE, SILTY SH W/ A 10cm THK ORNG-PURPLE DOLSTS AT TOP BEDDED ≤ 1/cm. V LIKE 285m

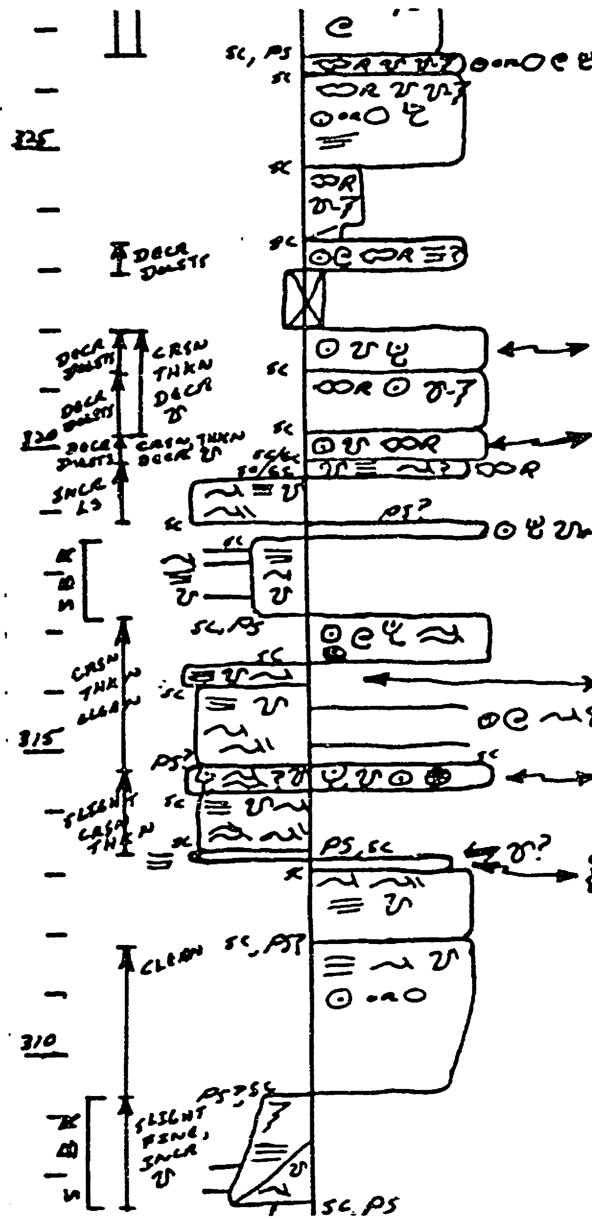
GRAY ⊙(≤ ½ mm) PK/GRST, BDD 7 & 50cm. 7cm BED SS CLEANS AT TOP. 50cm BED SS PUNKY, W/ SILICEOUS SANDS & MUD.

RED, PURPLE SILTY SH LIKE 265m. MICACEOUS. V LIKE 272m & 285m

LT GRAY MUDDY, VFSS; FINES UP TO GRAY GREEN SILTY MDST; FINES UP TO GREEN, SILTY, MICACEOUS SH

PINK DOLSTS, W/ SILT & VF SAND QTZ GRAINS. BDD ≤ 5-8 mm

⊘ WKST, LWR UNIT W/ MUD MATRIX & UPPR W/ SILT MATRIX. GREEN, PINK, ORNG. BDD 7→20-30cm. ⊘ ≤ 4cm, MOST ≤ 2cm



≤1-2cm & IN [illegible]. ⊙ OR ○ (⊙/○)

LIKE 325m

GRAY LS PK/GRST, BDD ≤1-8cm. W/ ≤10% ORNG DOLSTS & IN [illegible]. MUCH OF LS SS [illegible]. ⊙ ≤ 1/4 → 3/4 mm.

GRAY LS, RECESSIVE WEATHERING W/ ORNG DOLSTS. LS BDD ≤2-4cm. DOL BDD ≤5mm; IN [illegible] & DISCONT INTERLAMS. LS MAY BE A PK/GRST.

GRAY LS PK/GRST BDD ~3-7cm. W/ ORNG DOLSTS INTERLAMS ≤5mm & [illegible]. DOLSTS DECR UP FROM ~5-10% TO <5%. ⊙ ≤ 1/4 mm

COVER. LIKE 319.5m OR 319.0m.

GRAY ⊙ GRST W/ SOME VF LS GRST & ORNG DOLSTS. ⊙ (1/4-1/2 mm) LS BDD ≤2 UP TO 20cm. DOLSTS ≤1cm. SOME ⊙ DOLZD. DOLSTS INTERLAMS & [illegible]. ~10% UP TO ≤2-3%

LITHS LIKE 321 1/2 m. ⊙ (≤ 1/4-1/2 mm). LS ≤1 UP TO 7cm. DOL ≤1/2 cm. DOLSTS ~35% UP TO ~10%.

LITHS LIKE 32 1/2 m. ⊙ (1/4-1/2 mm). LS ≤1 UP TO 4cm. DOL ≤1cm. DOL ~20% UP TO <5%

GRAY LS VF & F AREN & PINK STS. BOTH BDD ≤1 1/2 cm. SOME QTZ SAND

GRAY, TAN, PINK VF & F QTZ SS & STS W/ SOME CARBONATE SAND GRAINS. MOST BDD ≤1cm. SOME SS 1-4cm. MICACEOUS

GREEN ⊙ (1/4-3/4 mm) LS GRST. SOME ⊙ DOLZD.

GREEN, SILTY SH, BDD ≤5mm, W/ INTERBEDS OF VF SS & STS, MOSTLY ≤1cm, SOME ≤3cm. SH MICACEOUS

LT YELLOWISH GREEN ⊙ (≤1/4-1/2 mm) GRST, BDD ≤3-20cm

GREEN GRAY F QTZ SS, BDD ≤1-10cm

LITHS LIKE 314m & INTERBDD ⊙ [illegible] LS PK/GRST, BDD ≤1-8cm. ⊙ ≤ 1/4-1/2 mm

MXT. VF-F SS & ⊙ (≤1/4 mm) LT YELLOWISH GREEN LS GRST, ALL BDD ≤ 6-20cm

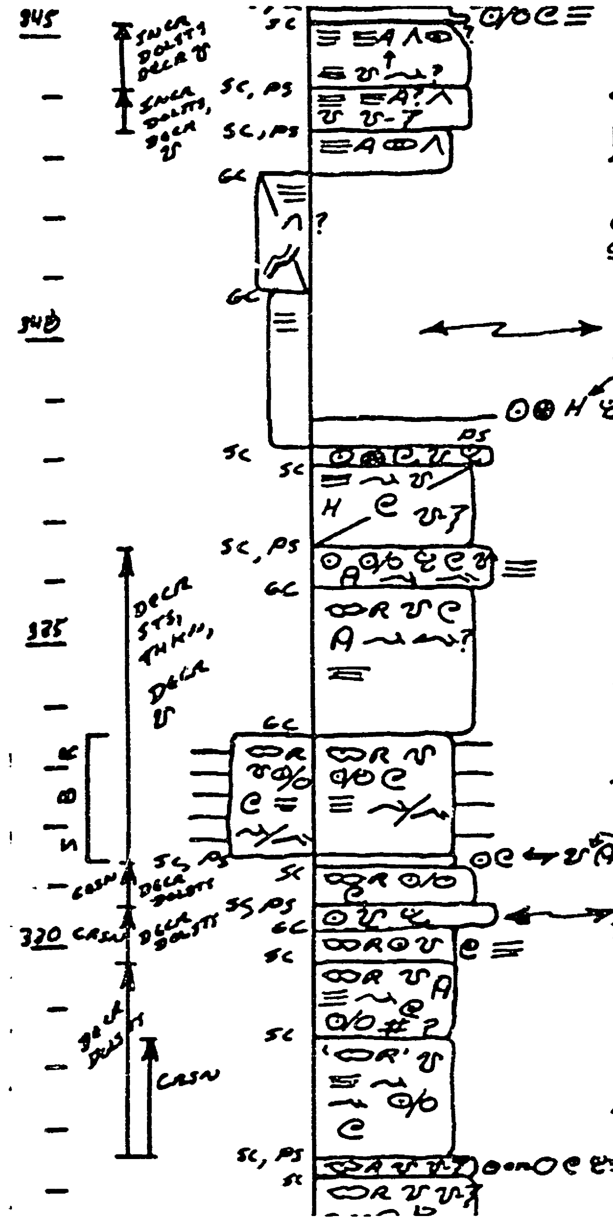
GRAY GREEN F & VF SS, BDD MOSTLY ≤1-20cm. SOME ≤10cm W/ INTERBDD STS & SILTY SH, BDD ≤1cm

GRAY LS [illegible] (≤1/2 x 10cm) PKST W/ MUDDY, SANDY MATRIX, 15cm BED [illegible] OF LITH BELOW BUT W/ MORE QTZ SAND GRAIN

PINK CARBONATE STS & GRAY LS VF AREN, MOST BDD ≤1-2cm, SOME ≤10cm. QTZ GRAINS MXT IN W/ CARBONATE.

GREEN, YELLOW, PINK & LT GRAY LS PK/GRST, BDD ≤1-3cm ⊙ & ○ ≤ 1/4 mm. CLEANS UP BY LOSING SILICEOUS SILT & SAND.

GREEN SILTY, SANDY, MICACEOUS MDST, BDD ≤1cm(?) W/ INTERBEDS OF VF SS, MOSTLY BDD ≤1cm; SOME ≤3cm. [illegible] VERTICAL, EITHER SKOLITHOS OR OPHIOMORPHA




GREEN LS AREN/STS (BDD ≤ 1cm) CHANGE UP TO PINK DOLSTS TO ORNG DOLSTS (BOTH BDD ≤ 1cm TO MM-LAMD. STRUCS CHANGE AS SHOWN. CHANGES ARE GRADUAL. LS ~70cm THK.

GRAY LS AREN/STS CHANGE UP TO TOP ~10cm OF ORNG DOLSTS MM-LAMD FOR ALL.

PINK, CHANGING UP TO ORNG DOLSTS / MM-LAMD.

GREEN & LT GREEN SILTY SH, MM-LAMD. // MAY BE TECTONIC OR MAY BE DUE TO ∧/#. SOMEWHAT TALCOSE.

GREEN, SLIGHTLY SILTY, CHLORITIC SH, MM-LAMD W/ ONE 7cm THK BED OF LT GREEN GRST, ⊙ & ⊛ (¼-½ mm) W/ TOP POSSIBLY REWORKED BY ?/~? SHARP UPPER & LWR CNTX

GREENISH-YELLOW ⊙ (≤ ¼ mm) GRST, BDD 1-2 TO 15cm.

YELLOWISH-GREEN LS ⊙ (≤ ½ mm) GRST W/ VF LS AREN & STS W/ QTZ SAND & SILT. ALL GRST & AREN BDD ≤ 1-8cm. STS BDD ≤ 1cm

GREEN LS AREN & ⊙ (≤ ⅛-½ mm) GRST, LS BDD ≤ 1-2cm, W/ A 20cm ? BED. DOLSTS IN ? & DISCONT INTERLAMS

GREEN VF LS AREN W/ QTZ SAND, BDD ≤ 1-3cm & INTERBDD PINK DOLSTS W/ QTZ SILT, BDD ≤ 1-2cm. DOLSTS DECR UP ~50-60% TO 35%

INTERMIXT & REGRESSIVE PINK STS & VF-FSS W/ DOLSTS & LS PK/GRST, ALL BDD ≤ 1-2cm. STS ≈ 55-60% ⊙ (≤ ¼ mm)

GRAY LS PKST, BDD ≤ 3-5cm, ⊙ (≤ ½-1mm)

LS PK/GRST, ⊙ (≤ ½ mm). BDD ≤ 2cm W/ DOLSTS LIKE 329m, BDD ≤ 2cm, DECR UP ~10-15% TO ≤ 5%

GRAY ⊙ (≤ ½-1mm) LS GRST. BDD ~5-15cm. DOLSTS ≤ 5% LIKE 329m.

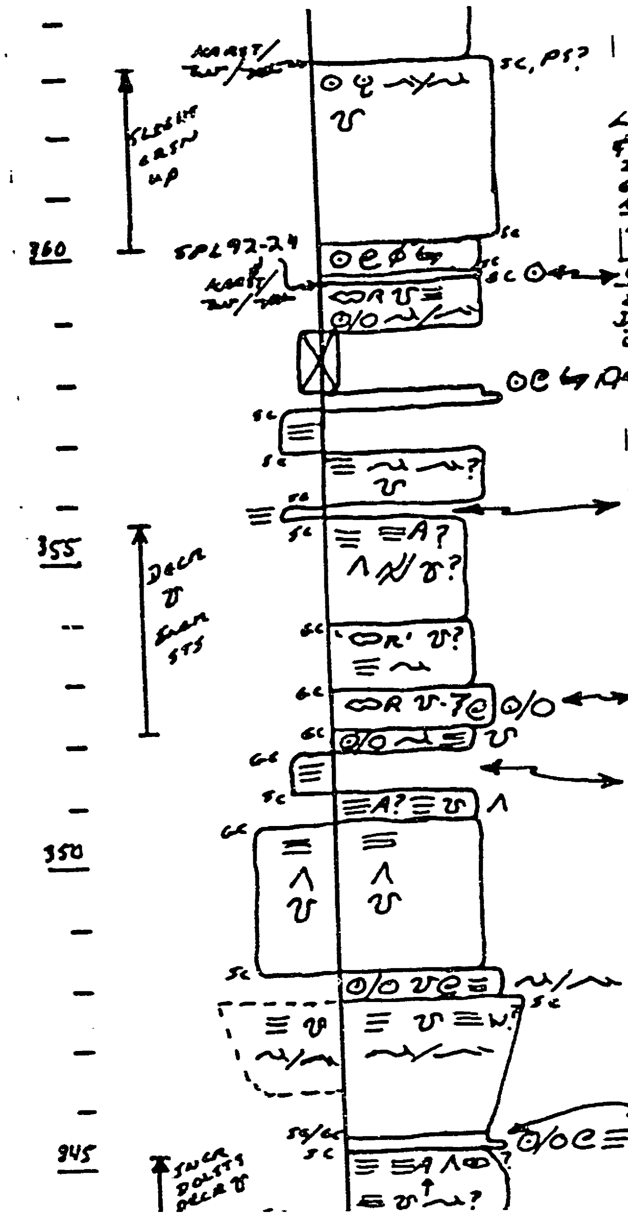
GRAY LS ⊙ (≤ ⅛-1mm) GRST, BDD ≤ 1-3cm W/ PINK DOLSTS LIKE 329m, DECR UP ~80% TO ~25%

GRAY LS VF AREN/STS & PKST, BDD ≤ 1-3cm W/ ONE ⊙ BED AT TOP 8cm THK. INTERBEDS OF PINK DOLSTS LIKE 327m, ≤ 1cm & ?. DOLSTS ~30% UP TO ~10-15%. # MAY BE ?. ⊙ ≤ ½-1mm.

GREEN LS STS/AREN, BDD ≤ 1-3cm W/ SOME ⊙ (≤ ½ mm) @ LS PK/GRST, BDD ≤ 1-3cm & INTERBDD PINK DOLSTS, ~40%, ≤ 1-2cm & IN ?. ⊙ OR ○ (⊙/○)

LIKE 325m

GRAY LS PK/GRST, BDD ≤ 1-8cm: W/ ≤ 10% ORNG DOLSTS IN ?.




LS ⊙(≤⅛-1mm) GRST, BDD ≤ 8cm W/KHAKI-GREEN DOLSTS DRAPES & DISCONT. INTERLAMS, ≤5dcm TO MM-LAM'D. SOME ⊙ DOLZD. TOP SURFACE SHARPLY IRREGULAR. LIKE 359.5m BETWEEN KARST OR DISSOLUTION OR SCOURED OR SOME COMBINATION OF ALL 3.

PINK & GRY LS, SOME ℓ ø (BOTH ≤1cm) PK/GRST & SOME ⊙(≤¼-½mm) GRST, BOTH BDD ≤1-10?cm. RECESSIVE WEATHERING

GRY PK/GRST, 10cm BED. ⊙(≤½mm).

DK GRY LS PK/GRST BDD ≤ 1-3cm W/ INTERLAMS OF ORNG DOLSTS, ≤5mm; & IN ʊ. ~≤5-7% DOLSTS. TOP SURFACE SHARPLY IRREGULAR

COVER

GREEN LS PK/GRST ⊙(≤¾mm) (≤1mm & ≤ 3mmX20mm) OVER GRY LS VF AREN

SH LIKE 355.7 m

TAN, LT GREEN VF LS AREN & STS, BDD ≤ 1-3cm

GREEN, CHLORITIC, SLIGHTLY SILTY SH, MM-LAM'D

PINK & REDDISH-ORNG DOLSTS, BDD MOSTLY ≤ ½cm W/ SOME ≤1cm.

PINK, TAN, YELLOW DOLSTS W/ LS VF AREN & PK/GRST INTERBEDS. ALL BDD ≤1-2cm

GRY LS PK/GRST, BDD ≤1-2cm. W/ PINK DOLSTS, BDD ≤1cm, IN DISCONT LAMS & ʊ. ⊙/O ≤ ¼mm.

ORNG DOLSTS, BDD ≤1cm TO MM-LAM'D. W/ GREEN LS PK/GRST, ≤1cm BDD. ⊙ ≤ ¼mm

GREEN, SLIGHTLY SILTY, CHLORITIC SH, MM-LAM'D

ORNG DOLSTS, BDD ≤1cm TO MM-LAM'D

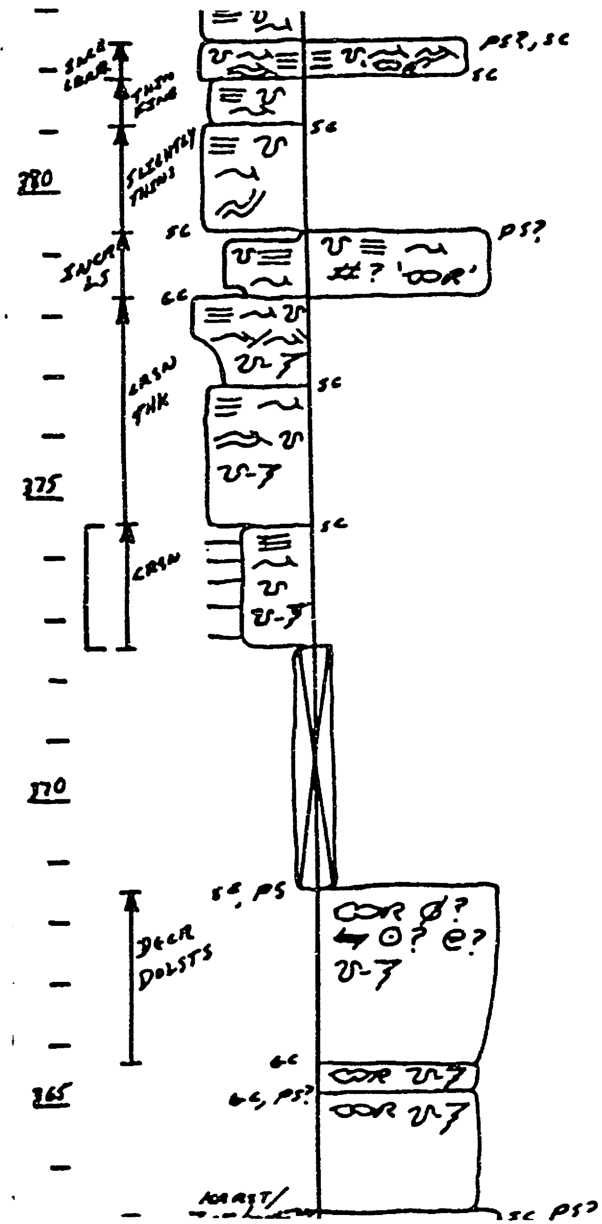
PINK DOLSTS/SILICEOUS STS W/INTERBEDS OF GREEN CHLORITIC, SLIGHTLY SILTY SH. ALL BEDS ≤1cm TO MM-LAM'D

LT GREEN LS PK/GRST, BDD ≤1-4cm. ⊙/O(≤¼mm).

PINK DOLSTS, BDD ≤ ½cm, CHANGES UP TO PINK & TAN DOL/LS VF & F AREN W/ LOTS OF QTZ GRAINS. ≡ IN TOP 15-20 cm. AREN BDD ≤1cm, SOME 1-2cm.

GREEN, PINK GRST FINE UP TO LS STS (≡), BOTH BDD ≤ 1-2cm GREEN LS AREN/STS (BDD ≤1cm) CHANGE UP TO PINK DOLSTS UP TO ORNG DOLSTS (BOTH BDD ≤1cm TO MM-LAMD. STRUCS CHANGE AS SHOWN. CHANGES ARE GRADUAL. LS ~70cm THK.

... UP TO TOP ~10cm OF ORNG DOLSTS




GREEN VF LS ARGN W/ LOTS OF QTZ SAND & ~40% BRWN VF SS. BOTH BDD ≤1-3 cm. SILICA & CARBONATE CEMENTS. ≈ BROAD & LOW AMPLITUDE.

LT BRWN VF SS, SLIGHTLY FINER THAN UNIT BENEATH. BDD MOSTLY 2-3 cm. SOME ≤4 cm

LT BRWN VF SS, BDD ≤1-10 cm. IN BTM 70 cm, BDD ~40 cm

MIX OF BRWN VF SILICA-CEMENTED SS & GREEN VF-F LS ARGN W/ LOTS OF QTZ GRAINS. LS ≤1-5 cm. SS BDD ≤1-2 cm. ~50% LS. BTM 5-10 cm SS & STS. TOP 10-15 cm ONLY LS.

BRWN MIXED STS & VF SS CHANGES UP TO VF-F SS. SS BDD ≤5 cm. STS BDD ≤1-2 cm. MICA.

BRWN VF SS, BDD ≤10 cm, MOST ≤2-3 cm W/ MDST INTERBEDS ≤ 2-3 cm. SOME INTERFERENCE RIPPLES. MICA.

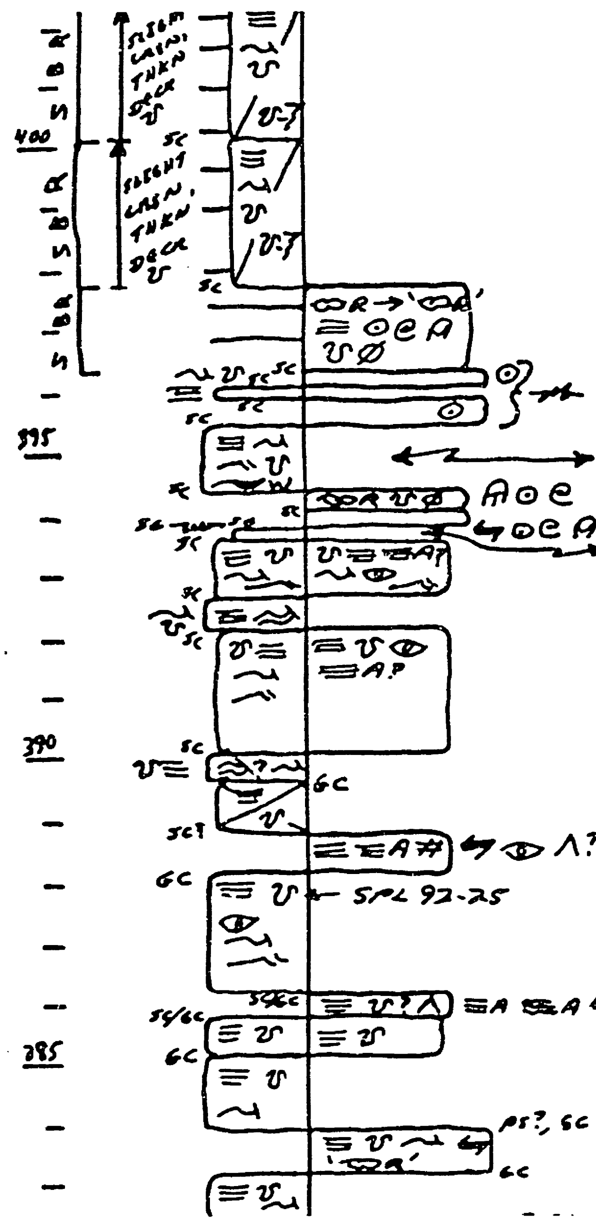
BRWN, SILTY, SANDY, MICACEOUS MDST, BDD ≤ 2 cm, W/ VF SS INTERBEDS, ≤3 cm

COVER. PROBABLY RED, TAN, BRWN, SILTY, VF SANDY, MICACEOUS, SILICEOUS MDST

SAME AS 364 m W/ SOME DEFINITE GAST, ESPECIALLY NEAR TOP. BDD ≤5 cm? ⊙ ≤1 mm. ⇆ & Ø ≤1-1½ cm. QUESTIONABLE IDENTIFICATION OF GRAINS DUE TO DARK COLOR. DOLSTS DECR UP ~5-10% TO <5%

SAME AS 364 m, ~75% DOLSTS IN

DK GRY VF? PK/GAST (OR MDST) W/ ORNG DOLSTS, ~5-10% IN




SAME AS 399m W/SOME SS BDD ≤ 3cm.

PURPLISH-BRWN, SANDY, SILTY, MICACEOUS MDST W/INTERBEDS OF VF SS. MDST BDD ≤ ½ cm. SS MOSTLY BDD ≤ 1cm, SOME ≤ 2cm.

GREEN & BRWN LS, ALL BDD ≤ 1-5cm. Ø (≤ 1cm) PKST, & ⊙ (≤ ½ mm) @ GRST & PKST & LS VF ARGN & LS STS & DOLSTS & QTZ VF SS & STS

GREEN ⊙ (¼-½ mm) LS GRST, BDD ~15-20cm W/ ORNG-BRWN VF SS/STS BDD ≤ 2cm IN MDL ~15 cm THK. ⊙ IN SS/STS, CARBONATE CEMENT.

LT BRWN VF SS W/ INTERBEDS OF STS & SOME SH. ALL BDD ≤ ~3cm

2 LS PK/GRST, TOP W/ OR TEXTURE, BDD ≤ ~2cm. BTM SS 25 cm BED. ⊙ (⅛-¾ mm). [illegible] OF DOLSTS ≤ 1½ × 20 cm W/ BSG CLASTS IN BTM BED. MOST ≤ 1×1 cm. Ø (≤ 2cm). (T) (≤ 4×4 cm) & Ø IN TOP 10 cm ONLY

BRWN STS W/ CARBONATE CEMENT, BDD ≤ ~3cm

MIXED LITH LIKE 391m, MOST BDD ≤ ½ cm, SOME ≤ 1cm

GRY, LT BRWN VF SS, BDD ≤ 1 → 10cm

MIXED BRWN, TAN SILICEOUS STS (BDD ≤ ½ cm) & VF SS (BDD ≤ ½ cm W/SOME ≤ 1cm) & ~50% ORNG, REDDISH ORNG DOLSTS (≤ ½ cm)

VF SS BDD ≤ 5 → 15-20 cm

VF SS BDD ≤ 1-3cm, W/ STS BDD ≤ 5mm

ORNG DOLSTS W/ SOME VF SS, BOTH BDD ≤ 1cm. SS SILICA-CEMENTED. [illegible] OF DOLSTS, ≤ 2cm × 5mm.

LT BRWN VF SS, MOSTLY BDD ≤ 1cm EXCEPT IN MIDDLE WHICH IS BDD ≤ 2-3cm - W/ ORNGISH-BRWN STS (DOL? SILICEOUS?), BDD ≤ 1cm, INTERBEDS. SIMILAR TO 385 ½ m.

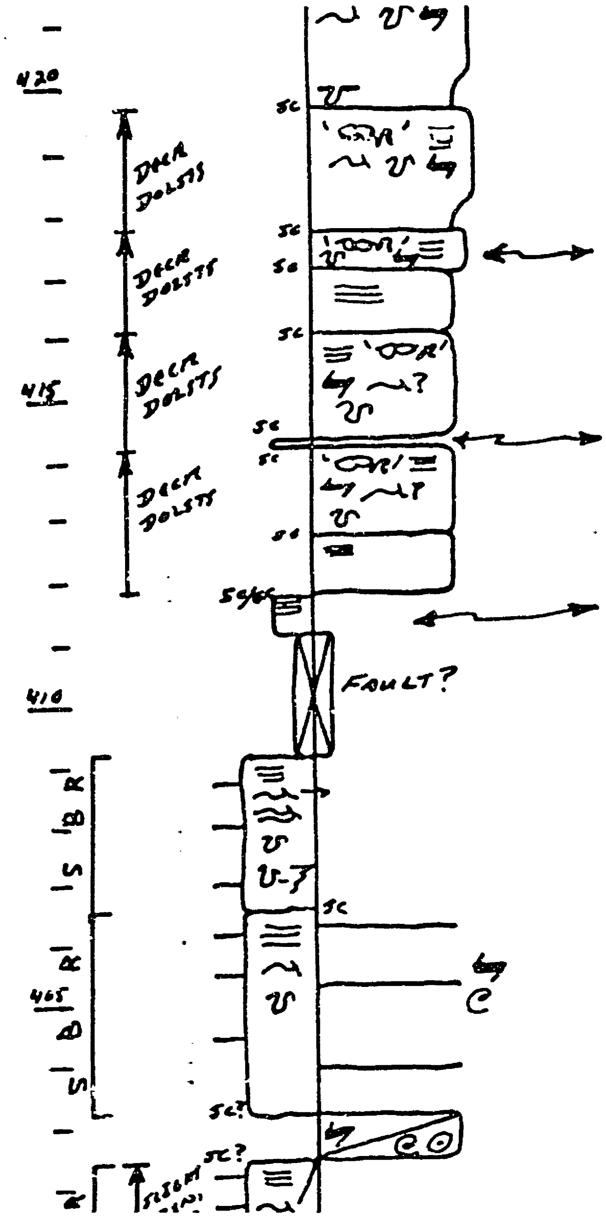
ORNG DOLSTS, ≤ 1cm. [illegible] ≤ ½ × ½ cm. Λ ≤ 1cm HI.

BRWN VF SS (≤ ~2cm) & ORNG-BRWN (≤ 1cm) DOLSTS, BDD (≤ 1cm)

GREENISH-BRWN VF SS, BDD ≤ 1-10cm. W/ LOTS OF MM-LAMS W/IN BEDS. CARBONATE CEMENT.

GREEN LS VF ARGN W/ LOTS OF QTZ SAND & LT BRWN VF SS W/ CARBONATE CEMENT. BOTH BDD ≤ 1-3cm, ~30-35% SS. [illegible] ≤ 1×1 cm OF CARBONATE

BRWN VF SS, BDD ≤ 1-5cm. MDL ~10-15cm W/ CARBONATE CEMENT. REST SILICA CEMENT




THAN GREEN. BTM 7-12 cm SS 100% DOLSTS W/ LOADED (Ʋ) INTO ST.

LITHS LIKE 417m W/ SOME LS VF AREN AS WELL AS LS STS. LS BDD ≤ 1-4cm. DOLSTS MOSTLY BDD ≤ 1cm, SOME ≤ 2-3cm. BASAL PART 100% DOL. DECR TO ~40% DOL AT TOP

LITHS LIKE 413½m. LS BDD ≤ 1-3cm, DOL BDD ≤ 1cm. OF LS ≤ 1cm. ~60% DOLST

ORNG DOLSTS LIKE 412m W/ LITTLE LS STS. ~95% DOL.

LITHS SAME AS 413½ m, EXCEPT LS BDD ≤ 3cm, MOST ≤ 1-2cm, DOLSTS BDD ≤ 1cm. LS CRSR & MORE Ʋ THAN DOL. DOL DECR UP FROM ~50% TO ~30%

10cm OF RED SILTY SH

ORNG & GREEN DOLSTS & LS STS, BDD LIKE 412m, ~40% DOLSTS AT TOP

ORNG-TAN DOLSTS, mm-LAM'D TO ≤ 1cm BDD. ~100% DOLSTS AT BTM.

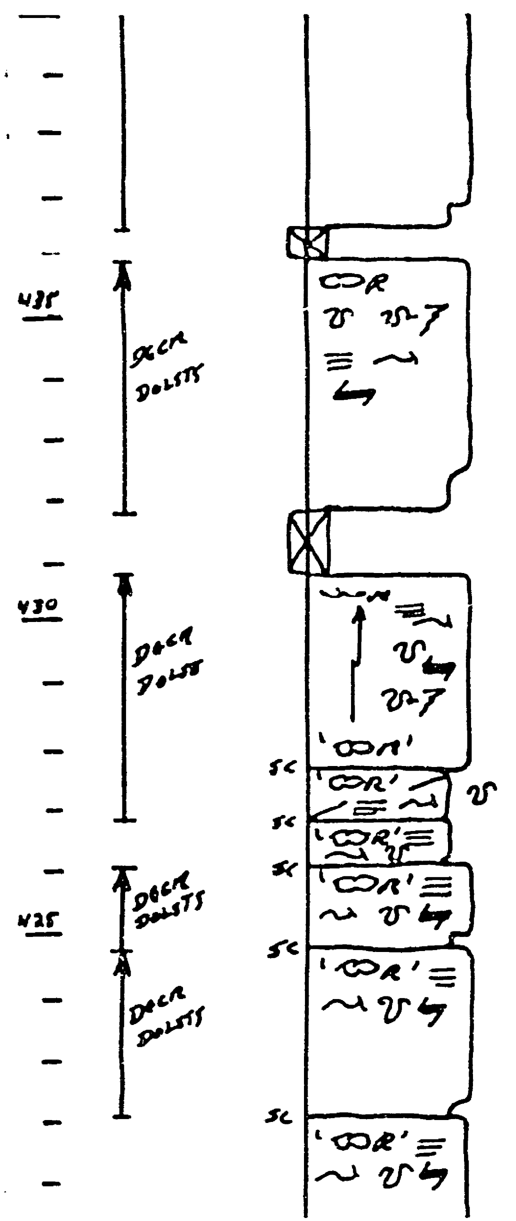
PURPLISH-GRAY, SILTY, MICACEOUS SH, mm-LAM'D W/ SOME DOLOMITIC CEMENT

COVER. POSSIBLE FAULT

MIXED LITHS LIKE 399m. LESS SS THAN 405m SS BDDS 3cm.

MIXED LITHS LIKE 399m W/ ADDITION OF PKST BEDS LIKE 403m, BDD ≤ 3cm.

GREEN-BRWN PKST, BDD ≤ 2cm, MICACEOUS. ⊙ ≤ ½mm ≤ ½ x 5cm




GRAY LS ARGN/STS ADD ≤1-7cm W/ OCCASIONAL LS PKST
ADD ≤1-3cm & ORNG DOLSTS ADD ≤1-2cm.
DOLSTS DECR UP FROM ~35-50% TO ~20%

BASAL 30cm W/REDDISH STS & GRAY LS STS
COVER.

GRAY LS ARGN/STS W/ORNG DOLSTS LIKE 429m. LS
ADD ≤1-4cm. DOL ADD ≤1-2cm, DOLSTS DECR UP ~40-50%
TO ~20-25%

BASAL 50cm OF REDDISH STS

COVER. PROBABLY LIKE 427m

GRAY LS ARGN/STS, ADD ≤1-5cm W/ ~20% ORNG DOLSTS
ADD ≤1-2cm

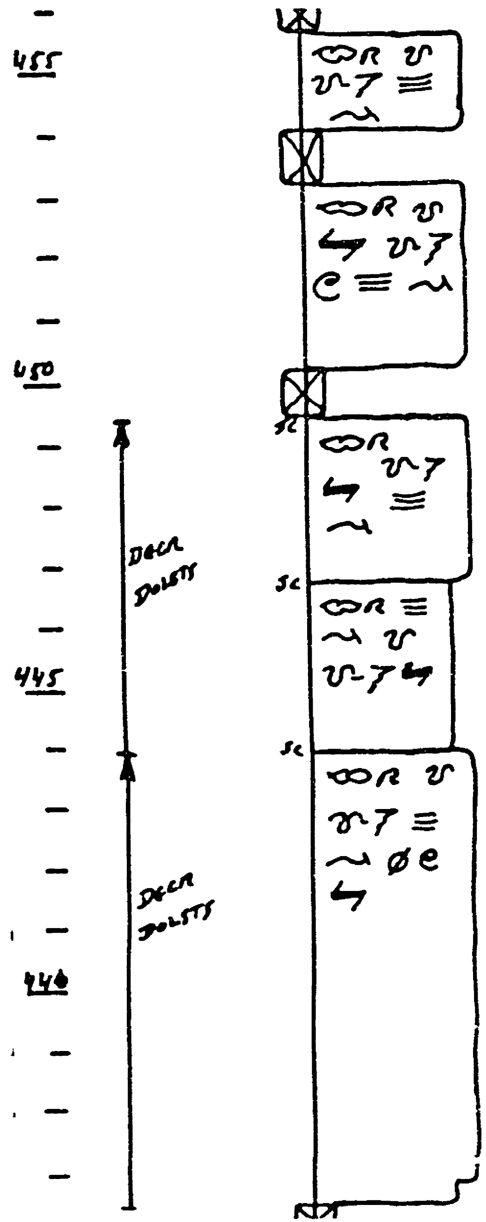
GRAY LS STS, ADD ≤1-4cm W ~35% REDDISH DOLSTS
ADD ≤1cm

GREEN LS STS ADD 1-2cm W/INTERBEDS OF DOLSTS,
ADD ≤½cm, ~20%

LITHS LIKE 424m, LS IS GRAY & ADD ≤2-4cm. STS
ADD ≤1cm. DOL DECR FROM ~90% UP TO ~20%

LITHS LIKE 421m. LS MED LT GRAY & ADD ≤1-5cm. DOL
ADD ≤1-2cm W/ A COUPLE OF BEDS 6-8cm THK. BASAL
PART ~95% DOL DECR UP TO ~40-50%.

LITHS LIKE 419m BUT MORE ʊ & LS IS MORE GRAY
THAN GREEN. BTM 7-12cm IS 100% DOLSTS W/LS
LOADED (ʊ) INTO IT.




LSTHS LIKE 448m. LS BDD ≤ 1-7cm DOL BDD ≤ 1-2cm, ~25%.

COVER

LSTHS LIKE 448m. LS BDD 1-4cm. DOL BDD ≤ 1-2cm, ~40%.

COVER

GRY LS ARGN/STS, BDD ≤ 1-3cm & ORNG DOLSTS, BDD ≤ 1cm. DOLSTS CONTINUES TO DECR UP FROM LWR UNIT TO ~10% AT TOP.

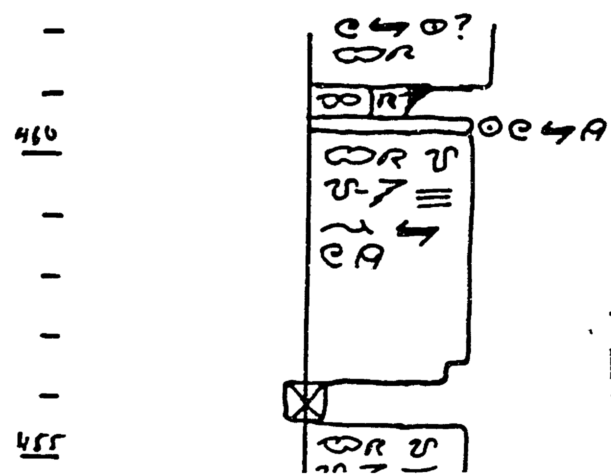
REDDISH & ORNG DOLSTS, BDD ≤ 1-2cm, W/ MED LT GRY LS STS BDD ≤ 1-3cm. DOLSTS DECR UP FROM ~50-60% TO ~10% AT TOP OF NEXT UNIT.

GRY LS ARGN/STS BDD ≤ 1-7cm W/ OCCASIONAL LS PEBB & BDD ≤ 1-3cm & ORNG DOLSTS BDD ≤ 1-2cm. DOLSTS DECR UP FROM ~35-50% TO ~20%

BASAL 30cm W/ REDDISH STS & GRY LS STS COVER.

SECTION 92-2

SO. RESTING SPG RANGE




DK GRY OOR W/ PK/GRST, LS ARGN/STS, GRST.

BONANZA KING FM

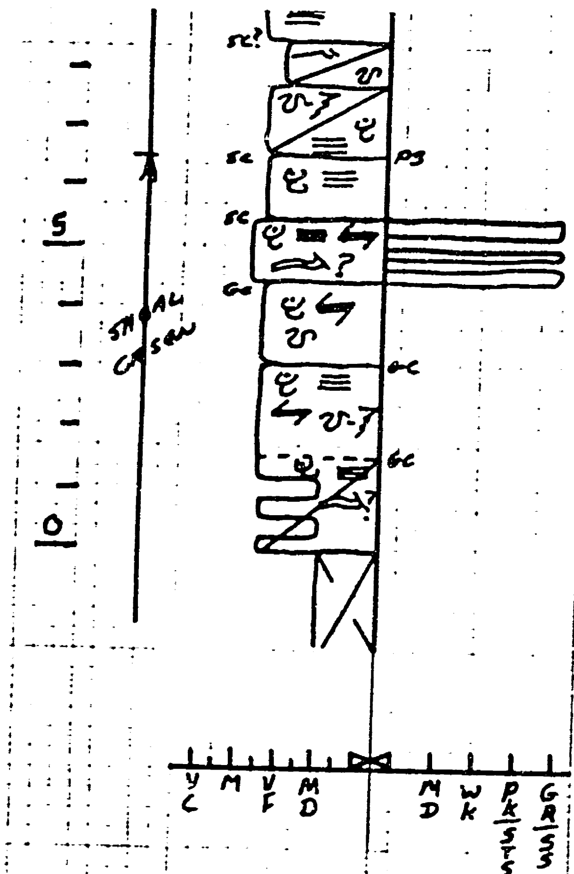
LS WKST — CARRARA FM

LS PK/GRST, BDD ~6 cm AT TOP & BTM, MDL BDDS 2cm. ⊙ ≤1mm. ≤1cm. ~40-50% INTERBDD DOLSTS

LITHS LIKE 448 m W/ PKST, BDD 1-7cm. LS. RED/ STS BDD 1-7cm. DOLSTS BDD ≤1-2cm. DOLSTS ~40-50% IN BTM 1½ m, DECR UP TO ~15% AT TOP

BASAL 30 cm OF REDDISH DOLSTS. COVER

LITHS LIKE 448 m. LS BDD <1-7cm ...




DIP: ' /

GREENISH SH & F SS

GREEN, MUDDY F SS, BDD ≤ 5 cm. MOSTLY ʊ-ʒ

DK GRY, ALMOST PURPLISH F QTZ SS, BDD 15-20 cm

3 INTERVALS OF F-M QTZ SS, BDD 5-15 cm. 3 W/ $CO_3$ (≤ 1x1 mm → 1x4 mm), BROWN & DOL'C, 20-35 cm THK. 2 OF CLEAN, GRAY SS, 15-25 cm THK. ɛ 15 cm, ≡ ≈ 5 cm

LS & 2.0 m. ɛ 5-10 cm. ≤ 1x6 mm

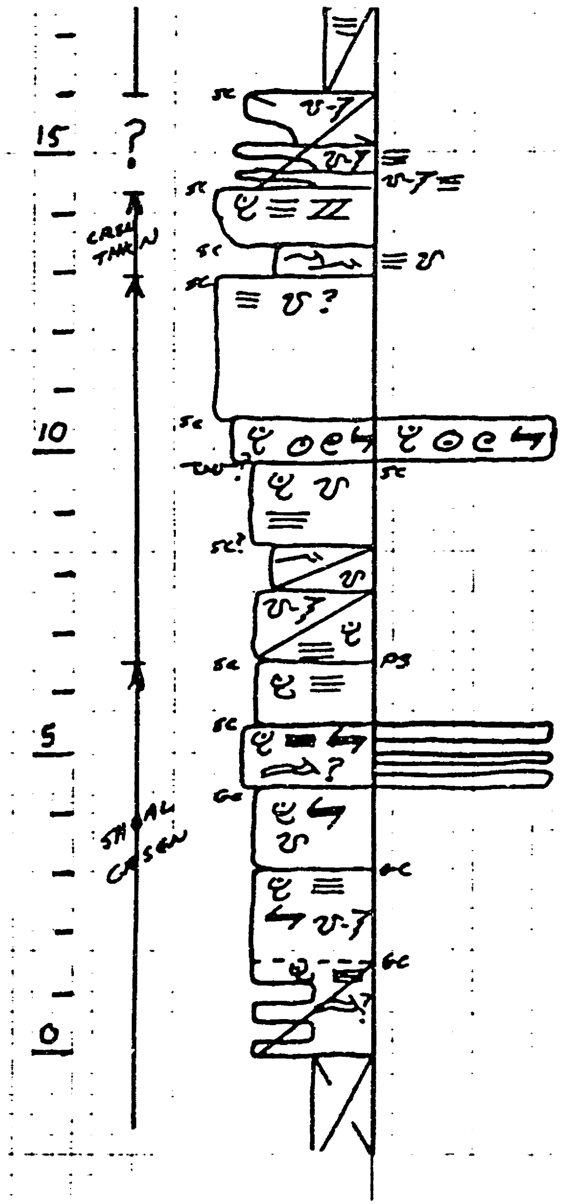
LT BROWN F SS, W/ THIN CLAY RIPUPS, BDD ~ 3-10 cm. RIPUP CLASTS < 10 x 1 mm.

LT GRY F SS IN 10-15 cm BEDS; GREEN, MICACEOUS SILTY SH & MIC. STS, BOTH IN BEDS ≤ 1-2 cm. SS W/ ɛ ≈ ?. SH & STS W/ ≡

GREEN, SILTY SH & STS

SECTION 92-3

LAS VEGAS RNG, NV




BROWN, SILTY SH TO MDST, BDD 1-3mm

YELLOWISH BROWN, MUDDY F-C SS W/ SILTY MDST & SOME SH. SS BDD ≤ 5-10cm; MDST & SH ≤ 1cm.

CREAM & TAN M-C, SOME VF SS, MOSTLY BDD ~5cm

BROWN & MAROON SILTY SH & VF, F SS, BDD ≤ 1-3cm

DK BRWN TO MAROON/BROWN C QTZ SS, BDD 5-15cm.

MIXED BROWN MED SS & ⊙(≤1mm) GRST, BDD ≤ 5-15cm. IRREG. ⊙ GRST LAYERS NEAR BASE. OF VF ⊙ PK/GRST.

GREEN & GREY F SS BDD ≤ 5-15cm. CLEAN UP & LESS UP.

GREENISH SH & F SS

GREEN, MUDDY F SS, BDD ≤ 5cm. MOSTLY

DK GRY, ALMOST PURPLISH F QTZ SS, BDD 15-20cm

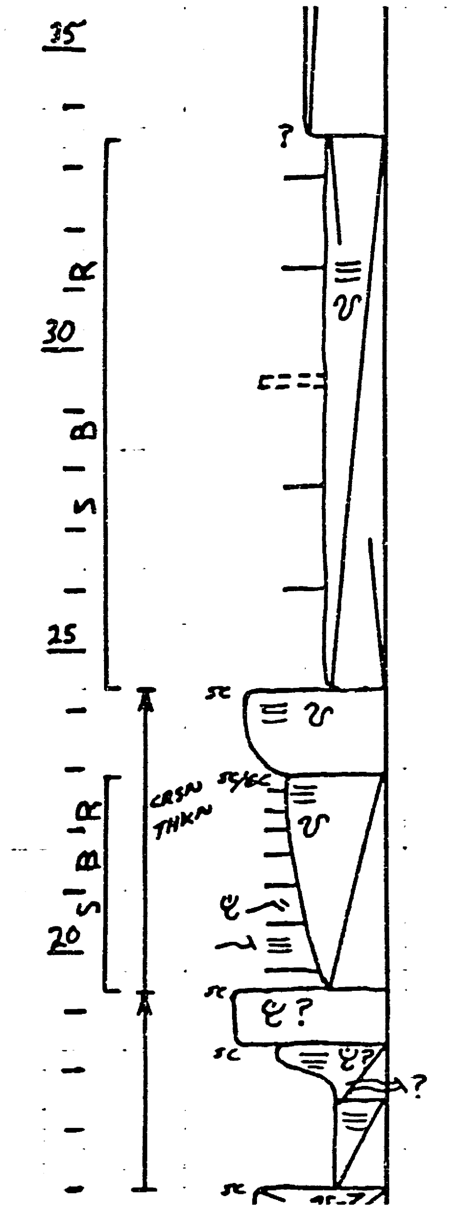
3 INTERVALS OF F-M QTZ SS, BDD 5-15cm. 3 W/ $CO_3$ (≤ 1x1mm → 1x4mm), BROWN & DOL'C, 20-35cm THK. 2 OF CLEAN, GRAY SS, 15-25cm THK. 15cm, 5cm

LSG 7.0m.. 5-10cm. ≤ 1x5mm

LT BROWN F SS, W/ THIN CLAY RIPUPS, BDD ~ 3-10cm. RIPUP CLASTS ≤10 x 1mm.

LT GRAY F SS IN 10-15cm BEDS; GREEN, MICACEOUS SILTY SH & MED. STS, BOTH IN BEDS ≤ 1-2cm. SS W/ ? SH & STS W/

GREEN, SILTY SH & STS




CARRARA
ZABRISKIE

BROWN & GREEN, MICACEOUS SILTY SH & MDST W/ OCCASIONAL MED. OR FINER SS BEDS ≤10 cm, MOSTLY ≤2-3 cm. ONE SS BED ~20 cm THK IN MIDDLE OF INTERVAL

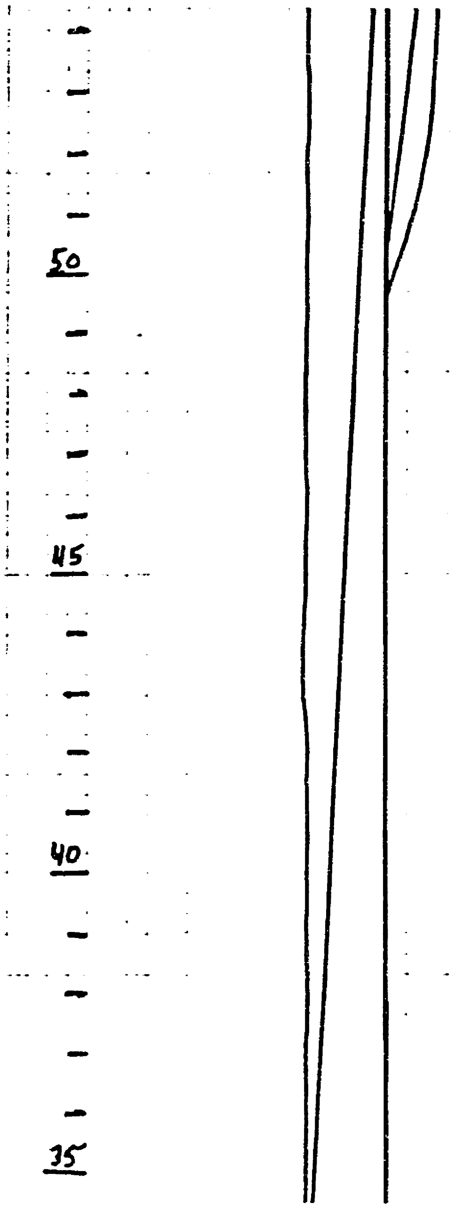
BROWN F UP TO M SS (3→20+ cm THK) W/INTERBDD MDST/STS

BROWN, MIC. SILTY MDST (≤1-2 mm LAMS) W/ OCCASIONAL VF→M SS INTERBEDS (≤1-10 cm THK)

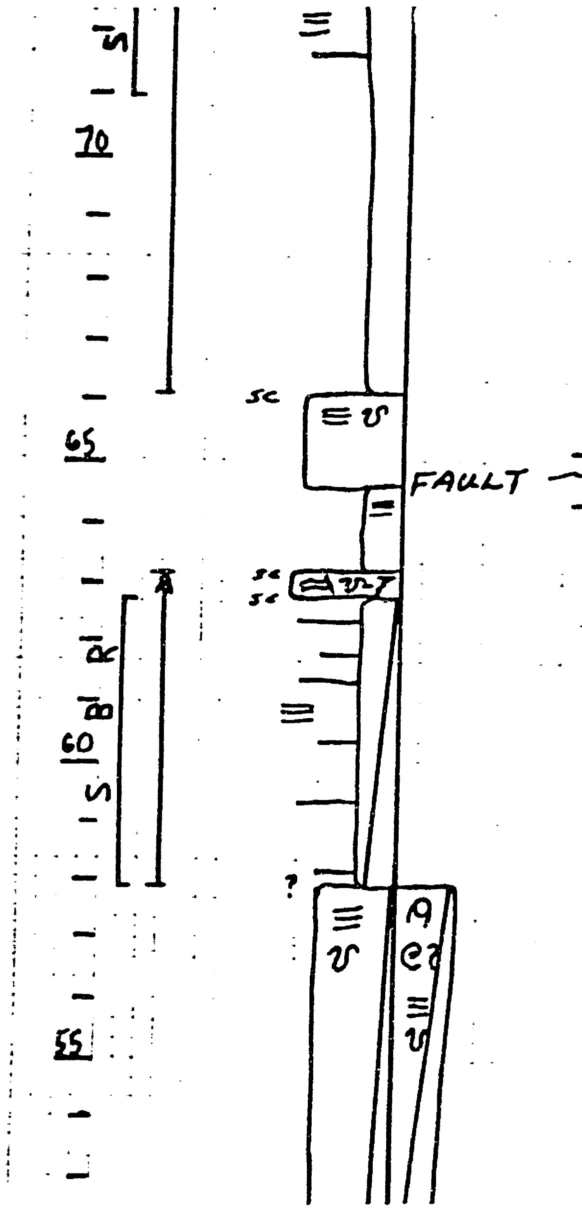
BROWN-MAROON M-C SS. POSSIBLY CHANNEL-FILL

BROWN, MICACEOUS, MUDDY VF-F SS (3-10 cm) & SILTY MICACEOUS MDST (≤1 cm)

BROWN, SILTY SH TO MDST, BDD 1-3 mm




YELLOWISH-TAN TO YELLOWISH-GREEN SILICEOUS
MDST TO STS, MOSTLY BDD ≤2-3cm W/A FEW 5-10cm BEDS.
CALCAREOUS. IN UPPR 1/3, IT IS V. CALCAREOUS W/
CARBONATE MDST BEDS, BEDD AS IS SIL. BEDS.
NO #, ∧, ⊕ SEEN.




W/ VF SS INTERBEDS (≤ 2-3cm) IN UPPR ½. NO #, ∧ RECOGNIZED. VFEW ϑ IN LWR ½.

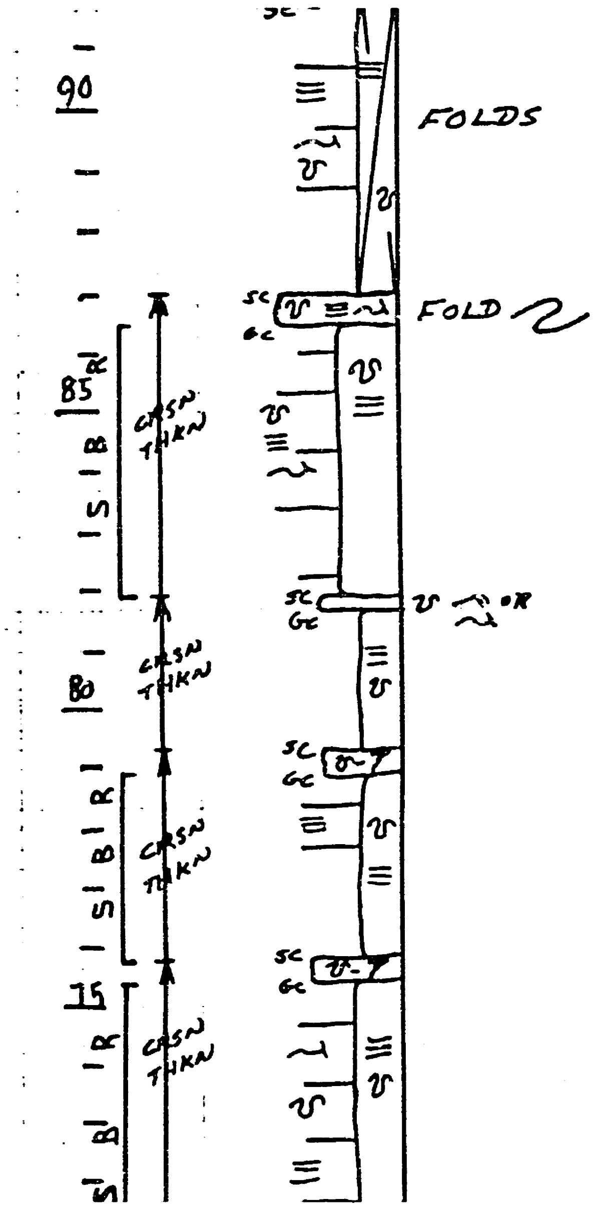
GREEN, SILTY MDST/MUDDY STS (BDD ≤1-3cm) & CREAM, VF, F SS (BDD 3-5 cm)

FAULT → 30° DISCORDANCE ACROSS SURFACE. SUB// FAULT. UNKNOWN AMT OF SECTION LOST

MAROON, SLIGHTLY SILTY, CHLORITIC SH, LAMINATED ≤ 1-2mm

GREEN & BROWN VF & F SS, POSSIBLY SOMEWHAT MUDDY. BDD ≤5-7cm. ≃7cm

MAROON-BROWN SILTY, CHLRITIC SH W/ INTERBDD STS TO VF SS, BDD ≤ 1-3cm. NO # or ϑ RECOGNIZED.




MOSTLY COVERED. 2 PATCHES OF INTERBDD MAROON, CHLRTC SLTY SH & VF-F MUDDY SS. SH LAMD ≤1-3mm. SS BDD ≤ 5 cm.

BROWN SS & MDST. SS BDD ≤ 1-8 cm; MDST ≤ 1-3mm

MAROON, CHLRTC, SLTY MDST & SH (BDD ≤ 1-3mm) W/VF, F SS INTERBEDS (≤ 1-8 cm)

VF, MUDDY SS, BDD ≤ 5 cm

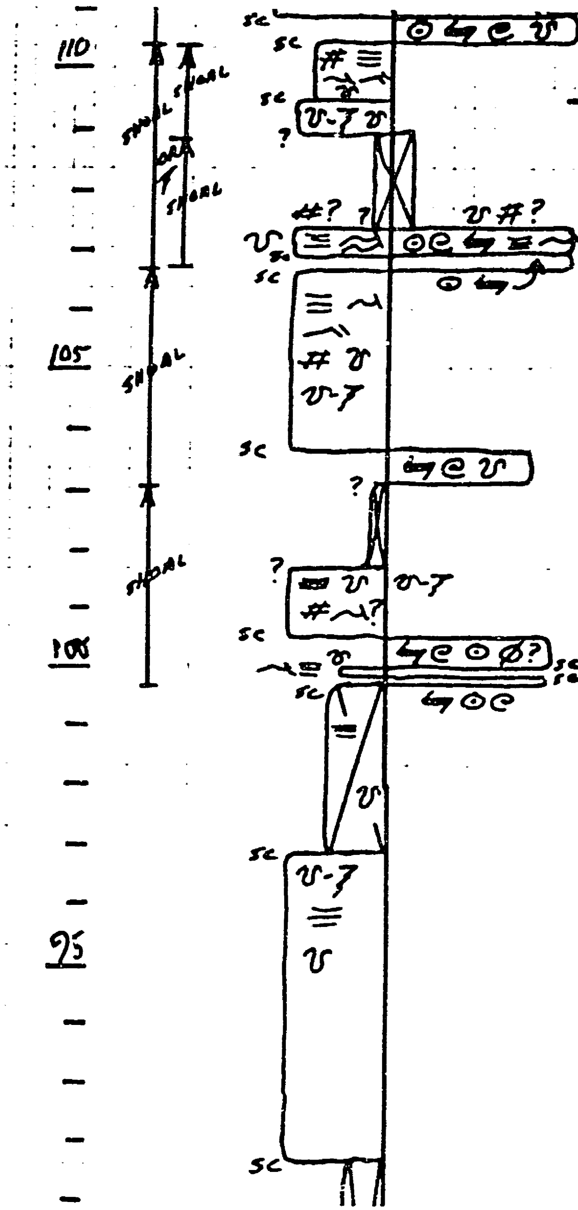
MAROON, CHLRTC, SLTY MDST, mm-LAMD

MAROON, SILTY, SANDY MDST (≤ 1-2 cm BDD)

MAROON, CHLORITIC, SLIGHTLY SILTY SH (mm-LAMD) W/ A FEW VF SS BEDS (≤ 1-2 cm BDD)

GREEN, MUDDY, VF SS, BDD ≤ 5cm. SMALL FOLDS IN UNIT

MAROON, CHLORITIC, SLIGHTLY SILTY SH (mm LAMD) W/ VF SS INTERBDS (≤ 2-3 cm) IN UPPR ½.




A FEW Ø IN UPPER PART.

KH GREEN & TAN MDST TO VF SS, BDD ≤ 1-3cm. GOOD #, ESP. IN TOP 40 cm

BROWN & TAN VF SS BDD ≤ 1-2cm. V-7 IN TOP 20 cm

COVER

MXT STS/VF SS & Ø (≤ ½ mm) GRST & LS AREN/STS. ALL BDD ≤ 1-3cm

GRY ⊙ (½ mm) (≤ 3×8 cm) GRST, BDD ≤ 10 cm W/ BRWN DOLSTS INTERLAMS ≤ 1 cm

KH. GREEN & TAN SILTY MDST, STS & VFSS; ALL BDD ≤ 1-4 cm
V. FEW #. SEVERAL HORIZONS ARE V-7

GRY @ PKST BDD ≤ 1-3cm W/ INTERBEDS OF KH. GREEN & TAN MDST TO VF SS BDD 1-3 cm. ALSO SOME DOLSTS INTERBEDS.

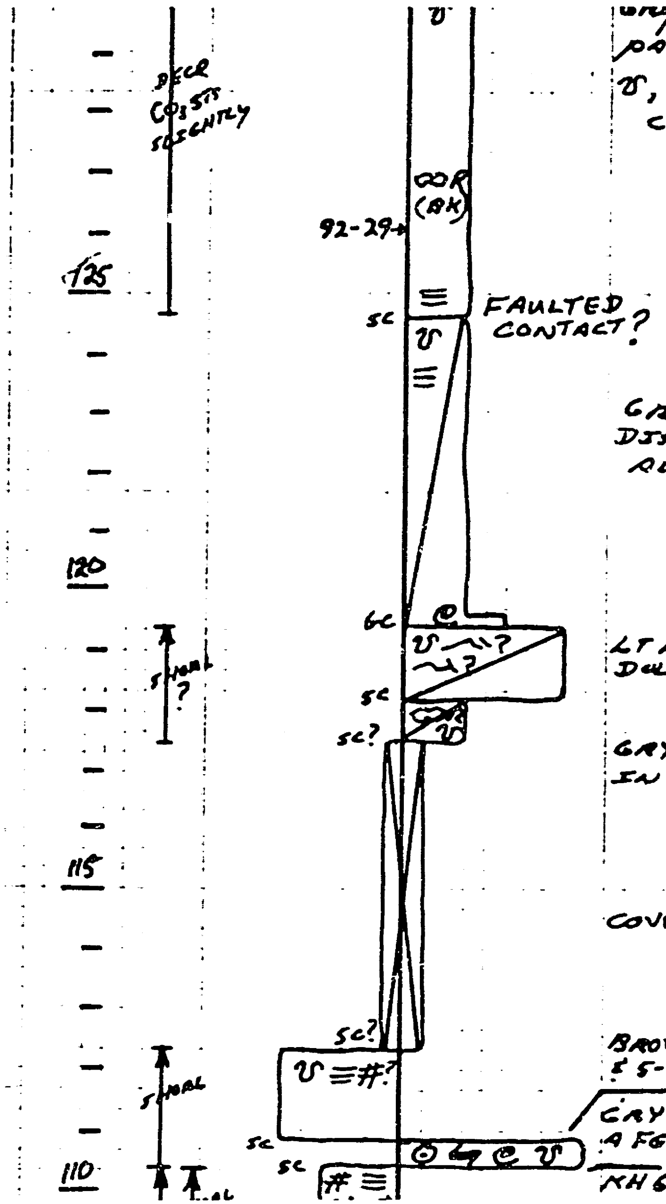
LIKE UNIT IMMED. BELOW.

KHAKI-GREEN MUDDY VF SS, STS & SLTY MDST. ALL BDD ≤ 1-3cm
V & # SPARSE. TOP 10-15 cm SS V-7

2 GRY & BRWN PK/GRST, UPR BDD ≤ 10-15 cm, LWR BDD 5 cm. 20 cm THK GREEN, CHLRTC SLTY SH/MDST BETWEEN, BDD ≤ 1 cm, MOSTLY LAM'D ≤ 1-2 mm. ⊙ ½ mm, ≤ ½×5 cm, Ø? ≤ 1 cm. @ MAY BE ECHINOID FRAGMENTS.

YELLOWISH GREEN, CHLRTC, SLTY MDST, BDD ≤ 1 cm

GREENISH GRAY, TAN, LT BROWN VF SS, BDD ≤ 1-3 cm W/ SOME SH INTERLAMS. NO # SEEN. TOP 10-20 cm SS V-7. MOST OF UNIT IS SPARSELY V.




[illegible] LS MDST W/ ~10-15% CO3 STS IN U [illegible] IRREG
PARTINGS. SLIGHT ↑ DECR IN % STS. SOME SPAR-FILLED
U, ESPECIALLY IN LWR ½. ≡ IN BTM 40 cm
CO3 STS DECR FROM ~10-15% ↑ ≤ 10%

GRAY LS MDST W/ ~25% ORNG DOLSTS IN U & IRREG,
DISCONT PARTINGS. BASAL ~20 cm IS A @ WKST.
ALL LS BDD ≤ 3-4 cm.

LT BROWN LS/DOL STS & AREN, BDDS 1-3 cm. ~60%
DOLSTS

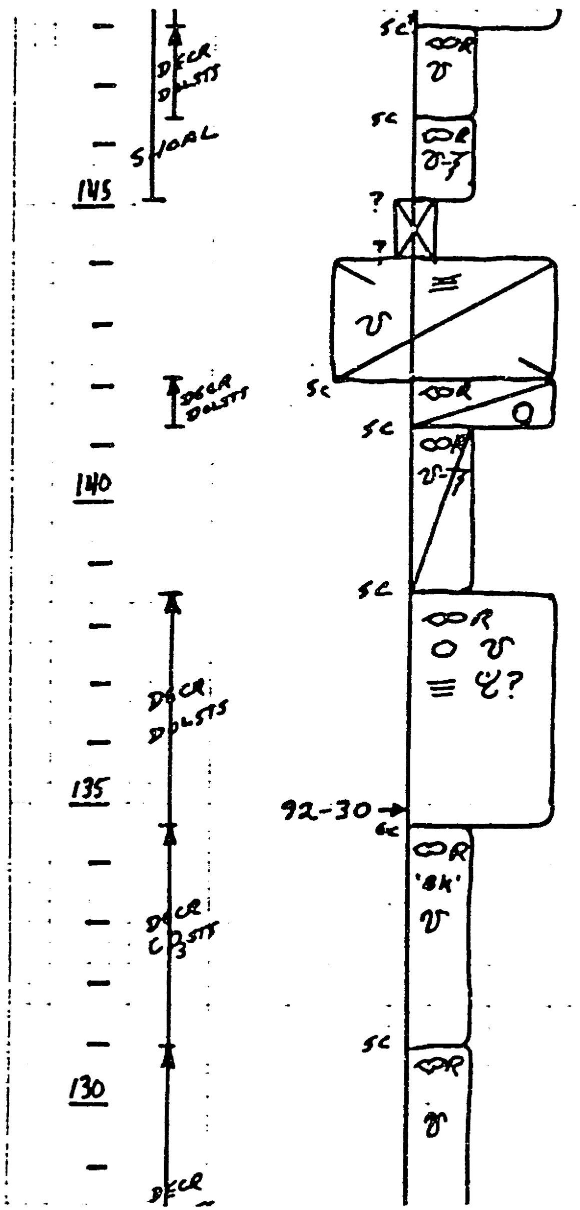
GRAY LS MDST (≤ 1-3 cm BDD) W/ORNG DOLSTS (BDD ≤ 1 cm)
IN U & DISCONT. INTERLAMS (~25%)

COVER

BROWN VF & F SS W/SOME CO3-CMTD BEDS. ALL BEDD ≤ 1-3 cm
& 5-10 cm. THINNER BEDS W/ # & CO3 CMT

GRAY ⊙(½-1 mm) GRST, BDD 7-10 cm. [illegible] (≤ 2×8 cm) IN BTM 10 cm.
A FEW U IN UPPER PART

KH GREEN & TAN MDST TO VF SS, BDD ≤ 1-3 cm. GOOD # BED




GRY LS MDST. W/~50% ORNG DOLSTS, BOTH BDD ≤ 1-3cm. SLIGHT DECR UP IN DOLSTS, ~60% ↑ 40%

GRY LS MDST W/~45% ORNG DOLSTS. BOTH BDD ≤ 1-2cm

COVER

TAN, CALCAREOUS STS. MAY BE DOLOMITIC. DEFINITE QTZ GRAINS. BDD ≤ 1-2 cm

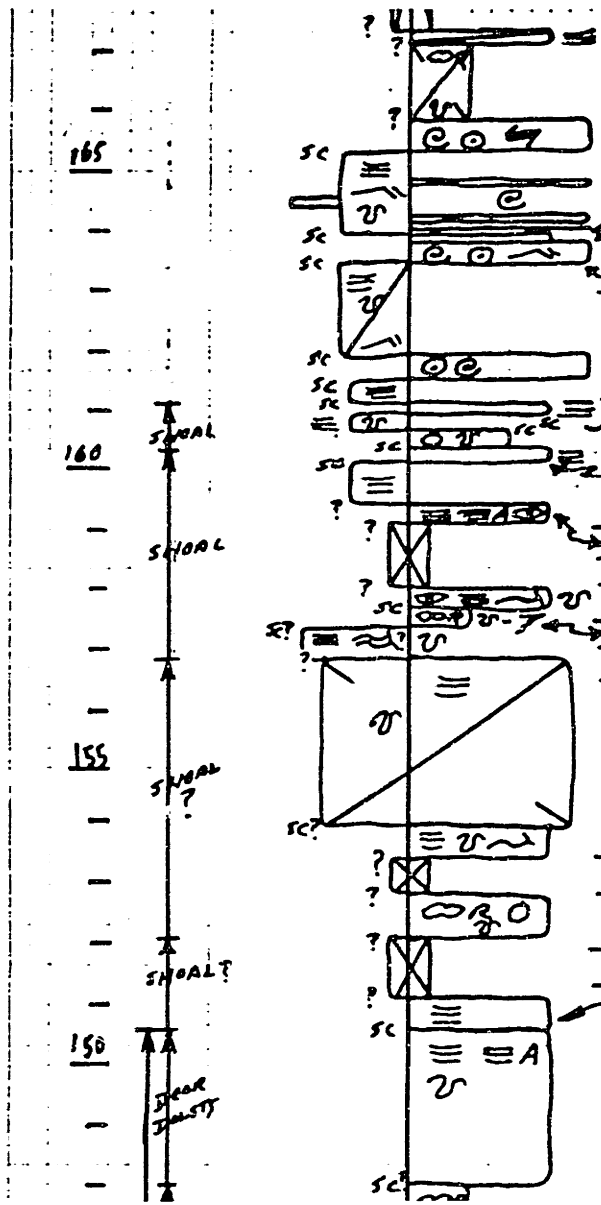
GRY & PKST O ≤ ¼mm. BOTH BDD ≤ 1-3cm. DOLSTS DECR. ORNG DOLSTS 80% up to 20%

GRY LS MDST (BDD ≤ 1-2cm) W/~25-35% ORNG DOLSTS (BDD ≤ 5mm)

GRY LS O(≤ ¼mm) PKST W/ ≤ 5-7% GREEN & TAN DOLSTS IN ʊ & INTERLAMS ≤ 5mm. PKST BDD ≤ 1-10cm W/ ? ≤ 20cm NEAR TOP OF UNIT. DOLSTS DECR ↑.

GRY LS MDST (BDD ≤ 1-4cm) W/ < 10% GREEN $CO_3$ STS IN ʊ's INTERBEDS ≤ 1cm. A FEW SPAR-ʊ. PROBABLY SOME O PKST INTERBEDS AS WELL. $CO_3$ STS DECR ↑ ~15-20% ↑ ≤ 5%

GRY LS MDST W/ ~10-15% $CO_3$ STS IN ʊ's 1-2mm, IRREG PARTINGS. SLIGHT ↑ DECR IN % STS. SOME SPAR-FILLED ʊ [illegible]




BROWN $CO_3$ STS, BDD ≤ 5mm. NOT ♉

GRY & ORNG MARLY LS/DOL. ALMOST ENTIRELY COVERED

CREAM ECHQ GRST, BDD 5-10cm. ⊙ ~ ½-1mm. ≤ ½ x 1cm

GREEN, CLUD, CHRTC, MIC, SILTY MDST w/ AT LEAST 3 GRST INTERBEDS (2-8 cm) w/ ⊙ & FAREN. 18 cm SIBED.

GREEN PKST, SN 10 cm BED. ≤ ½ x 1cm

CREAM GRST. BDD 5-15cm. ⊙ ~ ½ mm. @ ECH.

KH-BROWN, CLEAVED, CHLRTC, MIC, SILTY MDST & STS, BDD ≤ 1cm

CREAM LS GRST. ⊙ ¼-1mm. @ ECHINOID FRAGMENTS. BDD ≤ 10 cm

GREEN, CHLRTC, MIC., SLTY MDST. BDD ≤ 5mm

PINK, CHLORITIC MDST TOPPED w/ 10 cm OF $CO_3$ STS, BOTH BDD ≤ 5 mm

GRY LS ⊙ (~1mm) WKST, BDD 2-5cm

ORNG DOLSTS, BDD ≤ 1cm

ORNG & PINK CALCAREOUS MDST, ≤ 1cm

ORNG DOLSTS, BDD ≤ 1cm

COVER

BROWN DOLSTS, BDD ≤ 1-3cm

GRY LS MDST w/ ~35% ORNG DOLSTS, DISRUPTED BDD ≤ 1cm

BROWN VF-F SS, BDD 2-5cm

MIX OF TAN $CO_3$ STS/VF AREN w/ GREEN & TAN SILTY MICACEOUS MDST, STS & VF S. ALL BDD ≤ 1-3cm

GRY LS STS w/ ~60% ORNG DOLSTS. BOTH BDD ≤ 1-2cm. DOLSTS DECR UPWARD SLIGHTLY.

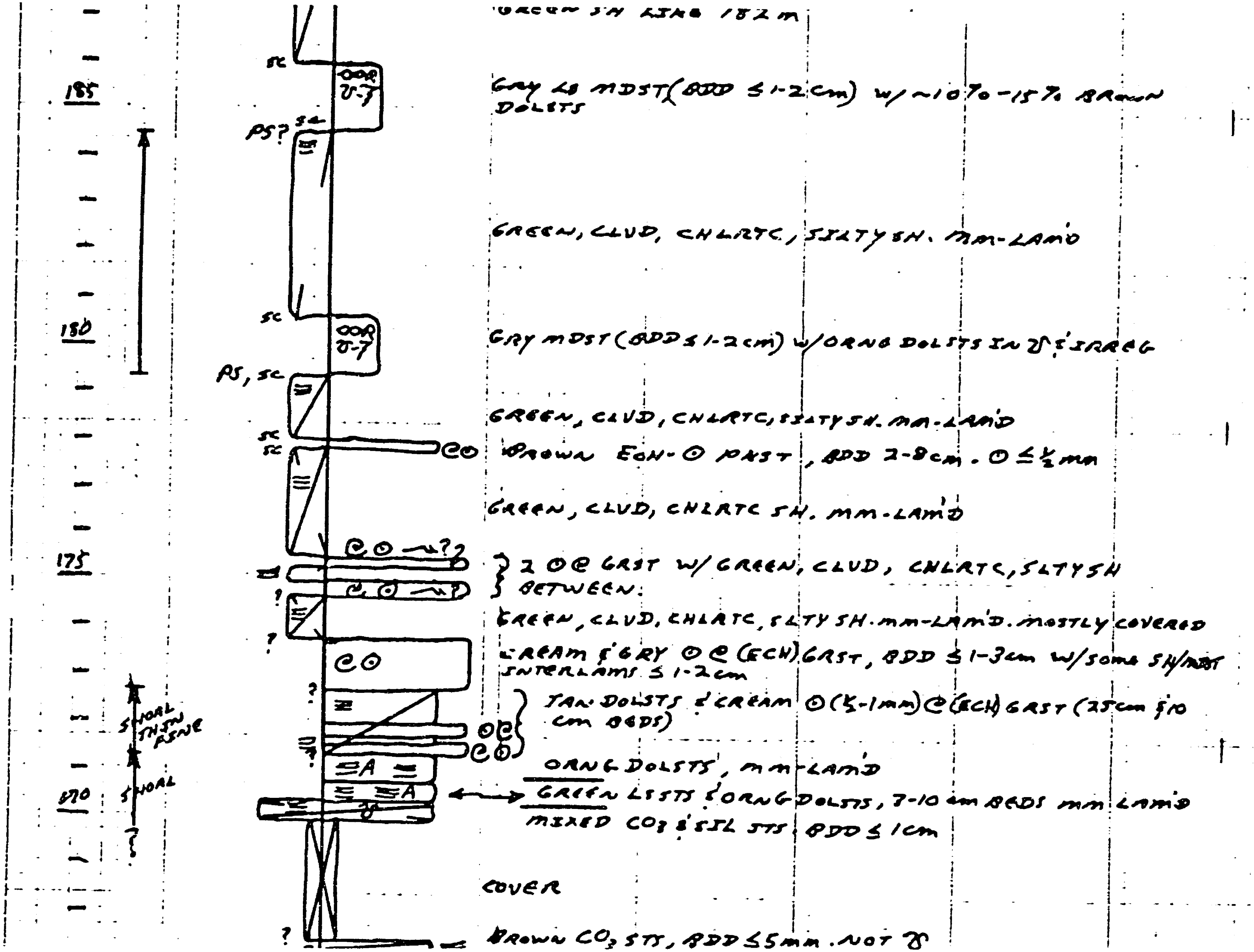
COVER

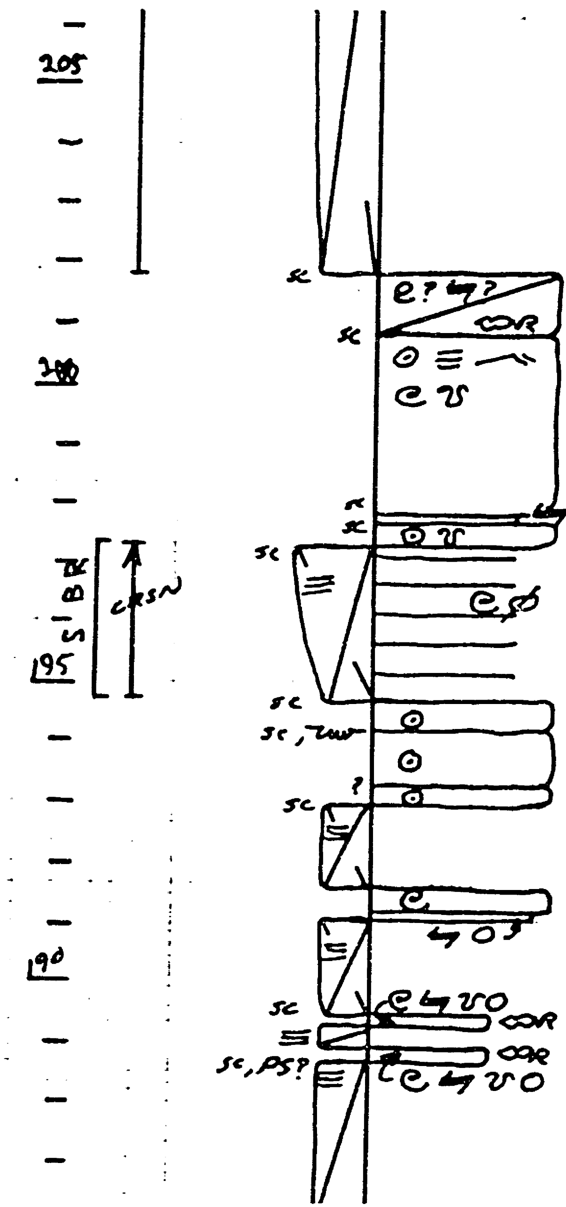
GRY LS ⊙ (≤ ½mm) PKST (BDD ≤ 1-2 cm) w/ ~25-30% ORNG DOLSTS IN ♉ & IRREG INTERLAMS (≤ 1cm).

COVER

GRY LS STS w/ SOME DOLSTS. MM-LAM'D

MOSTLY ORNG DOLSTS w/ A LITTLE QTZ GRAINS. MORE GRY & TAN LS IN UPPR ½. ALL BDD ≤ 1cm. DECR DOLSTS & ≡A UPSCTN.


GREEN SH RISE 182 m
GRY LS MDST (BDD ≤ 1-2 cm) w/ ~10%-15% BROWN DOLSTS
GREEN, CLVD, CHLRTC, SILTY SH. mm-LAM'D
GRY MDST (BDDS 1-2 cm) w/ ORNG DOLSTS IN ∇ & IRREG
GREEN, CLVD, CHLRTC, SILTY SH. mm-LAM'D
BROWN EON-O PKST, BDD 2-8 cm. O ≤ ½ mm
GREEN, CLVD, CHLRTC SH. mm-LAM'D
2 O@ GRST w/ GREEN, CLVD, CHLRTC, SLTY SH BETWEEN.
GREEN, CLVD, CHLRTC, SLTY SH. mm-LAM'D. MOSTLY COVERED
CREAM & GRY O@ (ECH) GRST, BDD ≤ 1-3 cm w/ SOME SH/MDST INTERLAMS ≤ 1-2 cm
TAN DOLSTS & CREAM O (½-1 mm) @ (ECH) GRST (25 cm & 10 cm BEDS)
ORNG DOLSTS, mm-LAM'D
GREEN LSSTS & ORNG DOLSTS, 7-10 cm BEDS mm LAM'D
MIXED CO3 & SIL STS, BDD ≤ 1 cm
COVER
BROWN CO3 STS, BDD ≤ 5 mm. NOT ∇
185
180
175
170
SHOAL
THSN FSNE
SHOAL
sc
PS? sc
PS, sc
sc sc




LT BROWNISH GRY SILTY MDST CRSNING UP TO MUDDY ST. BOTH CHLRTC, MIC, BDD ≤ 1 cm.

GRAY, COARSE GRST (BDD 2-4 cm?). GRAINS 1+ mm IN SIZE. SOME INTERLAMD ORNG DOLSTS, FORMING A ...R-LIKE TEXTURE. GRAINS EITHER SMALL ECH FRAGS. OR ...

BROWN & GRY ⊙ (≤ ½ mm) GRST, BDD ≤ 1-3 cm

10 cm BED OF ORNG DOLST W/ ... ≤ 3×10 cm - POSSIBLY DISCONT.

BROWN ⊙ (≤ ⅓ mm) GRST, BDD ~10 cm W/ INTERBEDS OF ORNG DOLSTS (≤ 2 cm) & ...

BACKGROUND SS BROWNISH-GREEN MDST CRSNING UP TO PINK-ORNG STS, BOTH CHLRTC & MIC, BDD ≤ 1-2 cm & CLVD. INTERBEDS OF LS ARGN, STS & @ Ø PKST, BDD ≤ 1-5 cm. Ø ≤ 1½ cm

GRAY & TAN ⊙ GRST. BTM UNIT BDD IN 10 or 2 BEDS, ⊙ ≤ ¼ mm. MDL UNIT BDD 2-7 cm, ⊙ ≤ ¼ mm. TOP UNIT BDD 2-5 cm, ⊙ ½-¾ mm

SH. LIKE 182 m

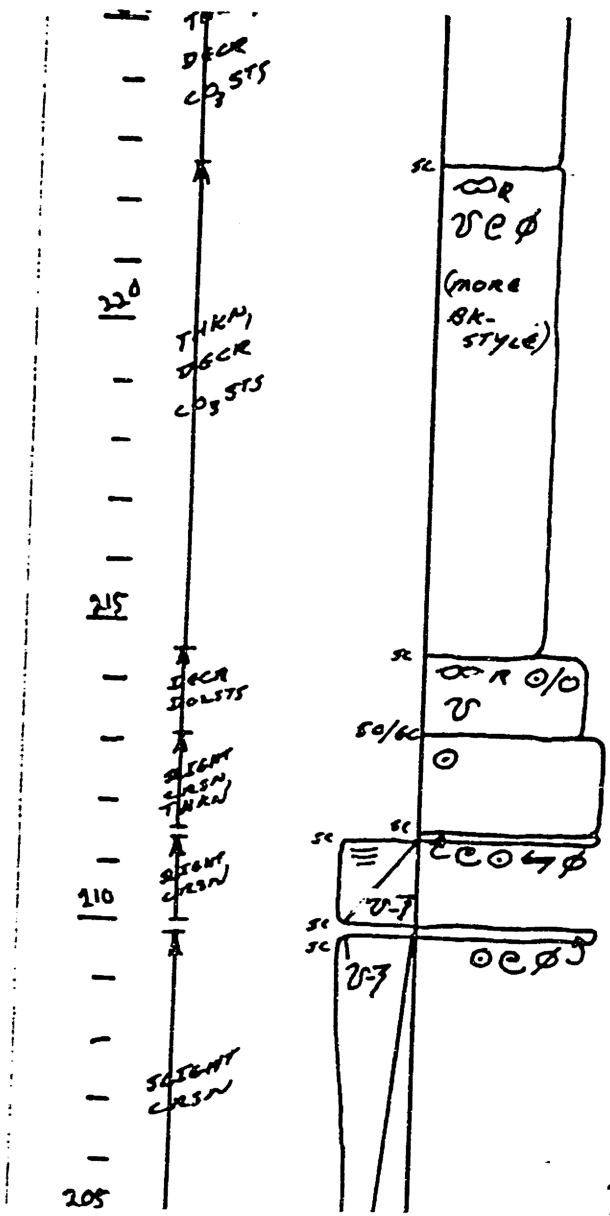
LT BROWN @ (ECH, OTHER) GRST

LT BROWN ... ⊙ PK/GRST. ⊙ ≤ ¼-½ mm. ... ≤ ½×5 cm. @ INCL. ECH. FRAGMENTS & OTHERS.

SH LIKE 182 m

2 GRAY & BROWNISH-GRAY WK/PKST, BDD ≤ 1-5 cm W/ 5-10% & ~20% DOLSTS, SEPARATED BY GREEN SH LIKE 182 m

GREEN SH LIKE 182 m




LIKE 220M, BUT ADD ≤1-2cm UP TO ≤1-3cm & STS DECR UP ~20% TO ~5%

MED DKGRY LS WK-PKST W/ OCCAS'L GRST & KH-GREEN & KH-BROWN LT STS. ADD ≤1-2cm & THKNS UP TO ≤1-4cm. SOME SPAR-FILLED V. LIKE BK-STYLE R, BUT MORE PK & GRST, LESS MD & WKST THAN NORMAL, STS DECR UP FROM ~40% TO ~10%. STS IN V & IRREG INTERLAMS

GRY PK & GRST W/ BRWN DOLSTS, ADD ≤1-3cm. O/O ≤¼-½mm. ~10% DOLSTS; DECR UP ~15% TO ~5%

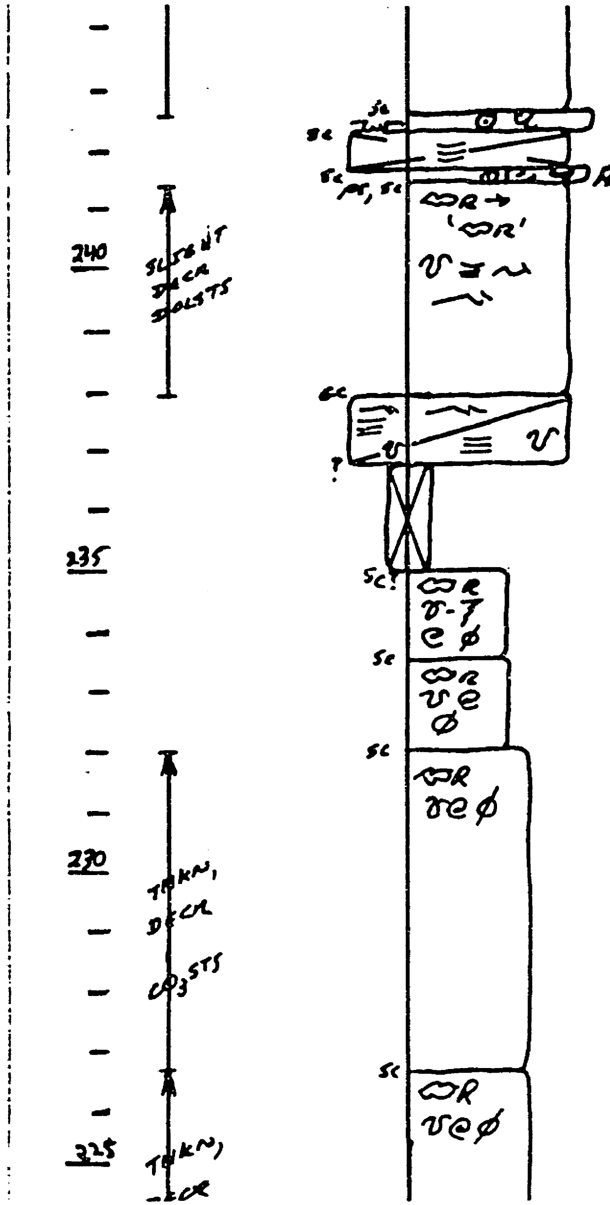
BRWN & GRY ⊙ (¼-½mm) GRST, ADD ≤1-3cm. UPPR CNTC GC OVER ~15cm.

GRY GRST W/ ⊙(≤½mm), (≤½x2cm), Ø(≤1cm), BED AS A 15cm BED

LT BRWN STS & VF SS, BOTH MUDDY, MIC, ADD ≤1-2cm?

GRST W/ ⊙(¼-½mm), Ø ≤½cm. BEDD AS ONE BED OR AS SEVERAL ≤1-2cm

LT BROWNISH GRY SILTY MDST CRSNING UP TO MUDDY ST.




BROWN ⊙ (½–¼ mm) GAST, BDD 5-10 cm w/ REMNANT INTERBEDS OF GRY LS VF AREN/STS

MXT BEDS LIKE 237 m, BDD ≤ 2 cm.

BROWN ⊙ (¼-1 mm) GAST, BDD 5-10 cm. @ A (≤ ½ x 2 cm) IN BTM BED.

GRY LS VF AREN & STS, BDD ≤ 1-3 cm w/ ~35% ORNG DOLSTS IN ℧ & CONT. INTERLAMS ≤ 1 cm. SLIGHT UP-DECR IN DOLSTS

MXT REDDISH BRWN CHERTC, SLTY MDST & GREEN LS STS/VF AREN, ALL BDD ≤ 1 cm. MDST CLUD w/ NO # RECOGNIZED

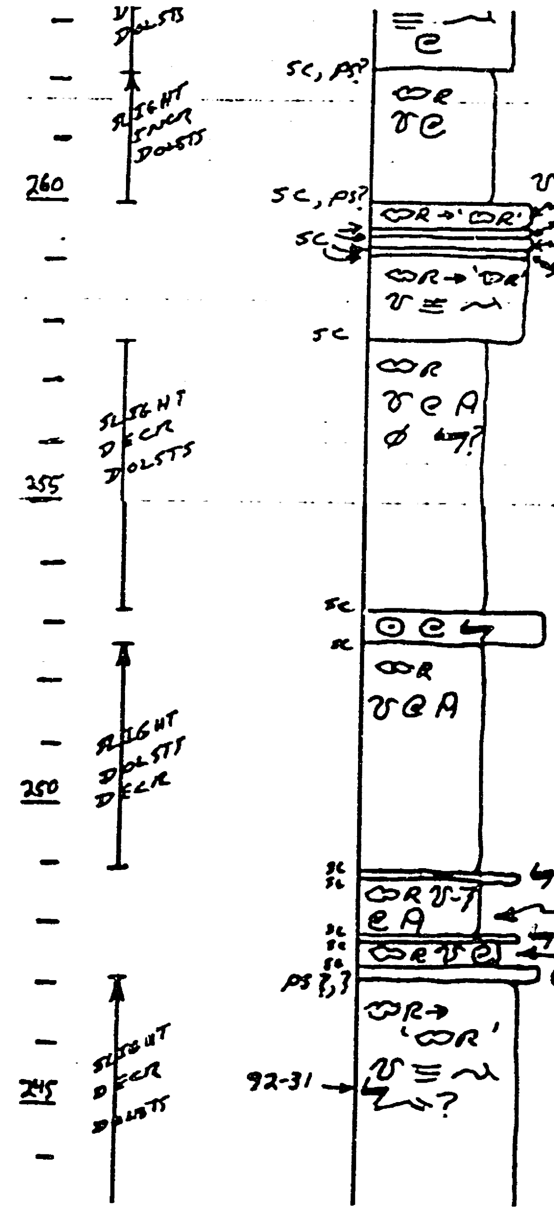
COVER

LIKE 233 m, BDD ≤ 1-2 cm

LIKE 220 m, BUT MOSTLY WAST. MORE ℧ & MORE SPAR-℧, BEDD ≤ 1-3 cm THRU-OUT w/ ~15% STS

LIKE 220 m, BUT BDD ≤ 1-2 cm UP TO ≤ 1-5 cm & STS DECR UP ~25% TO ~15%

LIKE 220 m, BUT BDD ≤ 1-2 cm UP TO ≤ 1-3 cm &




MXT GRY LS AREN/STS & WKST & PKST, ALL BDD = 1-3 cm W/ ORNG DOLSTS IN ℧ & INTERLAMS ≤ 1 cm. DOLSTS DECR UP ~35% TO ~15%

GRY LS WKST & PKST, BDD ≤ 1-3 cm W/ ~15% DOLSTS (ORNG) IN ℧ & INTERLAMS ≤ 1 cm. DOLSTS INCR UP ~10% TO ~20%.

(2 INTERVALS OF AREN/STS, BDD ≤ 1-4 cm W/ ~10-15% ORNG DOLSTS & 2 INTERVALS OF PK/GRST W/ ≤ 1X5 cm, BDD AS 10 cm BEDS

LS AREN/STS, BDD ≤ 2-5 cm W/ ~20% ORNG DOLSTS IN ℧ & INTERLAMS ≤ 1-2 cm

GRAY WKST & PKST, BDD ≤ 1-5 cm W/ ~18% ORNG DOLSTS IN ℧ & DISCONT INTERLAMS ≤ 1 cm. Ø ≤ ½ cm. ≤ ½ cm.

BROWN & GREY STRIPED ⊙ (3/4-1 mm) GRST, BDD 2-4 cm W/ ≤ ½ x 1 cm.

GRY LS WKST & PKST, POSSIBLY SOM VF AREN/STS BDD ≤ 1-4 cm W/ ~25% ORNG DOLSTS; BDD ≤ ½-1 cm.

~10 cm BED PK/GRST W/ ⊙ (½ mm), ≤ (½ x 3 cm) & SHELTER POROSITY

GRY WK/PKST, BDD ≤ 1-4 cm

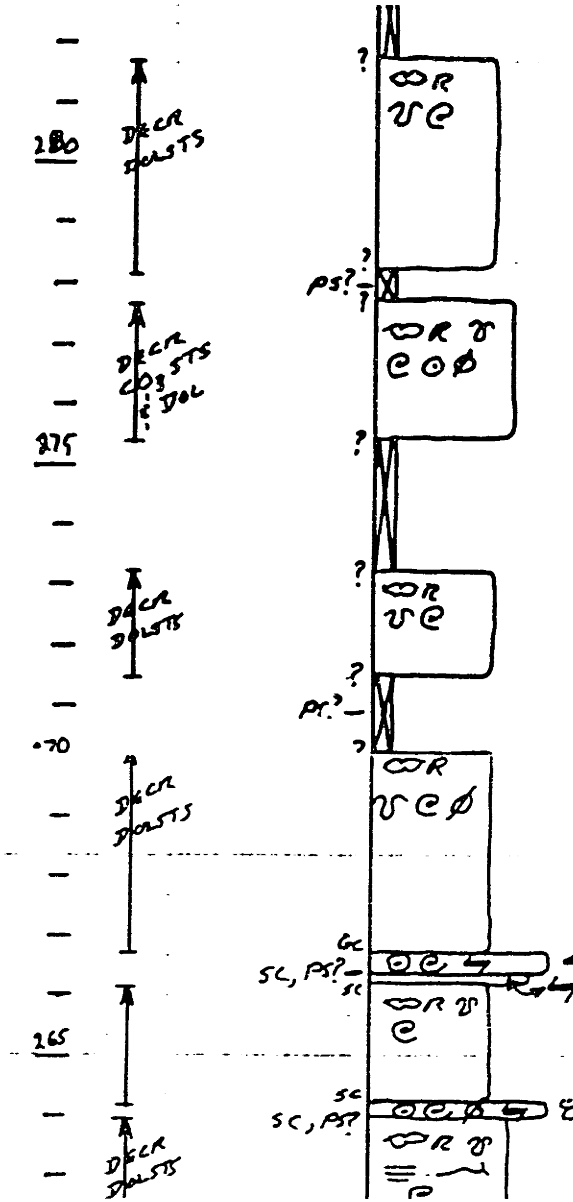
10 cm BED PK/GRST W/ ⊙ (½-1 mm), (≤ 1 x 5 cm) & SHELTER POROSITY

PINK/ORNG DOLST W/ ~40% GRY LS AREN/STS + WKST + PKST
ALL BDD ≤ 1 cm

20 cm BED OF ⊙ (½ mm) GRST, W/ (≤ ½ x 7 cm)

GRY LS VF AREN/STS BDD ≤ 1-4 cm W/ ~20% ORNG-BRWN DOLSTS BDD ≤ 1 cm. ONE 2-5 cm THK (≤ ½ x 2 cm) PK/GRST W/ SHELTER POROSITY (SPL 92-31)

TARRARA




GRY WKST & PKST, BDD ≤ 1-3cm W/ ORNG-BROWN DOLSTS IN ʊ & INTERLAMS ≤1cm. DOLSTS DECR UP FROM ~25% TO ~10%

COVER

MED DK GRY LS WKST, PKST & GRST, BDD ≤ 1-3cm W/ INTER-BDD ORNG-BROWN DOLSTS & GREEN-BROWN LS STS, BOTH IN ʊ & INTERLAMS ≤ 1cm. DECR % CO3 STS UP FROM ~10-15% TO ~5%, AS WELL AS GO FROM DOLSTS UP TO LS STS ⊙ ~⅛ mm. Ø ≤ ½ cm

COVER

GRY WKST & PKST, BDD ≤ 1-3 cm W/ ORNG & ORNG-BROWN DOLSTS IN ʊ & INTERLAMS. DOLSTS DECR UP ~20% TO ~10%

GRY WKST & PKST, BDD ≤ 1-5 cm W/ ORNG-BROWN DOLSTS IN ʊ & INTERLAMS ≤ 1 cm. DOLSTS DECR UP ~20-25% TO ~15%. Ø ≤ ½ cm

GRY & BROWN ⊙ (½-1+mm) GRST BDD 3-5cm W/ ≤ ½ x 1cm

10cm BD OF GRY PK/GRST W/ ≤ 1x10 cm & Ø ≤ ½ cm

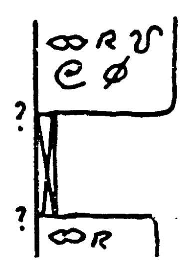
GRY WKST & PKST, BDD ≤ 1-4 cm W/ ORNG DOLSTS IN ʊ & INTERLAMS ≤ 1cm. DOLSTS DECR UP ~20% TO ~15%

GRY & BROWN ⊙ (½-1+mm) GRST, BDD 5-10cm. W/ ≤ ½ x 2 cm & Ø ≤ ½ cm.

MXT GRY LS AREN/STS & WKST & PKST, ALL BDD ≤ 1-3 cm W/ ORNG DOLSTS IN ʊ & INTERLAMS ≤ 1cm. DOLSTS DECR UP ~35% TO ~15%

SECTION 92-3
LAS VEGAS RNG, NV.

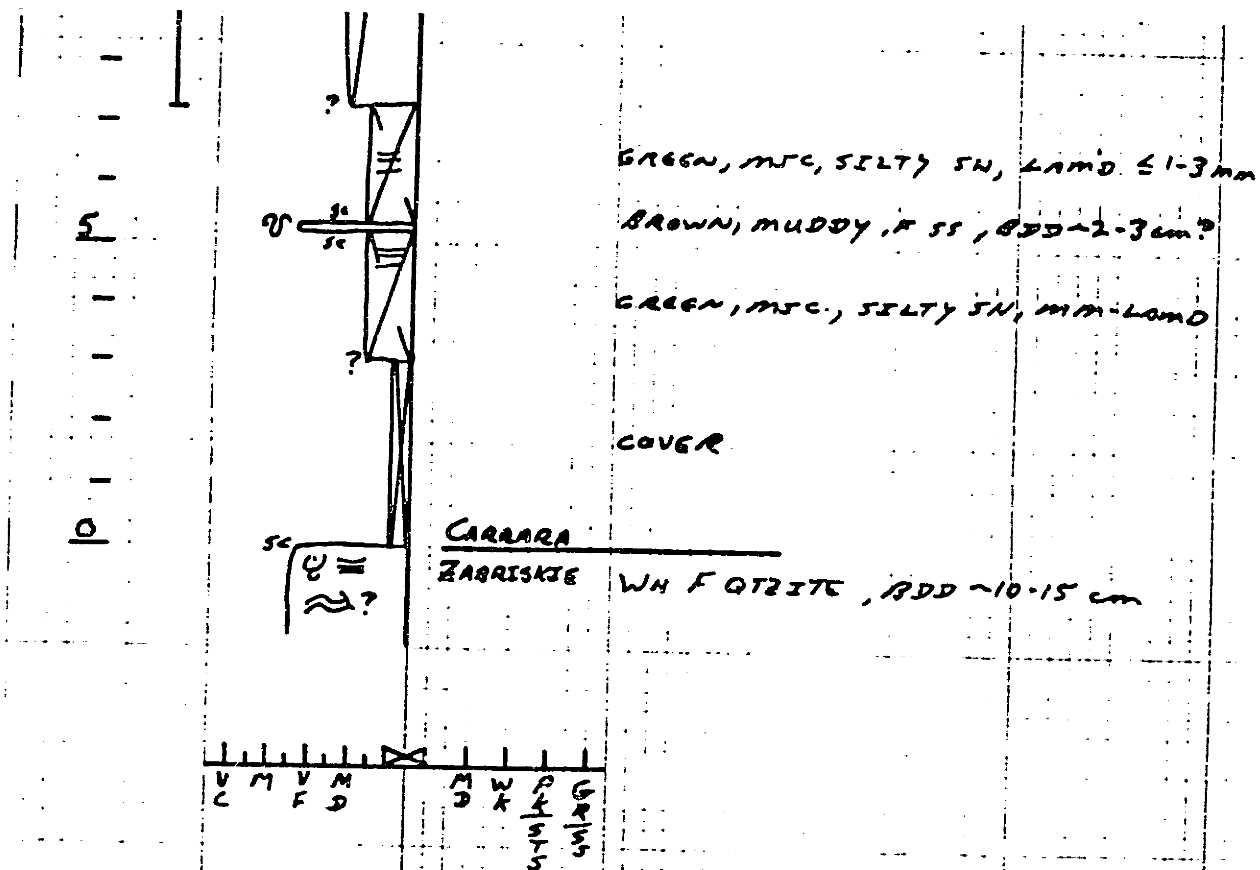
285



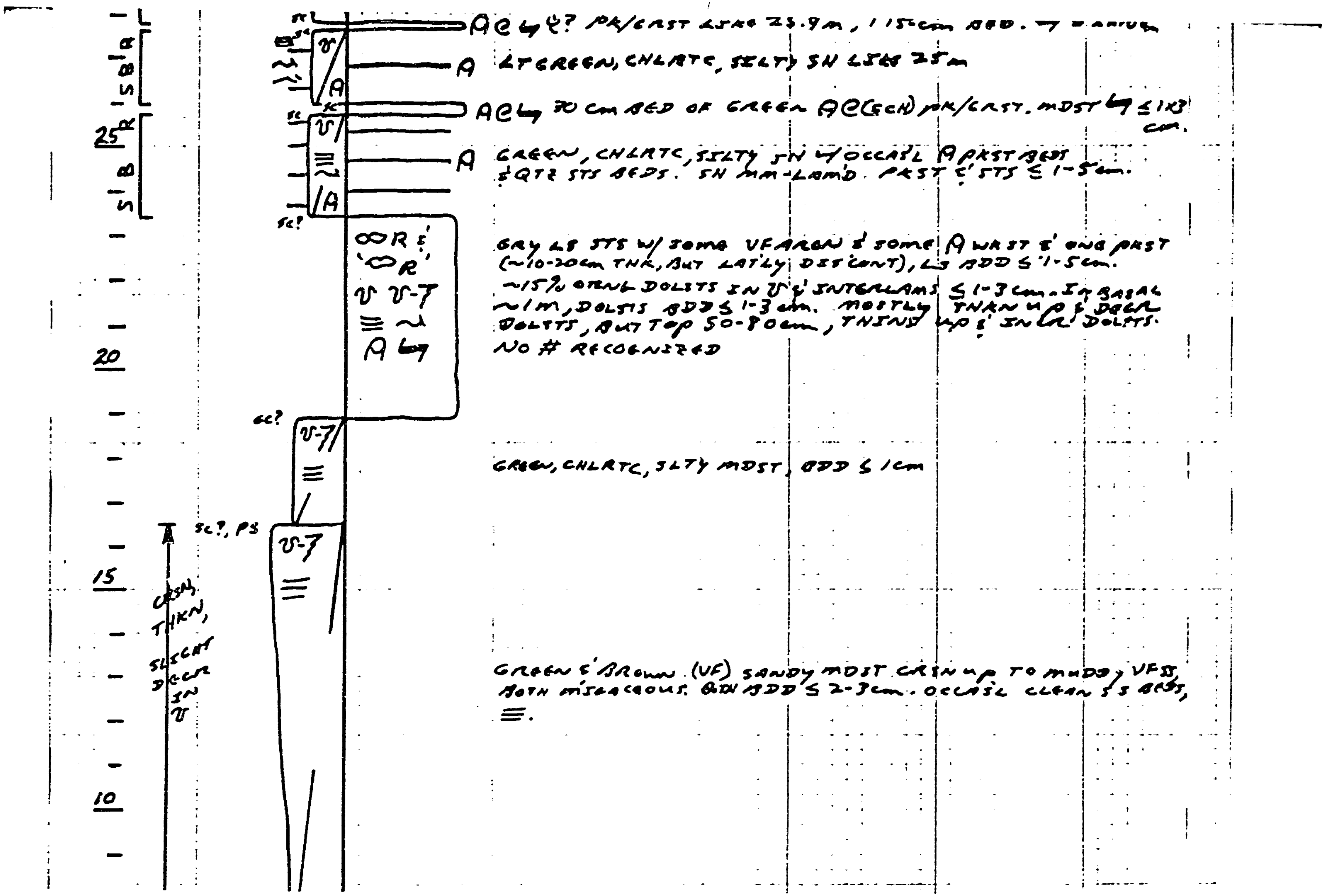
MED DK GRY PKSTS/WKST W/SOME GRST, ALL BDD ≤ 2-5cm. GREEN-BROWN LS STS IN ... & INTERLAMS ≤ 1cm. LS STS ≤ ~10-15%

COVER BONANZA KING / ARRARA

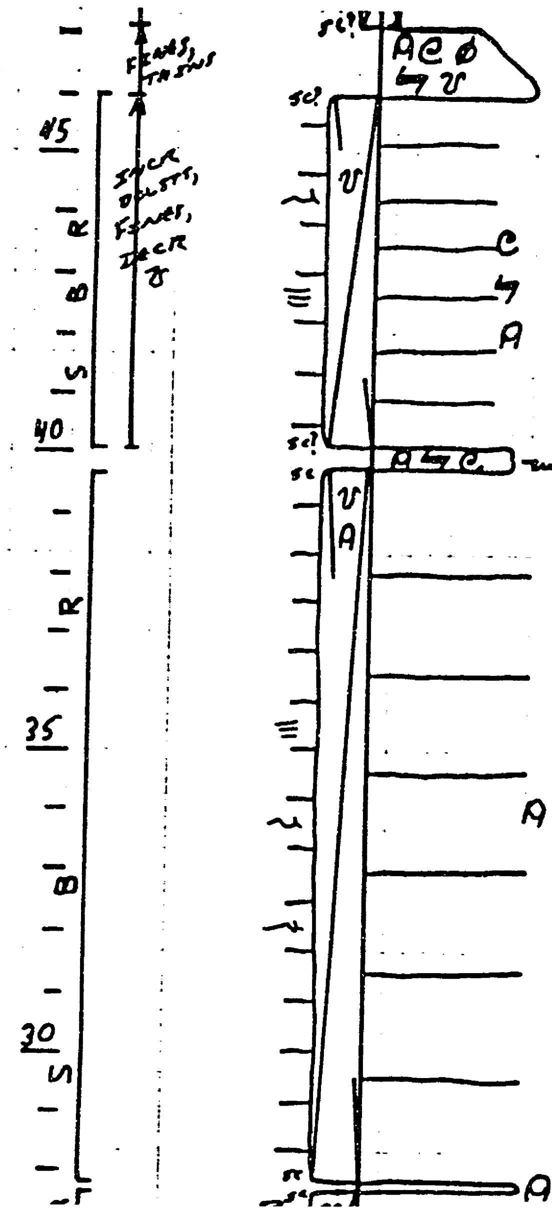
GRY WKST & PKST. BDD ≤ 1-3cm W/ ORNG-BROWN DOLSTS IN




SECTION 92-4
TITUS &' TITANOTHERE CYNS,
GRAPEVINE MTNS, CALIF.



AC ? PK/GRST LSKE 25.9m, 115cm BED.
LT GREEN, CHLRTC, SILTY SH LIKE 25m
AC 30 cm BED OF GREEN AC(GCN) PK/GRST. MOST ≤ 1x3 cm.
GREEN, CHLRTC, SILTY SH W/OCCASL A PKST BEDS & QTZ STS BEDS. SH MM-LAMD. PKST & STS ≤ 1-5cm.
GRY LS STS W/ SOME VF ARGN & SOME A WKST & GNS PKST (~10-20cm THK, BUT LATLY DISCONT), LS BDD ≤ 1-5cm.
~15% ORNG DOLSTS IN V & INTERLAMS ≤ 1-3cm. IN BASAL ~1m, DOLSTS BDD ≤ 1-3cm. MOSTLY THKN UP & DECR DOLSTS, BUT TOP 50-80cm, THINS UP & INCR DOLSTS.
NO # RECOGNIZED
GREEN, CHLRTC, SLTY MDST, BDD ≤ 1cm
GREEN & BROWN (VF) SANDY MDST CRSN UP TO MUDDY VFSS, BOTH MICACEOUS. BDD ≤ 2-3cm. OCCASL CLEAN SS BEDS.
CRSN, THKN, SLIGHT DECR IN V
SC?, PS
25
20
15
10



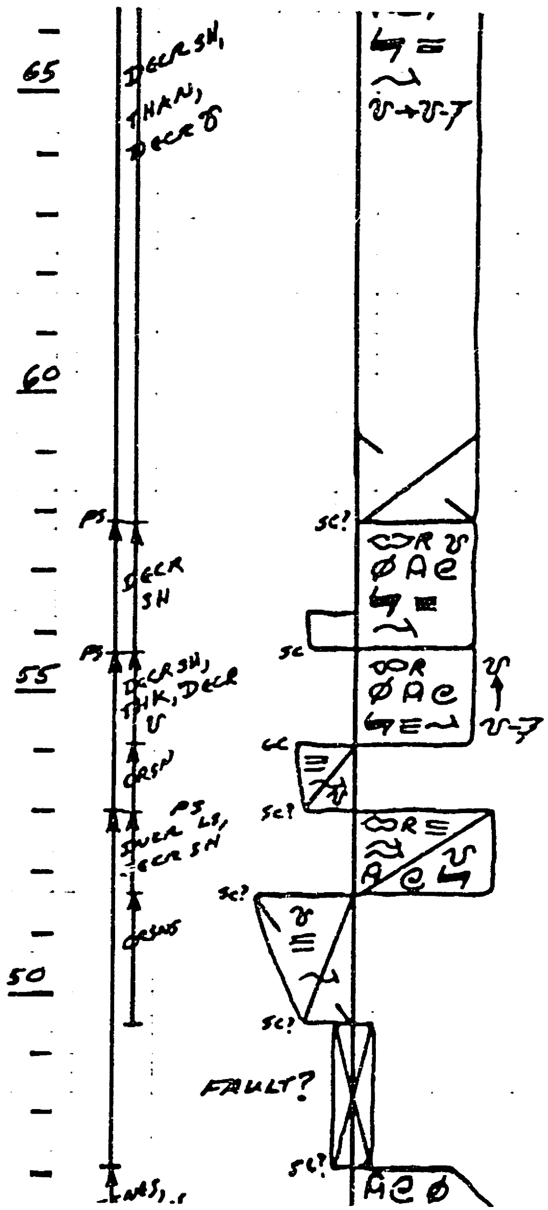

GRY LS, BDD ≤ 10-12cm, THINNING UP TO ≤ 3-5cm, PK/GRST UPTO WKST, W/ ORNG DOLSTS IN ? & DIS CONT, IRREGULAR INTERLAMS, ≤ ½cm. ≤ 1X3cm

GREEN, CHLRTC, SILTY SH, ≤ 5mm-LAMD W/ WKST'S STS INTERBEDS ≤ 1-5cm

GREEN & BRWN PKST, BDD 10-30cm. ≤ 2X10cm. SHLY INTERLAMS BETWEEN BEDS. BASAL BED A PKST 10cm THK.

SAME AS 27m, SH LAMD ≤ 5cm. PKST & STS ≤ 1-5cm

? PK/GRST LSNS 25.9m, 1 15cm BED. ≤ 2X10cm




GRY & GREEN @ WKST & LS STS (≡, ~) W/ REDDISH-ORNG CALCAREOUS, MSC, SILTY SH. LS BEDS THKN FROM ≤ 1-5 cm TO ≤ 3-15 cm IN TOP 1½ m. SH THNS FROM ≤ 1-5 cm UP TO ≤ 1-3 cm & DECR FROM ~45% UP TO ~15%

SAME LSTNS AS 55 m, W/ SH ~ 60% IN BASE, DECR UP TO ~30% LS BDD ≤ 1-4 cm. SH ≤ 1-2 cm. AMOUNT OF ɤ ~ CONSTANT

GREEN Ø (≤ 1½ cm) @ WK/PKST & UNCOMMON LS STS, BOTH BDD ≤ 1-9 cm, W/ MSC, CHLRTC, SILTY SH, SH ≤ ... cm, ≤ ½ x 3 cm. DECR SH UP FROM ~35% UP TO ~20% - SH IN ɤ & INTERLAMS

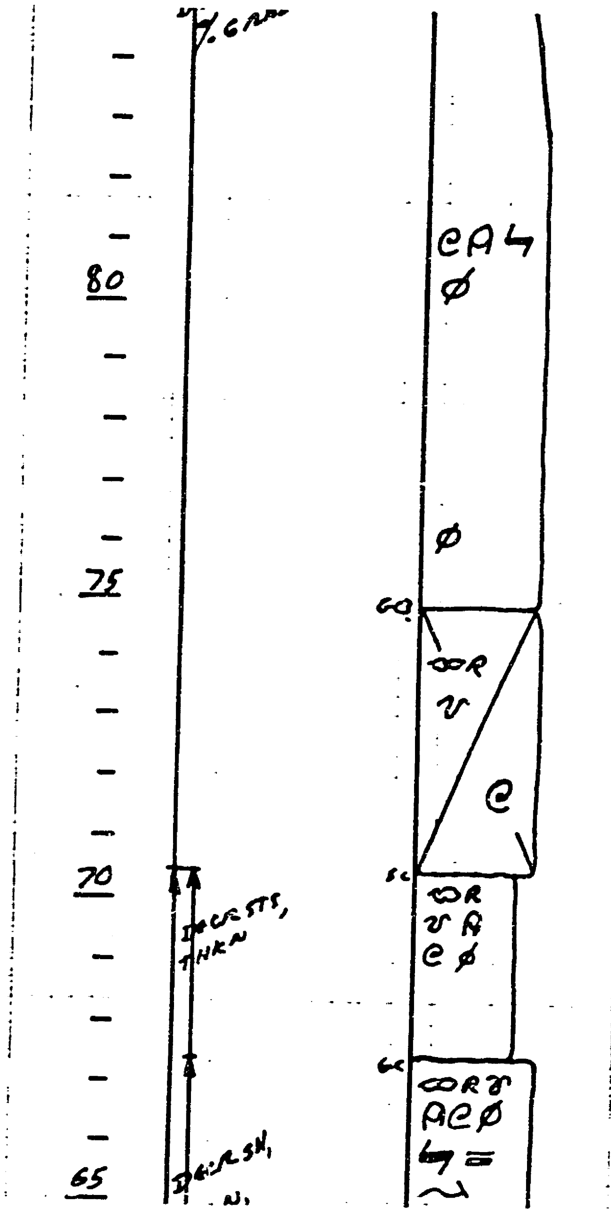
REDDISH-BROWN & GREEN SILTY SH CRSN UP TO SILTY MDST, BOTH MSC, MM-LAMD

GREEN LS PKST & STS/UFAREN, BDD ≤ 1-5 cm W/ REDDISH-ORNG, MSC, SILTY SH IN ɤ & INTERLAMS. ≤ 1-3 cm. INCR LS, DECR SH FROM ~50% TO ~25%

REDDISH BROWN, SILTY SH CRSNS UP TO (UP) SANDY & SILTY MDST W/ OCCAS'L VF SS & STS INTERBEDS. SH & MDST ≤ 5 mm-LAMD. SS, STS ≤ 1-3 cm

COVER

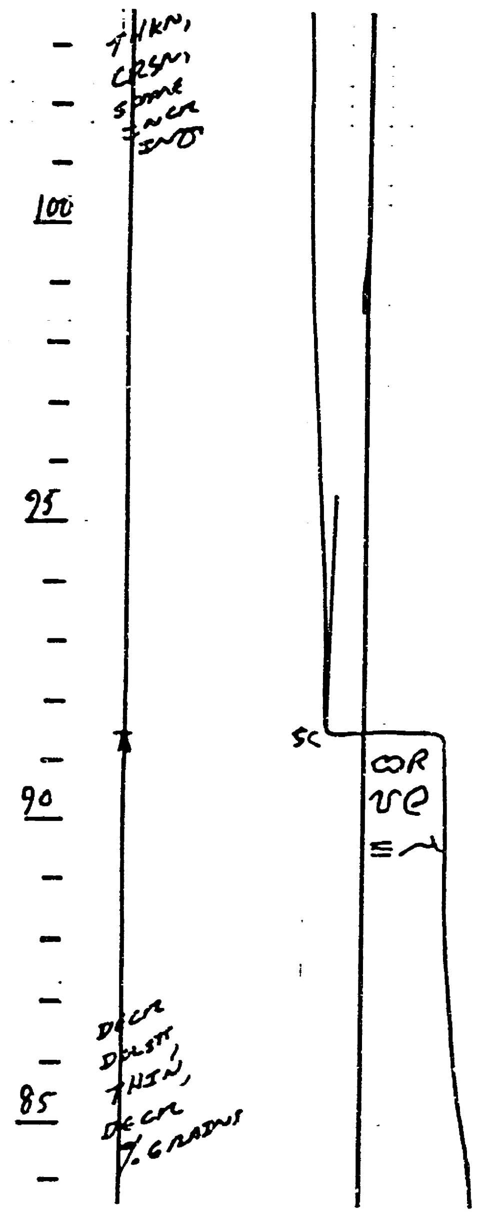
GRY LS, BDD ≤ 10-12 cm, THINNING UP TO ≤ 3-5 cm,



DOL'C & A FEW UN-BURROWED LS STS/NF ARGN BEDS, MOSTLY IN THE LOWER 10 M. LS BDD ≤ 1-3cm, THINNING TO ~1-2 cm IN TOP 6M. STS THKNS ≤ 1cm TO ≤ ½cm. DECR DOLSTS FROM ~15-20% TO ~5-10%. DECR AMOUNT OF ø(≤ 2cm) & [burrow](≤ ½ x 2-3 cm) UP-SCTN, SO THAT TOP ~6m MORE MD/WKST. NO #, NO EVENT BEDS OR SURFACES RECOGNIZED BETWEEN 70.5M & 91.5m.

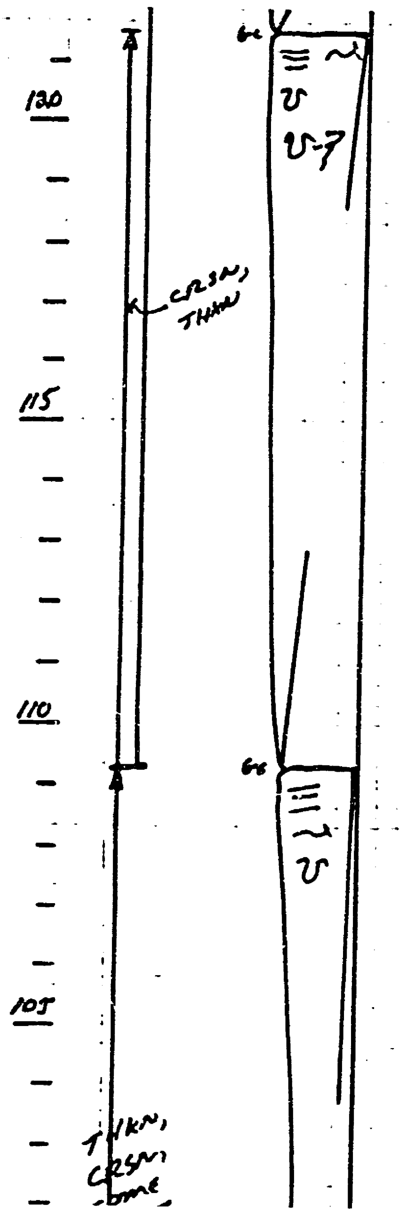
GRY. WR/PKST, BDD ≤1-3cm W/ REDDISH BROWN, MUDDY, MSC, DOL'C? STS ∞ & INTERLAMS ≤ 1cm, ~15-20%

GRY LS @ WKST, BDD ≤ 1-10cm, W/ REDDISH BROWN, MUDDY, MSC, STS MOSTLY IN ∇ & SOME IRREG DISCONT INTERLAMS ≤ 1cm. DOLSTS DECR SLIGHTLY FROM ~15% UP TO ~10%. [burrow] ≤ ½ x 2cm. ø ≤ 2cm



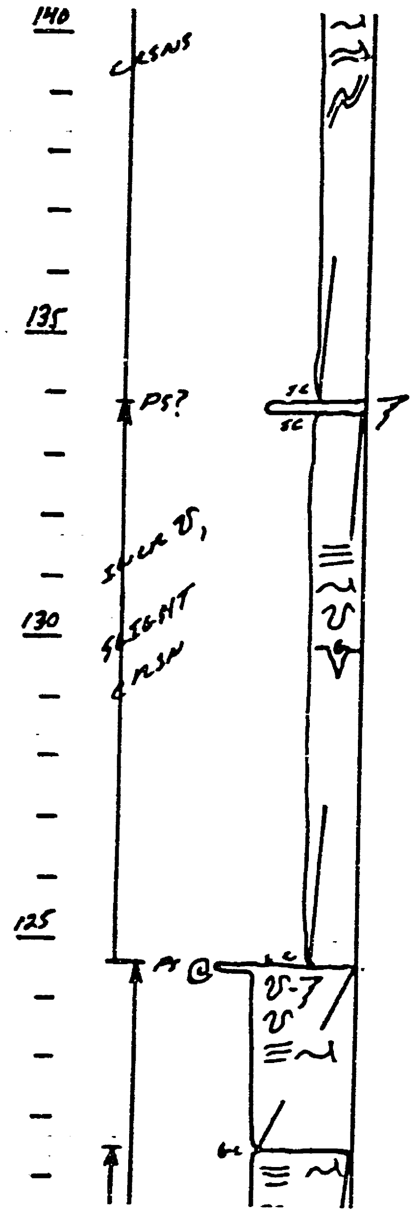

GREEN, SLIGHTLY SILTY SH, CRSN UP TO ALMOST A SILTY MDST; BOTH CHLRTC, MIC., & W/ ... INTERBDD VF SS (..., ~, ...) & STS. SH & MDST MM-LAMD TO ≤ 5 MM. SS, STS BDD ≤ 1-6 CM, W A COUPLE OF 5-10 CM SS BEDS NEAR TOP.

GRY WK/PKST W/ REDDISH-BROWN, MIC, MUDDY STS, POSSIBLY DOLIC & A FEW UN-BURROWED LS STS/VF ARGN BEDS, MOSTLY IN THE LOWER 10 M. LS BDD ≤ 1-3 CM, THINNING TO 1-2




GREEN, CHANGING UP TO PURPLE/PURPLISH BROWN, CHLORITIC, SILTY MDST (V, V-7), ADD S1 cm? w/ INTERBEDS OF VF & F SS (=, ~, V) ADD S1-10cm. BOTH SILICIOUS & CALCAREOUS CEMENTS.

GREEN, SLIGHTLY SILTY SH, CRSN, UP TC ALMOST A

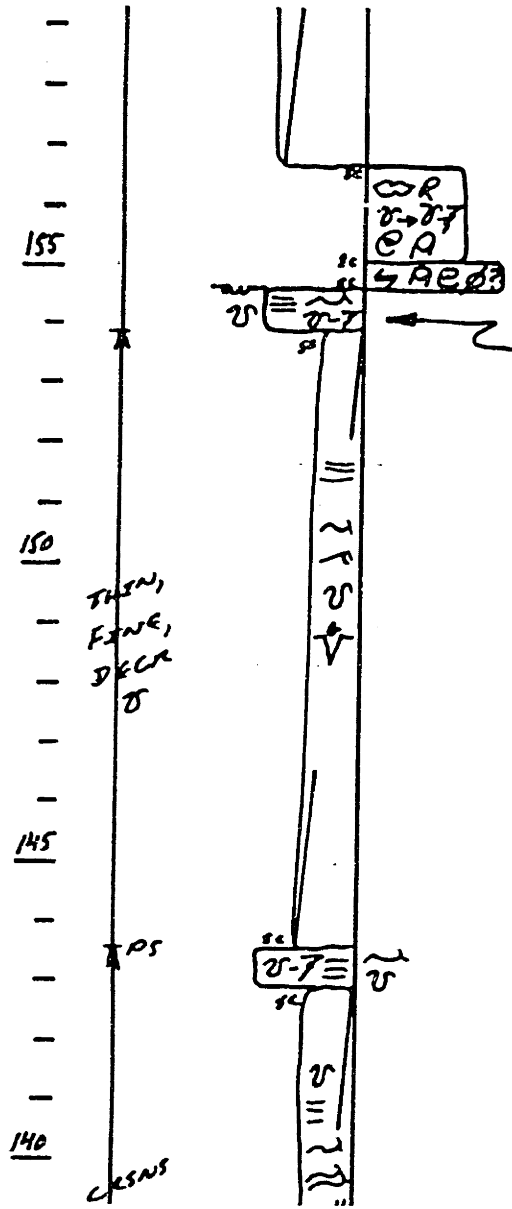



PURPLISH-BROWN–PURPLE, MIC., CNLRTC, SILTY SH, MOSTLY MM-LAM'D, SOME ≤ 5MM W/ VF & F SS INTERBEDS ≤ 1-5cm. ~ IN SS BEDS ~5cm THK

P1 PURPLE, MIC, MUDDY VF SS, BDD ≤ 1-2cm?

PURPLE/PURPLE-BROWN, SILTY, CNLRTC, MIC SH, LAM'D ≤ 1-3MM W/ INTERBEDS OF SLT & VF SS, BDD ≤ 1-3cm (≡, ~). GUTTER CASTS ( ) ≤ 2×2cm, IN BASE OF SOME SS BEDS

PURPLE & PURPLISH-BROWN SANDY & CNLRTC MDST W/ VF & F SS INTER BEDS LIKE 115m, BUT MORE V'S & V-7 IN SS THAN 115m. 4cm BED OF F-M SS W/ @ AT TOP.




GREENISH-GRAY WKST, ADD ≤ 1-2cm, W/ BROWN STS IN ῡ & INTERLAM, ADD ≤ ½ cm.

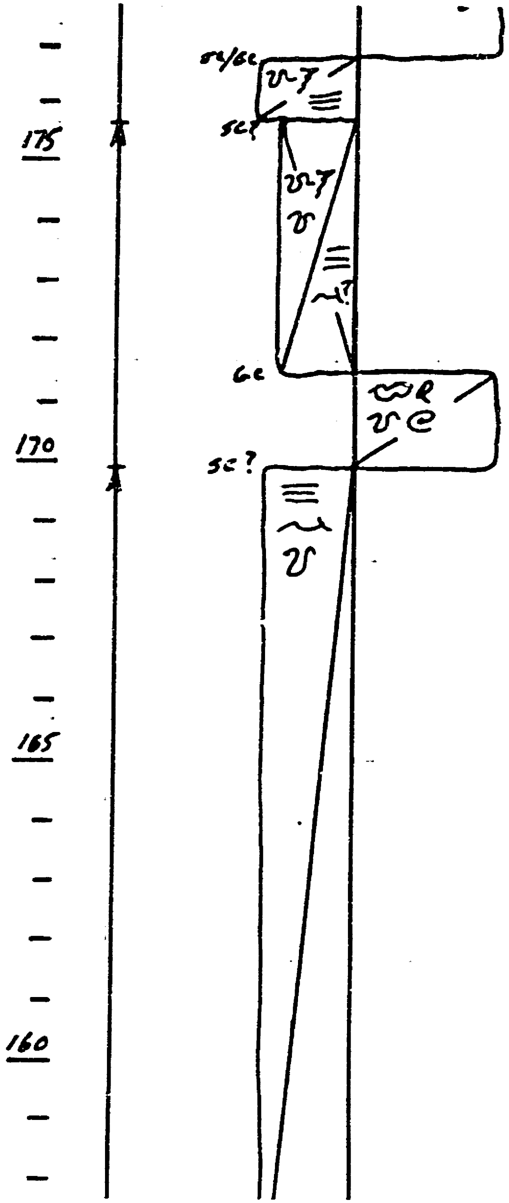
GREENISH-GRAY PKST, POSSIBLY ONE BED & PROBABLY LENTICULAR OVER 10 TO 100 m LATERALLY. [illegible] OF SS ≤ 3x10cm. [illegible] OF CO3 [illegible] ½ x 3cm. MANY SS [illegible] ALSO ≤ ½ x 3cm. [illegible] ½ cm

BROWN VFSS & MUDDY SS ῡ-7) CLEAN SS ≡, ~, ῡ. BOTH ADD ≤ 1-5cm

GREEN, SILTY, MIC, CHLRTC SH, MOSTLY MM-LAM'D, SOME ≤ 5mm W/ INTERBEDS OF VFSS & STS IN LWR PART, FINING UP TO INTERBEDS OF STS ONLY, INTERBEDS THIN FROM ≤ 1-5cm UP TO ≤ 1cm

LIKE 133.8 m. ADD ≤ 1-5cm. TOP 10cm ~ & ≡

PURPLISH-BROWN-PURPLE, MIC. CHLRTC [illegible]



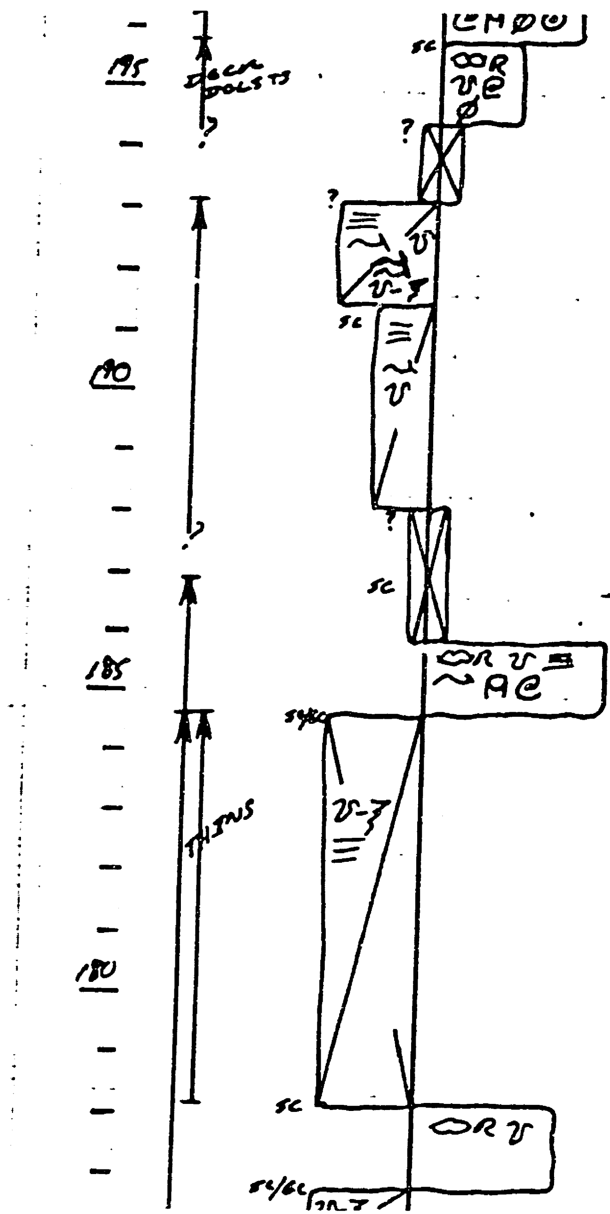

MIC ... [illegible]

TAN, CALC, MUDDY, MIC VFSS BDD ≤ 1-2 cm. POSSIBLY SOME $CO_3$ INTERBEDS OR AREN/STS

GRAYISH-TAN SANDY, MIC MDST, ALMOST A MUDDY SS, BDDS ≤ 2cm

MED LT GRY STS W/ @ (MD/WKST %), BDD ≤ 1-3cm, W/ TAN DOL/SIL STS INTERVALS, BDD ≤ 1-2cm IN V'S' IN INTERLAMS.

TAN, CALC, MIC, MUDDY VFSS'S'STS, BOTH BDD ≤ 1-4cm. MAY HAVE SOME LS STS/VF AREN BEDS MIXED IN.




…LAMS ≤ 1-2cm, ~20-25% DOLSTS OVERALL. DOLSTS DECR UP FROM ~40% TO ~10%. Ø ≤ 1mm. Ø ≤ ½ cm

GRAY LS MDSTS & WAST, BDD ≤ 1-5cm W/ REDDISH-ORANGE DOLST IN V & INTERLAMS ≤ 1cm. DECR DOLSTS FROM ~15% UP TO ~5%. Ø ≤ ½ cm

COVER

BROWN & GREEN, CLEAN & MUDDY, MSC VF SS, BDD ≤ 1-5cm W/ A FEW 5-10cm BEDS NEAR TOP. CLEAN SS ≡, ~, V. MUDDY SS V-Z.

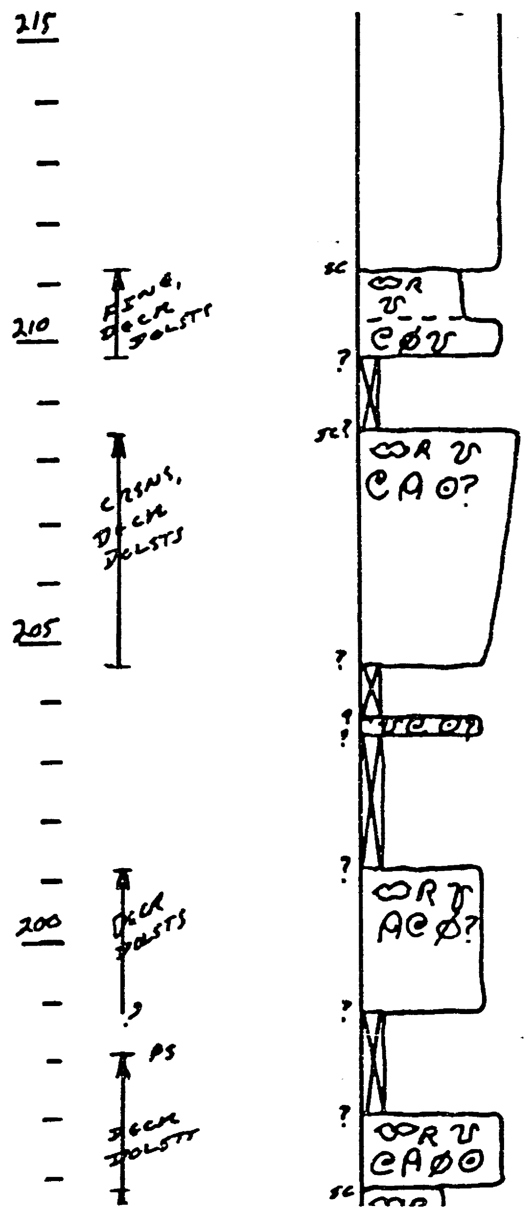
GREEN, CHLRTC, SILTY SH, LAM'D ≤ 5mm W/ INTERBEDS OF STS & SOME VF SS, BDD ≤ 1-4cm, MOST ≤ 1-2 cm. ~50% SH.

COVER

GRAY VF LS AREN, BDD ≤ 1-3cm W/ ~30-35% TAN, MUDDY, MSC, CALC STS BDD ≤ 1-2cm. SLIGHT DECR UP IN % STS

TAN & BROWN VF MUDDY, MSC, CALC SS, W/ BDDNG THINNING UP FROM ≤ 5-10cm TO ≤ 1-3cm. SOME $CO_3$ STS/MUD NODULES IN UPPER ½ TO ¾ M.

GRAY LS STS/VF AREN W/ INTERBDD TAN, CALC, MUDDY, MSC STS. BOTH BDD ≤ 1-3cm. ~45-50% STS




BG STS, ADD ≤ 1-4cm w/ TAN DOLSTS (~15%) IN V &
INTERLAMS ≤ 1cm

GRY PKST FINING UP TO WKST, ADD ≤ 1-3cm w/ ~10-15% TAN DOLSTS, ADD ≤ 1cm. SLIGHT DECR UP IN DOLSTS. Ø ≤ ½ cm.

COVER

GRY LS WK/PKST CRSNING UP TO PK/GRST, ADD ≤ 1-4cm, w/ REDDISH-ORNG & ORNG DOLSTS IN V & INTERLAMS ≤ 1.2 cm. DOLSTS DECR UP FROM ~20% TO ≤ 5%. ⊙ ≤ ½ mm.

COVER

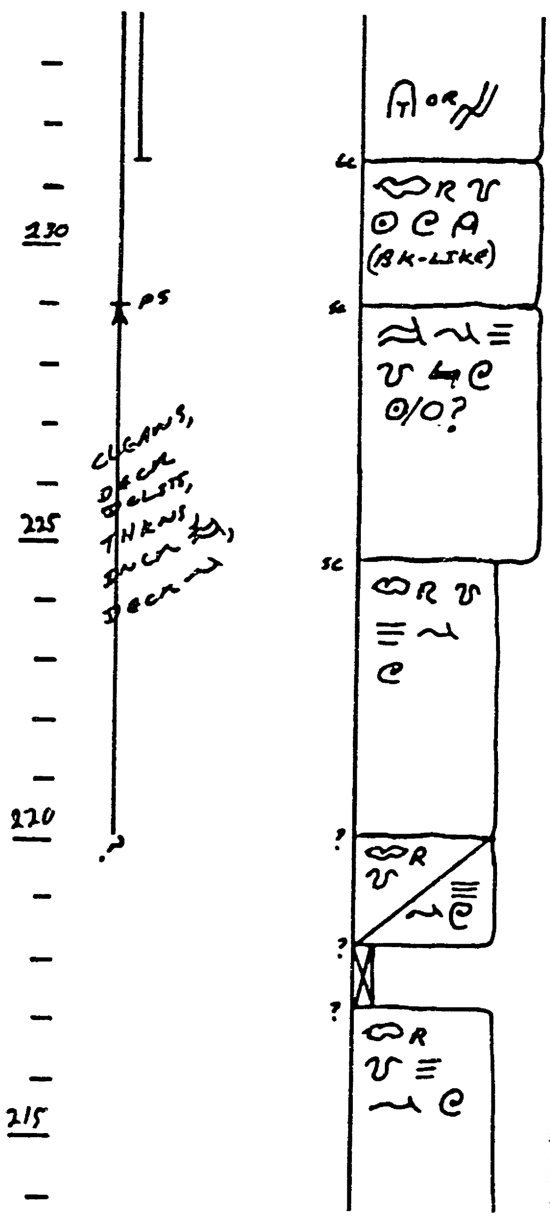
GRY WK/PKST, ADD ≤ 1-3cm w/ DISCONTIN. STRINGERS OF TAN STS. ⊙? ≤ ½ mm.

COVER

GRY WK/PKST, ADD ≤ 1-4 cm w/ REDDISH ORNG & ORNG DOLSTS IN V & INTERLAMS, ≤ 1.2cm, DECR DOLSTS UP FROM ~20% TO ~10%. Ø? ≤ ¼ cm

COVER

GRY LS WK/PKST & GRST, ADD ≤ 1-4cm w/ DOLSTS IN V & INTERLAMS ≤ 1.2cm, ~20-25% DOLSTS OVERALL. DOLSTS DECR UP FROM ~40% TO ~10%. ⊙ ≤ 1mm. Ø ≤ ½ cm




MED-DK GRY VF & F AREN & ⊙ (≤¼mm) GRST w/<10% @ (MOSTLY IN LWR ½), ALL BDD ≤ 1-3 cm(?). BROWN DOLSTS IN ᘯ & INTERLAMS ≤ 1 cm, MOST <½ cm. Bᘯ w/ SPAR. BK-LIKE BUT NOT A MDST.

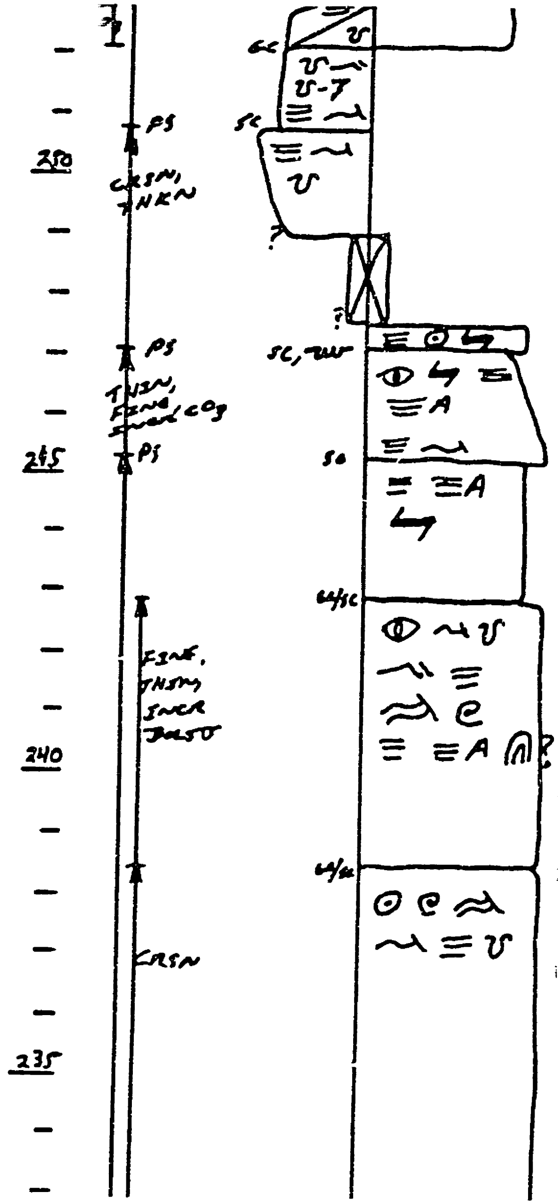
GRY LS VF AREN, MOSTLY BDD ≤ 2-5 cm OR 5-15 cm, w/ SOME ⇌ BEDS 25-45 cm TOWARDS TOP. ORNG DOLSTS INTERBEDS & INTERLAMS, ≤ 1 cm & 1-4 cm, OFTEN ~ & ≡ AT TOP LS ⇌; ~15-20% OVERALL. TOP 1 m w/ AN INCR IN DOLSTS. ⊙/0? MAY EVEN BE SMALL, ROUNDED LS GRAINS

GRY LS STS w/ RARE @, BDD ≤ 1-3 cm w/ TAN, ORNG & REDDISH-ORNG DOLSTS, BDD ≤ 1 cm, IN ᘯ & INTERLAMS, ~20%

LIKE 215 m

COVER

MED-DK GRY LS, PROBABLY ALL STS, BUT SOME MAY BE STS, BDD ≤ 1-4 cm w/ TAN DOLSTS (~15%) IN ᘯ & INTERLAMS ≤ 1 cm




UP TO MM-LAMD TO ≤ 1 cm

GREEN, MUDDY, CHLRTC, MSC, STS & VFSS ADD ≤ 1-2 cm.

BROWN & PURPLE, MSC, MUDDY & CLEAN VFSS & STS, ADD ≤ 1 cm UP TO ≤ 1-5 cm

COVER

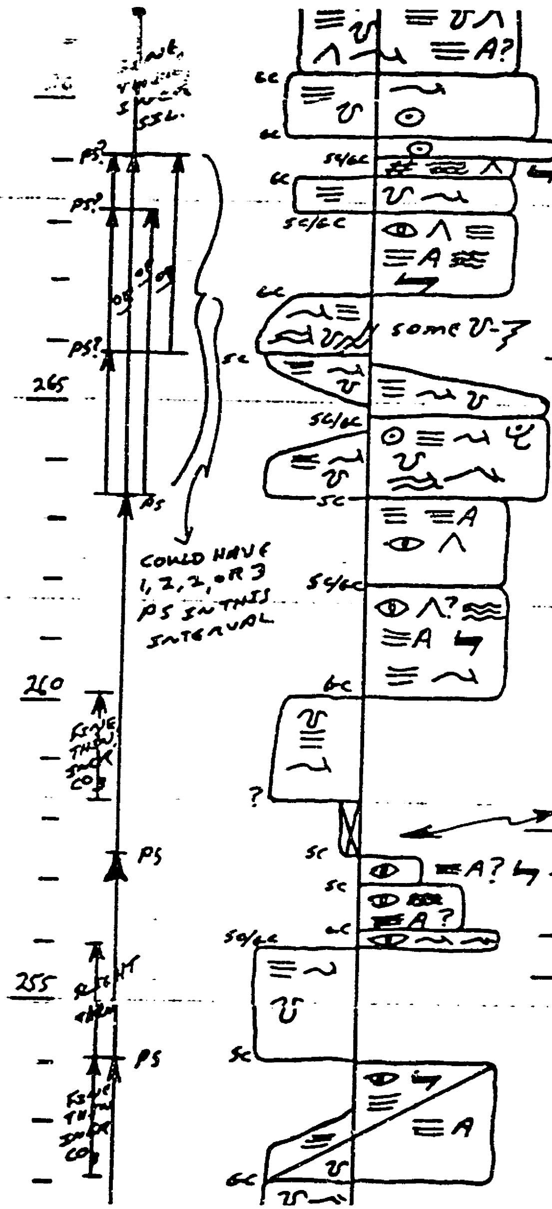
BROWN STS & VF AREN W/ QTZ GRAINS, MM-LAMD W/ 10-15 cm OF GRAY PK/GRST, ADD ~5 cm, W/ ⊙?, ≤ ½ × 3 cm OF DOLSTS

ORNG, PINK & BROWN VF AREN & STS & DOLSTS, W/ QTZ GRAINS. ADDG THSNS UP FROM ≤ 1-8 cm TO ≤ 1-3 cm TO MM-LAMD

ORNG, TAN, CREAM DOL & LS STS & VF AREN, MM-LAMD. ≤ ½ × 2 cm

GRAY UP TO LT GRAY ⊙ (≤ 4 mm) GRST & LS AREN, THINNING UP FROM ≤ 3-10 cm TO ≤ 1-4 cm W/ SOME TAN & ORNG DOLSTS (≡, ≡A, ⋒?), ADD ≤ 1-4 cm IN INTERBEDS ⋒? ≤ 2 × 2 cm.

GRAY & MED-DK GRAY ⊙ (≤ ½ mm) GRSTS & VF-FLS AREN ADD ≤ 5-10 cm W/ A LITTLE BROWN & TAN DOLSTS, MOSTLY IN ʊ & SOME INTERLAMS ≤ 1-2 mm. VERY DK, VERY IRREG. SHAPED POSSIBLE ⋒ OR ≈ IN BASAL 1-2 m.




TAN, PINK, BROWN, RED STS (QTZ, $CO_3$) W/ LESS VF SS/AREN, ALL ADD ≤ 1-2 cm, W/ CHRTC, MIC MUD DRAPES

PINK & BROWN STS & VF SS, BOTH QTZ & $CO_3$, ADD ≤ 1-2 cm. ⊙ GRST [illegible] IN BTM

GRY ⊙ (≤ 1/8 mm) GRST, ADD ≤ 1-2 cm W/ SOME RED DOLSTS INTERLAM

≡ A ⊙ ORNG DOLSTS, MM-LAM'D. ≤ 1/4 x 5 cm
MM-LAM'D → ≤ 1 cm

ORNG DOLSTS MM-LAM'D TO ≤ 1-2 cm. ≤ 1/4 x 3 cm OF STS.

BROWN & GREEN, CLEAN & MUDDY (MIC) VF-F SS FINING UP TO VF SS & STS. STS ADD ≤ 1-3 cm. SS ≤ 1-12 cm. THINS UP

GRY VF LS AREN & STS CHANGING UP TO BROWN QTZ VF SS & STS, ALL ≤ 1/2-1 cm ADD. W/ SOME MUD/SH. INTERLAMS, ≤ 1-2 MM, MIC, CHLRTC

GRY LS VF & F AREN & ⊙ (≤ 1/4 mm) W/ TAN DOLSTS & TAN $CO_3$-CMTD VF QTZ SS, ALL ADD ≤ 1-10 cm. 5-10 cm.

ORNG & BROWN DOLSTS W/ QTZ GRAINS, MM-LAM'D TO ≤ 1 cm ADDG

ORNG DOLSTS, ADD ≤ 1-3 cm. ≤ 1/4 x 2 cm, OF STS

GREEN & BROWN, MUDDY, CHLRTC, CALC, MIC, STS W/ SOME VF SS. THINS FROM 2-4 cm BEDS UP TO ≤ 1-2 cm

COVER

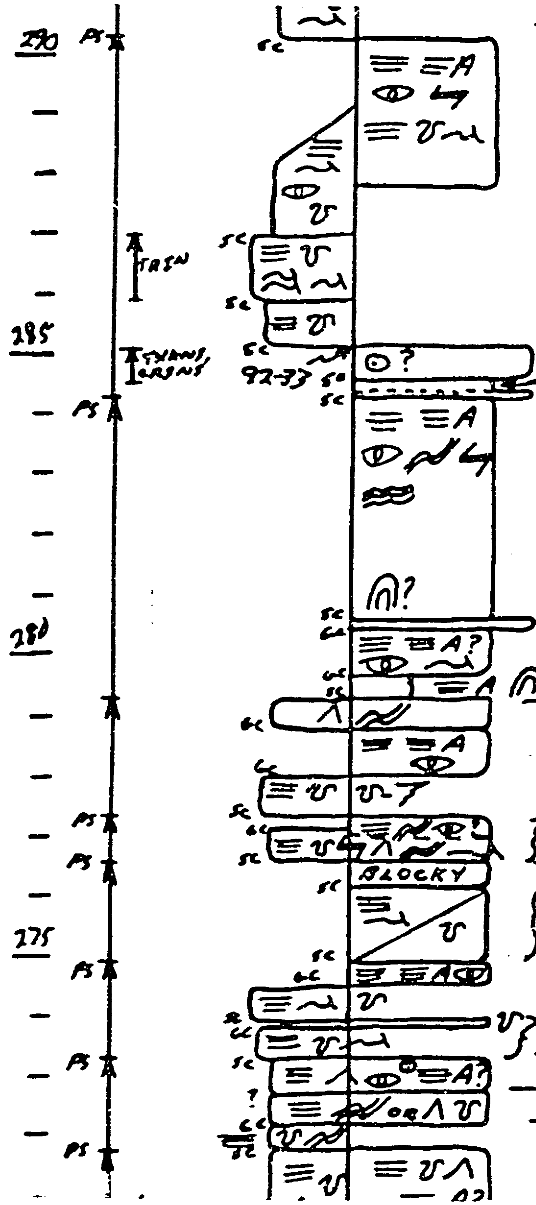
GRY MDST W/ IN TOP 5-10 cm. TOP 15-20 cm ADD ≤ 1 cm, BTM LOOKS HOMOGENOUS

GRY & TAN LS & $CO_3$ STS & DOL. MDST, ALL ADD ≤ 1-5 mm. TOP 5-10 cm IS RED DOLSTS

REDDISH-ORNG DOLSTS, ≤ 1 cm BEDS

REDDISH-BROWN, MIC, SLIGHTLY MUDDY VF SS, ADD ≤ 1-6 cm

ORNG & BROWN VF SS & STS & DOLSTS. THINS UP FROM ≤ 1-5 cm UP TO MM-LAMD TO ≤ 1 cm




[illegible]

BROWN, TAN QTZ & DOL STS CHANGING UP TO ORNG DOLSTS. ALL BDD MM-LAM'D TO ≤1-2 cm

GRAY & TAN, MUDDY, MSC VF STS, BDD ≤2-10 cm w/ ONE 15-cm BED

RED, GRAY & TAN STS, BDD ≤ 1 cm

GRAY LS ⊙? (≤ 1/4 mm) GRST, BEDD ≤ 1-2 cm, THINNING UP TO ≤ 1-5 cm.

RED DOLSTS, BDD ≤ 1 cm → MM-LAM'D. A 1-5 cm ⊙ (≤ 1/4 mm) GRST (GRAY) AT BASE.

ORNG DOLSTS, MM-LAM'D TO ≤ 1-2 cm BEDS, EXCEPT FOR AN ~50 cm INTERVAL WHICH LOOKS BLOCKY, 1-4 cm BEDS W/ LAMS & ⊕

⊙ ⊕ GRAY ⊙ (≤ 1/4 mm) GRST, BDD ≤ 1-2 cm w/ RED DOLSTS INTERBEDS

RED & GRAY DOL & LS STS, MM-LAM'D TO ≤ 1-2 cm

GRAY ⋂ MDST, W/ UPWARD DECR IN SIZE FROM ~10×10 cm TO ~2×2 cm

BROWN, GRAY, PINK MXTCO$_3$ & QTZ STS
ORNG DOLSTS
GREEN, CHLRTC, MUDDY STS
} ALL BDD ≤ 1-2 cm

GRAY & RED QTZ STS & DOLSTS, BDD ≤ 1-2 cm W/ TOP 15 cm OF ORNG DOLSTS & GRAY LS AREN W/ QTZ, MM-LAM'D TO ≤ 1 cm BDD

RED & REDDISH-ORNG DOLSTS, BDD ≤ 1-2 cm W/ TOP 50 cm 2-8 cm BDD.

ORNG DOLSTS
GREEN, MUDDY, MSC, CHLRTC STS
} BOTH MM-LAM'D TO BDD ≤ 1 cm

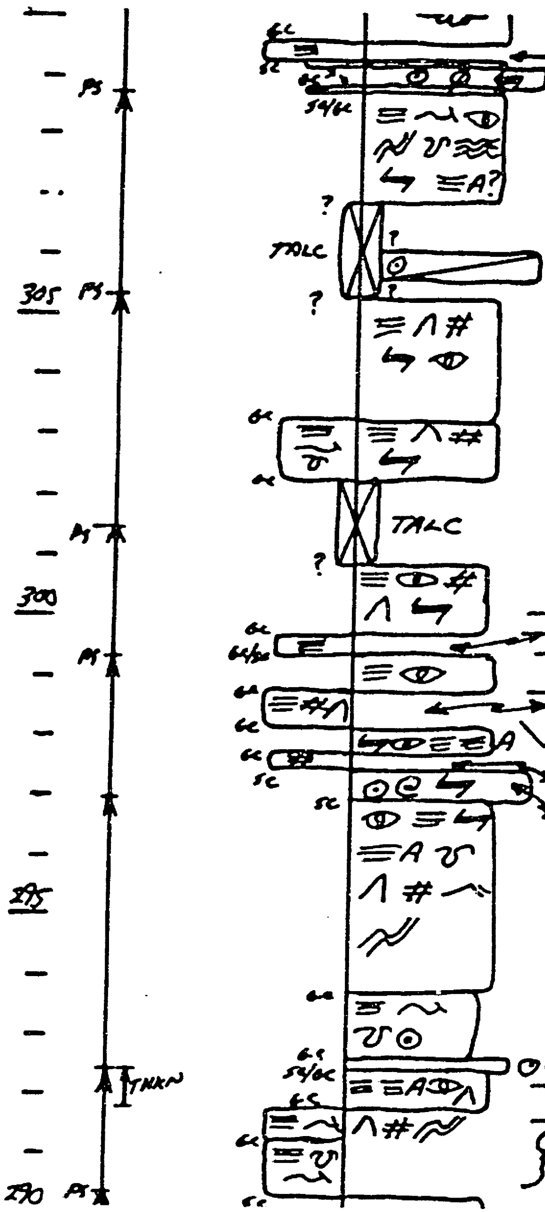
GRAY, TAN, MUDDY, MSC STS TOPPED BY GRAY LS STS ~10-15 cm THK

RED DOLSTS & SIL STS, MM-LAM'D TO ≤ 1 cm. TOPPED BY 0-3 cm OF GRAY ⊙ (≤ 1/4 mm) GRST

REDDISH-ORNG DOLSTS & MSC. QTZ SS, BDD 1-3 cm, THIN UP TO ≤ 1 cm

REDDISH-BROWN, MUDDY, CHLRTC STS, BDD 1-3 cm, W/ SOME CLAY/MUD DRAPES ≤ 1-2 mm

TAN, PINK, BROWN, RED STS (QTZ, CO$_3$) W/ LESS VF SS/AREN, ALL [illegible]




... 7 cm HI X 70 cm WIDE.
BROWN VF QTZ SS, MM-LAM'D

GREEN ⊙ (≤ 1/4 mm) ⌀ ≤ 1 cm GRST, ADD ≤ 1-5 cm, W/ MARLY STS ABOVE & BELOW.

RED & ORNG DOLSTS & SOME VF, GREEN LS AREN, BOTH MM-LAM'D TO ≤ 1 cm & A FEW BLOCKY BEDS ~10-15 cm THK.

~30 cm OF ⊙ GRST, 10 cm ADD?

RED & ORNG DOLSTS, MOST ≤ 1 cm ADD W/ SOME BLOCKY RED ~10 cm THK

5 ALTERNATING STS UNITS: 3 GREEN, CHRTC, MUDDY, CALC, QTZ STS & 2 RED DOLSTS; ALL MM-LAM'D, EACH UNIT ~20 cm THK

ORNG & RED DOLSTS, MOSTLY MM-LAMD → ≤ 1 cm, W/ SOME BLOCKY BEDS IN UPPR ½

GREEN & GRAY, CALC, MIC, MUDDY STS, MM → ≤ 1 cm

ORNG DOLSTS, MM-LAM'D → ≤ 1 cm. ≤ 1 X 3 cm OF DOLSTS.

GRY CALC, MUDDY QTZ STS & MDST MM-LAM'D → ≤ 1 cm IN UPPR PART, MASSIVE IN LWR. # ONLY IN UPPR ½

ORNG DOLSTS, MM-LAM'D TO 6 / cm. OF STS, ≤ 1 X 3 cm

GREEN, MIC, MUDDY STS, MM-LAM'D

GREENISH-GRY LS GRST, POSSIBLY A 50-cm BED. ⊙ ≤ ½ mm. ≤ 1 X 1 cm

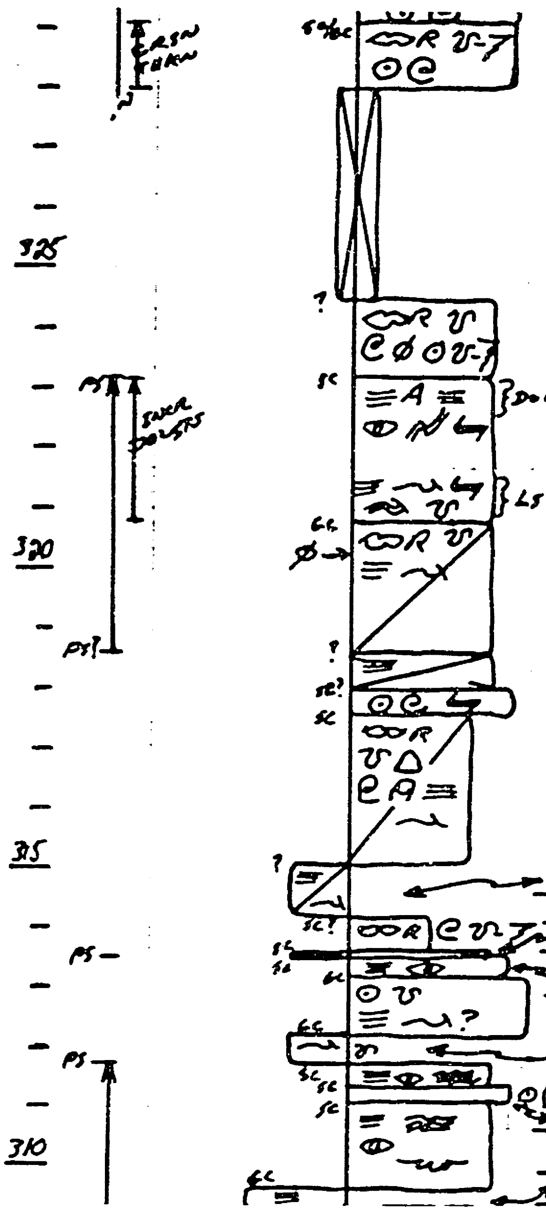
RED & ORNG DOLSTS, MM-LAM'D TO BEDS ≤ 1-2 cm

RED & TAN DOLSTS W/ OCCASIONAL ⊙ GRST BEDS. ADD ≤ 1-2 cm TO MM-LAM'D

ORNGY GRY ⊙ (≤ 1/4 mm) GRST, ADD ≤ 1-2 cm W/ RED DOLSTS INTERLAMS

RED & ORNG DOLSTS, MM-LAM'D TO ≤ 1 cm BEDS IN LWR ½, BLOCKY IN UPPR ½

GRAY & PINK, MIC., MUDDY STS, MM-LAM'D TO BEDS ≤ 1 cm




GRAY LS PK/GRST, BDD ≤ 1-4 cm, W/ ORNG-BROWN DOLSTS IN Ʊ & IRREG INTERLAMS, ≤ 1 cm. ⊙ ≤ 1/4 mm.

COVER

GRAY & GREEN LS PKST & STS, BDD ≤ 1-3 cm W/ BROWN DOLSTS IN Ʊ & INTERLAMS (DISCONT) ≤ 1/8-1 cm. ⊙ ≤ 1/4 mm. Ø ≤ 1 cm

MXT GREEN LS STS, BDD ≤ 1-3 cm, & REDDISH-ORNG DOLSTS, BDD ≤ 1-2 cm & MM-LAM'D

GRAY LS STS, BDD ≤ 1-5 cm W/ REDDISH-ORNG DOLSTS, BDD ≤ 1 cm
Ø (≤ 4 cm) WKST, ~10-20 cm THK AT ~ 320.0 → 320.4 m

RED DOLSTS, BDD ≤ 1 cm

GRAY PK/GRST, BDD ≤ 10-20 cm. ⊙ ≤ 1/2 mm, ≤ 1 X 1 cm

GRAY LS: A MIX OF WKST, WK/PKST & VF AREN, ALL BDD ≤ 1-4 cm W/ REDDISH DOLSTS IN Ʊ & INTERLAMS ≤ 1 cm. ≡, ~ IN AREN/STS

GREEN, CHLRTC, SLIGHTLY SILTY SH & STS, LAM'D ≤ 5 mm

GREEN MD/WKST BDD ≤ 1-2 cm W/ BROWN DOLSTS IN Ʊ

GREEN & GRAY MIXED QTZ & CO3 STS, MM-LAM'D

RED DOLSTS W/ LENSES & BEDS OF ⊙ (≤ 1/4 mm) GRST, BOTH BDD ≤ 1 cm

GREEN ⊙ (≤ 1/4 mm) GRST, BDD ≤ 1-3 cm W/ BROWN DOLSTS IN INTERLAMS ≤ 1/2 cm

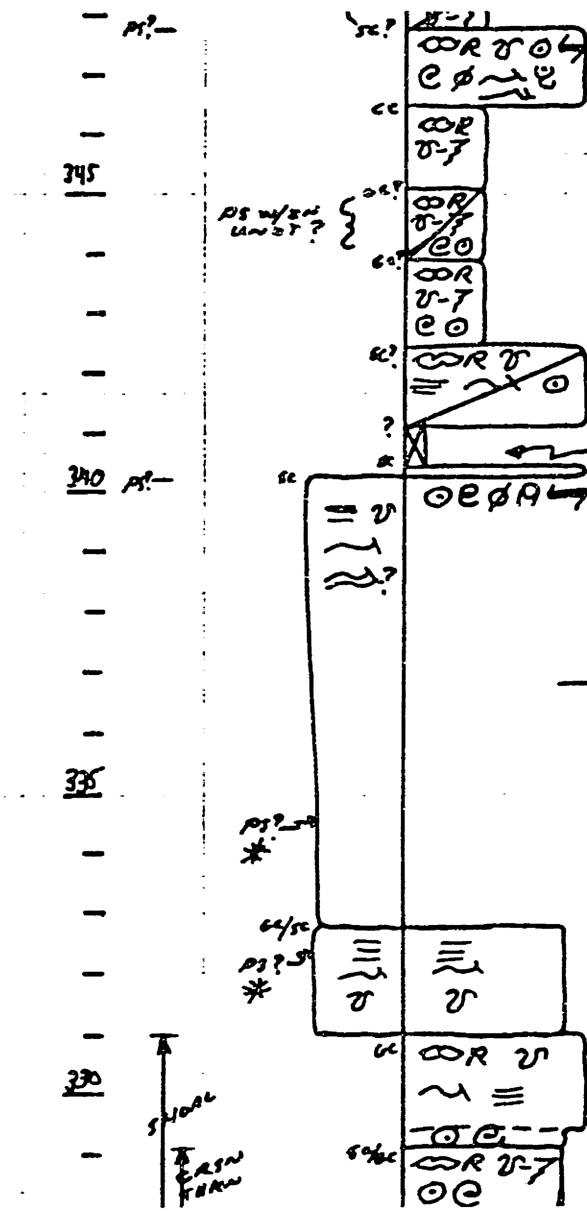
GREEN, CHLRTC, SILTY MDST, BDD ≤ 1 cm

SAME AS 310 m

⊙ @ YELLOW-GREEN PK/GRST, BDD 2-5 cm. ⊙ ≤ 1/2 mm. ≤ 1/2 X 3 cm, OR STS

ORNG & RED DOLSTS, MM-LAM'D TO ≤ 1 cm W/ SOME ~5 cm BEDS NEAR TOP. LG INTERNAL SCOURS & SLUMPS, EG 4 cm HI X 40 cm WIDE.

BROWN VF QTZ SS, MM-LAM'D




MED-DK GRAY GRST, BDD ≤ 2-10 cm W/ ~10% BROWN DOLSTS IN ʊ & INTERLAMS. ⊙ ≤ 1/4 - 3/4 mm · ≤ 1/2 x 1/2 cm · ∅ ≤ 1/2 cm.

SAME AS 343 m

SAME AS 343 m. SOME SPAR ʊ

MED-DK GRAY MD/WKST & OCCAS'L PK/GRST, ALL BDD ≤ 1-3 cm, W/ BROWN DOLSTS IN ʊ & V. IRREG, OFTEN DISCONT INTERLAMS ≤ 2-3 mm (~15% DOLSTS)

GRAY VF AREN & ⊙(≤ 1/2 mm) GRST, BOTH BDD ≤ 1-3 cm W/ BROWN DOLSTS IN ʊ & IRREG INTERLAMS ≤ 1 cm.

COVER

GREEN GRST IN A 10 cm BED. ⊙ ≤ 1/2 mm ≤ 1 x 4 cm ∅ ≤ 1 cm.

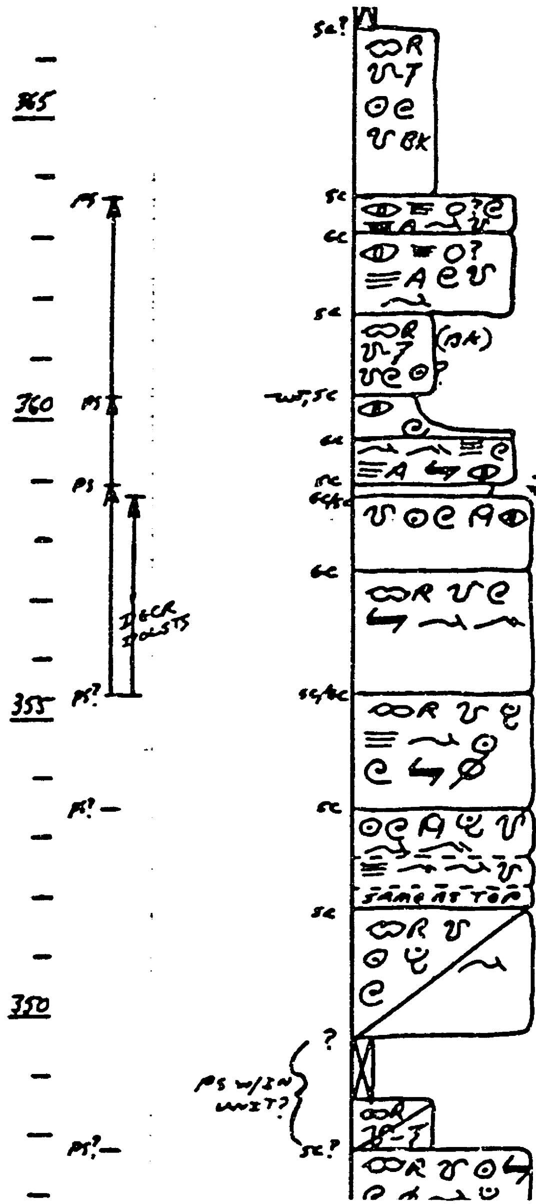
BROWN VF SS & STS W/ OCCAS'L LS STS/AREN, ALL BDD ≤ 1-8 cm

* "PS?": 2 POSSIBLE PARASEQUENCE BOUNDARIES, AT 333.3 m & 334.55 m, BOTH MARKED BY AN INCR IN % $CO_3$ SEDIMENTS JUST ABOVE THE BOUNDARIES

MXT BROWN QTZ STS & VF SS W/ GREEN LS STS & VF AREN, ALL BDD ≤ 1-3 cm. ~40% $CO_3$

GRAY & GREEN LS AREN, BDD ≤ 1-5 cm W/ REDDISH STS/DOLSTS IN ʊ & INTERLAMS ≤ 1-2 cm. BTM ~20 cm A PK/GRST OF ⊙ & ◎.

GRAY LS PK/GRST, BDD ≤ 1-4 cm, W/ ORNG-BROWN DOLSTS IN




COVER

MED-DK GRAY MD/WKST LIKE 361M, BDD ≤ 1-3 cm W/~10-15% REDDISH DOLSTS IN [symbol]. OCCAS'L LS PK/GRST BEDS. SPAR-[symbol]

SAME LS AS 362.0M W/ ORNG DOLSTS INTERBEDS IN ALTERNATING BEDS, BOTH ≤ 1-2 cm & MM-LAMD, ≈ 40% DOLSTS

LT GRAY, CLOTTED, PELLETED?, [symbol] PK/GRST OR MDST, MM-LAMD & ≤ 1-2 cm W/ SOME REDDISH DOLSTS IN [symbol]. [symbol], [symbol] INCR UP. SPARSE [symbol]. ⊙ ≤ ½ mm.

MED-DK GRAY MD/WKST, BDD ≤ 1-3 cm W/ ≤ 5% BROWN DOLSTS MOSTLY IN [symbol] & ≤ 1-3 mm INTERLAMS. SPAR [symbol] ALSO

GRAY LS MDST W/ ~20 cm OF STS AT BASE. [symbol] THRU-OUT

GRAY LS VF AREN & STS W/ TAN DOLSTS, BOTH BDD ≤ 1-2 cm TO MM-LAMD. [symbol] (≤ ½ x 5 cm) OF STS IN OCCAS'L PK/GRST BEDS

[symbol] ORNG DOLSTS, MM-LAMD

GRAY LS VF & F AREN & ⊙ (≤ ¼ mm) GRST, BDD ≤ 2-15 cm W/ OCCAS'L DOLSTS IN [symbol] (≤ 3%). [symbol] IN TOP 20 cm

GRAY LS VF & F AREN, THKNNG FROM ≤ 1-3 cm UP TO ≤ 1-5 cm W/ BROWN DOLSTS IN [symbol] & INTERLAMS & BEDS THAN THINNG FROM ≤ 3-5 cm UP TO 1-2 cm. DOLSTS DECR UP ~45% TO ~15%. [symbol] ≤ ½ x ½ cm.

GRAY LS VF AREN W/ OCCAS'L ⊙ (≤ ½ mm) & ⊙ [symbol] (≤ 1 x 3 cm) [symbol] Ø (≤ ½ cm) GRST, BDD ≤ 1-7 cm, W/ REDDISH-DOLSTS IN [symbol] & INTERLAMS & BEDS ≤ 1-2 cm (~20-25%). [symbol] IN ⊙ GRST.

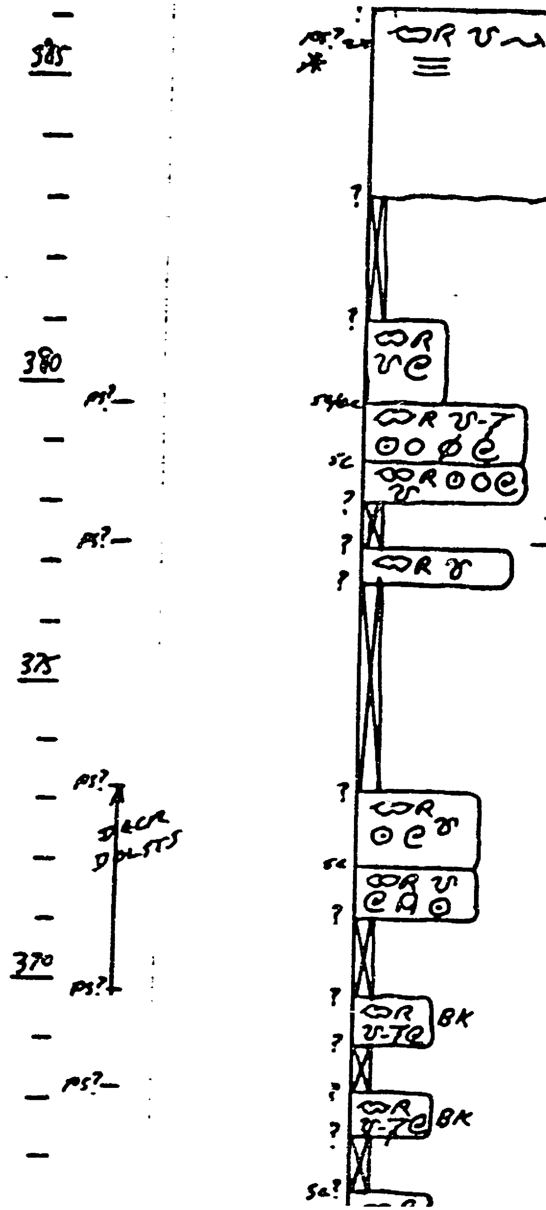
GRAY ⊙ (≤ ½-¼ mm), BDD ≤ 2-5 cm & [symbol] ~5-15 cm, W/ BROWN DOLSTS IN [symbol] & DISCONT INTERLAMS ≤ 1 cm (~5-10% DOLSTS); MAKE UP TOP & BTM UNITS. MDL IS ≈ 50 cm OF ALTERNATING ⊙ GRST & ORNG DOLSTS, BOTH BDD ≤ 1-3 cm, ~50% OF EACH.

GRAY LS AREN & ⊙ (≤ ½ mm) GRST, BDD ≤ 1-10 cm W/ ORNG-BROWN DOLSTS IN [symbol] & OCCAS'L INTERLAMS & INTERBEDS ≤ 1-3 cm (~10-15%)

COVER

MED-DK GRAY MD/WKST W/ ≤ 10% BROWN DOLSTS IN [symbol]. VERY LIKE 343 m

MED-DK GRAY GRST, BDD ≤ 2-10 cm W/ ~10% BROWN DOLSTS IN [symbol] & INTERLAMS. ⊙ ≤ ¼-½ mm. [symbol] ≤ ½ x 4 cm. Ø ≤ ½ cm.




MED DK GRAY LS VF AREN/STS, BDD ≤1-2 cm W/ TAN & BROWN DOLSTS IN ℧ & INTERLAMS (CONT.) ≤5 mm. ~10% DOLSTS. SOME SPAR-℧ IN TOP 50 cm.
*SURFACE W/ MORE ℧ & LESS DOLSTS IN BELOW THAN ABOVE. MAY BE A PARASEQ. BOUNDARY

COVER

MED-DK GRAY MD/WKST, BDD ≤1-5 cm W/ ORNG DOLSTS IN ℧ & INTERLAMS ≤1-3 mm (≤5-10%)

MED-DK GRAY PK/GRST BDD ≤1-4 cm W/ ≤5% ORNG DOLSTS IN ℧. ⊙ & ⊙ ≤ 1/4-1/2 mm. ∅ ≤1 cm

GRAY PK/GRST, BDD ≤1-3 cm, W/ ~30% REDDISH-ORNG DOLSTS IN ℧ & INTERLAMS ≤1 cm. ⊙ ≤ 1/4-1/2 mm, AS ARE ⊙

COVER

GRAY VF AREN/STS, BDD ≤1-4 cm, W/ ORNG DOLSTS (≤5%) IN ℧ & INTERLAMS ≤1-3 mm

COVER

MED-DK GRAY WK/PKST, BDD ≤1-5 cm, W/ ORNG DOLSTS IN ℧ & IRREG INTERLAMS ≤1 cm; ~5-10% DOLSTS

GRAY WK/PKST, BDD ≤1-3 cm, W/ ~25-30% REDDISH-ORNG DOLSTS IN ℧ & INTERLAMS ≤1 cm

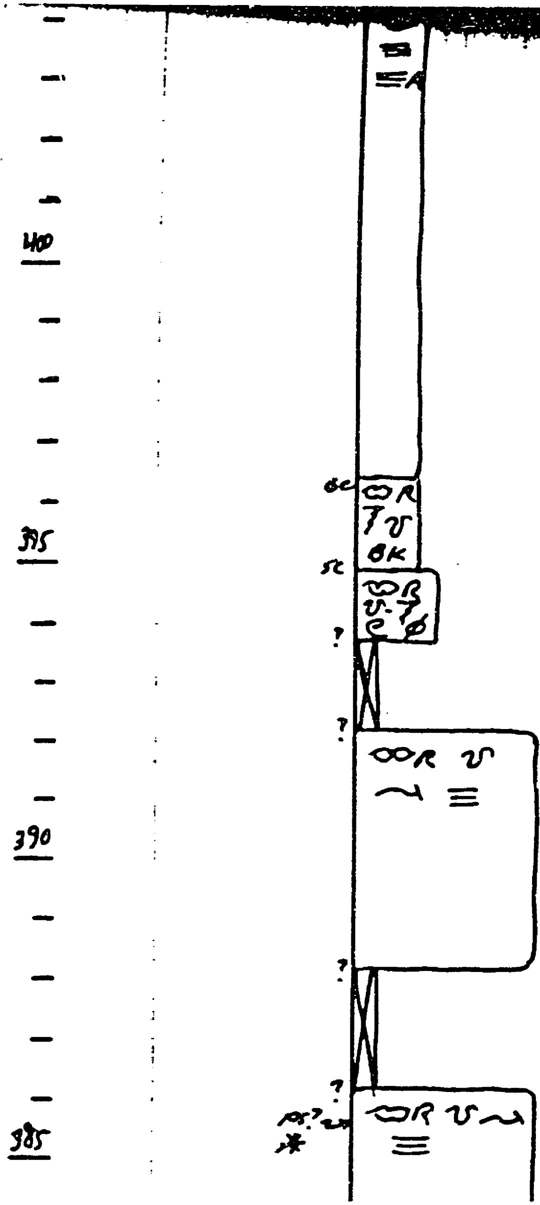
COVER

LIKE 361 m, LS BDD ≤1-5 cm W/ ≤5-7% DOLSTS IN ℧. SPAR-℧

COVER

MED-DK GRAY MD/WKST LIKE 361 m. W/ ONLY ≤5% DOLSTS IN ℧. SPAR-℧

COVER




LT GRAY LS MDST, ADD MOSTLY ≤1-2 cm w/ SOME ≤1-5 cm. ≡, ≡A NOT WELL DEVELOPED

GRAY MDST & GREENISH-BROWN DOLSTS IN ʊ. TEXTURE LOOKS ALMOST A-LIKE. SPAR-ʊ ALSO

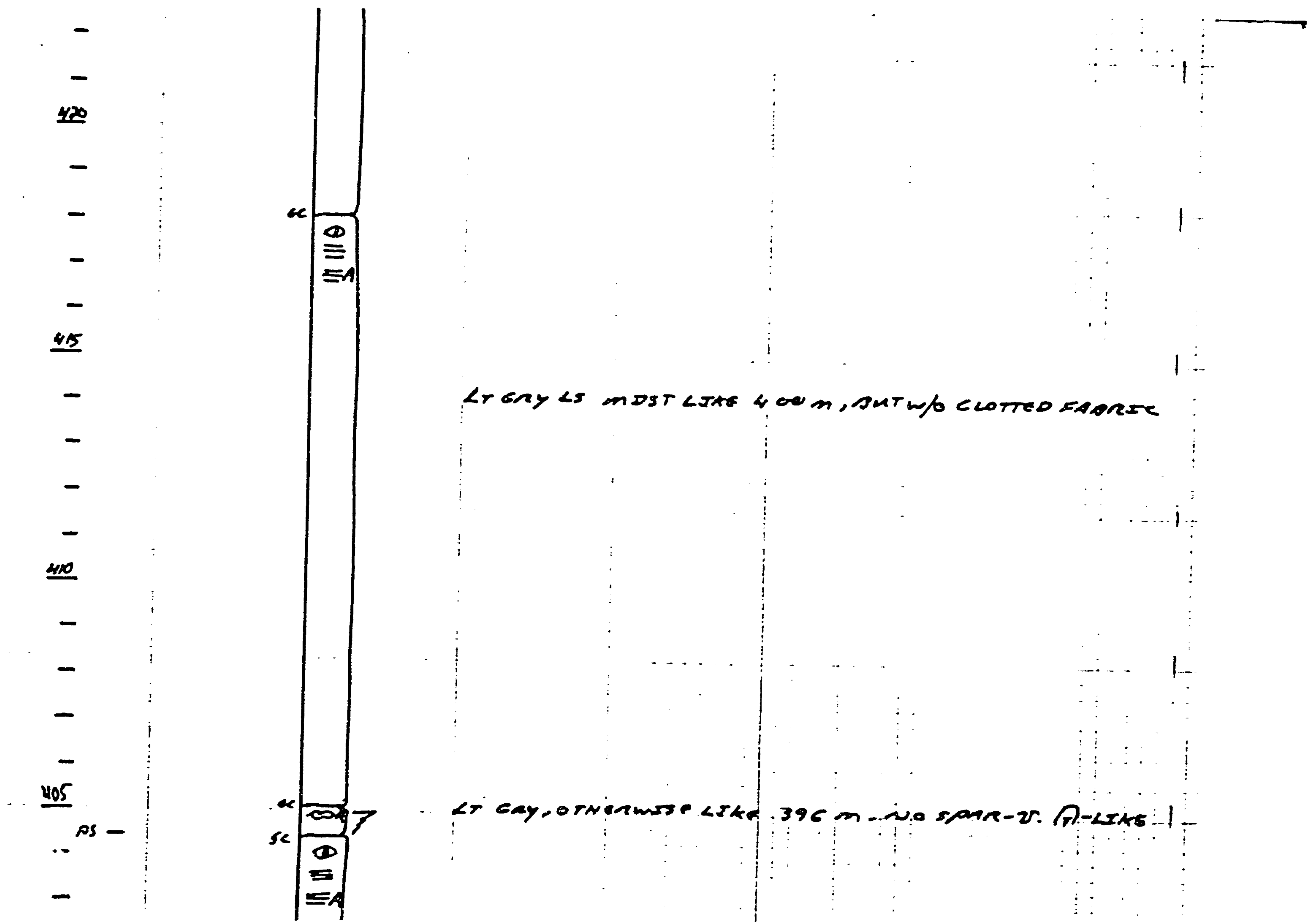
MED-DK GRAY LS MD/WKST, ADD ≤1-4 cm W/~10% REDDISH-ORNG DOLSTS IN ʊ

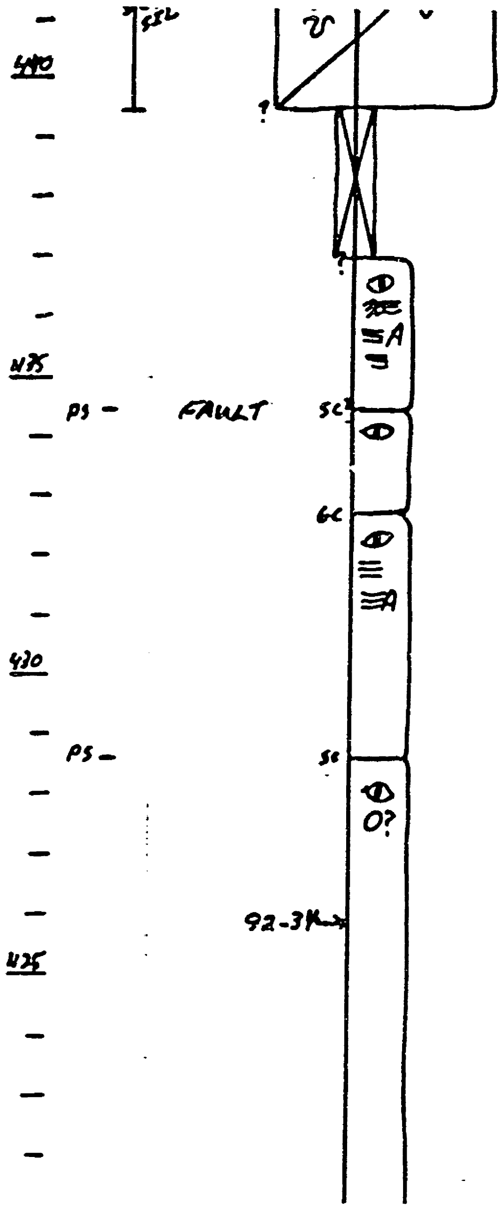
COVER

LIKE 384 m

COVER

MED DK GRAY LS VF ARENI/STS, ADD ≤1-2 cm w/ TAN & ARENI DOLSTS IN ʊ & INTERLAMS (CONT.) ≤5 mm. ~10% DOLSTS.


420
415
410
405
PS
LT GRAY LS MOST LIKE 400 m, BUT w/o CLOTTED FABRIC
LT GRAY, OTHERWISE LIKE 396 m - NO SPAR-V. (T)-LIKE




TOLS INCR FROM ≈ 5-10% UP TO ~50-60% IN TOP ~ 1 m

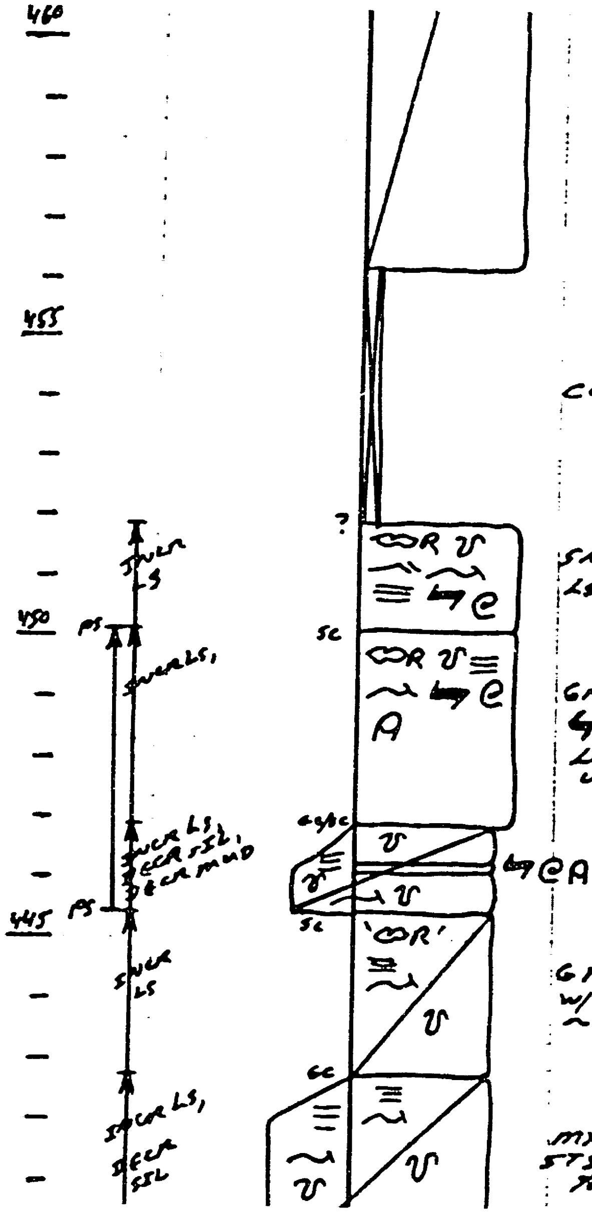
COVER, W/ SOME ORNG DOLSTS SHOWING THRU W/ ≡, ≡A, & PS-30 cm OR ALKY ≡, ≡A, MICRO Ⓐ? OR ≡A? W/ Ⓣ?

LT GREENISH-GRY LS Ⓣ MDST, ADD ≤ 1-3 cm W/ BROWN DOLSTS ≤ 1 cm

GRY LS MDST LIKE 420 m

CREAMY, TAN Ⓣ MDST SIMILAR TO 415 m, ADD ≤ 1-5 cm, MOST ≤ 1-2 cm; W/ OCCASIONAL & DISCONT INTERLAMS OF REDDISH-ORNG DOLSTS

GRY LS MDST W/ CLOTTED-O TEXTURE. O ≤ ½ mm. LESS ≡, ≡A & Ⓣ LESS WELL ORGANIZED INTO LAYERS




COVER

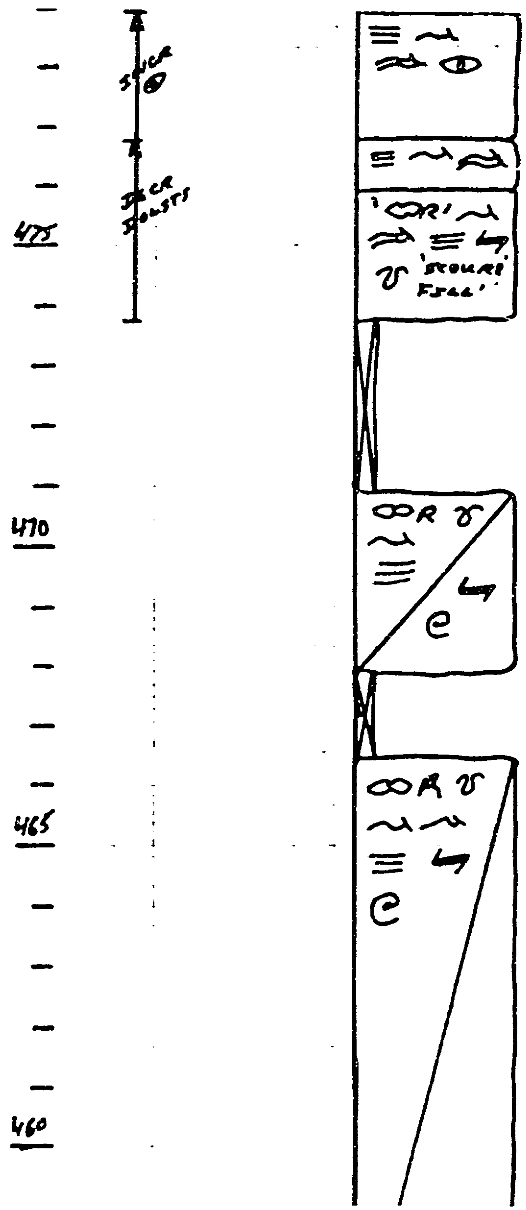
SAME LITHS AS 458M. ALL LITHS BDD ≤ 1-2cm. ≤ 1x1cm. LS INCR FROM ~45-50% UP TO ~70%

GRY LS STS & VF AREN, BDD ≤ 1-3cm, MOST ≤ 1-2cm) & OCCAS'L (≤ 1x4cm) @ A PAST BEDS 7-8cm THK. W/ DOLSTS IN ℧ & INTERLAMS ≤ 1-2cm. GREEN LS STS IN BTM 50 cm. LS INCR UP FROM ~55% TO ~70%. NO # SEEN.

@ A REDDISH-BROWN QTZ STS & DOLSTS W/ OCCAS'L GREEN LS STS, ALL BDD ≤ 1-2cm W/ A 10-cm BED OF (≤ 1x4cm) @ A PART IN THE MIDDLE. LS INCR UP FROM ~5% LS TO ~30% LS

GREEN LS STS & BROWNISH-ORNG DOLSTS, BOTH BDD ≤ 1-2cm W/ DOLSTS IN INTERLAMS & ℧. LS INCR UP FROM ~50-60% UP TO ~65%. NO # SEEN

MXT REDDISH-BROWN QTZ STS & DOLSTS W/ OCCAS'L LS STS INTERBEDS, MUCH IN MM-LAMS & BEDS ≤ 1-2cm. %LS INCR UP FROM ≤ 5-10% UP TO ~50-60% IN TOP 20cm




SAME AS 476 m w/ APPEARANCE OF ⊕. SOME ADDS ≤10cm, w/ ⊕ ARE FINING UP

GRY LS VF AREN & STS, ADD ≤ 3-15 cm w/ ALMOST NO DOLSTS (≤2%)

GRY LS AREN & STS, ADDS ≤ 1-10 cm w/ REDDISH-ORANGE DOLSTS (<10%), ADDS 1cm: FEW ⊽. SCOUR/FILL ~17 cm HT × 1.7 m WIDE

COVER

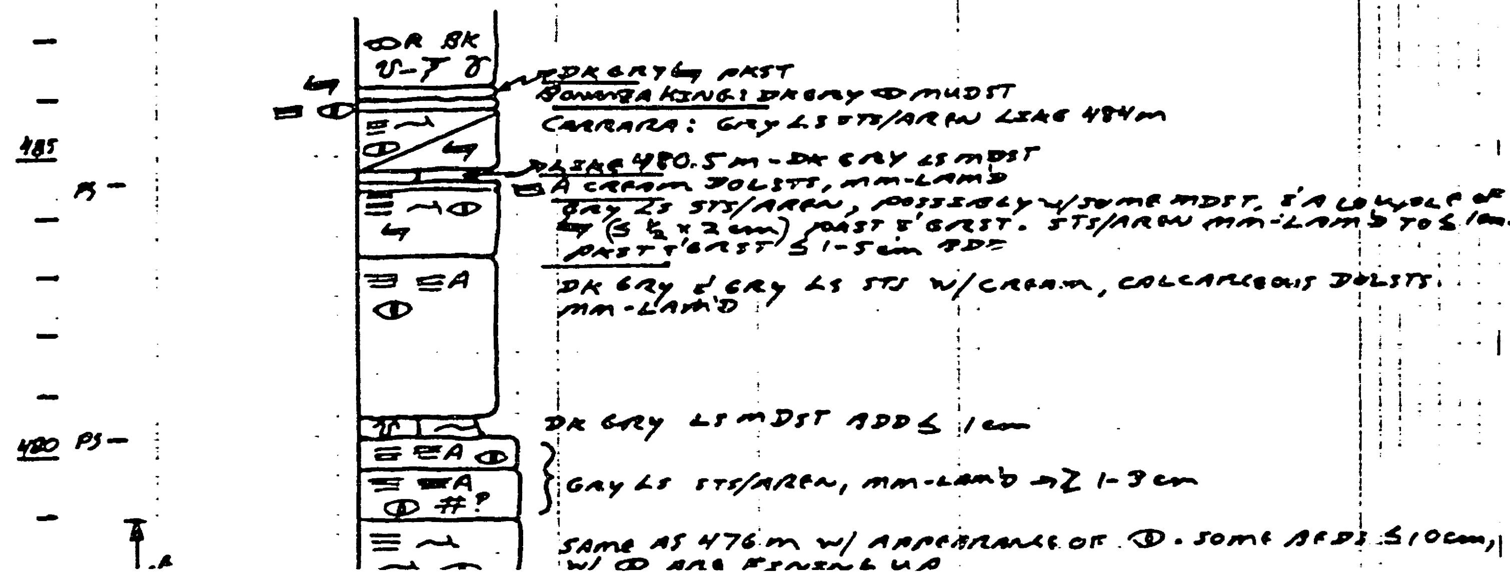
GRY LS STS & AREN, ADDS 1-4 cm & OCCAS'L (≤1×2 cm) PKST ADD ≤1-10 cm, w/ DOLSTS (~5-10%), ADD ≤ 1cm.

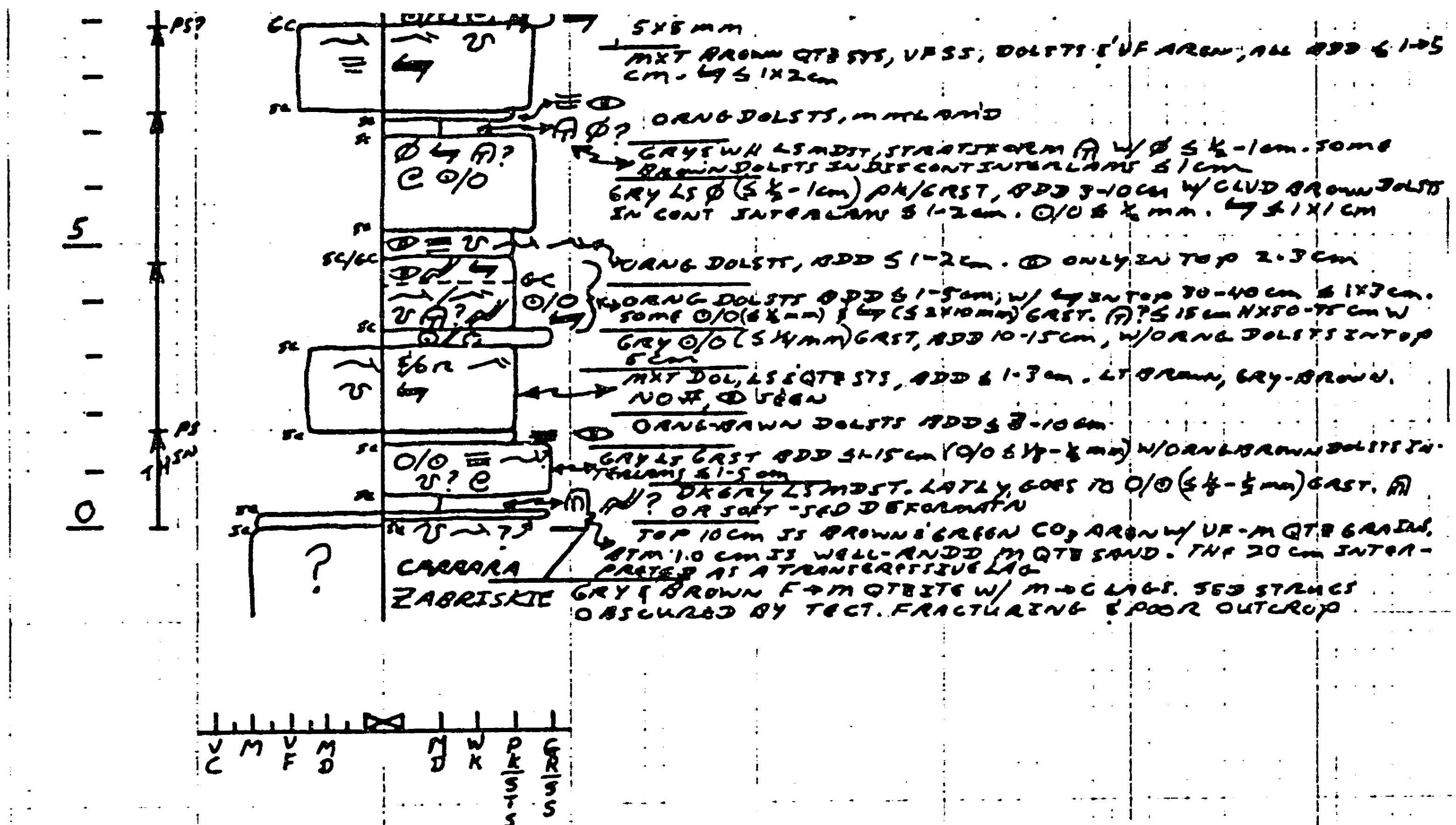
COVER

SAME LITHS AS 448 m. LS ADDS 1-3 cm, DOLSTS ADD ≤1cm, PKST ADD ≤1-8 cm. DOLSTS VARIES FROM ~5→20%. ≤1×2 cm

SECTION 92-4

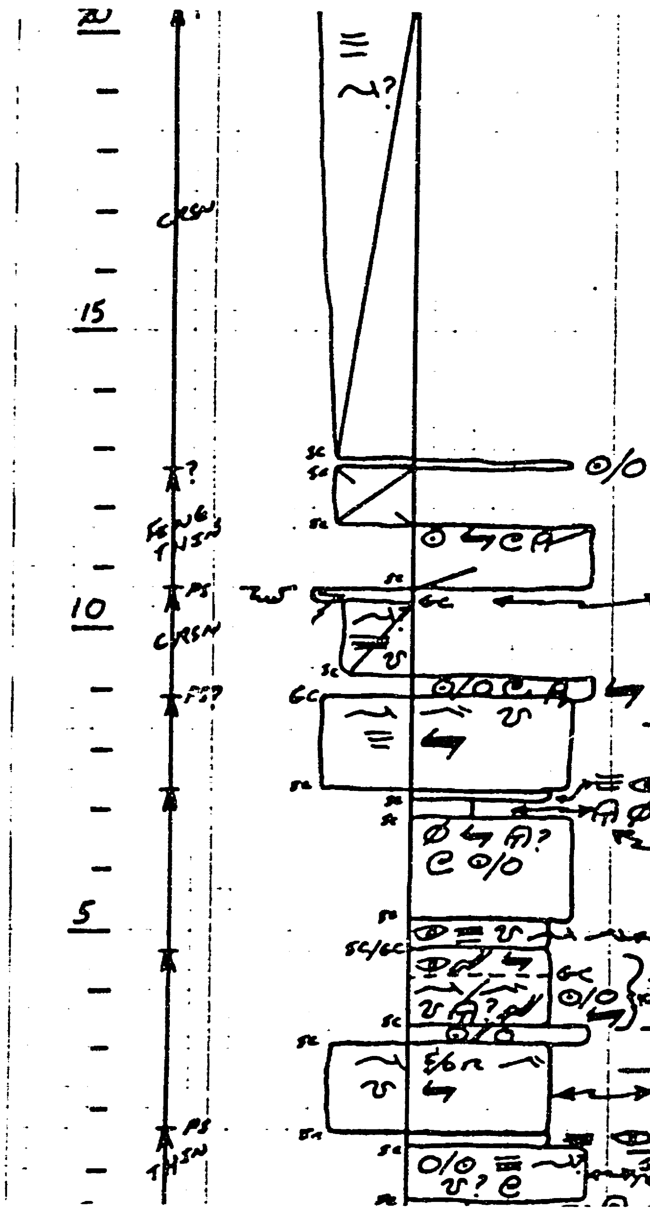
TITUS & TITANOTHERE CYNS, CALIF






SECTION 92-5

LAST CHANGE RNG, CALIF



GREENISH-BROWN PK/GRST, ADD 3-10cm W/ DOLSTS INTERLAMS ≤1-3mm. O/O ≤ 1mm

GREEN, MSC, CHLRTC, SANDY MDST CRSNUPTO MUDDY SS, ADD ≤ 1cm. CLVD.

BROWN O/O (≤ ½ mm) PK/GRST

GREEN, CLVD, CHLRTC, MSC, SANDY MDST/MUDDY SS

GREENISH-BROWN GRST, ADD ≤ 1-20cm. O ≤ 1mm. ≤ 2x8cm

GREEN, MSC, MUDDY VF-F SS

GREEN, MSC, CHLRTC, CLVD, SANDY MDST, ADD ≤ 1cm

MXT GREEN LS VF, F AREN & O (≤ cm) GRST, ODD ≤ 2-10cm. ≤ 5x5mm

MXT BROWN QTZ SS, VF SS; DOLSTS & VF AREN; ALL ADD ≤ 1-5 cm. ≤ 1x2cm

ORNG DOLSTS, MMLAMD

GRY & WH LS MDST, STRATIFORM A W/ Ø ≤ ½-1cm. SOME BROWN DOLSTS IN DISCONT INTERLAMS ≤ 1cm

GRY LS Ø (≤ ½-1cm) PK/GRST, ADD 3-10cm W/ CLVD BROWN DOLSTS IN CONT INTERLAMS ≤ 1-2cm. O/O ≤ ½ mm. ≤ 1x1cm

ORNG DOLSTS, ADD ≤ 1-2cm. ONLY IN TOP 2-3cm

ORNG DOLSTS ADD ≤ 1-5cm; W/ IN TOP 30-40cm ≤ 1x3cm. SOME O/O (≤ ½ mm) & (≤ 2x10mm) GRST. A? ≤ 15cm HX50-75cm W

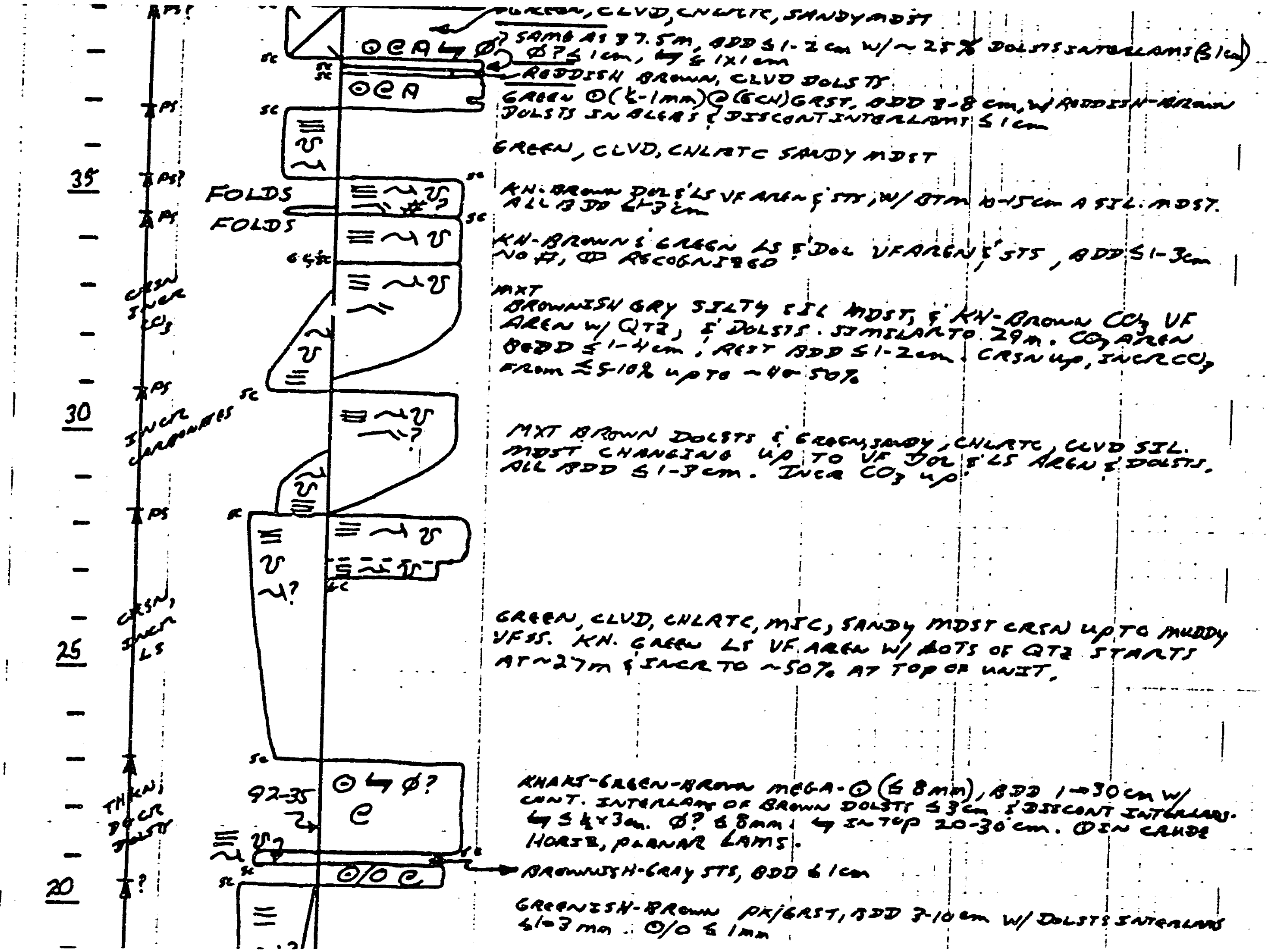
GRY O/O (≤ ½ mm) GRST, ADD 10-15cm, W/ ORNG DOLSTS IN TOP 5cm

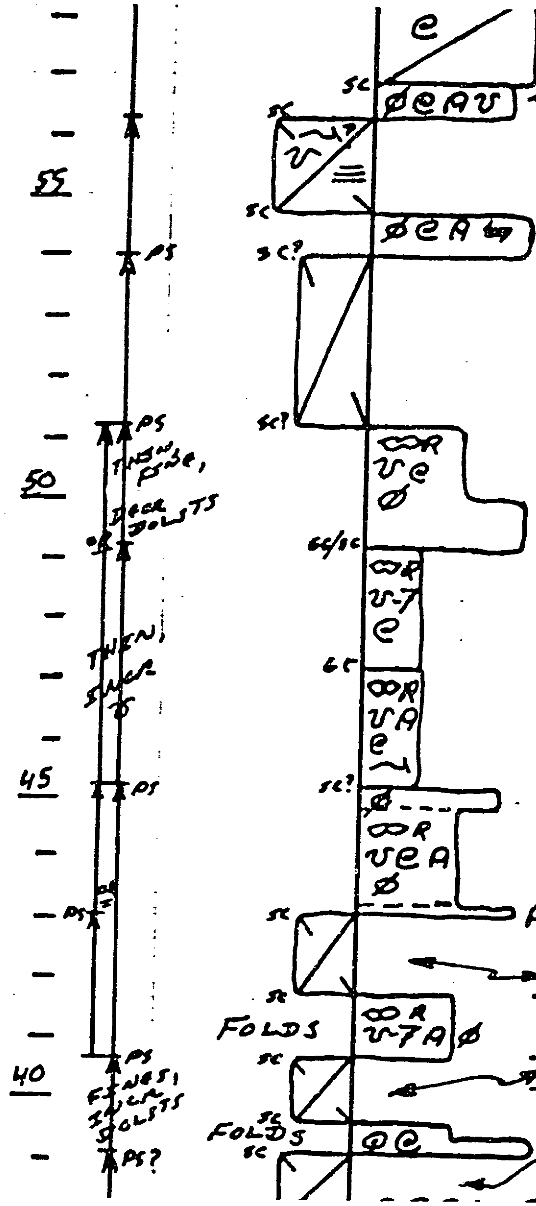
MXT DOL, LS & QTZ SS, ADD ≤ 1-3cm. LT BROWN, GRY-BROWN. NO #, SEEN

ORNG-BROWN DOLSTS ADD ≤ 3-10cm

GRY LS GRST ADD ≤ 1-15cm (O/O ≤ ⅛-⅛ mm) W/ ORNG-BROWN DOLSTS INTERLAMS ≤ 1-5cm

DK GRY LS MDST. LATLY GOES TO O/O (≤ ⅛-⅛ mm) GRST. A


35
30
25
20
FOLDS
FOLDS
CRSN INCR CO3
INCR CARBONATES
CRSN, INCR LS
GREEN, CLVD, CHLRTC, SANDY MDST
SAME AS 37.5m, BDD ≤1-2cm W/~25% DOLSTS INTERLAMS (≤1cm)
Ø? ≤1cm, ↳ ≤ 1X1cm
REDDISH BROWN, CLVD DOLSTS.
GREEN ⊙(½-1mm) ⊙(≤CM) GRST, BDD 3-8 cm, W/ REDDISH-BROWN DOLSTS IN BLEBS & DISCONT INTERLAMS ≤1cm
GREEN, CLVD, CHLRTC SANDY MDST
KH-BROWN DOL & LS VF AREN & STS, W/ BTM 10-15cm A SIL. MDST. ALL BDD ≤1-3cm
KH-BROWN & GREEN LS & DOL VF AREN & STS, BDD ≤1-3cm NO #, ⊙ RECOGNIZED
MXT BROWNISH GRY SILTY & SIL MDST, & KH-BROWN CO3 VF AREN W/ QTZ, & DOLSTS. SIMILAR TO 29m. CO3 AREN BDD ≤1-4cm, REST BDD ≤1-2cm. CRSN UP, INCR CO3 FROM ≤5-10% UP TO ~40-50%
MXT BROWN DOLSTS & GREEN, SANDY, CHLRTC, CLVD SIL. MDST CHANGING UP TO VF DOL & LS AREN & DOLSTS. ALL BDD ≤1-3cm. INCR CO3 UP.
GREEN, CLVD, CHLRTC, MIC, SANDY MDST CRSN UP TO MUDDY VFSS. KH. GREEN LS VF AREN W/ LOTS OF QTZ STARTS AT ~27m & INCR TO ~50% AT TOP OF UNIT.
KHAKI-GREEN-BROWN MEGA-⊙ (≤8mm), BDD 1-30cm W/ CONT. INTERLAMS OF BROWN DOLSTS ≤3cm & DISCONT INTERLAMS. ↳ ≤ ½×3cm. Ø? ≤8mm. ↳ IN TOP 20-30cm. ⊙ IN CRUDE HORIZ, PLANAR LAMS.
BROWNISH-GRAY STS, BDD ≤1cm
GREENISH-BROWN PK/GRST, BDD 3-10cm W/ DOLSTS INTERLAMS ≤1-3mm. ⊙/⊙ ≤ 1mm




MIXED GREEN LS STS & VF MDST w/ SOME GONE PKST & BROWN DOLITS. PKST BDD ≤ 1-3 cm. REST BDD ≤ 1 cm.

GREEN PKST, BDDS ≤ 1-3 cm w/ BROWN DOL. STS IN Ʊ & INTER-LAMS ≤ 1 cm. @ ECH. Ø ≤ ½ x 3 cm, DISCOIDAL

GREEN & BROWN, MUDDY MSC, BADLY CLVD VF SS w/ SOME BROWN $CO_3$-CMTD BEDS

GREEN PK/GRST, BDD 3-10 cm. ≤ 1x3 cm. Ø ≤ 1½ cm. @ ECH

GREEN, CLVD, CHLRTC, SANDY MDST w/ A FEW BROWN, $CO_3$-CMTD VF SS INTERBEDS ≤ 1-2 cm.

GRY LS PK/GRST FINES UP TO @ WKST, BDD ≤ 2-10 cm, w/ ORNG DOLSTS IN Ʊ & DISCONT & CONT INTERLAMS ≤ 1 cm. Ø ≤ 1 cm

GRY MDST w/ ORNG DOLSTS IN Ʊ & LARGE BLEBS & DISCONT LAMS, BOTH BDD ≤ 1-2 cm

GREENISH-GRY MDST. & OCCAS'L @ PK/GRST BEDS, BOTH BDD ≤ 1-4 cm, w/ ORNG DOLSTS IN Ʊ & CONT LAMS ≤ 1 cm. SOME ...

GREEN Ø (≤ ½ x 4 cm) PKST BDD ≤ 1-3 cm, w/ ~15% DOLSTS IN Ʊ & CONT INTERLAMS. Ø ARE DISCOIDAL FOR ~2 m INTERVAL

GRY LS WKST, BDD ≤ 2-5 cm, w/ ORNG DOLSTS (~15%) INTERLAMS ≤ 1 cm. Ø ≤ 1 cm

A GREEN A PK/GRST IN A 10 cm BED

GREEN, CLVD, CHLRTC, SANDY MDST

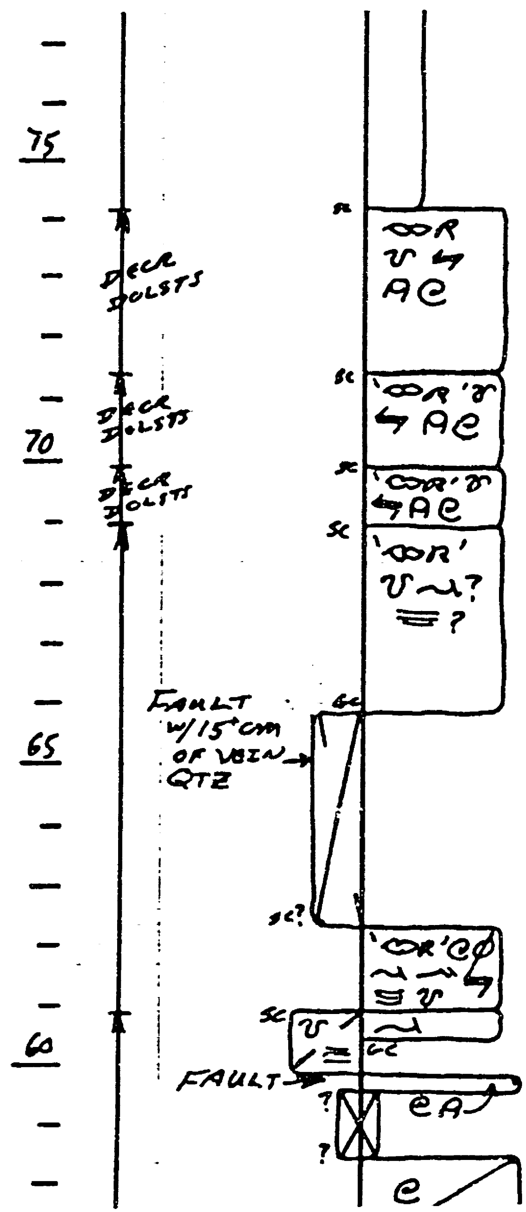
GREEN WKST, BDDS 1-4 cm w/ ORNG DOLSTS, ~20%, IN IRREG, OFTEN DISCONT INTERLAMS ≤ 1-2 cm

GREEN, CLVD, CHLRTC, SANDY MDST

GREEN LS GRST FINES UP TO MDST. GRST BDD ≤ 10 cm, MDST BDDS ≤ 1-20 cm, w/ BROWN DOLSTS INTERLAMS IN UPPER PARTS ... Ø ½-1 mm @ ECH & OTHERS

GREEN, CLVD, CHLRTC, SANDY MDST

SAME AS 37.5 m BDD ≤ 1-2 cm w/ ~25% DOLSTS INTERLAMS ...




DISCONT INTERLAMS

SAME AS 69.5m EXCEPT PAST & PK/CRST ADD ≤ 2-8cm, DOL ADD ≤ 1-3cm & DOLSTS DECR UP FROM ~60% TO ~15%

SAME AS 69.5m, EXCEPT DOLSTS ADD ≤ 1-4cm W/DECR FROM ~50% TO ~25%

GREEN LS STS & (≤ ¼x1cm) & @(ECH) PAST, BOTH ADD ≤ 1-4 cm, W/ ORNG DOLSTS IN CONT INTERLAMS ≤ 1-2cm. DOLSTS DECR UP FROM ~40% TO ~15%

GREEN, CLVD LS STS, ADD ≤ 1-3cm, W/ ~25% ORNG-BROWN DOLSTS INTERLAMS ≤ 1-2cm. NO #, ⊕ RECOGNIZED, POSSIBLY DUE TO CLEAVAGE.

SILVER, CHLRTC SCHIST/SILTY SH W/SOME GREEN CHLRTC SILTY SH

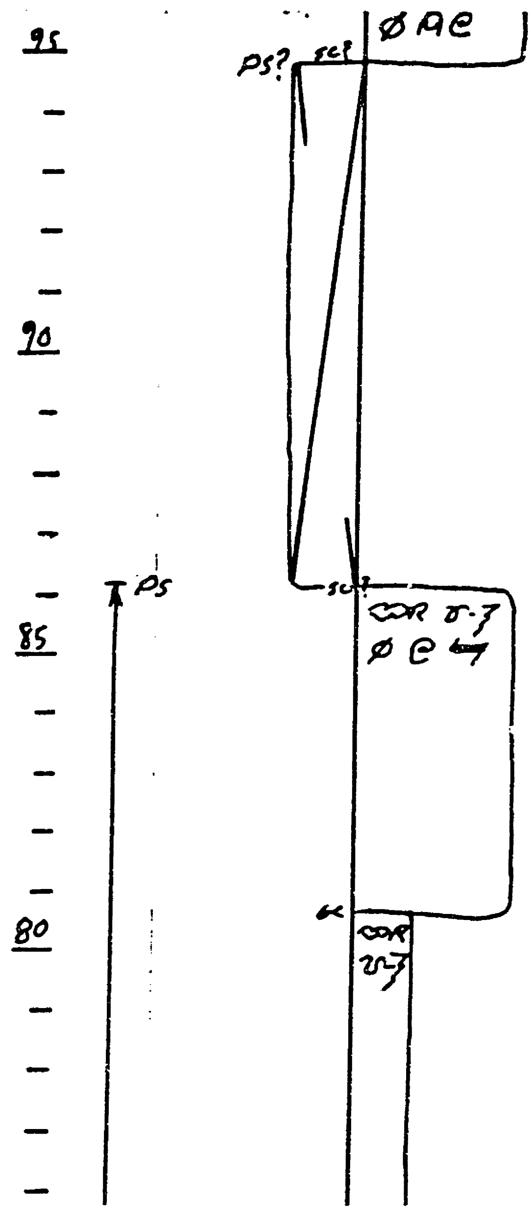
GREEN & BROWN LS & DOL STS, ADD ≤ 1-2cm, W/A FEW @(ECH) ∅(≤1cm) (≤1x8cm) PK/CRST BEDS, ≤ 5-10cm THK. MOST ≤ ½x3cm.

GRY-GREEN, CLVD CHLRTC SANDY MDST W/~35% BROWN DOL/LS STS, ADD ≤ 1cm, MOSTLY IN UPPER ½

MOSTLY VEIN QTZ & SILVER MICA/CHLORITE SCHIST. ALSO HAVE ≥ 5-10cm OF GREEN AC PK/GRST

COVER. PROBABLY CHLRTC, CLVD, SANDY SIL MDST LIKE 52m.

MIXED GREEN LS STS & VF ARGN W/ SOME GON@ PAST & BROWN DOLSTS - ...

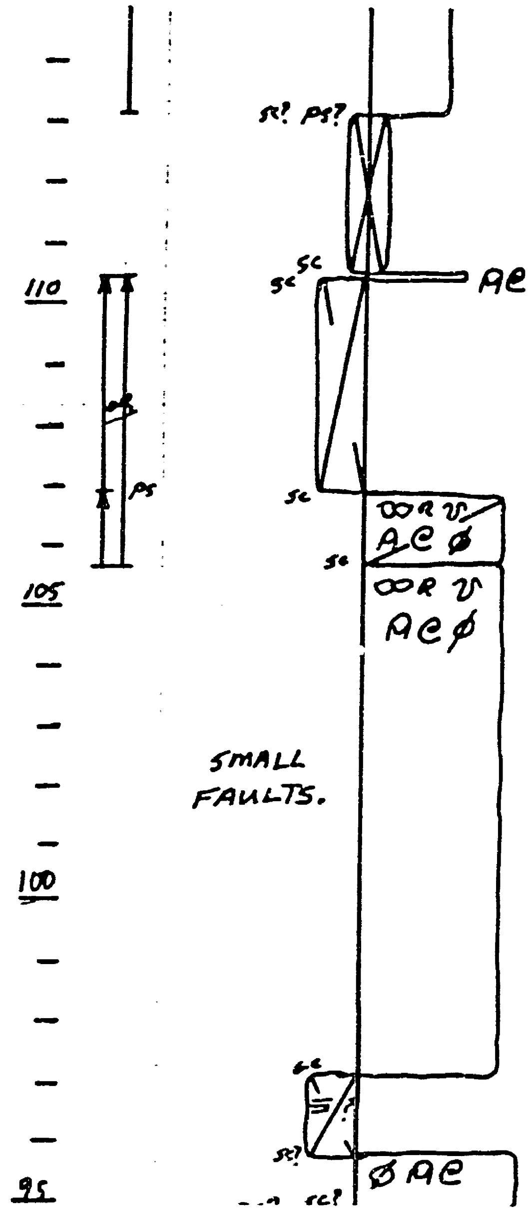



GREEN LS PK/GRST, BDD 5-10cm, W/ BROWN DOLSTS IN DISCONT, IRREG INTERLAMS. @ ECN. Ø ≤ 1cm

GRY, SILVGRY, SCHISTOSE, CHLRTC, SANDY MDST, MOSTLY COVERED EXCEPT NEAR TOP

GRY LS PK/GRST & PKST & PROBABLY LS STS, ALL BDD ≤ 1-4cm, W/ DOLSTS (ORNG) IN V & IRREG, ALGBDY, DISCONT. INTERLAMS ≤ 1cm

MED DK GRY LSMDST W/ ORNG DOLSTS, BOTH BDD ≤ 1-2cm. DOLSTS ~5-10%, IN V & IRREG ALGBS & DISCONT INTERLAMS




DECR UP ~ 25-30% TO ≤ 5 1/10 % & IS ONLY IN ∇ IN TOP.

COVER, BUT SOME GREEN, CHLRTC, SILTY SH IN BTM 20-30cm

GREEN LS WKST, 2 BEDS 3-4cm & 6-7cm

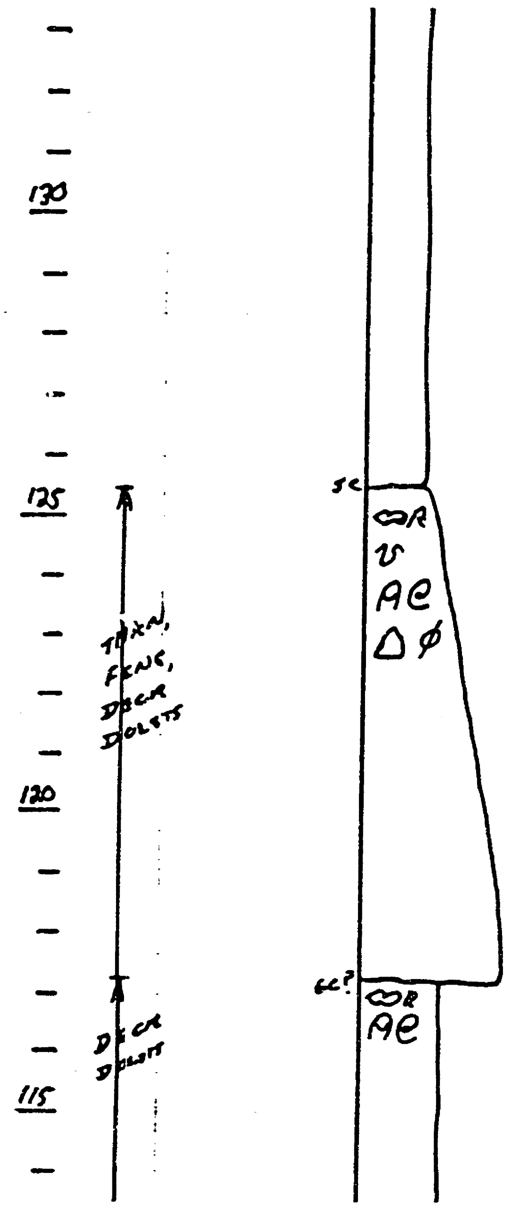
GREEN & TAN, CLVD, CHLRTC, MIC, SILTY SH

SAME AS 107m, EXCEPT LS BDD ≤ 1-2cm EXCEPT FOR 2 PK/GRST BEDS NEAR TOP, BDD 5 & 8cm.

GRY LS STS & WKST, PKST, & PK/GRST, ALL BDD ≤ 1-8cm, W/ ORNG DOLSTS IN ∇ & INTERLAMS ≤ 1-2cm. ~15-25% DOLST. AE CHS & OTHERS: Ø ≤ 1cm. DID NOT ATTEMPT TO PICK CYCLES DUE TO FAULTING.

GREEN & TAN SILTY SH, MM-LAMD?

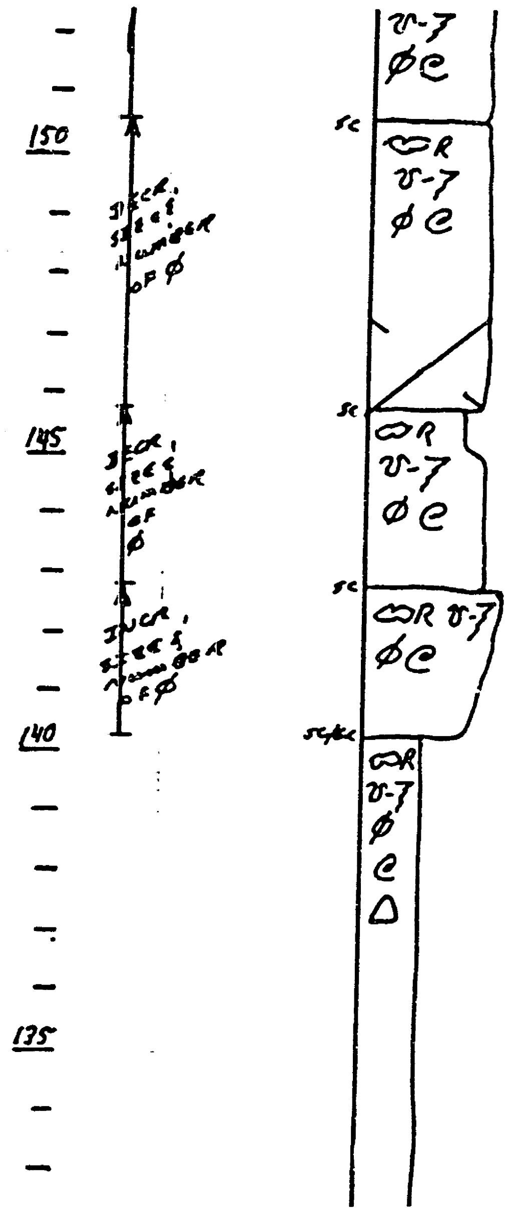
GREEN LS PK/GRST, BDD 5-10cm, W/ BROWN DOLSTS IN




DOLSTS IN Ʊ: IRREG BLEBS, & IRREG, DISCONT INTERLAMS ADD ≤ ½ cm. ≤5-10% DOLSTS. OCCASL SPAR-Ʊ RARE @. ø UNCOMMON I'S ≤ 1 cm

GRY TO MED-DK GRY PKST FINING UP TO MDST, BOTH ADD 2-5 cm UP TO 2-10 cm, W/TAN GOING UP TO ORNG DOLSTS IN Ʊ'S INTERLAMS ≤ 1-2 cm. DOLSTS DECR UP FROM ~35% TO ≤5-10%. @ ECH. ø ≤ 1½ cm. OCCASL SPAR Ʊ.

GRY MD/WKST W/OCCASL WK/PKSTS PKST, ALL ADD ≤ 1-5 cm, W/ORNG DOLSTS IN Ʊ'S INTERLAMS ≤ 1-2 cm. DOLSTS DECR UP ~25-30% TO ≤ 5-10% & IS ONLY IN Ʊ IN TOP.



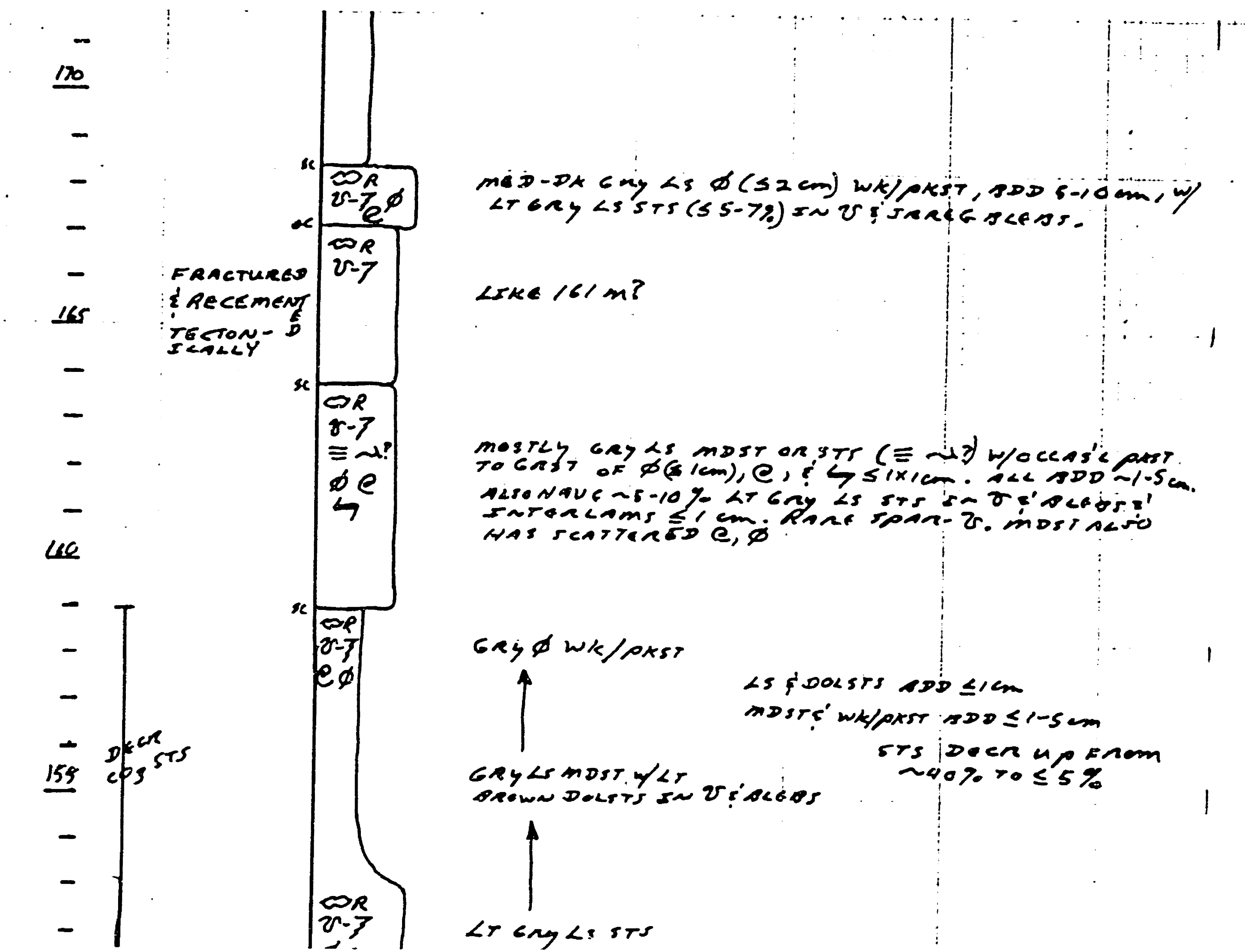

LT GRAY LS STS

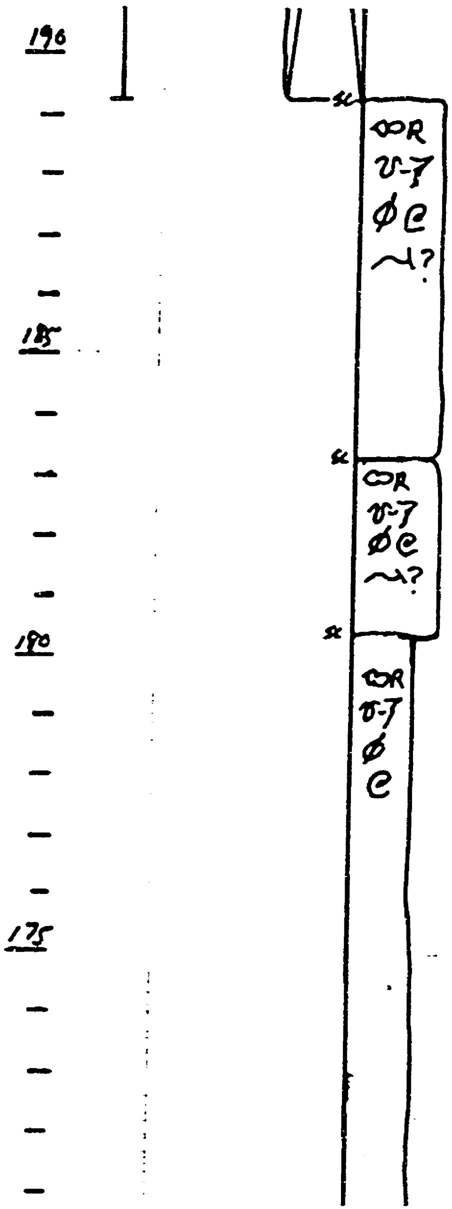
SAME AS 144m. Ø ≤ 4 cm.

GRAY Ø (≤ 2½ cm) WKST TO PKST, ADD ~2-5? cm, w/ LT BRWN DOLSTS LIKE 141 m. OCCAS'L SPAR-V

GRAY Ø (≤ 3 cm) WKST TO PKST, ADD ~2-5? cm, w/ ≤5% LT. BROWN DOLSTS IN V'S & IRREG BLEBS. OCCAS'L SPAR-V

MED-DK GRAY LS MDST ADD ≤1-5 cm, w/ TANNISH-BROWN DOLSTS IN V'S, IRREG BLEBS, & IRREG, DISCONT INTERLAMS, ADD ≤ ½ cm. ≤5-10% DOLSTS. OCCAS'L SPAR-V

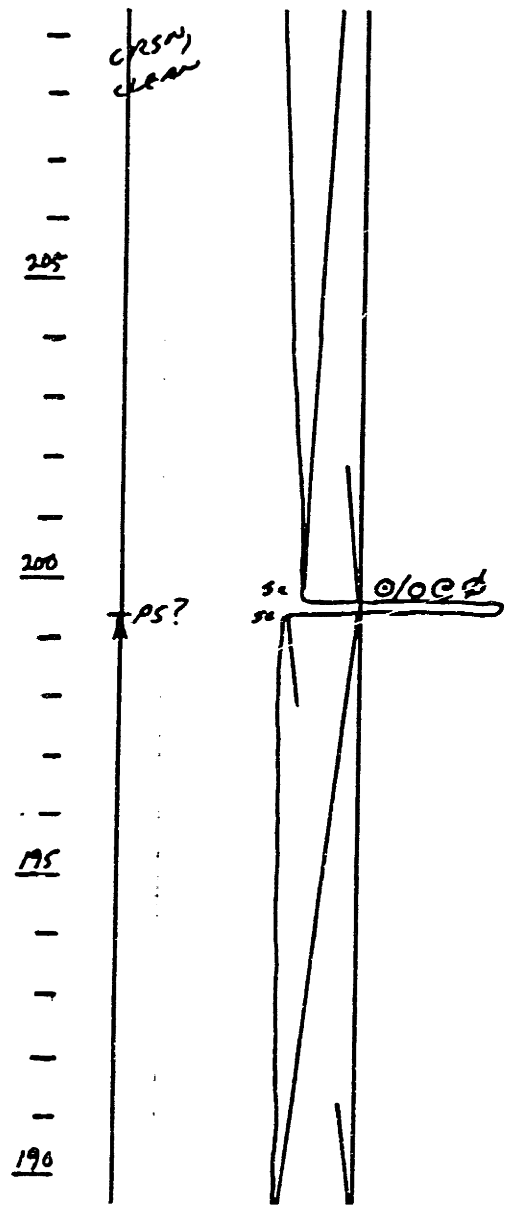

170
165
160
159
FRACTURED & RECEMENTED TECTONICALLY
DECR COS STS
MED-DK GRY LS Ø (≤2cm) WK/PKST, ADD 5-10cm, W/ LT GRY LS STS (≤5-7%) IN V & IRREG BLEBS.
LIKE 161 m?
MOSTLY GRY LS MDST OR STS (≡ ~?) W/OCCAS'L PKST TO GRST OF Ø(≤1cm), @, & ≤1X1cm. ALL ADD ~1-5cm. ALSO HAVE ~5-10% LT GRY LS STS IN V & BLEBS & INTERLAMS ≤1 cm. RARE SPAR-V. MDST ALSO HAS SCATTERED @, Ø
GRY Ø WK/PKST
LS & DOLSTS ADD ≤1cm
MDSTS & WK/PKST ADD ≤1-5cm
STS DECR UP FROM ~40% TO ≤5%
GRY LS MDST W/LT BROWN DOLSTS IN V & BLEBS
LT GRY LS STS




SAME LITHS AS 182M, EXCEPT ~10-20% STS, W/STS ORNG DOLSTS IN TOP 3 M.

MD-DK GRY LS MDST, MD/WKST, & OCCAS'L STS (~?), BDD ~2-10 cm. W/~10% LT GRY LS STS IN V & ALGAL & INTERLAMS ≤ ½ cm. SOME 10 cm BEDS ARE ⊤ DOWN 5-8 cm. Ø ≤ 1 cm. SPAR-V COMMON

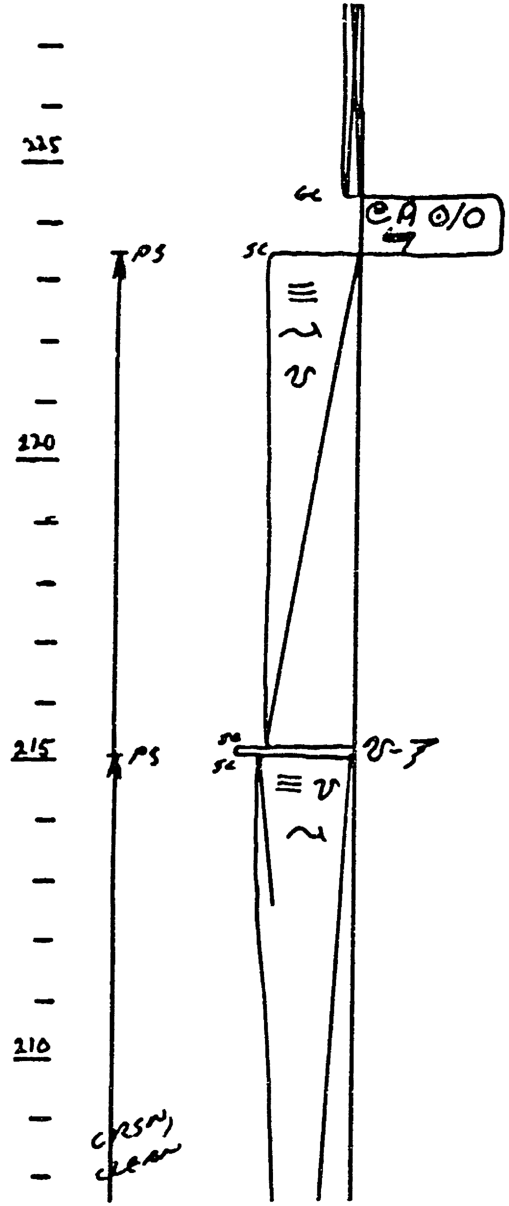
MOSTLY MED-DK GRY LS MDST W/OCCAS'L WKST TO PKST OF Ø (≤ 2 cm) & @, BDD ~3-10 cm, W/ TAN & LT GRY DOL & LS STS IN V & ALGAL & DISCONT INTERLAMS. COMMON TO ABUNDANT SPAR-V. Ø & @ SCATTERED IN MDST




GREEN, CLVD, MSC, CHLRTC, SANDY MDST UP TO
MUDDY SS, W/CLEAN VF SS BEDS IN UPPER ½;
MOSTLY CONCENTRATED IN TOP 1½-2M. BEDS ≤ 1-2cm

15 cm BED OF BROWN ⊙/O (≤ ½-1mm) C(ECH; OTHERS) PKST.
Ø ≤ 1cm

GREEN, CLVD, MSC., CHLRTC, SANDY MDST TO MUDDY VFSS



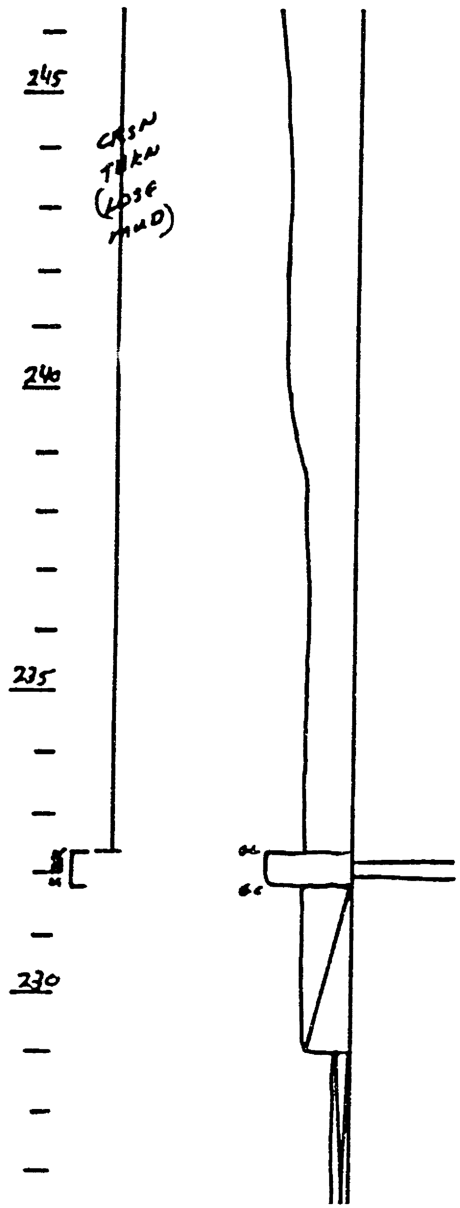

COVER. LATERALLY IS GREEN & BROWN, CLVD, CHLRTC SILTY, SANDY MDST W/ LS NODULES IN BTM 2m

GREEN & BROWN PKST, BDD ≤1-4cm. O/O ≤ ½-1mm. @ ECH + OTHERS. ≤ 2x3cm

GREEN, MSC, MUDDY VF ST, W/OCCASL CLEAN VF SS BEDS, ≤ 1-2cm

BROWN, CALC-CEMENTED VF, F QTZ SS. POSSIBLY ONE 15cm BED

GREEN, CLVD, MSC, CHLRTC, SANDY MDST UNTC



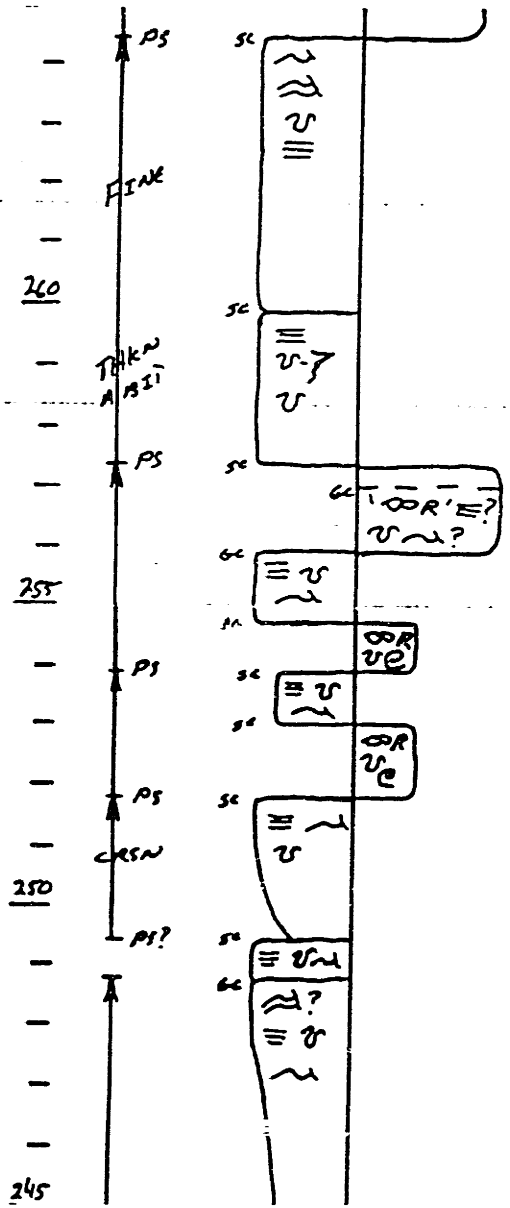

SANDY, CHLRTC, CLVD MDST

LWR 6 m MOSTLY COVERED & SILTY, CLVD CHLRTC SH

GREEN & BROWN, CLVD, MUDDY STS & VF SS W/SEVERAL GREEN LS @? WKST BEDS ~2cm THK.

GREEN & BROWN, CLVD, CHLRTC, SILTY SH

COVER. LATERALLY IS GREEN & BROWN, CLVD, CHLRTC SILTY, SANDL MDST ...




BROWN & GREEN, CHLRTC, MSC, CLEAN & MUDDY VF SS, BDD ≤ 1-5 cm

TAN MUDDY, MSC, VF SS, BDD ≤ 2-10

TOP 30 CM BLEACHED TO PALE GREY & TAN
ORNG DOLSTS, BDD ≤ 1-4 cm, W/~30% LS GREEN STS, BDD ≤ 1-2 cm. MUCH QTZ SILT IN BOTH.

GRY & BROWN MSC, MUDDY VF SS, BDD ≤ 1 cm

GREEN LS MDST, BDD ≤ ~2 cm, W/ORNG DOLSTS IN ?? & INTERLAMS ≤ 1 cm

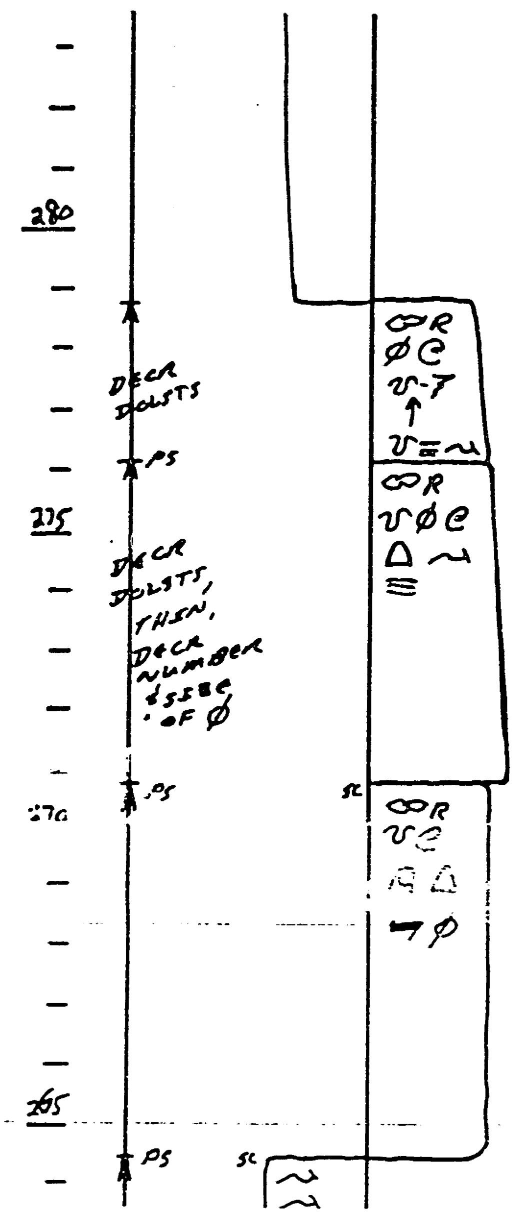
BROWN, MSC, MUDDY VF SS & SANDY MDST

MED-DK GRAY LS MDST, BDD ≤ 1-2 cm W/ORNG DOLSTS IN ?? & IRREG CONT INTERLAMS, ≤ 1 cm. ~20-25% DOLSTS.

GRY, BROWN & GREEN, CHLRTC, CLVD, SANDY MDST UP TO MUDDY SS; BDD ≤ 1-2 cm

BROWN VF SS, BDD 1-2 cm. MXT $CO_3$ & SIL CMT

GREEN, GRY & BROWN VF MUDDY, MSC, CLVD SS

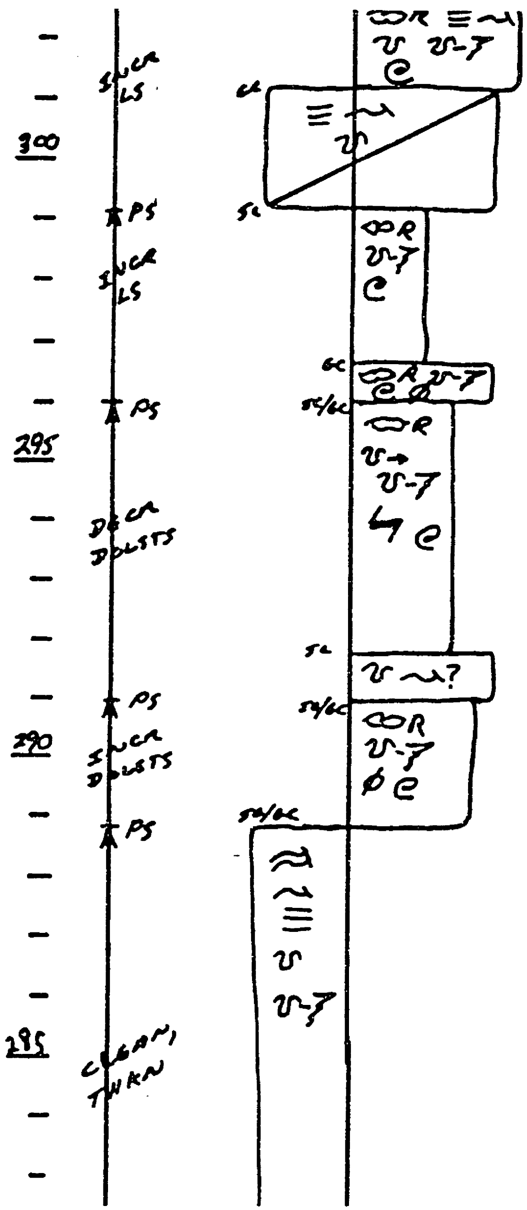



≡, ~, [illegible]

SAME LITHS AS 274 m, EXCEPT NO WK/PKST. LS ADD ≤ 1-3 cm, DOL ADD ≤ 1-2 cm. Ø ≤ 3 cm. DECR DOLSTS Up FROM 100% TO ~35-40%. ≡, ~ IN STS

GREEN & GRY LS WKST & WK/PKST, AEDD ≤ 2-6 cm AIN LWR PART, THIN up TO ≤ 1-2 cm. W/ORNG DOLSTS, ADD ≤ 2-5 cm, THIN up TO ≤ 1/cm. QTZ SILT IN STS. Ø ≤ 2½ cm. DOLSTS DECR up FROM ~90-95% TO ~35-40%. ~ & ≡ IN LWR DOLSTS

GREEN & GRY LS WKST TO PKST, ADD ≤ 1-5 cm W/ORNG DOLSTS IN [illegible] & INTGRLAMS ≤ 1 cm. ~10-15% DOLSTS. [illegible] ≤ 1x1 cm; RNDD. SOME [illegible] MAY BE Ø.




[illegible] DOLSTS. IN ∇ & INTERLAMS ≤ 1 cm. LS BDD ≤ 1-2 cm. ~35% DOLSTS w/ SLIGHT UP DECR IN % DOLSTS. AREN TENDS TO ≡, ~, ∇. MUDDY LS STS IS MORE ∇-7

MXT GREEN, TAN & LT GRY, MUDDY & CLEAN, STS & VF SS BOTH $CO_3$ & QTZ, ALL BDD ≤ 1-4 cm.

MED-DK GRY LS MD/WKST, BDD ≤ 1 cm w/ ORNG DOLSTS IN ∇ & THIN, IRREG INTERLAMS ≤ ½ cm. ~5-10% DOLSTS

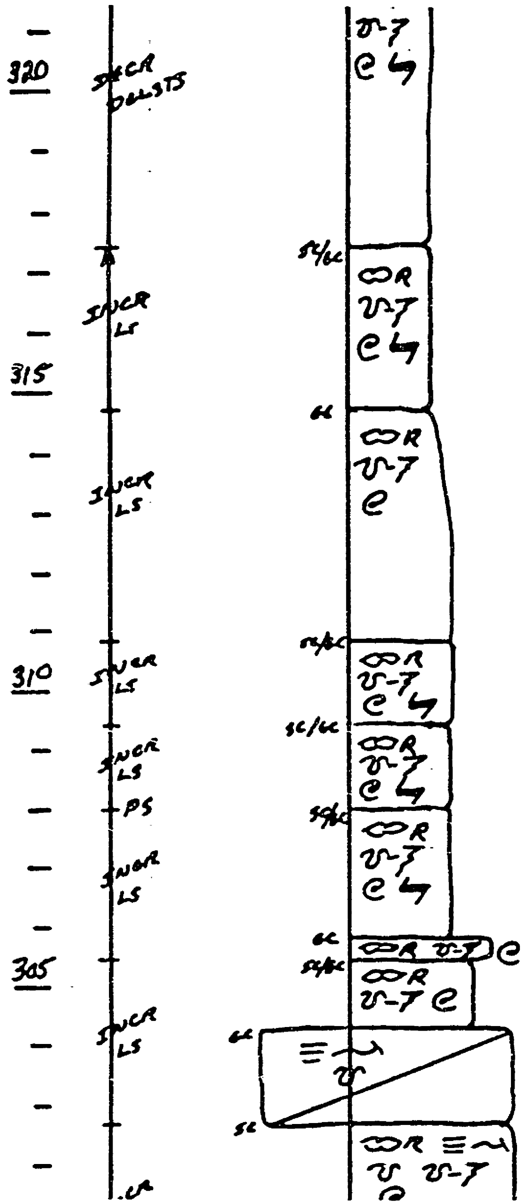
BRIGHT ORNG DOLSTS W/ GREEN LS WKST IN BLEBS. ≤ 20% LS. Ø ≤ ½ cm

GREEN & GRY LS WKST, BDD ≤ 1-2 cm w/ ORNG DOLSTS IN ∇ & CONT, IRREG INTERLAMS ≤ 1 cm. DOLSTS DECR UP FROM ~30% TO ~5-10%

LT GREENISH-GRY, MUDDY $CO_3$ STS w/ SOME QTZ GRAINS. BDD ≤ 1-2 cm

GREEN LS WKST W/ ORNG-BROWN DOLSTS, BOTH BDD ≤ 1-2 cm. DOLSTS INCR UP ~40% TO ~50%. Ø ≤ 3 cm & OVOID/DISCOID

TAN MUDDY & CLEAN, MIC VF SS, BDD ≤ 1-15 cm, W/ MOST ≤ 1-5 cm. CHANGE UP FROM ≡, ~ TO ≡, ~, ≈




GRY LS MD/WKST & MDST, BDD ≤ 1-2 cm w/ TAN & ORNG DOLSTS, BDD ≤ ½ cm. DOLSTS ~25% IN BTM ~25 cm w/ REST ~10%. ≤ ½ x ⅛ cm

GRY LS MD/WKST, BDD ≤ 1-2 cm w/ ORNG & TAN DOLSTS, BDD ≤ ½ cm. DOLSTS ~35% IN BASAL 75 cm, REST IS ~5-7%

GRY LS WKST w/ SOME WK/PKST CHANGING UP TO MD/WKST, BDD ≤ 1-2 cm, w/ TAN & ORNG DOLSTS BDD ≤ ½ cm. BASAL ~25 cm ~35%-40% DOLSTS, DECR UP TO ≤ 5%

SAME AS 307 m. BASAL ~25 cm ~35% DOL w/ REST ~10-15%

SAME AS 307 m. BASAL ~25 cm, ~20% DOL w/ REST ~10%

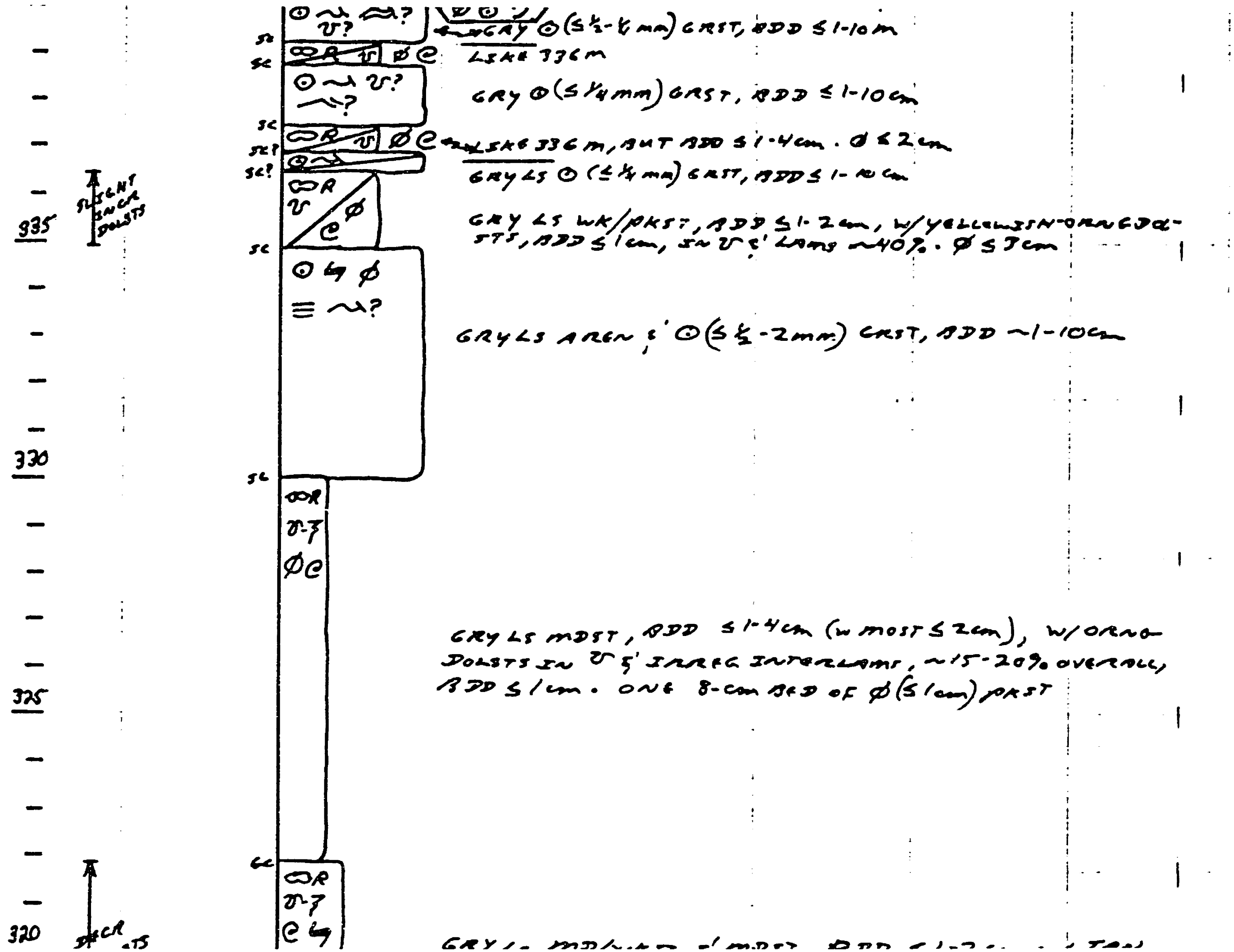
GRY LS WKST & SOME WK/PKST, BDD ≤ 1-2 cm, w/ ~5-7% TAN DOLSTS IN U & IRREG INTERLAMS ≤ ½ cm. ≤ ½ x ½ cm, COMMON SPAR-U

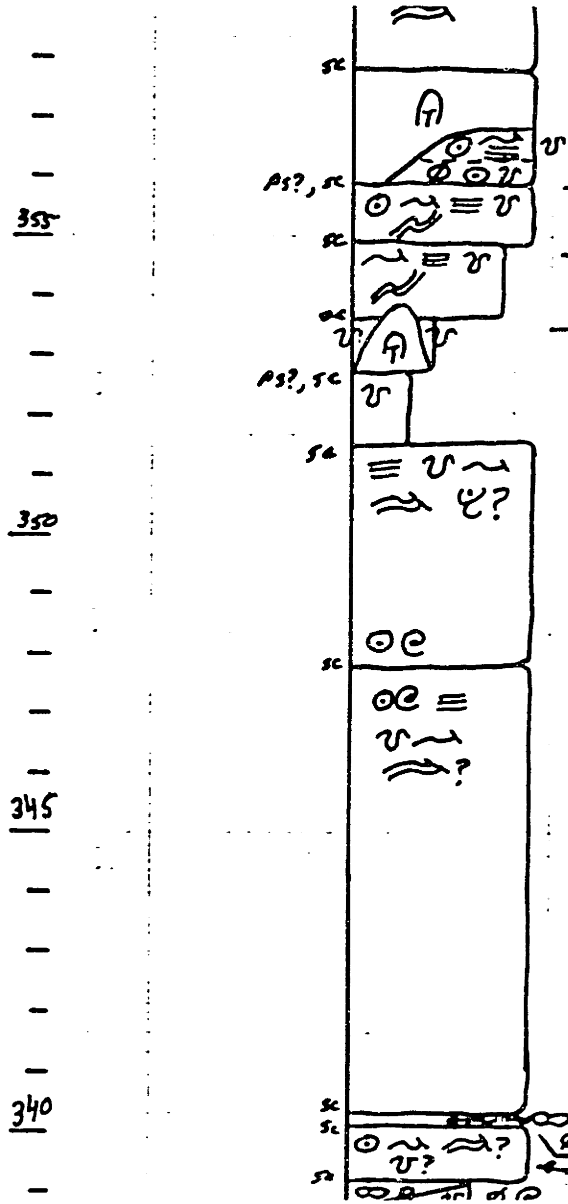
ORNG-TAN & BROWN DOLSTS w/ ~20% GREEN LS WKST, BOTH BDD ≤ 1 cm.

GREYISH-GREEN LS WKST w/ ORNG & TAN DOLSTS IN U & INTERLAMS, BOTH BDD ≤ 1-2 cm. DOLSTS DECR UP FROM ~60% TO ~25%

LITHS LIKE 300 m w/ SOME GREEN VF LS AREN. ALL BDD ≤ 1-2 cm

LTGRY VF LS AREN & MUDDY LS STS w/ ≤ 10% @, & ORNG DOLSTS IN U & INTERLAMS ≤ 1 cm. LS BDD ≤ 1-2 cm. ~35% DOLSTS w/ SLIGHT UP DECR IN % DOLSTS. AREN TENDS TO


GRY ⊙(≤½-¼ mm) GRST, BDD ≤1-10cm
LIKE 336m
GRY ⊙(≤¼mm) GRST, BDD ≤1-10cm
LIKE 336m, BUT BDD ≤1-4cm. Ø ≤2cm
GRY LS ⊙ (≤¼ mm) GRST, BDD ≤1-10cm
GRY LS WK/PKST, BDD ≤1-2cm, W/YELLOWISH-ORNGE DOLSTS, BDD ≤1cm, IN ʊ & LAMS ~40%. Ø ≤3cm
GRY LS AREN & ⊙(≤½-2mm) GRST, BDD ~1-10cm
GRY LS MDST, BDD ≤1-4cm (w MOST ≤2cm), W/ORNG DOLSTS IN ʊ & IRREG INTERLAMS, ~15-20% OVERALL, BDD ≤1cm. ONE 8-cm BED OF Ø(≤1cm) PKST
SLIGHT INCR DOLSTS
335
330
325
320




CUT-&-FILL' ≤ 29cm HI X 1&+2m WIDE. TOP CONTACT W/ ~10-20 cm OF LOCAL RELIEF. CAN'T TELL IF DEPOSITIONAL OR EROSIONAL

LAT'L EXTENT OF (A) NOT KNOWN. MED-DK GRY LITHS. Ø(≤1cm) ⊙(≤1/4mm) PK/GRST IN LWR ~25cm. OVERLAIN BY 70-80 cm OF ⊙(≤1/2 mm) GRST, ADD ≤1-5?cm. GRST IS GRY LATLY

MED LT GRY ⊙(≤1/2 mm) GRST, ADD ≤1-5 cm W/ TAN DOLSTS IN DISCONT. LAMS ≤1-4cm & W/ ≡, ~? . ≈ IS GENTLE, ALMOST SOUPY-LOOKING/SOFT-SED?

GRY ⊙ (≤1/4 mm) PKST & GRST, ADD ≤1-3cm W/ SOME ORNG DOLSTS IN DISCONT DRAPES ≤1/2-2cm THK. Ʊ OR // NEAR TOP

GRY LS MDST W/ Ʊ W/ SPAR-CMT. (A) ~1.2m HI X 2m WIDE ON SHARP SURFACE. SURROUNDED BY MDST.

GRY LS MDST, Ʊ W/ SPAR-CMT

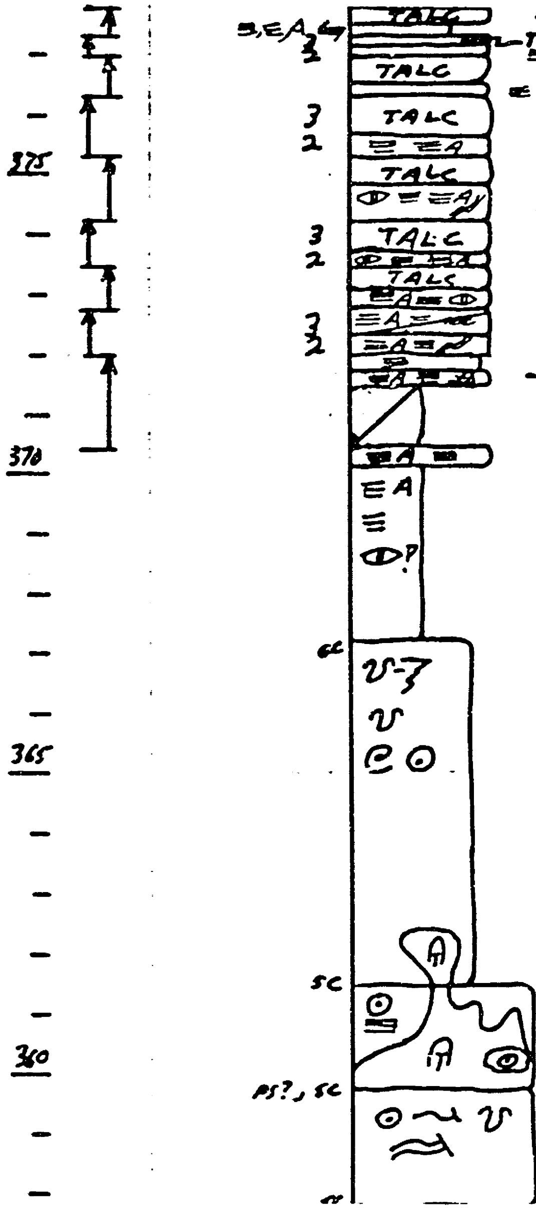
GRY LS GRST, ADD ≤1-10cm. ⊙ ≤1mm. BTM ~50cm W/ ~20% DOLSTS IN CONT. INTERLAMS ≤1-2cm BETWEEN LS ADDS 3-8cm

GRY ⊙(≤1mm, MOST ≤1/4-1/2 mm) GRST, ADD ≤1-10cm

(⊙ OR Ʊ?) YELLOW-GRY LITHS LIKE 33cm, ADD ≤1cm. Ø ≤1cm

(Ø ⊙) GRY ⊙(≤1/2-1/4 mm) GRST, ADD ≤1-10m

LIKE 33cm




∥ PROBABLY FROM DE-WATERING. COULD BE INCIPIENT ∧ ALSO

FACIES 3: TAN, GRY, & ORNG DOLSTS, BDDS ≤ 1cm & mm-LAMD. OFTEN GOES TO TALC

1+TALC

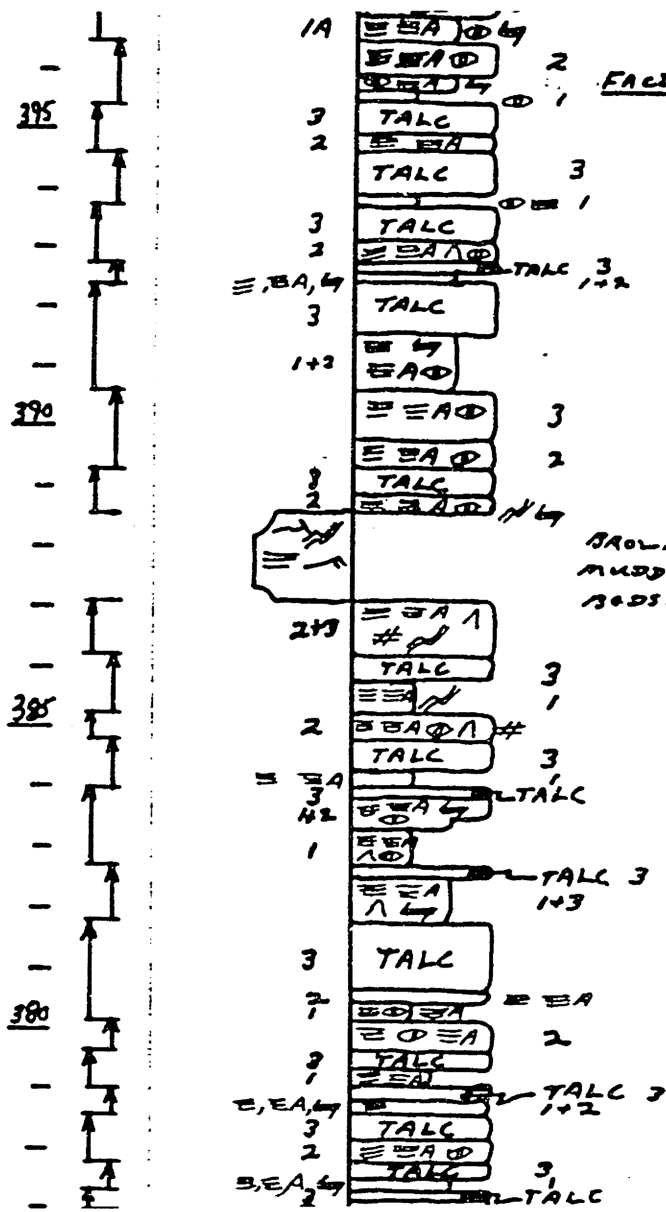
FACIES 2: ORNG, BLOCKY WEATHERING DOLSTS

FACIES 1: WHITE, REX'L'ZD (≤~1mm) LS W/PALE ORNG DOLSTS INTERLAMS. FORMERLY ⊕ MOST?

GRY LS WK/PKST W/SOME ORNG-BROWN DOLSTS IN ⅁, BLEBS, & DISCONT INTERLAMS IN UPPR ½. LWR CONTACT: DISTINCT LITH CHANGE ACROSS. A APPEARS TO GROW THRU ~1m INTO UNIT.

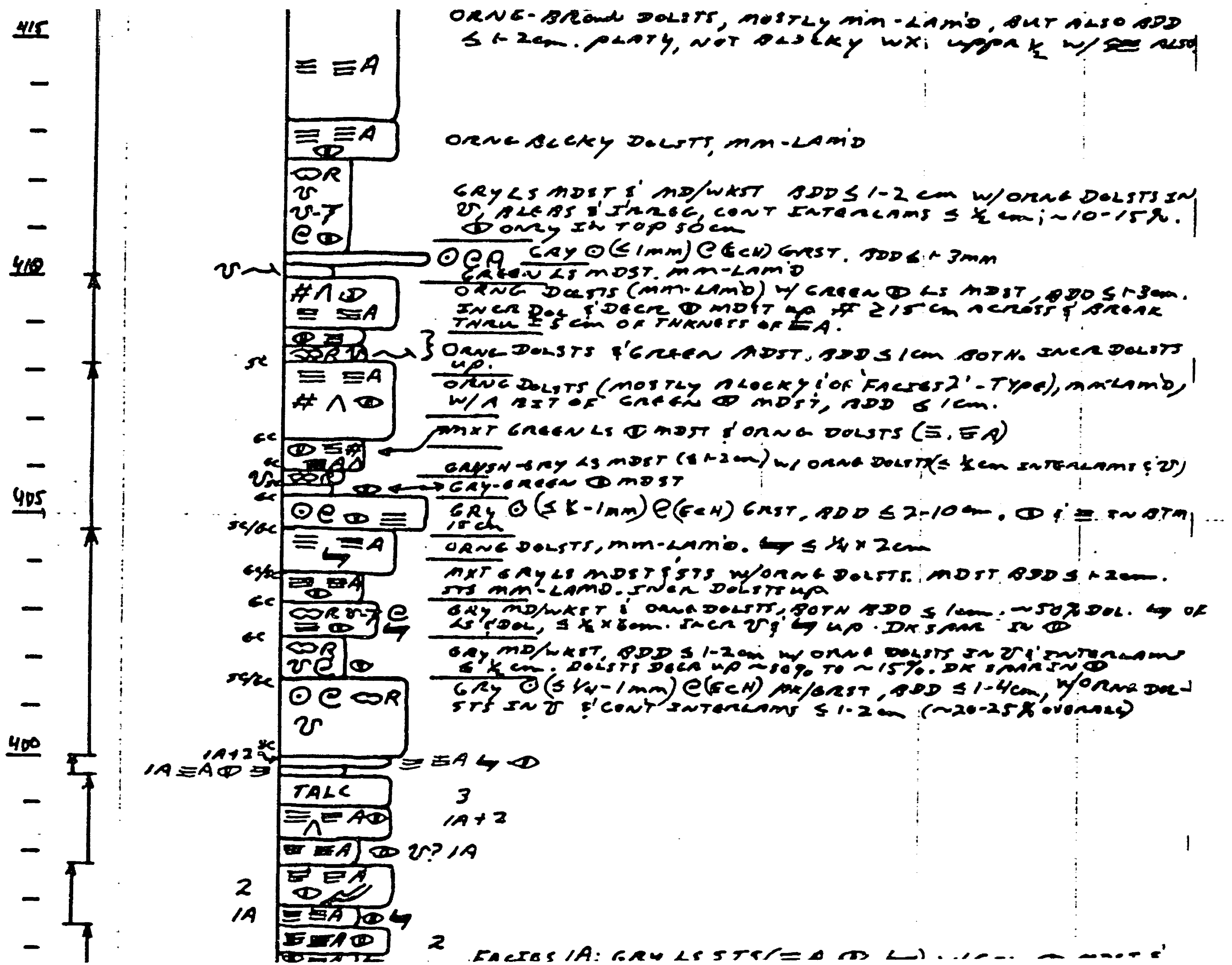
GRY LS ⊙(≤ ¼mm) DEPOSITED ON & IN GRY A

MED LT GRY ⊙ (≤ ¼mm) GRST, BDDS 1-15cm. SOME CUT-&-FILL ≤ 25cm HT X 1½→2m WIDE. TOP CONTACT W/ ~10-20 cm OF LOCAL RELIEF. CAN'T TELL IF DEPOSITIONAL OR EROSIONAL



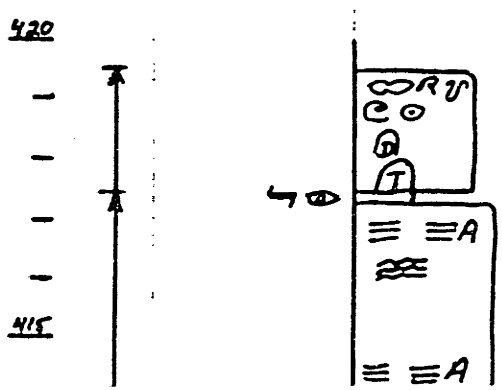

FACIES 1A: GRY LS & TS (≡A, ⦶, ⤳) W/ GRY ⦶ MDST & SOME ORNG DOLSTS (≡, ≡A) AS INTERLAMS. THIS MAY BE UNRE-XL'ED FACIES 1.

BROWN & LT GRY CLEAN VF QTZ SS SANDWICHED BETWEEN MUDDY, SILTY SS, BOTH ADD 5 cm MOSTLY, W/ SOME 1-4 cm BEDS.


415
410
405
400
ORNG-BROWN DOLSTS, MOSTLY MM-LAM'D, BUT ALSO BDD ≤ 1-2cm. PLATY, NOT BLOCKY WX; UPPER ½ W/ ALSO
ORNG BLCKY DOLSTS, MM-LAM'D
GRY LS MDST & MD/WKST BDD ≤ 1-2cm W/ORNG DOLSTS IN ϑ, BLEBS & IRREG. CONT INTERLAMS ≤ ½ cm; ~10-15%.
ONLY IN TOP 50cm
GRY ⊙(≤1mm) Ɛ(ECH) GRST. BDD ≤ 1-3mm
GREEN LS MDST. MM-LAM'D
ORNG DOLSTS (MM-LAM'D) W/ GREEN LS MDST, BDD ≤ 1-3cm. INCR DOL & DECR MDST UP. ≥ 15cm ACROSS & BREAK THRU ≤ 5cm OF THKNESS OF ≡A.
ORNG DOLSTS & GREEN MDST. BDD ≤ 1cm BOTH. INCR DOLSTS UP.
ORNG DOLSTS (MOSTLY BLOCKY (OF 'FACIES 2'-TYPE), MM-LAM'D, W/A BIT OF GREEN MDST, BDD ≤ 1cm.
MXT GREEN LS MDST & ORNG DOLSTS (≡, ≡A)
GRYSH-GRY LS MDST (≤ 1-2cm) W/ ORNG DOLSTS (≤ ½cm INTERLAMS & ϑ)
GRY-GREEN MDST
GRY ⊙(≤ ½-1mm) Ɛ(ECH) GRST, BDD ≤ 2-10cm.
15cm
ORNG DOLSTS, MM-LAM'D. ≤ ¼ × 2cm
MXT GRY LS MDST & STS W/ORNG DOLSTS. MDST BDD ≤ 1-2cm. STS MM-LAM'D. INCR DOLSTS UP
GRY MD/WKST & ORNG DOLSTS, BOTH BDD ≤ 1cm. ~50% DOL.
GRY MD/WKST, BDD ≤ 1-2cm W/ ORNG DOLSTS IN ϑ & INTERLAMS ≤ ½ cm. DOLSTS DECR UP ~30% TO ~15%.
GRY ⊙(≤ ¼-1mm) Ɛ(ECH) PK/GRST, BDD ≤ 1-4cm, W/ORNG DOLSTS IN ϑ & CONT INTERLAMS ≤ 1-2cm (~20-25% OVERALL)
TALC
3
1A+2
ϑ? 1A
2
1A
2
1A+2
1A ≡A

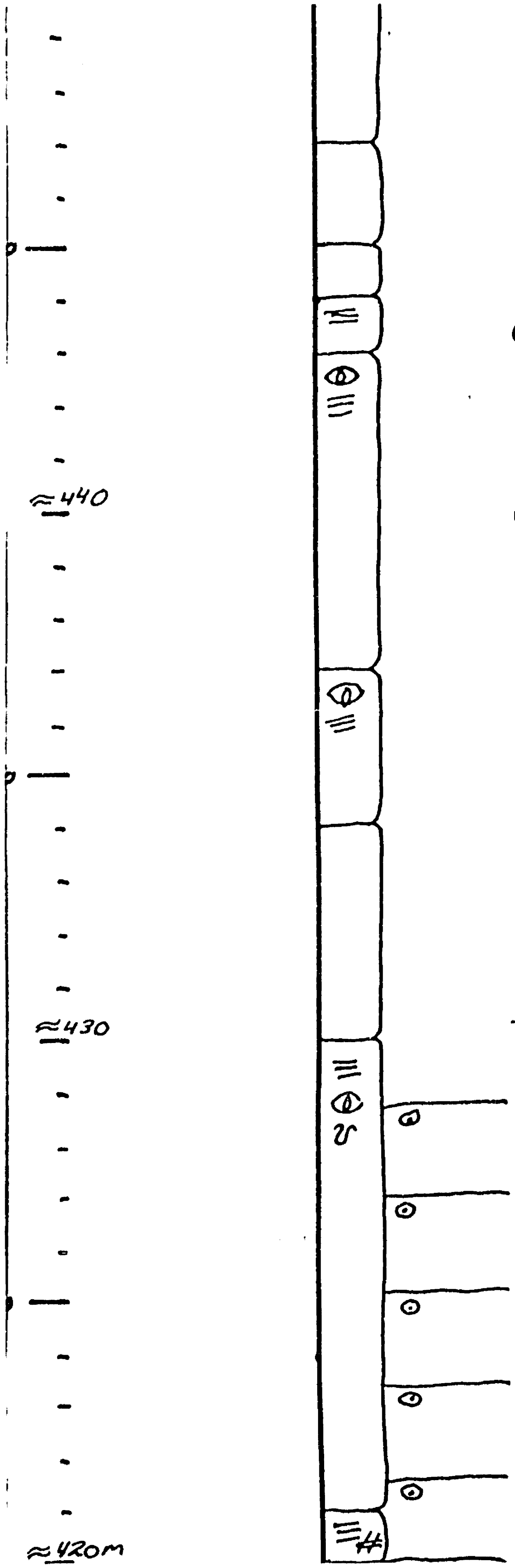
Section 92-5
Last Chance Rng., Calif

Carrara Fm. continues above this point




GRY LS WK/PKST, BDD ≤ 1-4cm, MOST ≤ 1-2cm W/ BROWN DOLSTS IN B & INTERLAMS ≤ 1/2 cm. HORIZON AT ~418.15 → 418.35; VARIES IN THKNESS FROM ≤ 20cm. T AT BASE, ≤ 75cm HI, NUCLEATING ON OR CLOSE TO BOUNDARY & COEVAL W/ OR. CREAMY, TAN MDST, ≤ 5mm BDD. A FEW DOLSTS & DOLSTS INTERLAMS

ORNG-BROWN DOLSTS, MOSTLY MM-LAM'D, BUT ALSO BDD ≤ 1-2cm. PLATY, NOT BLOCKY WX. UPPER 1/2 W/ ALSO




(62) … MOTTLED.

(61) F LS, THIN-BDD. BASE IS DK GRY, EVEN-BDD. GRADES UP INTO BRWN, IRREG-BDD.

(60) F LS, DK GRY W/ ORNG DOL'C PARTINGS

(59) ARGILL. DOL, BRWN, THN-BDD, LAM'D. PERHAPS FERROAN

(58) LS, WH, THK-BDD, ⦶ THRU-OUT. ≡ IN SOME AREAS. 1ST CLIFF-FORMER IN JANGLE.

(57) LS, PINK, ⦶ THRU-OUT. ≡ IN SOME AREAS

(56) F LS, DK GRY, THN-BDD

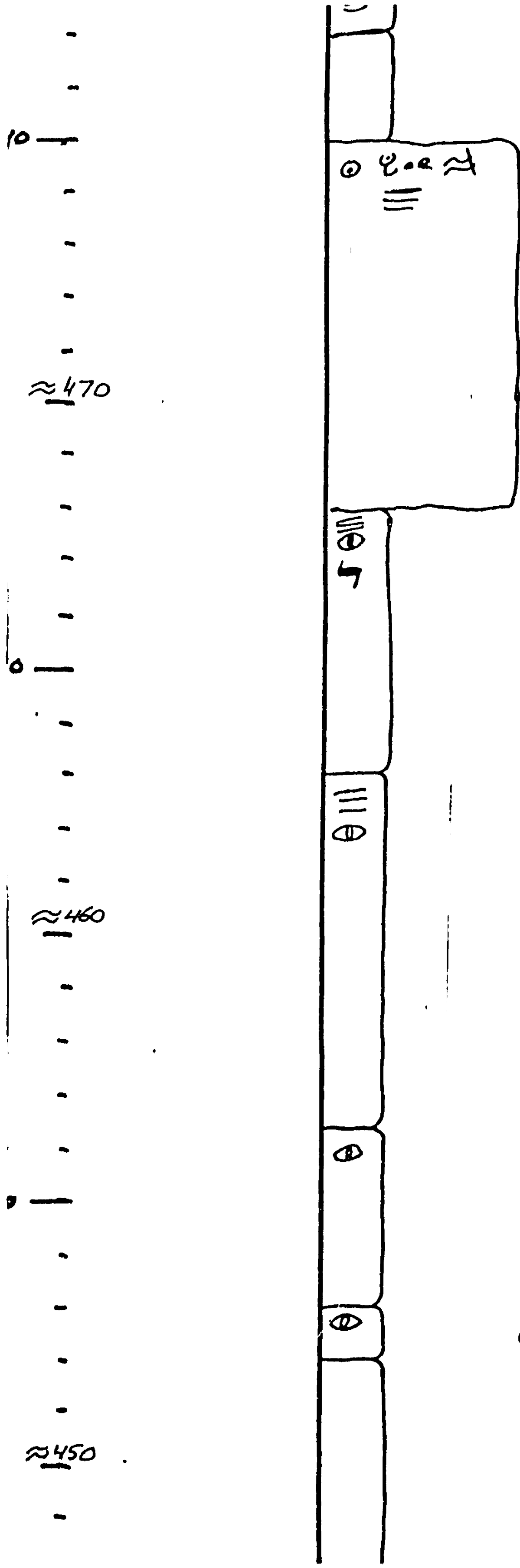
↳ INTERVAL NUMBERING SYSTEM OF HALLEY, 1974

NOTE:

FROM ≈ 420-560 m, THE SECTION MEASUREMENTS & DESCRIPTIONS ARE FROM THE THESIS OF ROBERT B. HALLEY, 1974.

(55) ALT'NG LS & DOL.
DOL: BRWN, M-BEDD, LAM'D
LS: LT GRY → WH, THN-BDD, ⦶ BIRD'S-EYE. SOME LS BEDS W/ SPAR-FILLED, SUBVERT ʊ & POCKETS OF OOLITE

LS, ≡ & #
(54)




(69) GRY ON FRESH. LAM'D

(68) LS, DK GRY, THN-BDD W/ BRWN ARGILL INTERBEDS & MOTTLING

(67) LS OOLITE, DK GRY, MED-BDD, LO-4 X-BDD OR ≡ BDD.

(66) DOL, LAM'D, W/ SOME AREAS OF INTERLAM'D LS-DOL, ⦶ & RIP-UP INTRAFM'L CONGL.

DESERT LS MBR

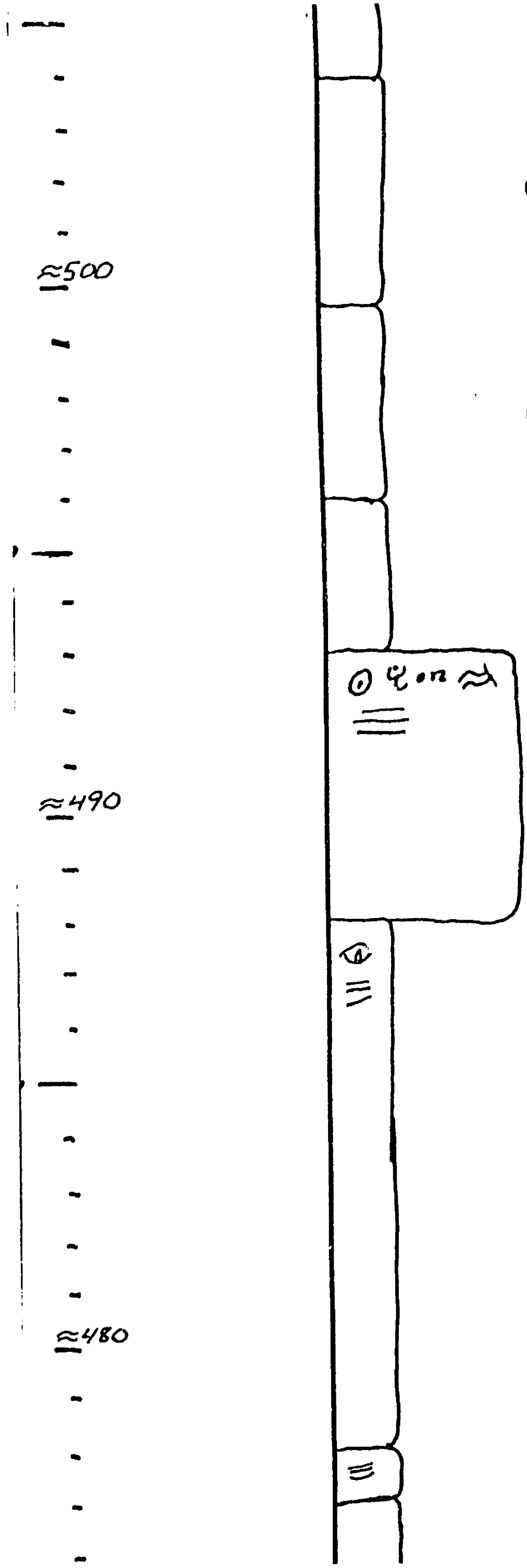
JANGLE LS MBR

(65) LS, LT GRY, M-BDD, ≡ & ⦶ THRU-OUT

(64) LS, WH, THN-BDD, ⦶ THRU-OUT W/ SOME ⦶ FILLED W/ DOL. ARGILL LS PARTINGS

(63) DOL, BRWN, THN-BDD. RARE ⦶ SCATTERED THRU-OUT

(62) LS, DK GRY, THN-BDD & IRREG. PARTING OF ARGILL BRWN LS - MOTTLED.




(74) F LS, DK GRY, THN-BDD, WAVY BDDG W/ BRWN, SLTY, DOL'C PARTINGS

(73) LS, LT GRY → WH, MED OR THK-BDD. MOTTLED

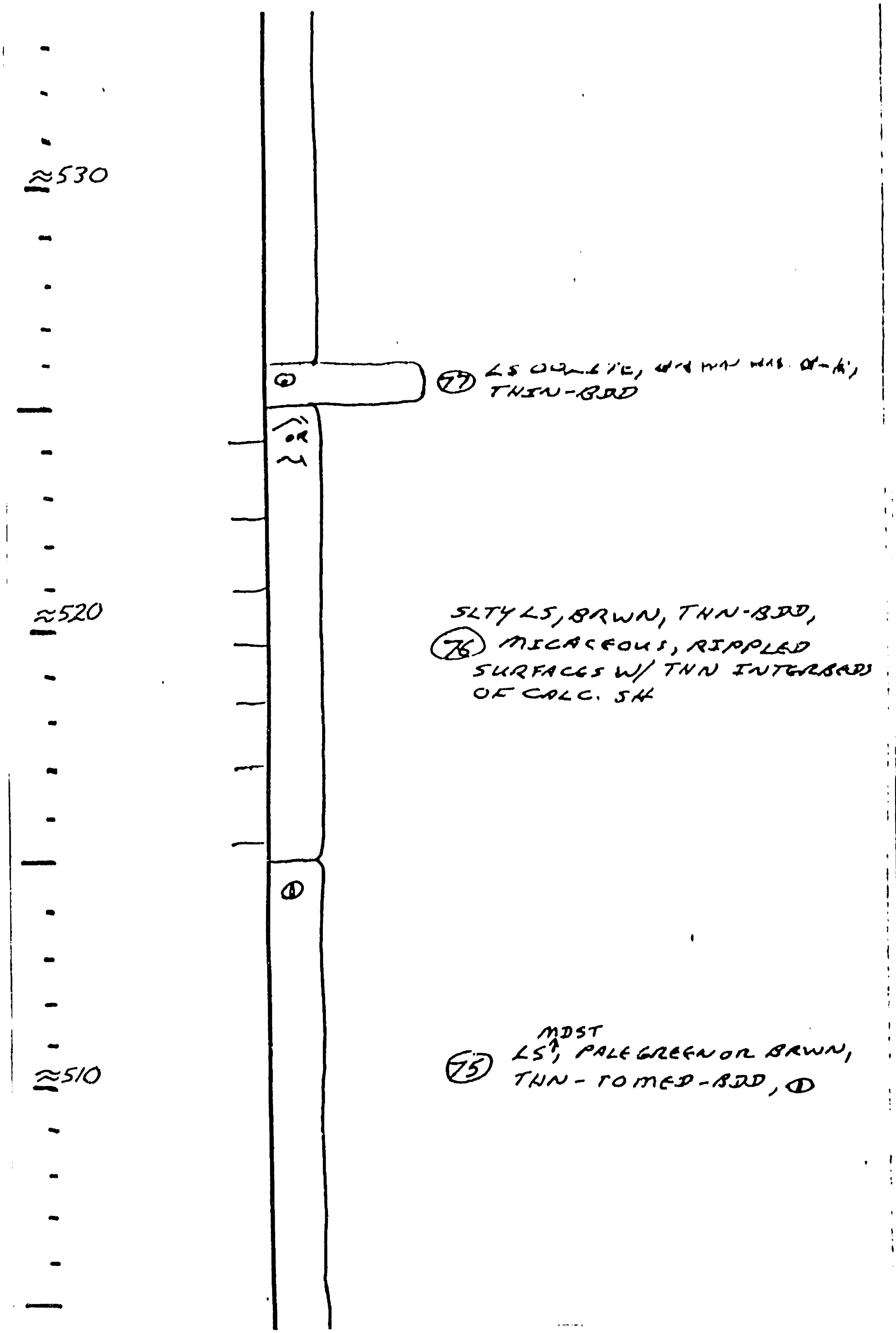
(72) LS MDST, DK GRY, THN-BDD W/ WAVY ARGILL. PARTINGS

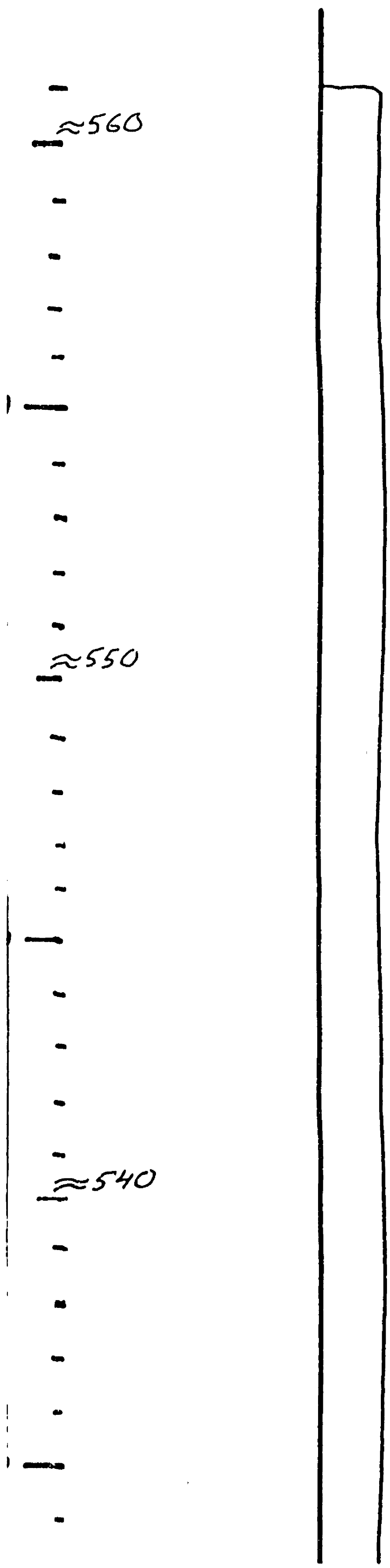
(71) LS OOLITE, DK GRY, LO-∤ X-BDD OR ≡. NO ʊ. OCC'L REGULAR LENSES OF DOL

(70) LS, DK GRY, THN-BDD. ⦶ THRU-OUT. ≡ (LAM'D) IN BASAL ½ m & IN SEVERAL THIN DOL BEDS ≤30cm THK

(69) DOL, BRWN ON WX SURFS, GRY ON FRESH. LAM'D

(68) LS, DK GRY, THN-BDD W/ BRWN


≈530
≈520
≈510
77 LS OOLITIC,
THIN-BDD
SLTY LS, BRWN, THN-BDD,
76 MICACEOUS, RIPPLED
SURFACES W/ TNN INTERBEDS
OF CALC. SH
MDST
75 LS, PALE GREEN OR BRWN,
THN-TO MED-BDD




GRAD'L CNTC: BONANZA KING Fm / DESERT MBR. OF CARRARA Fm

SECTION 92-5, LAST CHANCE RANGE, CALIFORNIA.

NOTE:
FROM ≈420-560 m, THE SECTION MEASUREMENTS AND DESCRIPTIONS ARE FROM THE THESIS OF ROBERT B. HALLEY, 1974.

LS MDST, BRWN, THN-BDD, (78) ARGILL. GRADES INTO THE CLEANER BON. K. Fm

Cyclicity:
A
Stratigrapher's
Lament.

The slower I go, the more I look. The more I look, the more I see. The more I see, the slower I go.

6 March, 1990
R. D. A.