STRATIGRAPHY, SEDIMENTOLOGY, AND TECTONIC EVOLUTION OF THE 1.86 Ga EL SHERANA AND EDITH RIVER GROUPS, NORTHERN TERRITORY, AUSTRALIA

by

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Abstract

The 1.86 Ga El Sherana/Edith River Basin of Northern Territory, Australia formed during a period of documented world-wide orogenesis. The basin stratigraphy overlies Wilson cycle sediments of the Pine Creek Orogen, the final stages of which resulted in foreland basin sedimentation and deformation, metamorphism, and uplift of the entire early Proterozoic sedimentary prism. The El Sherana and Edith River Groups consist of braid-plain sediments, ignimbrites and felsic volcanics, and lacustrine turbidites. These units pinch-out against antecedent valley-and-ridge topography, the geometry of which is chiefly controlled by structures in the underlying Pine Creek Supergroup.

All members of the El Sherana and Edith River Groups are bounded by erosional disconformities. These are documented by reversals in paleocurrent trends and by depocenter migration, syntectonic sedimentation, erosional removal of stratigraphy, and erosional paleovalleys with sedimentologically distinct fill. One episode of syntectonic sedimentation is preserved in a small strike-slip basin exhumed in the center of the study area. A tectonic origin is suggested for unconformity generation.

The El Sherana/Edith River stratigraphy developed during orogenesis to the north. Basin subsidence began within only several million years of foreland deposition, compressional deformation, and metamorphism in the underlying Pine Creek Supergroup. Observed faults within the basin take the form of strike-slip, reverse, and normal faults. Due to the uncertain location and geometry of the initial basin margins, it is uncertain what the immediate mechanism for basin subsidence was; however, it may ultimately be related to synorogenic collapse.

There are striking similarities between events in Pine Creek and northern Australia and events in northwest Canada from ~2.0-1.65 Ga. This observation prompts a tentative correlation.

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Introduction

The end of the Early Proterozoic, from 2.0-1.8 Ga, was a period of global orogenic activity characterized by the assemblage of micro-continents into larger blocks (Ethridge et al., 1986; Hoffman, 1990). The Pine Creek orogen, Northern Territory, Australia, is an inlier from this period containing sediments from a full orogenic cycle. Deposition of the El Sherana and Edith River Groups (Needham et al., 1980, 1988; Stuart Smith et al., 1980, 1988) immediately followed unroofing of the Pine Creek Orogen. They are exposed in the South Alligator Valley (Fig. 1), an area of economically significant mineral deposits, chiefly uranium, with the recent discovery of economic Au-P.G.E.

The origin of the El Sherana/Edith River basin is difficult to assess, since its margins are hidden and the present geometry of the basin is probably not representative its original size. It is thus difficult to accurately predict the local geology and to understand the regional tectono-stratigraphic framework. By determining the stratigraphy of the basin and by mapping contacts, however, one can characterize the processes which dominated basin formation. In addition, paleocurrent analysis, petrography, and detailed sedimentological studies provide new constraints on timing of faulting, provenance of sediments, depositional environments, and tectonic style. Contributions of this project could include a detailed look at a volcanic-sedimentary basin during an intriguing period in Earth history, further constraints on mineralization in the South Alligator Valley, and evaluation of basin formation models.

Data presented in this paper are the result of three months in the field and several months laboratory work. The results are part of the Bureau of

Mineral Resources ongoing resource assessment of the Kakadu Stage 3 Conservation Zone. The paper begins with discussion of the stratigraphy and sedimentology of the Pine Creek Supergroup and the El Sherana and Edith River Groups. Petrographic analyses of the El Sherana/Edith River sediments, a tectonic overview and interpretation, and conclusions regarding the basin as a whole then follow.

Pine Creek Supergroup

The Pine Creek Supergroup is a new term proposed for the sequence of low-grade metasedimentary rocks which serve as basement for the El Sherana and Edith River Groups in the South Alligator Valley and are present in other parts of the orogen. It is convenient to refer to this sequence with one term, which reflects a history of successive rifting, thermal subsidence, and foreland basin evolution.

Previous Work

The Pine Creek Stratigraphy is well described and summarized in Needham et al. (1988) and Stuart Smith et al. (1988) as the following groups: the Namoona Group, the Mount Partridge Group, the South Alligator Group, and the Finniss River Group. Needham et. al. (1980) and Ethridge et al. (1986) interpret these units to represent discrete tectonic depositional regimes as interpreted from the dominant lithofacies. The Namoona and Mount Partridge Groups, composed chiefly of interbedded meta-siltstones, dolomitic sandstones, and coarse quartz sandstones and conglomerates, represent continental rifting. The South Alligator Group consists of fine siliciclastics and minor banded ironstone, graphitic siltstone, and tuff; it represents sedimentation during thermal contraction of extended lithosphere. The Finniss River Group, synorogenic feldspatholithic sandstones and siltstones, records sedimentation in a convergent foreland basin. All of these groups and their respective members crop out within the study area.

Needham et al. (1985) and Stuart-Smith et al. (1988) interpret the Mount Partidge Group and South Alligator Group as shallow-water facies and the Finniss River Group as distal turbidites.

The Koolpin Formation: Observations and Discussion

The predominant stratigraphic unit of the Pine Creek Supergroup developed in the study area is the Koolpin Formation, the lower unit of the South Alligator Group. It consists of finely interbedded hematitic siltstone and chert. It can be subdivided into several units: a basal sequence of chert or jasper and iron siltstone, with bed thicknesses of several centimeters; an interval of interbedded fine sandstones and siltstones, typically highly cleaved and altered; and a felsic volcanic member several meters thick with rare quartz phenocrysts approximately one millimeter in size. It is capped by the Gerowie Tuff, a felsic crystal tuff which acts as a regional marker horizon.

There are additional minor intervals of interbedded cherty ironstone, which vary in bed thickness and continuity (R. Valenta, pers. comm., 1989). One interval is characterized by millimeter-scale lamination of chert and iron siltstone continuous for hundreds of meters. Another interval below the felsic volcanic unit and above the siltstone member contains nodular chert nodules several centimeters across which define a single horizon within iron-rich siltstone.

The frequency and degree of tight, isoclinal folding at all scales within the Koolpin Formation and overlying units suggests significant shortening with respect to the underlying Mount Partridge Group. One documented thrust occurs north of the study area within the Mundogie 1:100,000 scale map sheet (Stuart-Smith et al., 1984) in which Mundogie Sandstone of the Mount Partridge Group is thrust above Koolpin Formation, using the Koolpin as a detatchment. Future work could further differentiate between all chert and hematitic siltstone units within the Koolpin Formation based on the small scale bedding habit of the chert. This would provide the tools necessary to recognize minor or major thrust faults of pre El-Sherana age which are likely to exist (R. Valenta, pers. comm. 1989). Deformation in the Pine Creek Supergroup is discussed under Tectonic History below.

Stratigraphy and Sedimentology

The El Sherana and Edith River Groups overlie Early Proterozoic (~2.1-1.85 Ga) Pine Creek Supergroup and underlie the middle Proterozoic (~1.65 Ga) Kombolgie Sandstone of the Katherine River Group. The El Sherana Group consists of three units: the Coronation Sandstone, the Pul Pul Rhyolite, and the Big Sunday Formation. The Edith River Group is made up of the Kurrundie Sandstone and the Plum Tree Volcanics. Each of these five units is separated by an erosional unconformity named after the unit which overlies it. The Plum Tree Volcanics are not considered here; descriptions are presented in Needham et al., (1988).

Previous Work

Walpole et al. (1968) first synthesized the regional stratigraphy and recognized the units discussed here. The Edith River Group was mapped as part of the Katherine River Group and the Kurrundie and Plum Tree as members of the Kombolgie Formation. At the same time, the El Sherana Group was mapped as the Edith River Volcanics.

Stuart-Smith et al. (1988) and Needham et.al. (1988) revised the stratigraphy of Walpole et al. Their interpretation is shown in (fig. 2a). They recognized the El Sherana Group and Edith River Group as independent from the overlying Kombolgie Sandstone and each other and outlined the key stratigraphy described below. These groups form an intermediate sequence between the underlying Pine Creek Supergroup and the overlying Katherine River Group. They also identified a major unconformity between the El Sherana and Edith River Groups, which they attributed to the Maud Creek Event. The current study attempts to further refine the stratigraphic relationships within and between the El Sherana and Edith River Groups.

El Sherana Group

Coronation Unconformity

The lowermost contact between the Pine Creek Supergroup and the El Sherana/Edith River Groups is the Coronation Unconformity. Units of the El Sherana and Edith River Groups lap out against steeply dipping paleotopography along this contact. Resistant units in the Pine Creek Supergoup, such as the cherty ironstone of the Koolpin Formation or the Mundogie sandstone, form resistant ridges, while less resistant units like the Finniss River Group form deep paleo-lows. This valley-and-ridge topography parallels the regional northwest strike of structural elements in the Pine Creek Supergroup, and is locally exhumed such that one may walk out paleovalley margins for several hundreds of meters.

Before development of this unconformity, Pine Creek Supergroup sediments underwent burial, greeschist-grade metamorphism, deformation, and uplift (Stuart-Smith et.al., 1980). The Gerowie Tuff, a crystal tuff roughly in the middle of the South Alligator Group, is well constrained in age at 1.885 Ga ± 2 Ma , while the uppermost unit of the El Sherana Group, the Tollis Formation, the stratigraphic equivalent of the Big Sunday Formation, is dated at 1.890±18/15 Ga (Page and Williams, 1988). This could provide, as a conservative maximum, a 10 Ma year interval for burial, metamorphism, deformation, and uplift and is likely to have been shorter.

Locally along the Coronation Unconformity, there is a siliceous, hematitic, phosphatic breccia known as the Scinto Breccia. Its characteristics, interpretation, and significance are described and discussed below under petrography.

Coronation Sandstone

Facies: In most places, the Coronation Sandstone is typically < 100 m in thickness, although it can reach thicknesses of over 600 m. It has a varying, lensoidal geometry on a scale of several kilometers and pinches out locally against antecedent topography, with up to 60 m relief. Using the classification scheme of Miall (1977), the Coronation Sandstone consists of a basal composite of Gm, Gp-Sp, and Sh, a thick horizon of St, and minor Fl. In addition, it contains several interbedded mafic and felsic volcanic flows, which act as prominent marker horizons.

There are several facies in the basal Coronation Sandstone (see Table 1). The coarsest, Gm, is a massively bedded, clast-supported, imbricated-cobble conglomerate (fig. 4a). Basal deposits are lensoidal and pinch out against paleotopography on a scale of 1/2 km. Beds are typically 1-5 m thick, with one amalgamated deposit attaining a thickness of > 44 m. Cobbles are well-rounded to rounded with mean maximum clast size of 38.5 cm and the largest clast at 55 cm. Another basal facies, Sh, exhibits decimeter-scale planar bedding with interbedded matrix- and clast-supported conglomerates, occasionally imbricated, and fine to coarse sandstones. Sandstones range from poorly sorted, medium-sized to coarse, massively bedded sequences to fine- to medium-grained, planar-laminated deposits. Local centimeter- to meter-scale scours are filled with an overlying facies, most often either Sh or St. Lastly, there is a planar-crossbedded facies Gp-Sp (fig. 4b), with clast-supported, imbricated, rounded-pebble conglomerate grading to and interbedded with planar-crossbedded pebbly sandstone. Beds are typically ~ 1 m thick, ranging from 10 cm to ~ 5 m. Numerous erosional surfaces with as much as 4 m relief cut across bedding within the sequence (fig. 5); these surfaces are commonly overlain by a lag of coarse imbricated clasts which grades abruptly into planar-crossbedded pebbly sandstone. This facies had a mean maximum clast size of 49 cm, with blocks of Koolpin Formation as large as 70 cm long. The polymictic variations among these three facies can be seen in Table 1.

The basal assemblage is incised and overlain by a coarse to very coarse, pebbly, trough-crossbedded sandstone, St, with a maximum observed thickness of 75 m. These deposits are relatively continuous and can be walked out along strike for over 10 km. Individual troughs are 30 to 150 cm thick, 2 to 10 m in length (fig. 4c), and often have a coarse lag at their base; mean maximum clast size is 19 cm, with the largest 30 cm. Grain size is generally 1 to 2 mm with few pebbles. The trough unit is also better sorted compositionally, with monocrystalline quartz and chert as the dominant framework grains.

There are minor intervals of fine sediment, Fl, outcropping only in the area of the "syncline" (fig. 1), where an abnormally thick section of Coronation Sandstone has been preserved. Here, decimeter- to meter-sized beds of very fine to medium sandstone containing current ripples are interbedded with 2 to 3 m intervals of laminated mudstone. In all other study areas, this facies is absent, with the exception of rare intraclasts.

The volcanics of the Coronation Sandstone are typically altered and contain hematite, amorphous or microcrystaline silica, chlorite, and sericite. This makes field classification difficult. Two units, one felsic and one mafic, are continuous over several kilometers and relatively unaltered. The felsic volcanic unit is a 4 to 6.5 m thick rhyolite containing quartz and potassium feldspar phenocrysts lacking macroscopic fiammi or lappili. The mafic unit is a basalt up to 40 m thick containing amygdules of chert or calcite up to 10 m below the present top. The basalt occurs high in the section, and can be found to rest directly on paleohighs defined by erosional relief on older units. It should be stressed, however, that despite being excellent marker horizons, the volcanics are volumetrically small.

Interpretation: The facies of the Coronation Sandstone are most consistent with those of braided river systems (Miall, 1977; Cant, 1978). Most of the conglomerates are clast-supported, imbricated-clast cobble conglomerates indicating channel or bar-avalanche deposition. Paleocurrents (fig. 6) are unimodal with low dispersion. Matrix-supported conglomerates are rare, with no evidence for debris-flow deposits. This suggests that there are no alluvial-fan sequences preserved in the Coronation Sandstone or that the basin margins are not proximal to the study area. The paucity of fine sand and the lack of mud suggests a lack of overbank deposits, which is interpreted as relating to slow subsidence rates and thereby removal by scouring. The area of the thickest section, the "syncline", was probably the deepest paleovalley in the region.

Given the size of planar tabular bedforms (minimum of four meters), the minimum water depth at time of deposition was roughly 10 m, (Middleton and Southard, 1984), with a likelihood for considerably deeper water. This suggests a large river system of considerable length (e.g. Cant, 1978), which in turn implies a basin larger than the outcrop reaches of the South Alligator Valley. This is consistent with the lack of well defined basin margins or facies which suggest deposition near the basin margins. It is therefore likely that the true extent of the Coronation Sandstone paleovalley is greater than present exposure would indicate.

Pul Pul Rhyolite Unconformity

A major erosional surface below the Pul Pul Rhyolite removes as much as 100 m of Coronation Sandstone stratigraphy. The units down to and including the basalt horizon are cut out (fig. 3) and filled with a variety of local facies.

A distinct facies which occurs along this horizon is a clast-supported conglomerate , <8 m in maximum thickness, composed predominantly of basalt clasts (Table 1, fig.7a). The basalt clasts are largely angular, whereas other types are rounded to well rounded. The conglomerate also contains many clasts of coarse, sub-angular to rounded sandstone, which are interpreted as being derived in part from the Coronation Sandstone. This facies laps out against either Coronation Sandstone or the metasedimentary basement and is overlain by the Pul Pul Rhyolite.

At El Sherana (fig. 1) there is evidence for growth faulting with syntectonic sedimentation which post-dates deposition of the Coronation Sandstone and pre-dates extrusion of the Pul Pul Rhyolite (fig. 8). A horizon of Coronation Sandstone and underlying basement were downfaulted ~50 m and both basement and Coronation Sandstone exhibits drag folding. A succesion of very coarse, matrix-supported conglomerates and coarse, poorly sorted sandstones, some containing basalt clasts, were deposited along the fault margin footwall. This event took place, however, before the deposition of the basalt-clast conglomerate horizon described above, which disconformably overlies both this package and the Coronation Sandstone. This tectonic and sedimentary activity, therefore, postdates the Coronation Sandstone and is probably related to readjustment of the regional base level, to the development of the Pul Pul Unconformity, and to the extrusion of the Pul Pul Rhyolite.

The Pul Pul Rhyolite

Facies: The Pul Pul Rhyolite is a unit of amalgamated felsic volcanics and interbedded volcaniclastics at least several hundred meters thick which rests on Coronation Sandstone, basalt-clast conglomerate, and Pine Creek Supergroup. There are two predominant facies in the study area, an ignimbrite flow and an upper quartz-feldspar porphyry. The Pul Pul Rhyolite extends at least 20 kilometers in all directions beyond the study area and thickens toward the southeast. For a detailed description of this unit beyond the study area, see the work in progress of E. Jagodzinski, Bureau of Mineral Resources.

The base of the Pul Pul Rhyolite is highly convoluted interval ~5 m thick which incorporates clasts of underlying lithologies (chiefly graywacke, sandstone, and dolerite cobbles); they are all typically well-rounded. The matrix is rhyolitic and contains fiammi which wrap around cobbles and flow breccia. Above this interval is a flow banded sequence containing thin layers of devitrified glass. This layer is locally incised and filled with thin beds of volcanic sand and silt.

The ignimbrite flow is distinguished by the presence of macroscopic fiammi ~1 cm to 15 cm long (fig. 7b). The fiammi are flattened at the base, and become less flattened towards the top of the flow. Their strikes and dips mimic local paleotopography. The groundmass is dense and vitreous, typically orange-pink, and contains abundant quartz and potassium feldspar phenocrysts. Columnar jointing is common. The flow(s) is at least 100 m thick, with its thickness varying chiefly as a function of antecedent topography.

The overlying quartz-feldspar porphyry is at least 130 m thick, typically lavender in color, and contains abundant alkali feldspar and quartz phenocrysts > 1 mm in size. The contact between the ignimbrite and the quartz-feldspar porphyry is sharp. The basal portion of the porphyry does not contain fragments of the ignimbrite, nor are the platy clasts obvious exhumed fiammi. It does, however, contains chips of angular lithic fragments, most commonly pale green and platy (fig. 7c,d), typically several cm in size; these are most abundant at the base. The porphyry commonly exhibits a white-mottled discoloration which nucleates about potassium feldspars and platy lithic fragments (fig. 7d).

Interpretation: Due to its presence above the Pul Pul Unconformity, and the reversal of paleocurrent data associated with the Big Sunday Formation (fig. 6), the extrusion of the Pul Pul Rhyolite is here genetically linked to the Pul Pul Unconformity and the growth of the Big Sunday deposystem. The contact between the ignimbrite flow and the quartz-feldspar porphyry is taken as the best available datum for reconstruction. Although commonly volcanic succesions thicken away from their vents (Cas and Wright 1988), the southeast-thickening geometry of the Pul Pul Rhyolite is probably at least in part related to uplift, erosion, and base level change in the north accompanying sedimentation in the Big Sunday Formation (see Generation of Unconformities below).

Big Sunday Unconformity

The top of the Pul Pul Rhyolite is deeply incised, with local paleo-valleys of 70 m or more filled with imbricated, clast-supported conglomerates (fig. 3, 11). In most of the study area, the valley fills are grouped with the overlying Kurrundie Sandstone, making that contact part of the Edith River Unconformity. To the southeast, however, the Big Sunday Formation sits above the Pul Pul Rhyolite and in turn is disconformably overlain by the Kurrundie Sandstone. Assuming that the extrusion of the Pul Pul Rhyolite occurred in a geological instant, this unconformity is likely to be genetically linked to the tectonic event which caused the Pul Pul Rhyolite Unconformity and ignimrite extrusion.

An incised valley crops out southeast of the study area. It was formed as part of the erosional event along Pul Pul Unconformity. The valley fill facies consist of interbedded rhyolite flows, epiclastic and quartz-rich sandstones and conglomerates, and peperites (usage after Cas & Wright, 1984), which are not found at any other location in the region. The rhyolite flows occur in beds ~ 1 m thick and are ignimbritic and aphanitic. One horizon contains abundant pumice fragments which grade laterally into a dense, aphanitic feldspar porphyry across several meters. Some flows include many well rounded cobbles in a volcanic matrix. These flows are probably linked genetically to the extrusion of the Pul Pul Rhyolite. The conglomerates are clast-supported and texturally mature. Clasts are rounded to well-rounded and are predominantly composed of vein quartz, dolerite, and felsic volcanic fragments. The sandstones are both compositionally and texturally immature. The peperites, (called 'cowpatites' by natives), consist of wispy patches of felsic volcanic resting in a matrix of immature sand, with coarse grains collecting along one edge of a felsic patch (fig. 9). This fill sequence appears to be disconformably overlain by the Big Sunday Formation; however, the contact between the valley fill and the Big Sunday Formation is not actually exposed.

Big Sunday Formation

Facies: The Big Sunday Formation is a succesion of tuffs, tuffaceous siltstones, graywackes, and sandstone in excess of 140 m. Although a complete section was not measured, the section presented (appendix A6) represents the largest continuous and correlatable exposure of the total thickness. The Big Sunday has been correlated to the 2200 m thick Tollis Formation to the south by Needham and Stuart-Smith (1985) on stratigraphic and lithologic grounds. The chief facies of the Big Sunday consist of tuffs and tuffaceous siltstones and include as well fine- to coarse-grained, massive- to planar-bedded feldspathic graywacke.

Tuffaceous sediment, either pyroclastic or epiclastic, is the chief component of the fine-grained rocks, although it often contains a component of quartz-rich silt and detrital mica. Tuffs dominate the lower half of the section as the volumetrically greatest unit in the first 76 m. Meter-scale intervals dominated by Bouma-sequence structures are present locally in the tuffs. Commonly, only parts of Bouma sequences are preserved, chiefly T_{c-e}, moving to T_{b-e} then T_{a-c} or just T_{a-b} towards the top of the section. Beds are frequently amalgamated. Because tuffaceous material of uniform grain size dominates the lower sequence, there may be no grain size variation between or within some turbidites, i.e., Tb-e have the same grain size. Upper bedding surfaces are often exposed and show exhumed climbing ripples. Basal exposures are rare; those exposed exhibit flute casts. At the base of the section, planar lamination alone is common. Typically, turbidite intervals lie between thick intervals of undistrubed finely laminated tuffaceous shales. Rarely, an undulose, low-angle cross-stratification is preserved in the rock higher in the section, occasionally with fully exhumed hummocks and swales. This can be confused with an undulose weathering pattern which discolors much of the tuff lower in the section. Many of the tuffs show sigmoidal jointing typical of tuffs (Cas & Wright, 1984).

The massive sandstones are feldspathic graywackes present in the upper half of the measured section. These represent T_a turbidites, as is evidenced by the infrequent preservation of T_{a-b} and T_{a-c}. Bed thickness increases towards the top of the sequence from < 10 cm to over one meter; grain size also increases from very fine to coarse. Many beds fine upward, but their contact with tuffs or other graywacke beds is always abrupt. Some beds exhibit intraclasts, predominantly fine-grained graywacke.

Interpretation: The dominance of classic turbidites (Walker 1984, 1978) strongly suggests that the bulk of the Big Sunday Formation is subaqueous. The stratigraphic position of the Big Sunday Formation between subaerially deposited sandstones and the restricted geography of the deposits suggest that they might be lacustrine. The occurrence of HCS high in the section, coarsening- and thickening-upwards packages, plus the increasing abundance of Bouma bc and Bouma abc structures, suggests overall shallowing upwards (Walker, 1978). The sequence matches descriptions of deltaic turbidites (e.g., Lunegard et al., 1985) and descriptions of submarine fan facies (Normark, 1978). These two depositional environments are difficult to distinguish, and insufficient cross-basin and strike-parallel work exists to document independently either geometry.

The likelihood of ongoing volcanism during deposition must have complicated sedimentation in the Big Sunday Formation. In addition to fluvial contributions to subaqueous fans, there may have been air-fall contributions as well as interbedded lava flows. Such additions could affect paleoslopes, channel patterns on fans, and timing of turbidity currents. Moreover, the influx of sediments to the basin slope setting was only in part epiclastic, and the volcanic component of the sediment came from both subaerial tuffs and the Pul Pul Rhyolite. This mixed-source material limits the conclusions one can draw from petrologic analyses. However, the abundance of mica in the graywackes suggests a metamorphic provenance, most likely from the Pine Creek Supergroup.

Edith River Group

The Kurrundie Unconformity

The Kurrundie Sandstone overlies the Pul Pul Rhyolite, the Big Sunday Formation, the Tollis Formation, and the Pine Creek Supergroup along the Kurrundie Unconformity. Stuart-Smith et al. (1988) attribute this unconformity to the Maude Creek Event, as evidenced in angular discordance between the Big Sunday Formation and the Kurrundie Sandstone. This discordance is not developed within the study area. Rather, one finds the Kurrundie Sandstone deposited in paleovalleys cut into the Pul Pul Rhyolite (fig. 10a). We interpret the unconformity to be a product of some tectonic event which may be related to development of the Palette Sub-basin. The genesis of the Kurrundie Unconformity is discussed with the Palette system below as well as in the tectonic history chapter.

Kurrundie Sandstone

These sandstones were deposited above the Big Sunday Formation south of the study area and directly on the Pul Pul Rhyolite above the Edith River Unconformity within the study area. It is a relatively thick succesion (> 300 m) of siliciclastic sediments capped by the Plum Tree volcanics and/or disconformably overlain by the platform cover sandstone of the Katherine River Group.

The Kurrundie Sandstone is pervasively iron-stained, ranging from a dark red-purple color to *liesegang* bands. This staining, although characteristic of the Kurrundie Sandstone, is neither ubiquitous nor restricted to this interval; *liesegang* banding occurs in the Coronation Sandstone, as well as the overlying Kombolgie Sandstone and even in portions of the Pul Pul Rhyolite.

Facies: The Kurrundie Sandstone displays a broad range of facies, including a cobble-boulder, channel-fill conglomerate, Gm; coarse- to fine-grained planar laminated sandstone, Sh; coarse- to fine-grained trough-crossbedded sandstone, St; planar-laminated siltstones/shales, Fl; and quartz-pebble conglomerate, Gp_q. These are assembled into a fining-upward sequence of Gm and Sh to St to Fl, with a return to St and introduction of Gp

The cobble-boulder conglomerate, Gm (fig. 10b), has a clast-supported framework of rounded to well rounded, imbricated clasts composed predominantly of Pul Pul Rhyolite, with a maximum mean clast size as large as 43.3 cm (Table 1). One bed is dominated by clasts of Pul Pul Rhyolite breccia (fig. 10b; refer to Palette Sub-basin stratigraphy and fig. 11a). Beds are typically several meters thick and are interbedded with St or Sh usually < 1 m in thickness (fig. 10a). Sandstone bodies rest in erosional scours on the conglomerate and are laterally discontinuous. This sandstone, as well as the matrix for the conglomerate, is composed mostly of lithic fragments.

Interbedded with Gm are decimeter- to meter-scale lenses of coarse- to fine-grained planar-laminated lithic to quartz arenite, facies Sh. These are gradually replaced with fine- to coarse-grained trough-crossbedded lithic to quartz arenite, St, towards the top of the conglomerates. Facies St then continues for at least 40 m above Gm. Troughs can be as large as four meters long, but are generally less than one meter long and 20 cm in relief (fig. 10c). In the coarsest sediment, rounded pebbles line the bases of individual troughs.

Siltstones, shales, and fine lithic to quartz arenites, Fl, rest abruptly above an interval of trough-crossbedded sandstone, though they ultimately grade upward into trough-crossbedded sandstone. The shales are quartz-rich and are interbedded with planar-laminated lenses of fine quartz sand several centimeters thick.

The upper section is a conglomeratic sequence, Gp_q, dominated by well rounded clasts of vein quartz 2-5 cm in size. Planar- and trough-crossbedded pebble sandstone and imbricated conglomerate are interbedded and grade between each other, with bed thickness ~ 30 - 150 cm. The sand is the most compositionally mature of the Kurrundie Sandstone samples (fig. 12).

Interpretation: A braid-plain environment is consistent with all facies except for the boulder conglomerates and the interbedded fine sands and siltstones. The conglomerate, like the Coronation Sandstone, suggests a valley-fill environment of deposition based on imbrication, clast size and rounding, clast-supported fabric, and lateral discontinuity. The 40 m thick interval of fine siliciclastics indicates distal sedimentation on the braid-plain. The abruptness of the transition from sand to shale suggests an episodic change in base level and basin equilibrium, which then gradually returned to a more proximal braidplain environment.

Palette Sub-basin

The Palette Sub-basin is an exhumed outlier on the Scinto Plateau and contains a number of facies not present in the El Sherana nor Edith River Groups. These facies represent a distinct tectonic environment within the larger succession and provide clear evidence for syntectonic sedimentation after the extrusion of the Pul Pul Rhyolite. The structure of the Palette sub-basin, described below in a seperate section, adds supporting evidence for many of the sedimentological interpretations.

Facies: The facies of Palette (fig. 11) are indicative of high-energy flow and mass wasting. They are sedimentary breccia sheet; massive to imbricated boulder-cobble conglomerates, Gm; matrix-supported conglomerates, Gms; and fine-medium grained sandstone, Sh, Sr, and St. These lithologies are related to growth faulting throughout the basin.

The breccia sheets (figs. 11a, b) consist of clasts of Pul Pul Rhyolite. Clasts are angular, and the sparse matrix comprises mostly Pul Pul Rhyolite debris, with occasional pockets of fine-medium sandstone. There is no clear bedding; minor beds of planar-laminated, fine-medium sandstone are present between breccia sheets. These are distinct from fine-medium grained sandstone dikes which locally cut breccia sheets,rarely with fitted fabrics (fig 11b), evidence of early cementation. The present mineralogy of the cement hematite, though the original cement could have been phosphate, carbonate, or even ferricrete.

There are several varieties of conglomerate, divisible by clast composition, rounding, and mean maximum clast size (Table 1, figs. 11c, d). Each deposit is incised and overlain by either another conglomerate or a lithic sandstone; the bounding surfaces may have as much as four meters relief (fig. 11d). The basal conglomerates, Gm, are massive to imbricated, boulder- to cobble-, polymictic, and clast supported, with interstitial medium to fine quartz sand. All other conglomerates, Gms, are matrix-supported, and clasts range from angular to rounded. Those at the base of the succession tend both to lack bedding, sorting, and clast imbrication, but the largest clasts also show the most rounding.

Well sorted, rounded to well rounded, fine to medium quartz arenites are interbedded with, and incise the conglomerates (fig. 11d,e). Planar lamination and trough crossbeds are common lower in the sequence; higher in the section climbing ripples appear and then dominate. Mud drapes (< 1 cm thick) separate many beds; drapes have abundant dessication cracks and form molds of oscillation ripples. Grain size and composition do not vary as a function of stratigraghic position and remain strikingly uniform throughout the sub-basin.

Towards the top of the sequence, conglomerates disappear altogether. The fine to medium sandstones do not continue to scour into underlying beds, but rather have sharp planar bases (fig. 11e). The quartz arenite laps against and ultimately overlies all primary growth faults, thus indicating when fault motion ceased. In at least one case a growth fault reactivated and folded the overlying sandstones (fig. 11f); these were in turn overlain by later flat-lying quartz arenites (fig. 11e).

Interpretation: The facies of the Palette Sub-basin are indicative of high-energy deposition, in particular the breccia sheets and conglomerates. The breccia sheets exhibit many characteristics of air-fall sedimentary breccias (e.g., Shreve, 1968). The structures of the quartz sandstones are characteristic of upper flow regime (Middleton & Southard, 1984), with the exception of the oscillation ripples and dessicated mud, which are interpreted as local, short-lived ponding. This assemblage of structures probably represents a system of alluvial fans (Rust and Koster, 1984; Winston, 1978) derived from and proximal to the margins of the sub-basin. Since the fine to medium sand overlaps all growth faults, it is derived from an altogether different location than the debris-flow conglomerates, which do not occur above the margins of the growth faults. This supposition is supported by the high maturity of the quartz sandstone (fig. 12) in contrast to the compositionally and texturally immature conglomerates, as well as by similarities between Palette sand and sand in other lithologies.

Figure 13 shows an interpretation of the sequence of events in the Palette sub-basin. This interpretation is constrained by mapping of stratigraphic and structural relationships and by composition and association of basin facies. The local tectonic environment resulted in high-energy facies and high compositional variance, yet development of the Palette sub-basin is likely to be related to a large-scale regional tectonic event. Due to the influx of quartz sand and the overlapping of growth faults by quartz sandstone, the Palette succesion probably belongs to some other regional sediment package.

The outstanding question of the Palette sequence is its age. It must have developed after the deposition of the Pul Pul Rhyolite, yet its minimum age is poorly constrained since it has no regionally recognizable stratigraphic cap. We here group the Palette facies with the Kurrundie Sandstone based on the following arguments. First, the Kurrundie Sandstone contains clasts of Pul Pul Rhyolite breccia sheet near Freezing gorge. Next, there is no evidence of the Edith River Group having been once deposited and then removed, either in the form of preserved stratigraphy or clasts elsewhere in the region. Last, the Palette sub-basin probably opened according to some basin-wide tectonic event which may be correlated to that which deformed the El Sherana group and reversed the basin gradient creating the Edith River Unconformity. The disparity between facies of Palette and the Kurrundie Sandstone would then be due to the different hydraulic conditions created by the tectonic setting. An alternative scenario would set basin developement syn- or post-Kombolgie. Evidence for this model is that faulting at Coronation Hill, believed to have developed contemporaneous with Palette, cuts the Kurrundie Sandstone. This is also supported by sediment maturity (fig 12).

Summary

The first-order distinctions between the stratigraphy of Needham et al. (1988) and the present interpretation can be seen in fig. 2. The authors' interpretation considers the stratigraphy in terms of chronostratigraphic blocks separated by unconformities along which there is demonstrable erosion and missing time. In addition, lithologic packages such as the Coronation sandstone are refined in terms of recognition of key event deposits and both facies- and time-dependent subdivisions of larger stratigraphic blocks. This reduces uncertainty with respect to the volume and range of volcanic and fine siliciclastic material in the section. Finally, the true original extent and geometry of the El Sherana/Edith River basin is poorly constrained due to erosion associated with unconformities, lack of preserved margins or marginal facies, and burial under later platform cover.

Petrography

Over one hundred samples were studied petrographically using a polarizing light microscope. Fifteen total point counts are presented in Appendix B, as well as key petrographic descriptions. The counts consider both present mineralogy and original composition of framework grains and, where possible, matrix.

Previous Work

Together, P. Stuart-Smith, S. Needham, and L. Bagas collected and described over one hundred samples for the Stow 1:100,000 map (L. Wyborn, pers. comm.). Those are brief petrographic descriptions to characterize representative rock types, not detailed analyses. In addition, Needham et al. (1988) includes six point counts of 1000 points each from the Tollis Formation, stratigraphic correlative of the Big Sunday Formation. Figure 12 includes the mean of these counts for comparison. Valenta (1989) included several petrographic descriptions from the El Sherana and Edith River Groups.

Needham et al. (1980) and Stuart-Smith et al. (1988) concluded that the El Sherana and Edith River Groups are unmetamorphosed. Contrary to their field and petrographic descriptions, optical analyses by G. Warren (pers. comm.) argue for lower greenschist metamorphism of these units based on the presence of chlorite and epidote in thin section.

Geochemical data from this stratigraphic interval is a presented in Ethridge et al. (1986) and Wyborn (1988). Based on a variety of geochemical evidence, L. Wyborn (1988) concluded that El Sherana and Edith River Group volcanics along with many other regional igneous rocks were derived from infracrustal sources. Zircons from the Pul Pul Rhyolite (Page, 1988) are highly discordant, and the Pul Pul Rhyolite contains considerable regional variation in composition as a function of hydrothermal alteration (R. Page and L. Wyborn, pers. comm.).

Methods

In order to improve accuracy of point counting, all sandstones and volcanics were stained for feldspar. After preparing samples as thin sections, we gave half of each slide a bath in dilute HF for approximately 10 seconds before staining. Staining was otherwise similar to Friedman (1967). This extremity of surface etching proved necessary, as the samples did not initially accept the stain, particularly sedimentary rocks. Half baths were given to provide a control for degree of acid etching and staining effectiveness. Unfortunately, due to the high degree of weathering and hydrothermal alteration proper identification and differentiation of lithic fragments and feldspars still proved difficult.

The 15 point counts included 275-350 points per slide. To achieve 95% accuracy, a sample will lie within 2σ of compositional assessments, varying from 0-100%, when within a range of 3-12% (Van der Plas and Tobi, 1965). This calculation assumes no further uncertainties; however, due to the advanced state of hydrothermal alteration and weathering in most specimens, there was occasionally considerable uncertainty in grain recognition. Dorsey (1985) assumes an uncertainty several percent greater than Van der Plas and Tobi (1965) to attain 95% confidence level for compositional estimates due to the likelihood of errors in grain identification. By the same reasoning, we assign a slightly greater uncertainty in compositional estimates, 10-20%, due to the advanced stage of alteration. It is worth noting, however, that the estimates of quartz composition are likely to be closer to the 3-12% statistical deviation due to their relatively pristene and unaltered condition and ease of recognition.

Coronation Sandstone

Siliciclastics. The Coronation Sandstone ranges in composition from quartz to lithic sandstone. Lithic fragments are mostly reserved as polycrystalline quartz and chert, with uncommon volcanic, sedimentary, and metasedimentary fragments. Alteration of volcanic fragments will be discussed below with the Pul Pul Rhyolite.

Feldspars are typically completely altered or replaced, the chief mechanisms being clay mineral replacement and vacuolization. It is therefore difficult in most circumstances to distinguish between K-spar and plagioclase populations. Other minerals are also uncommon; of these the most common are detrital micas, mostly chlorite then muscovite. Micas are considered to be detrital only when they exhibit deformation and fracture attributable solely to compaction, e.g., folding about a framework grain with a sharp contact between grains, or transport. It is therefore likely that some fraction of the phyllosilicate population which was not counted as detrital may be so. Also, detrital epidote grains appear throughout the section. Although often in a state of alteration, epidote grains can be quite pristene (fig. 14a,j).

The framework grains are bound chiefly by grain suturing and syntaxial overgrowths of quartz. Other matrix and cement is in the form of late-stage amorphous silica, probably chert. Much interstitial material is altered or replaced with high- and low-birefringent phyllosilicate minerals. These high-birefringence types include authigenic white micas including illite and chlorite both white and green, and the low-birefringence varieties are probably smectite and mixed-layer clays. Authigenic mineral size ranges from several microns to several hundred microns. Very large masses occur both as books and randomly oriented crystal aggregates which cut across the boundaries of framework grains. Chlorite also occurs within quartz as well, commonly as vermicular chlorite or as a thin blanket over portions of grains rather than as true replacement.

Due to this alteration, it is difficult to determine if earlier matrix or cements were important or common. However, there are rare patches of well preserved phosphate cements. Phosphate is suggested based on birefringence and crystal habit, which is akin to wavelite. The cement can have a coarse, bladed habit, which may be primary or secondary, or a multilaminate, colliform habit (c.f. Southgate, 1986), consisting of laminae composed of isopachous fibres (fig. 14b,c). In addition, one can observe that the cement has included small quartz grains within fibrous bundles. Quartz grains have pristene, unaltered boundaries, in contrast to small, high-birefringence clays which cut across relict fibrous bundles irregularly. This suggests that the authigenic minerals replace phosphate.

Volcanics. Most volcanics in the Coronation Sandstone are altered beyond recognition both in outcrop and under the microscope. The predominant replacement minerals are hematite and silica, and are probably related to both devitrification of groundmass and hydrothermal alteration associated with faulting and perhaps mineralization. The most important volcanic, both volumetrically and stratigraphically, is the thick amygdaloidal basalt horizon described above. In thin section, none of the original minerals remains; but in relatively pristene samples, mineral pseudomorphs are preserved, chiefly silica after plagioclase laths. In addition, silica pseudomorphs after fibrous rinds are common. Present amygdule fill consists of chert or calcite.

The rhyolite which lies below the basalt horizon near Saddle Ridge (Appendix Ac, fig. 3) is also relatively fresh. However, its petrography is essentially identical to the Pul Pul Rhyolite described below, and will not be elaborated upon here.

Conclusions. Detrital chlorite, muscovite, and epidote combined with the chert and metamorphic rock fragments and extremely low feldspar populations are most consistent with a provenance of underlying greenschist grade metasediments in the Pine Creek Supergroup. At the same time, the presence of detrital metamorphics argues against regional metamorphism or deep burial involving the Coronation Sandstone. Diagenesis involved precipitation of quartz cement overgrowths with minor pressure solution and suturing effects, with the possibility of early, volumetrically important phoscrete. The generation of clays and other phyllosilicates is likely to be a function of relatively recent deep weathering, consistent with the assemblage of illite and chlorite (Hoeve et al., 1980).

The volcanics form a compositional array which is best described as bimodal volcanism. This is part of the Barramundi orogenic association (Ethridge et al. 1986). Fabrics preserved as silica pseudomorphs in the mafic suite may represent groundmass dissolution and zeolite encrustation. A less likely alternative, yet consistent with pseudomorph habit, suggests that these rinds may have been palagonite replacement of mafic glass (Fisher and Schminke, 1984).

Pul Pul Rhyolite

Detailed work on the petrography of the entire package of volcanics included in the Pul Pul Rhyolite is part of the present research of E. Jagodzinski at Monash University. and the Bureau of Mineral Resources. The reader should examine her work for geochemical analyses, new geochronology, and interpretation. However, there are several salient features from our cursory petrographic analyses which concern the El Sherana and Edith River Groups' evolution and interpretation.

Mineralogical changes have largely obliterated microtextures in these rocks. The present ground mass has inverted to two dominant textures, one microcrystalline and one relatively coarse (fig. 14d,e). The microcrystalline fabric strongly resembles chert yet has slightly lower relief. A mineral replacement featuring a low-relief, low-birefringent, uniaxial +, blocky crystalline mosaic comprises the coarse fabric. The optical properties of the mineral are consistent with those of zeolite; however, the crystal habit is blocky and not acicular.

Fresh feldspars in the Pul Pul Rhyolite are extremely rare. Most have undergone complete replacement by sericite or some other clay mineral, and the rest are partially altered and replaced. Although the majority of quartz phenocrysts are fresh, many have undergone vacuolization, embayment, and partial dissolution. Lithic fragments, dominantly slates and phyllites with minor polycrystalline quartz, show occasional carbonate replacement as well, though this could be attributed to pre-detrital metamorphism.

Despite considerable alteration in the Pul Pul Rhyolite, there is no metamorphism. There are, however, minerals of metamorphic assemblages within the Pul Pul which are detrital rather than replacement. Evidence can be found southeast of the study area in the incised valley fill sequence. Clasts from conglomerates in the area show extensive metamorphism in clasts (fig. 14f,g). These include chlorite greenschists with chlorite pseudomorphs after plagioclase, well rounded detrital epidote, and several populations of plagioclase; others include detrital microcline and felsic volcanic fragments. Clasts are uniformly well rounded except for plagioclase. All detrital fragments lie in a siliceous matrix which shows no sign of metamorphism or alteration other than minor local development of authigenic clays. Given the unstable nature of volcanic glass, it would have been highly susceptible to even low-grade metamorphism. This demonstrates that metamorphic assemblages found within rocks of that stratigraphic level do not require metamorphism, but rather are incorporated framework constituents.

Conclusions. Metamorphic clasts may have been incorporated into the Pul Pul either from the surface as detritus or at depth as xenocrysts and xenoliths. The former is suggested by high frequency of the metamorphic minerals and clasts and supported by the observation of similar processes in the Coronation Sandstone. The likeliest explaination for the bulk of the replacement recrystallization fabric is devitrification of a pre-existing glassy matrix. This suggests a large component of primary glass independent of pumice fragments and fiammi.

Big Sunday Formation

The Big Sunday Formation consists of tuffs and tuffaceous silts to feldspatholithic sandstones and graywackes. These are the only rocks in the El Sherana/Edith River Groups to contain significant percentages of feldspars.

The tuffs have a microcrystalline matrix, and phenocrysts typically are $< 50\ \mu m$ in size. Quartz phenocrysts are angular, show unit extinction, and are fresh. No feldspars are visible in thin section, though staining turns the groundmass bright yellow. There are fine-grained clay pseudomorphs after feldspar, probably sericite, which in unaltered samples is distinct from the groundmass. Phenocrysts comprise < 5% total volume. Small round to angular cherty masses are fairly common, and are likely to represent devitrification of glassy tephra. Micas are common, though their small size and great abundance suggest they are later replacements.

Tuffs and tuffaceous siltstones are difficult to differentiate in outcrop and are best sorted by optical petrographic analysis. Quartz-rich laminae over 100 μm thick are common in tuffaceous siltstone, and may comprise as much as 40% bulk composition.

The feldspatholithic sandstones and graywackes contain abundant grains medium size or larger, and first occur roughly half-way up the section. The grains are dominantly quartz and feldspar, both potassium and plagioclase (fig. 14h,i). Quartz grains are fresh, though some have vermicular chlorite and corroded boundaries. There is on average more potassium feldspar than plagioclase, and subequal portions of quartz to feldspar with quartz slightly more common. Matrix volume is high even in the sandstones, and is predominantly siliceous and unaltered. Again, the predominant alteration is low-temperature chlorite and illite. Detrital chlorite is quite common; detrital muscovite is less so. Detrital and authigenic chlorites in part can be distinguighed in these units by refractive indexes and birefringence (Albee, 1962), which are high for the detrital fractions and very low, below plagioclase, for authigenic fractions which are often mixed with vermiculite (Deer, Howie, and Zussman, 1976). There are also infrequent detrital epidote grains.

Chlorite replacement is ubiquitous in all Big Sunday Formation units, resulting in a green color to most beds in outcrop. This contrasts with the Tollis Formation, the stratigraphic correlative of the Big Sunday, in which both matrix and grains are relatively unaffected by chlorite alteration and feldspars are fresh. Chlorite chiefly replaces matrix, especially tuffaceous matrix, though it can be seen to cut into and across grain boundaries.

Conclusions. The Big Sunday Formation has undergone alteration, yet it appears also to be low-temperature and low-pressure replacement. Low refractive index chlorite indicates a high-silica, low-iron composition (Albee, 1962), and this is often the case with authigenic chlorites (Velde, 1977), which show an iron enrichment trend increasing with depth. The iron content is also a function of brine chemistry and climate temperature (Velde, 1977), yet metamorphic chlorites show consistently higher iron fractions than authigenic chlorites (Albee, 1962).

Upward in the section, the tuffs become enriched with respect to quartz, and fresh feldspars and detrital mica become volumetrically important. Early tuffs, therefore, may represent pure ash composition, with an increasing component of Pul Pul Rhyolite epiclastic material upwards. In addition, the advent of coarse detrius, increasing volume of feldspars, and introduction of detrital micas and epidote probably correspond to uplift and erosion below the Pul Pul Rhyolite to metamorphosed Pine Creek Supergroup farther to the north. This is consistent with paleocurrent data, geometry of unconformities, petrography from the valley-fill sequence along the Big Sunday Unconformity described above, and the absence of Coronation Sandstone and ultimately Pul Pul Rhyolite far north of the study area. Discussion is continued under Generation of Unconformities below.

Kurrundie Sandstone

In general, the Kurrundie Sandstone is similar to the Coronation Sandstone both compositionally and texturally in outcrop and thin section. The chief compositional differences are the relative abundance of felsic volcanic lithic fragments (Table 1, fig. 12, fig.14j). There are no observed phosphate cements. Hematite staining and *liesegang* banding are not strongly developed petrographically. Heavy minerals, especially micas, are fresher in the Kurrundie than in the Coronation Sandstone (fig. 14j). In short, there is no petrographic evidence to indicate a provenance or depositional environment drastically different from that of the Coronation Sandstone except for large percentages of felsic volcanic fragments sourced at least in part from the Pul Pul Rhyolite.

The sediments of the Palette sub-basin reflect a bimodal sorting. Breccia sheets and fanglomerates are locally sourced and poorly sorted. In contrast, the medium to fine sandstones are very well sorted (fig. 12, Appendix B).

Provenance/Summary

Fig. 12 presents three ternary diagrams after Dickinson and Suczek (1979) which include the 15 point counts as well as counts from the Tollis Formation presented in Needham et al. (1988). There are no compositional trends within individual units. Total Q*L*F was not plotted, as it is a gauge of susceptibility to porosity occlusion; the Qm*Lt*F diagram is considered here to represent grain composition most accurately as it plots the total lithic fragment population versus quartz and feldspar (Dickinson and Suczek, 1979)

The units tend to cluster in relatively discrete groups. The Big Sunday Formation is most distinct from the other groups due to the large feldspar component. The Coronation and Kurrundie Sandstones fall within the same general field for all three diagrams. The Palette sub-basin sandstones, in contrast, containing greater compositional maturity than any other sediments in the El Sherana and Edith River Groups. It is possible, therefore, that the Palette sub-basin has a separate provenance as a function of timing of basin formation or paleogeography. All samples plot within the fields of either recycled orogen or continental block provenances, which is consistent with the regional environment which sourced these sediments.

The Tollis Formation was the subject of only one petrographic analysis, so little conclusive can be said about how it relates to the Big Sunday Formation. Nonetheless, there are considerable differences based on the data presented in Needham et al. (1988). The Big Sunday Formation and Tollis Formation are qualitatively discrete in fig. 12, suggesting that they had different provenances. This agrees with the stratigraphic evidence for local sourcing of the Big Sunday Formation from the Pul Pul Rhyolite during active volcanism in two ways. The Pul Pul would provide a source for fresh feldspar and quartz phenocrysts. What is probably the dominant effect, however, is that the Big Sunday Formation would be more suceptible to alteration based on the high tuff or volcanic content, and on these grounds lithic volcanic fragments might be very difficult to recognize.

The Tollis Formation is rich in volcanic lithic fragments but is less altered than the Big Sunday Formation. In addition, the Tollis Formation is thicker than the Big Sunday Formation by at least a factor of five and contains significant argillite. Finally, the Tolis Formation is penetratively deformed by tight folds while the Big Sunday Formation is undeformed. This evidence does not necessarily refute the stratigraphic evidence for correlation; nonetheless, the Big Sunday Formation and Tollis Formation may represent two geographically distinct basins, both of which antedate deposition of the Kurrundie Sandstone, and formed within similar tectonic circumstances. Studies of paleocurrent distribution within the Tollis Formation may shed light on this problem.

Scinto Breccia

This chemically complex unit is identified in the field as a breccia which is highly siliceous, hematitic, and in which the host lithology is indeterminable due to extreme replacement. Most previous examinations of the Scinto Breccia have suggested that this lithology represents a weathering horizon or saprolite which formed above carbonate in the Pine Creek Supergroup and lies below the Coronation Sandstone (Walpole et al., 1968; Stuart Smith et al., 1988). There is, however, new evidence that there are several units formed from different geologic processes in different environments which fit the above description.

Outcrop/hand sample scale observations. There are several places within the study area in which well developed Scinto Breccia is exposed. Most outcrops are siliceous, sub-vertical ridges which stand in relief to the earlier metasediments. However, one can often find stratigraphic offset across these ridges, thereby demonstrating that they represent tectonic or fault breccias rather than unconformity breccias. In several of these locations, such as near the Palette mine, one can walk along horizons of El Sherana Group sandstone or volcanics directly into these ridges. This demonstrates that ridges of Scinto Breccia are stratigraphically discordant with respect to their hosts.

Chemical zonation can be observed along faults characterized by Scinto Breccia. Closest to the fault, both silica and hematite replacement are strong.

Farther from the fault surface, silicification weakens and disappears, such that only hematite replacement and veining have altered the host; farther again, the host lithology is unaltered. This zonation is typically developed on the scale of decimeters to meters. In the host, veins with quartz cement lining have a late-stage fill of hematite. Additionally wavelite (S. Needham, pers. comm.) is formed as an additional phase interior to the hematite.

The interpretation of tectonic brecciation is supported by a peculiar local fabric which consists of angular, platy clasts. These clasts are oblate rectangles in cross section, typically composed of milky white, vitreous chert. Silica usually has replaced the host completely; however, some clasts show only partial replacement. In these half-altered clasts, the relics of crystal compromise boundaries are preserved as an uneven, jagged boundary which runs along the meridian of the clast, roughly bisecting the plate. In less altered clasts, silica replacement grades into unaltered quartz palisades. One scenario for clast genesis involves the existence of quartz veins which became rectangular, platy clasts as the host rock fractured. Both host and veins then underwent silica replacement. Similar observations and interpretation were made by Valenta (1989).

As discussed above with respect to the Coronation Unconformity, there are exposures of Scinto Breccia which may be unconformity related. The type location for this lithology is southeast and below the Saddle Ridge mine. Here, a broad, horizontal lens of Scinto Breccia can be found above an exposure of carbonate in the South Alligator Group. The unit is siliceous, hematitic, phosphatic, and the original composition of the host lithology is indistinguishable. One can not, however, actually demonstrate unequivocally at this location that Scinto Breccia lies below unaltered Coronation Sandstone.

Optical petrography. Development of Scinto Breccia involved a series of replacements and cements. Through cement stratigraphy we determined relative timing of hydrothermal events. These events all took place after the initial silicification of the host rocks, as all cement phases nucleate on either silicified host or later cements. It should be noted again that all mineral identification proceded solely from optical petrography.

Figure 15 shows a sequence of six successive mineralizing events under plain and polarized light. The first-stage mineral is a blocky phosphate cement which nucleates directly on the host. The second phase is apatite, with euhedral crystals nucleating on the earlier phosphate or on a silica base. These two stages are only locally developed. After apatite, quartz fills all vugs with large crystals with no fine crystal precursors. It is possible that more than one quartz precipitation event took place back-to-back based on slight optical discordance across cryptic surfaces within what otherwise appear to be single crystals. In many vugs or fractures, this is the last phase recorded.

The fourth-stage mineral is coarse, platy or bladed hematite. Single crystals can be as large as 500 μm. The fifth mineral phase is a late-stage phosphate cement, probably wavelite, which occludes remaining pore space, engulfing hematite laths which show local mild dissolution. The sixth phase develops as fine acicular needles. Its optical properties unfortunately are not observable at a scale to pose a compositional interpretation. In other veins, needles cut across quartz grain boundaries and nucleate on hematite laths. The fifth and sixth phases are not seen cutting each other, and may be contemporaneous.

Conclusions. Based on both outcrop and petrographic observations, we propose following scenario for paragenesis of Scinto Breccia. There may be additional events, chemical or tectonic, which have not been properly demonstrated.

The first stage is the formation of Scinto Breccia *sensu stricto*, namely as a hematitic, siliceous, phosphatic unconformity breccia. This would by definition occur at the base of the Coronation Sandstone and must predate later occurrences which cut the El Sherana Group. At Coronation Hill, Scinto Breccia affects the Kurrundie Sandstone, yet due to the uncertain timing of the Palette sub-basin, one can assert neither that Palette sub-basin postdates the Kurrundie Sandstone nor that there must be at least two temporally and geographically distinct occurrences of Scinto Breccia.

The following events are suggested to have been important in the timing of Scinto Breccia development. Enough fracturing must have occurred during initial tectonic brecciation to create veins of quartz with an interior specular hematite fill. Next, brecciation continued, either hydrothermal or tectonic, with continued silica and hematite alteration. These may have all been contemporaneous, or any pair of them contemporaneous provided brecciation is one of the first pair. Last, the series of cementation described above postdated that all of these, with wavelite as the last phase to form both in outcrop and in thin section. This invokes then at least two episodes of silica replacement followed by hematite.

It is unclear how the genesis of Scinto Breccia relates to mineralization. Silicification and hematite replacement are both hydrothermal phenomena, both acidic and oxidizing. This would be in agreement with the rough model proposed by Valenta, (1989), as a couplet to the basic, reducing, mineralizing fluid system and seems to be born out in several locations, including El Sherana, Saddle Ridge, Palette, and Coronation Hill. The prediction that zones of desilicification would occur below zoned of silicification has not been bourne out, however, and might be amended such that zones of desilicification and silicification simply are coupled. It is also possible that a study of regional geochemical variations within the Scinto Breccia could lead to conclusions regarding relative timing of events, composition of mineralizing fluids, and development of a predictive model for hydrothermal mineralization.

Tectonic History

Previous Work

Regional mapping, geochemistry, and geochronology conducted by the Bureau of Mineral Resources set the framework for tectonic interpretation of the South Alligator Valley. Needham et al. (1980, 1988) recognize deformation and metamorphism in the Pine Creek Supergroup and relate it to regional compression related to the Nimbuwah Event. In the study area, metamorphism involved lower-greenschist-grade alteration of Pine Creek Supergroup sediments. Deformation was chiefly observed as northwest-trending isoclinal folds in the Pine Creek Supergroup and northwest-trending subvertical faults, several kilometers long. Needham et al. (1988) concluded that movent along these faults began before El Sherana Group sedimentation based on stratigraphic thickness variations across the South Alligator Valley. Based on geometry, the faults were considered to represent chiefly strike-slip displacement. Valenta (1989) supports their conclusions, finding S-C foliations and fault lineations which suggest dextral displacement. He suggests that these faults may be as long as 20 km and attributes differences in deformational style across the faults partly to rheological changes from the Mount Partridge Group to the Koolpin Formation and to pre- El Sherana Group age faulting proposed in Stuart-Smith et al. (1980). Although Needham et al. (1980) invoke pre- El Sherana faulting near this contact, they consider the Mount Partridge-Koolpin contact to be an angular unconformity where exposed.

Johnston (1984) examined regional structure related to Pine Creek orogenesis. He concluded that thrust faulting could play an important role in regional faulting and that the Koolpin Formation acts as a regional décollement. Valenta (1988, 1989) conducted structural studies in the South Alligator Valley with an emphasis on the areas of greater deformation and U- and/or Au-PGE mineralization. He recognized four deformational styles, one of which is pervasive northwest-trending isoclinal folds. Valenta (1989) suggests that these areas relate to either restraining or releasing oversteps associated with strike-slip motion along these faults. Within this model, he describes El Sherana as restraining bend, the Scinto Plateau as an extensional duplex, and Coronation Hill as a rhombic syntectonic basin at a releasing overstep. Based on stratigraphic grounds, he suggests ~ 10 km offset along the major northwest faults before deposition of the Coronation Sandstone and less offset, ~3-5 km post-El Sherana and pre- Kombolgie time. In addition, he catalogued the dominant geometries of the South Alligator Valley into north-trending strike-slip or extensional faults, east-trending strike-slip or compressional faults, and northwest-trending dominantly strike-slip faults.

The earlier Nimbuwah Event (Needham et al., 1980; Stuart-Smith et al., 1980) is the end of a complete orogenic cycle and is part of the regional Barramundi orogeny (Ethridge et al., 1986). Burial, metamorphism, and deformation throughout the Pine Creek Supergroup is linked to the intrusion of orogenic batholiths several hundred kilometers to the northeast of the study area (Needham et al., 1988, Wyborn 1988). Page and Wilson (1988) used U-Pb zircon techniques to date Nimbuwah granulites and granites related to orogenic collision at 1.886± 5 Ga to 1.866± 8 Ga. The Gerowie Tuff in the South Alligator Group yields an age of 1.885± 2 Ga (Needham et al., 1988), setting a maximum age for El Sherana group sedimentation, including an antecedent interval of significant flysh sedimentation prior to El Sherana deposition. In addition, dacitic tuff from the Tollis Formation is dated at

$1.890\pm{}^{18}{}_{15}$ Ga (Page and Williams, 1988), setting a minimum age for El Sherana sedimentation at 1.875 Ga. These are in agreement with dates both for the Plum Tree Volcanics (1870-1860), which set a minimum age for Edith River Group sedimentation, and the Nimbuwah granulites and granites (1.886± 5 Ga to 1.866± 8 Ga) related to orogenic collision.

Faulting Patterns and Timing

Appendix C is a 1:10,000 scale map of the South Alligator Valley northeast of the South Alligator River. Faults with several recurring geometries cut rocks of the El Sherana and Edith River Groups within the map area, closely matching those described in Valenta (1989). East-trending, moderately dipping reverse faults, with stratigraphic displacements both to the north and south, have the best constrained geometries. These cut Pine Creek Supergroup and El Sherana Group. The Saddle Ridge fault is one of these, as is a reverse fault above and immediately north of Saddle Ridge which appearas to cut the Palette sub-basin sediments. The latter fault must be coeval with or postdate Palette sedimentation. A series of north-northeast-trending, southside-up reverse faults cut the El Sherana Group but have not been found to cut the Edith River Group. It is possible that these faults are relatively early and are cut by other faults. Moderately-dipping, north-northeast-trending, southside-down normal faults are common only along the Scinto Plateau, and are coeval with Palette sub-basin deposition, locally acting as growth faults.

Steeply dipping northwest-trending faults show variable stratigraphic displacement, typically less than 150 m. Stratigraphic arguments indicate that they may be either minor strike-slip faults, with less than one kilometer lateral displacement, or normal faults. These faults cut the Edith River Group, and may cut the Kombolgie Formation. The longest fault on the Appendix C map is the Fisher Fault, two kilometers in length. The new interpretation suggests that there is not one long, through-going fault, but that there is a zone of faulting with small *en echelon* faults of variable displacement and length. In this context, the Rockhole-El Sherana-Palette fault is reinterpreted as a discontinuous series of faults. This style of deformation is relatively common in areas featuring strike-slip faulting (Christie-Blick and Biddle, 1985).

The true length or displacement of the South Alligator fault is unclear as it is typically not exposed nor are both adjacent blocks. We therefore suggest that it may also be made up of several shorter faults, possibly unrelated.

Generation of Unconformities

As discussed above, the basal contacts of the Coronation Sandstone, Pul Pul Rhyolite, Big Sunday Formation, Kurrundie Sandstone, and Kombolgie Sandstone are regionally developed erosional unconformities. In addition, two episodes of basin gradient reversal (Fig. 14) correspond to both the generation of unconformities and minor syntectonic sedimentation. This evidence strongly suggests a tectonic origin for the unconformities.

The Coronation Unconformity resulted from an erosional event in which lower-greenschist-grade Pine Creek Supergroup was uplifted and denuded. This is the largest demonstrable erosion in the South Alligator Valley, and is linked directly to Nimbuwah orogenic activity, most likely as final uplift and erosion of thickened continental crust.

The Pul Pul Unconformity is associated with at least one normal growth fault at El Sherana of approximately 70 m throw (Fig. 6). It is therefore likely that the tectonic pulse responsible for the Pul Pul Unconformity was extensional rather than compressional. The greatest thickness of Coronation Sandstone at El Sherana is 50 m. In contrast, the preserved stratigraphic thickness of Coronation Sandstone at Saddle Ridge to the south is 160 m, with no preserved Coronation Sandstone north of Gunlom Falls. Therefore, the northwest end of the South Alligator Valley was raised relative to the southeast, thereby denuding the Coronation Sandstone and Pine Creek Supergroup to the North while depositing the Big Sunday Formation to the south. This model is consistent with petrologic data from the Big Sunday Formation.

The Kurrundie Unconformity was generated from the next tectonic pulse. It is unclear, however, whether such a pulse is responsible for angular discordance between the Big Sunday or Tollis Formation and the Kurrundie Sandstone. The discordance was related to the Maude Creek Event (Fig. 2; Stuart Smith et al., 1988) and may either be an artifact of tectonism associated with Kurrundie deposition or rotation from initial basin subsidence to the South. It is also possible that this tectonic event was related to deformation at Palette (Fig. 13). Regardless, the southern end of the Edith River Basin must have risen with respect to the northern end during this tectonic pulse, resulting in northwest-directed sedimentation in the Kurrunidie Sandstone.

Discussion

Appendix C reinterprets the stratigraphic thickness in several locations where fault repetition exaggerated previous estimates of thickness. The two most prominent areas are at Fisher and the Monolith (Fig. 1), where previous estimates of thickness for the Coronation Sandstone were ~160 and 140 m respectively (Valenta 1989, Fig 31). The present interpretation reduces these thicknesses to 70 and 60 m, roughly the same stratigraphic thickness from Rockhole to Palette. In addition, changes in thickness throughout this interval can be demonstrably attributed to either removal via erosion during generation of unconformities or pinch-out against antecedent paleohighs. This therefore implies that no synsedimentary block faulting occurred along either the South Alligator fault or the Rochhole-El Sherana-Palette fault during deposition of the Coronation Sandstone. It is also unlikely that any synsedimentary block faulting occurred before Coronation Sandstone deposition as there is no stratigraphic evidence of earlier sedimentation.

The only evidence for post-El Sherana syntectonic sedimentation is preserved in the 4 km^2 Palette sub-basin. The basin has a 3:1 length-to-width aspect ratio, which is typical of many strike-slip basins (Nilsen and McLaughlin, 1985). It is bounded by steeply dipping faults, shows a migrating depocenter, and is dominated by facies indicitive of active tectonism. Many faults in the area, particularly the E-W reverse and SSW-NNE normal faults, may be kinematically linked to the longer subvertical faults as antithetic and secondary synthetic shears respectively (Christie-Blick and Biddle, 1985). A strike-slip pull-apart mechanism for Palette extension explains these observations. Similar relations are reported from the Little Sulphur Creek Basins (Nilsen and McLaughlin, 1985).

Despite the likelihood of a local strike-slip origin for the Palette Sub-basin, evidence for major deformation and syntectonic sedimentation typical of transform zones and major strike-slip faults (Crowell, 1974; Crowell and

Link, 1982; Steel and Gloppen, 1980; Nilsen and McLaughlin, 1985) is absent in all other parts of the El Sherana/Edith River succession. Consequently, any through-going strike-slip faults in the South Alligator Valley probably are not of significant length or displacement. It is possible that Coronation Hill is also a remnant pull-apart basin, yet faults along which Scinto Breccia has developed cut the uppermost sediments at Coronation Hill. This presents a partial argument that deformation at Coronation Hill may entirely postdate deposition of the Kurrundie Sandstone. Thereby, Palette sedimentation is either contemporaneous with Coronation Hill and Palette sediments are not Kurrundie time equivalents, or deformation at Palette and Coronation Hill was not contemporaneous. In addition, the lack of evidence for pre-El Sherana faulting allows the estimate for translation of 10 km during this time period (Valenta, 1989) to be revised. Assuming no pre- El Sherana strike-slip deformation, the displacement along any of the northwest-trending faults is likely to be less than 5 km.

The reversal of paleocurrents and generation of unconformities linked to tectonic events is plausible in extensional basins and strike-slip basins. However, both basin types may occur in tectonic environments whose overall character is compressional (e.g., Tantalus and Sustut basins; Eisbacher, 1974). Since the margins of the El Sherana/Edith River basin are not exposed, one cannot determine bounding fault geometries. Also, proximal facies are not preserved, which could have been used to constrain the location or orientation of bounding faults. Moreover, because the generation of unconformities resulted in removal of geographically large portions of the Coronation Sandstone, the original size of the basin is also undetermined. It is therefore difficult to say with any degree of certainty what the actual mechanism of basin subsidence was.

It is possible that the El Sherana/Edith River basin formed from post-orogenic collapse. Dewey (1988) suggests that post-orogenic extension is both common and predictable and is at least partly due to subduction rollback. Given the timing of basin formation relative to timing of orogenesis described in Page and Williams (1988) and Ethridge et al. (1986), El Sherana sedimentation must have followed Pine Creek orogenesis closely. The maximum possible time between Gerowie Tuff crystallization and Tollis Formation dacite crystallization is 12 Ma. A mechanism similar to that proposed for intermontane basins in the Appenines or Carpathians (Horvath, 1983) could account for basin subsidence. This is a particularly appealing model, because these environments are characterized by both regional extension and strike-slip deformation (Horvath 1983). The basement to these basins also contains thick flysch sequences without molasse and has undergone low-grade metamorphism, and the early stratigraphy commonly shows volcanism, and extension. However, tilted normal fault blocks are a dominant basin-forming extensional mechanism in Mediterranean intermontane basins (Horvath, 1983; Kastens et al., 1988). The El Sherana basin shows no direct evidence of tilting in sediments related to extension, although such tilting is obvious only in area of large percentage extension and requires the presence of listric half grabens.

Regional and Global Ties

The Barramundi Orogeny (Ethridge et al., 1986) is a period of continental collision in Northern Australia chiefly represented by fold-thrust belts like the Pine Creek Inlier. The Barramundi Orogeny is typified by bimodal volcanism, chiefly mafic, low-grade metamorphism with elevated geotherms, and lack of evidence for formation of oceanic crust or tectonic highlands. In other Barramundi provinces (e.g., Davenport province, Gawler province) an episode of volcanism and subaerial to shallow-water clastic sedimentation occurred in a similar stratigraphic position as the El Sherana and Edith River Groups. Deposition post-dates earlier sedimentation characterized by thermal subsidence and foreland basin turbidites and fold-thrust deformation associated with convergence (Blake and Page, 1988; Fanning et al., 1988).

Wopmay Orogen (Hoffman, 1980; Hoffman and Bowring, 1984), in the northwest corner of the Canadian Shield, displays many of the same characteristics as the Barramundi Orogeny and occurred at roughly the same time as Pine Creek orogenesis (Ethridge et al., 1986). New stratigraphic correlations betweeen Wopmay Orogen and the Kilohigok Basin (Grotzinger, 1989) have revised the dates of orogenesis in Wopmay. Those dates include a crystal tuff date at 1.885±3 Ga for the transition from passive margin to foreland basin sedimentation (Bowring and Grotzinger, 1989) marked by the deposition of shales and distal turbidites of the Recluse Group (Hoffman and Bowring, 1984). This overlaps remarkably with the Gerowie Tuff age of 1.886+2 Ga, which is also overlain by fine siliciclastics and turbidites in the Finniss River Group. Both sediment cycles are then intruded by a series of mafic sills just prior to deformation, the Morel sills in Wopmay and the Zamu Dolerite in Pine Creek.

After collisional tectonism in Wopmay, there occurred an event of regional transcurrent faulting developed at all scales. Transcurrent faulting was accompanied by sedimentation of the Et Then Group in the Athapuscow basin (Hoffman et al., 1977; Bowring et al., 1984). This was followed by sedimentation of the Hornby Bay Group, part of the Coppermine Homocline (Ross, 1983). The Hornby Bay Group is a 1 km thick sequence, partly of fluvial sandstones, which covers a large portion of the northwestern Canadian shield. Timing of deposition is well constrained by bimodal volcanics dated at 1.663±8 Ga (Bowring and Ross, 1985). Again, this coincides very closely with the deposition of the Katherine River Group, another thick fluvial succesion dated with volcanics at ~1.650 Ga which overlies the El Sherana Edith River Groups and much of the Pine Creek Orogen.

There is striking similarity between events and correlative dates in northern Australia and northwestern Canada from roughly 1.9 to 1.6 Ga (Friedmann and Grotzinger, 1989). Figure 16 shows schematically the timing and nature of events in Wopmay Orogen, the Athapuscow Basin, and the Pine Creek Orogen. In each location, a full Wilson cycle of rifting, thermal subsidence, and basin closure occurred, followed by a tectonic episode featuring strike-slip deformation, and later deposition of extensive middle Proterozoic platform-cover sequences. Sedimentation was preserved in the Et Then, Edith River, and El Sherana Groups. Sedimentation may have occurred in Wopmay, but would have since eroded to deeper structural levels. In both the basal Et Then and El Sherana, coarse clastics lap out against antecedent paleohighs for several hundred meters of thickness within a lateral distance of less than five kilometers (Hoffman, 1969).

This correlation allows two possible interpretations. The first is a paleogeographic reconstruction in which northern Australia and northwestern Canada were near each other, at least from ~1.9 to ~1.6 Ga. This would imply such correlations as the Katherine River Group to the Hornby Bay Group or the Morel Sills to the Zamu Dolerite. The other explaination involves basin formation models, like that of Dewey (1988), which are related to orogenic activity in general. Since the period of time from 2.0 to 1.8 Ga is a period of global orogeny, one would expect to find the same pattern of events in many locations regardless of paleogeographic position. Such a conclusion would temporally link Wopmay and Pine Creek by coincidence.

Conclusions

The following conclusions can be drawn concerning the El Sherana/Edith River succession.

1) Sedimentation in the El Sherana and Edith River Groups probably was not controlled by northwest-striking strike-slip faults in the South Alligator Valley. There is little evidence for syntectonic sedimentation, and the facies patterns are not characteristic of proximal or predominantly strike-slip environments. Therefore, movement on the South Alligator fault or the Rockhole-El Sherana-Palette fault did not control sedimentation during El Sherana Group deposition. This significantly shortens the movement history of these faults from a maximum of 20 km to 5 km.

2) The Coronation Sandstone reflects sedimentation in a mature river system, uncut by syndepositional faulting, in a valley-and-ridge antecedent topography. The Big Sunday Formation is dominated by turbidites. There are no proximal facies of Coronation or Kurrundie Sandstone preserved in the South Alligator Valley, with the exception of the Palette sub-basin and possibly Coronation Hill. The lack of facies associated with active tectonism suggests that there was little synsedimentary tectonism in the South Alligator Valley.

3) Revised thickness estimates of the El Sherana Group suggest that cumulative thicknesses do not vary much locally but do show significant variations on a more regional scale. Thickness variations are a function of paleotopography and erosional events and not differential subsidence. Unconformities were generated as an erosional response to tectonic pulses in the Pine Creek Orogen.

4) The El Sherana and Edith River succession is dominated by the presence of regionally developed unconformities related to tectonic activity. Tectonism and volcanism are probably related to orogenesis in the Nimbuwah region.

5) Two events of basin gradient inversion are documented in the paleocurrent record. These events are related to tectonism and the generation of unconformities.

6) Provenance is strongly a function of development of unconformities, and in all circumstances suggests local sourcing. The Big Sunday Formation, in part, has a different provenance than other units and is compositionally controlled by erosion of the Pul Pul Rhyolite.

7) Metamorphism affects neither the El Sherana nor Edith River Groups. The presence of abundant chlorite in the Big Sunday Formation and epidote in the entire succesion is attributed to detrital components from the Pine Creek Supergroup. Alterations can be attributed to hydrothermal alteration or younger weathering.

8) The Scinto Plateau is an exhumed minor strike-slip basin with a depositional environment of active tectonism distinct from the rest of the El Sherana and Edith River Groups.

9) The Scinto Breccia is at least in part a fault breccia which cuts El Sherana stratigraphy and locally Edith River stratigraphy. In most locations within the South Alligator Valley it is not a siliceous saprolite. The breccia may record episodes of local silicification related to mineral paragenesis.

10) The present size and geometry of both the El Sherana and Edith River Groups is not representative of the original geometry of the basin. This is based on the lack of proximal facies in the Coronation Sandstone and the

Kurrundie Sandstone, unconformity-related erosion, and extensive platform cover.

11) The El Sherana/Edith River basin formed immediately after Pine Creek/Nimbuwah orogenesis. If genetically linked to Nimbuwah orogenesis, then basin formation may be related to post- or syn-orogenic collapse of thickened continental crust.

Recommendations

We make the following recommendations for continued work in the El Sherana/Edith River Groups:

1) The continuation of 1:25,000 scale mapping, particularly from El Sherana to Rockhole and farther north, in the area between Fisher and Koolpin Gorge focusing on Freezing Gorge, east-southeast of the "syncline", and on the southeast side of the South Alligator Valley. Particular attention should be paid to locations of possible syntectonic sedimentation and whether observed faults cut the Kombolgie Formation.

2) Measurement of sections through El Sherana and Edith River lithologies in these locations.

3) Detailed comparison between the Big Sunday Formation and the Tollis Formation to better understand how these formations relate. Paleourrent, petrographic, and sedimentologic studies should accompany 1;25,000 scale mapping

4) Detailed sedimentological work on the Kurrundie Sandstone to better constrain depositional environments and regional paleocurrent trends. In addition, mapping of the Kurrundie Sandstone-Pulm Tree Volcanics contact to assess the possibility of unconformity.

5) 1:5000 scale mapping of Coronation Hill and adjacent areas, to evaluate possible syntectonic sedimentation and constrain timing of deformation.

6) Detailed sedimentological and stratigraphic studies of the Pine Creek Supergroup, in particular the Koolpin Formation.

7) Possible examination of BHP cores to help constrain the sedimentology of sequences in the South Alligator, Mount Partridge, and Namoona Groups.

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Figure Captions

Fig 1. Geologic map. Locations for measured sections (Appendix A) as follows. (1) from the Monolith; (2) from Stag Creek; (3) from Saddle Ridge, (4) from the "syncline"; (5) from the Fisher, or "hog-backs"; (6) is from a waterfall along the South Alligator River south of the study area; (7) from northeast of Gunlom.

Fig 2. The El Sherana/Edith River stratigraphy in two interpretations. Figure 2a is the stratigraphy as presented by Stuart-Smith et al. (1988), figure 2b as presented in this study.

Fig 3. Fence diagram of the El Sherana/Edith River stratigraphy pinned locally to detailed measured sections. Major bounding surfaces were walked out in the field where possible.

Fig 4. Facies of the Coronation sandstone. (a) a thick (~4m) deposit of imbricate-boulder conglomerate at Stag Creek (*Gm* facies). (b) planar-crossbedded pebble sandstone (*Sp* facies). (c) large exhumed trough (*St* facies) (hammer for scale).

Fig 5. A map of bounding surfaces of a basal exposure of Coronation Sandstone near the Monolith. The bounding surfaces of the thickest line and largest number, e.g. 4, bound the grossest packages of sandstone *(c.f. Allen 1983; Miall, 1987)*. The thinnest lines break out three-dimensional outcrop relationships, i.e., boulders or ledges which lie in front of other exposures.

Fig 6. Paleocurrent data from the region, organized in ascending order through the sequence. Note the small dispersion of (a,b,c) vs. the large spread of paleocurrents from (d). The paleocurrent rosettes are scaled by area-proportion and not incremental axis length.

Fig 7. Facies of the Pul Pul Rhyolite. (a) Breccia/conglomerate of Coronation Sandstone basalt in sandy matrix. (b) partly silicified fiammi ignimbrite. (c) quartz-feldspar porphyry with lithic fragments. (d) alteration halo around lithic fragment.

Fig 8. Schematic interpretation of post-Coronation growth faulting at El Sherana. Note the footwall folding. The hatched line shows the lower limit of outcrop exposure. The two photos (one with interpretation drawn on) are taken from and of a ridge directly behind El Sherana.

Fig 9. Peperite associated with the Big Sunday Unconformity. Solid-line borders surround individual volcanic elements within the deposit.

Fig 10. Facies of the Kurrundie Formation. (a) Incision into the Pul Pul Rhyolite overlain by Kurrundie conglomerates and sandstones. (b) Boulder conglomerate containing clasts of Pul Pul Rhyolite Breccia Sheet (photo taken near Fisher). (c)Trough-cross-bedded sandstone (*St* facies)

Fig 11. Palette Sub-basin Facies. (a) contact between Pul Pul Rhyolite and overlying Pul Pul Rhyolite breccia sheet; notice fiammi within breccia clasts; (b) sandstone dike filling fracture within Pul Pul Breccia sheet; note fitted fabric; (c) two generations of conglomerates, the lower with large rounded sandstone boulders, the upper interbedded with and incising medium to fine sandstones; (d) incision of sandstones into both generations of conglomerate. Bounding surface has four meters of relief; (e) medium-fine quartz arenites which overlap a growth faulting surface; (f) the same sandstones deformed by a later growth faulting event.

Fig 12. Provenance Diagrams. Ternary diagrams and fields from Dickinson and Suczek (1979). • represents mean of Tollis Formation samples from Needham et al. (1988).

Fig 13. A schematic representation of the interpreted events at Palette. (a) El Sherana Group on Pine Creek Supergroup; view to the southeast (b) inital growth faulting with deposition of Pul Pul breccia sheets; (c) fault reversal with continued growth faulting, with basal conglomerate, incision, deposition of interbedded debris-flow conglomerates and sandstones, and fault scarp onlap and overlap by later sandstones; (d) final faulting and present basin configuration.

Fig 14. Photomicrographs of El Sherana/Edith River lithologies. (a) fresh detrital epidote from Coronation Sandstone, plane-polarized light; (b,c) phosphate cements from Coronation Sandstone; plane-polarized light and cross-polarized light. Note multi-colliform laminated fabric; (d,e) Alteration fabrics in Pul Pul Rhyolite, plane-polarized light and cross-polarized light; (f,g) clasts from conlgomerate in Big Sunday Unconformity valley fill facies. Includes detrital epidote bundle (f), chloritized dolerite (f), carbonate-replaced volcanic (g), and phyllite clast (g); plane polarized light and cross-polarized light; (h,i) feldspatholithic greywacke from Big Sunday Formation. Note fresh feldspars versus altered Pul Pul Rhyolite sample in (e), plane polarized light and cross-polarized light; (j) Kurrundie Sandstone with felsic rhyolite fragment and detrital epidote, plane-polarized light.

Fig 15 Void fill sequence in Scinto Breccia under crossed polarized light. (a) is blocky phosphate; (b) is apatite; (c) is quartz; (d) is needle or platy hematite; (e) is unknown fibrous mineral, (f) is latest stage wavelite. Sample taken from peak of Coronation Hill (fig. 1).

Fig 16. Schematic comparison between Wopmay Orogen, Athapuscow Basin, and Pine Creek Orogen from 2.0-1.6 Ga. Key similarities include basal Wilson cycles with foreland basin sedimentation beginning at 1.885 Ga, post-orogenic deformation and/or sedimentation, and 1.65 Ga platform cover.

Appendix A

Stratigraphic columns at various locations within and without the study area, (see fig.1) (1) Monolith; (2) Stag Creek; (3) Saddle Ridge, (4) the "syncline"; (5) Fisher. Section (6) is from a waterfall along the South Allligator River. A measured section north of the study area (7) is included here, but was not studied in detail and is not considered to be a precise reflection of the lithostratigraphy.

Appendix C

1:10,000 scale geologic map of the South Alligator Valley from El Sherana to Saddle Ridge. Map stratigraphy and key included.

						Lithotype (by percent)										
																mean
		coarse ss	fine ss	maf vlc	fel vlc	chert	vein quartz	shale	Fe-stone	scinto	gwke	qtze	alt/repl	tuff	largest	largest
Formation	Location									breccia						
Cor ss	Monolith, base	5.5	22.8		24.8	11	29.3	5.5			0.9				55/12 *	49/10 **
	Monolith, top	1	14		7	6	65	3			2				30	19
	Stag Creek, base	10	41		15	3	4	10	21		2			2	55	38.5
	Syncline 1	10**	16		4	22	10	12	1		1	8	14		38	32
Cor. Unc	Monolith	5.3	7.1	34.5	26.5	20.3	1.8	4.4							66	46
	Stag Creek	8	8	13	29	18	4	5		5					60	49
Kurr	Hogback A	1	4		94***	1									42	35
	Hogback B		1		87	1	1			1			8		45	36.3
	Hogback C	2	7		27	6	3		2		2		51§		67	43.5
Palette	Base 1	24	10	3	17	13	3	8		22					50	42
	Base 2	10	6		3	15	1	20	14	31					42	31
	Base, deb. flow	41.3	2.2		4.3	10.8	2.2	19.5	4.3	2.2			14.3		48	43.3
	middle	23	7	17(?)	2	16	2	7		12			6		<>	<>
	top	15	7		7	20	10	4		20			17		29	18.6

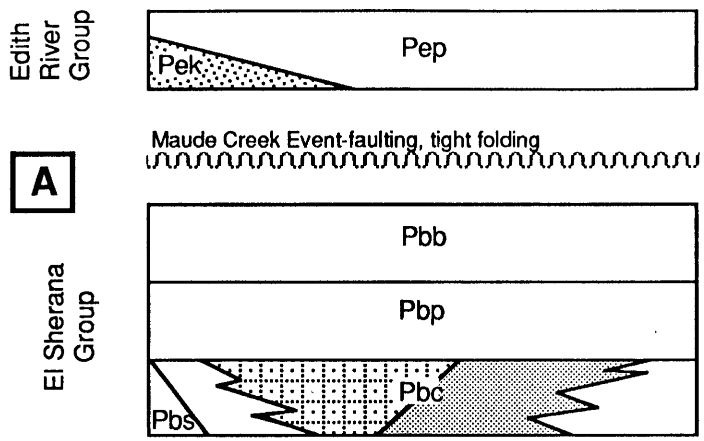
* largest and m.m.c. determined for undisputable koolpin fm./all other lithotypes.

** this also includes the only clasts of quartz-pebble conglomerates

*** these two layers are almost entirely composed of Pul Pul Rhyolite, and most of that from the qfp.

FIGURE 2

Previous Interpretation



Pep *Plum Tree Volcanics: Massive pink to purple rhyodacitic ignimbrite, minor rhyolite and tuff*

Pek *Kurrundie Sandstone: Massive purple clayey medium to coarse lithic sandstone, polymictic cobble conglomerate, massive to laminated white, pink to brown, fine to course quartz sandstone, minor brown micaceous sandy siltstone*

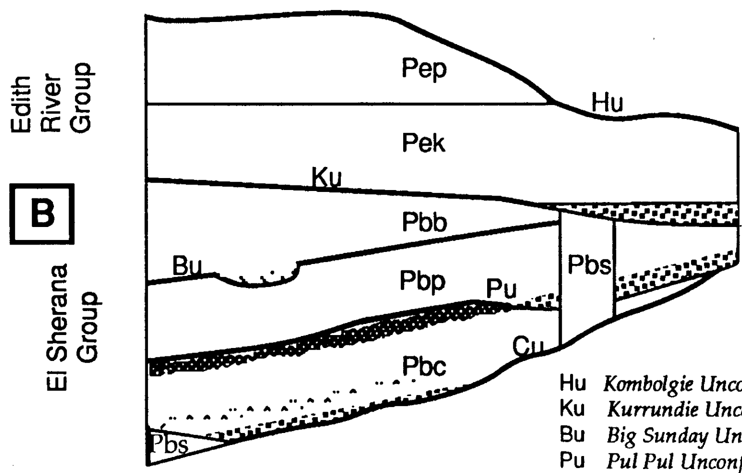
Pbb *Big Sunday Formation: Fine to course and pebbly volcanolithic greywacke, green shale, devitrified vitric tuff, and vitric crystal tuff, rhyolite, and ignimbrite.*

Pbp *Pul Pul Rhyolite: altered purple to pink rhylotic ignimbrite, minor agglomerate and glassy black rhyolite*

Pbc *Coronation Sandstone: clayey, purple, very course pebbly quartz sandstone,. massive polymictic conglomerate at base, denotes interbedded shale, siltstone greywacke, and felsic volcanics, denotes mafic volcanic lenses*

Pbs *Scinto Breccia: pink, siliceous, hematitic, phosphatic breccia*

Present Interpretation



Hu *Kombolgie Unconformity*
Ku *Kurrundie Unconformity*
Bu *Big Sunday Unconformity*
Pu *Pul Pul Unconformity*
Cu *Coronation Unconformity*
—— *Confdormable contact*
▬▬ *Unconformable contact*

Plum Tree Volcanics: Massive pink to purple rhyodacitic ignimbrite, minor rhyolite and tuff

Kurrundie Sandstone: Pervasive liesegang banding; medium to coarse lithic sandstone, massive to trough,-crossbedded, fine to course quartz sandstone, micaceous sandy siltstone, local fanglomerates and sheet breccias, denotes cobble conglomerate

Big Sunday Formation: Fine to coarse and pebbly lithic sandstone, green shale, devitrified tuff and crystal tuff, denotes peperites, rhyolite, and pebble conglomerate

Pul Pul Rhyolite: altered rhyolitic ignimbrite, quartz feldspar porphyry, denotes basalt clast conglomerate

Coronation Sandstone: very course pebbly quartz sandstone, denotes amygdaloidal basalt, denotes rhyolite, denotes boulder to pebble conglomerate

Scinto Breccia: pink, siliceous, hematitic, phosphatic breccia

FIGURE 3

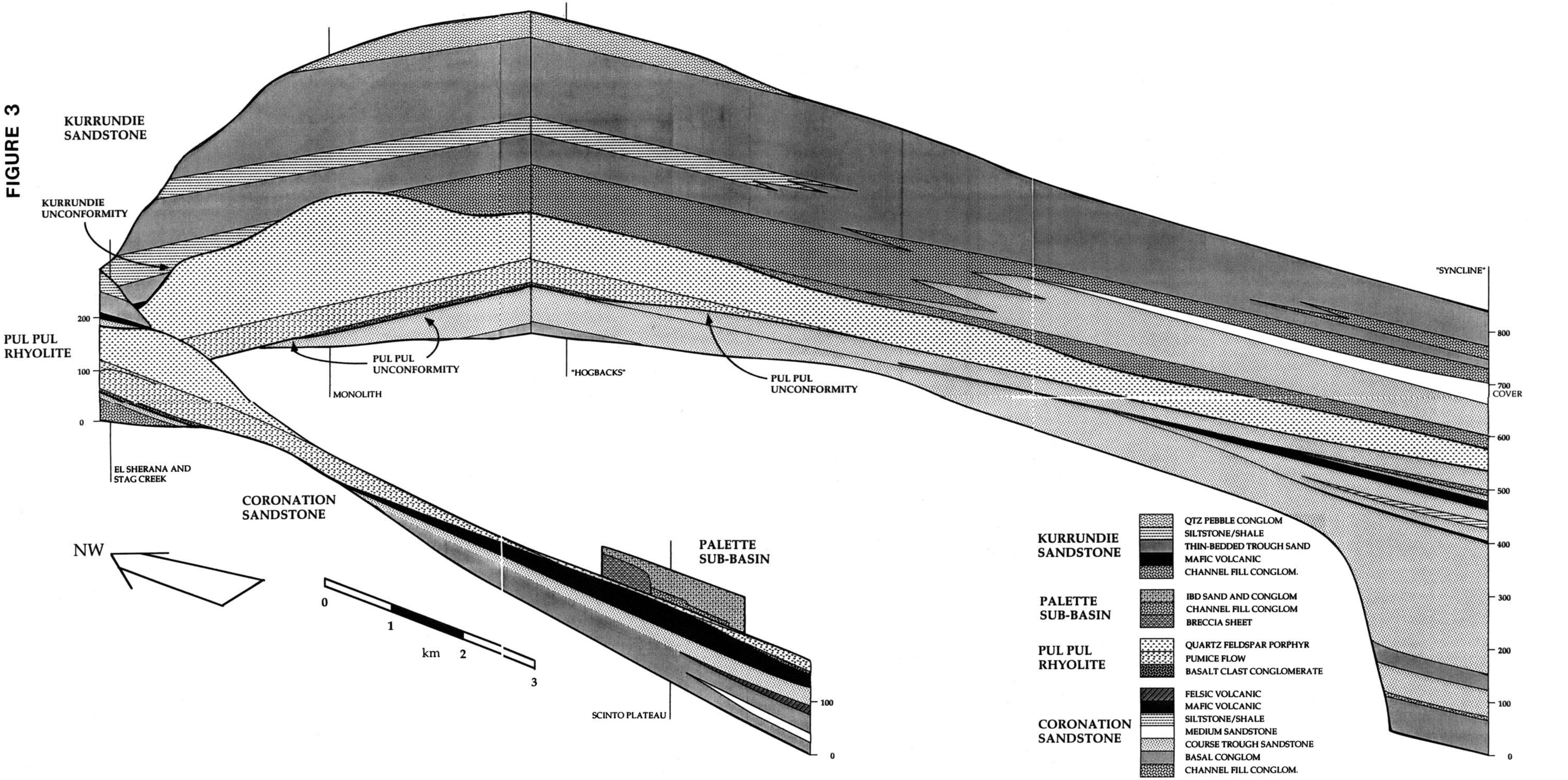

KURRUNDIE SANDSTONE
KURRUNDIE UNCONFORMITY
PUL PUL RHYOLITE
PUL PUL UNCONFORMITY
MONOLITH
"HOGBACKS"
PUL PUL UNCONFORMITY
"SYNCLINE"
COVER
EL SHERANA AND STAG CREEK
CORONATION SANDSTONE
NW
PALETTE SUB-BASIN
SCINTO PLATEAU
0 1 km 2 3
0 100 200
0 100 200 300 400 500 600 700 800
0 100
KURRUNDIE SANDSTONE
QTZ PEBBLE CONGLOM
SILTSTONE/SHALE
THIN-BEDDED TROUGH SAND
MAFIC VOLCANIC
CHANNEL FILL CONGLOM.
PALETTE SUB-BASIN
IBD SAND AND CONGLOM
CHANNEL FILL CONGLOM
BRECCIA SHEET
PUL PUL RHYOLITE
QUARTZ FELDSPAR PORPHYR
PUMICE FLOW
BASALT CLAST CONGLOMERATE
CORONATION SANDSTONE
FELSIC VOLCANIC
MAFIC VOLCANIC
SILTSTONE/SHALE
MEDIUM SANDSTONE
COURSE TROUGH SANDSTONE
BASAL CONGLOM
CHANNEL FILL CONGLOM.

Figure 4

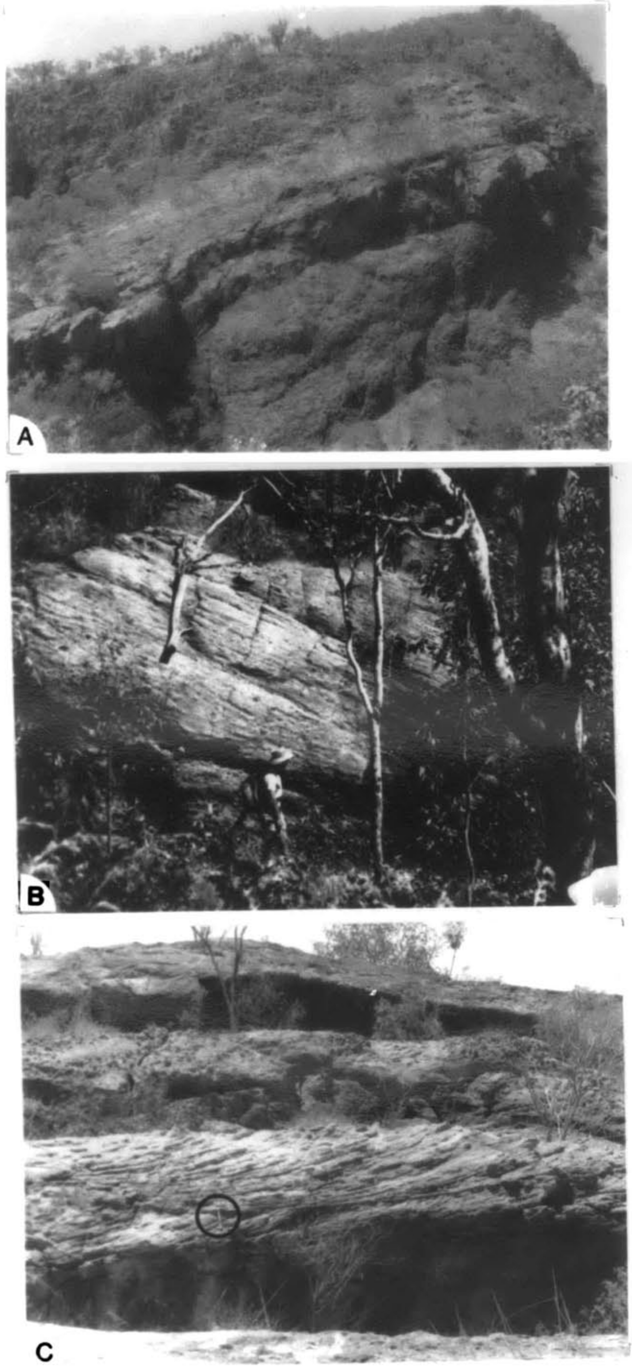


Figure 5

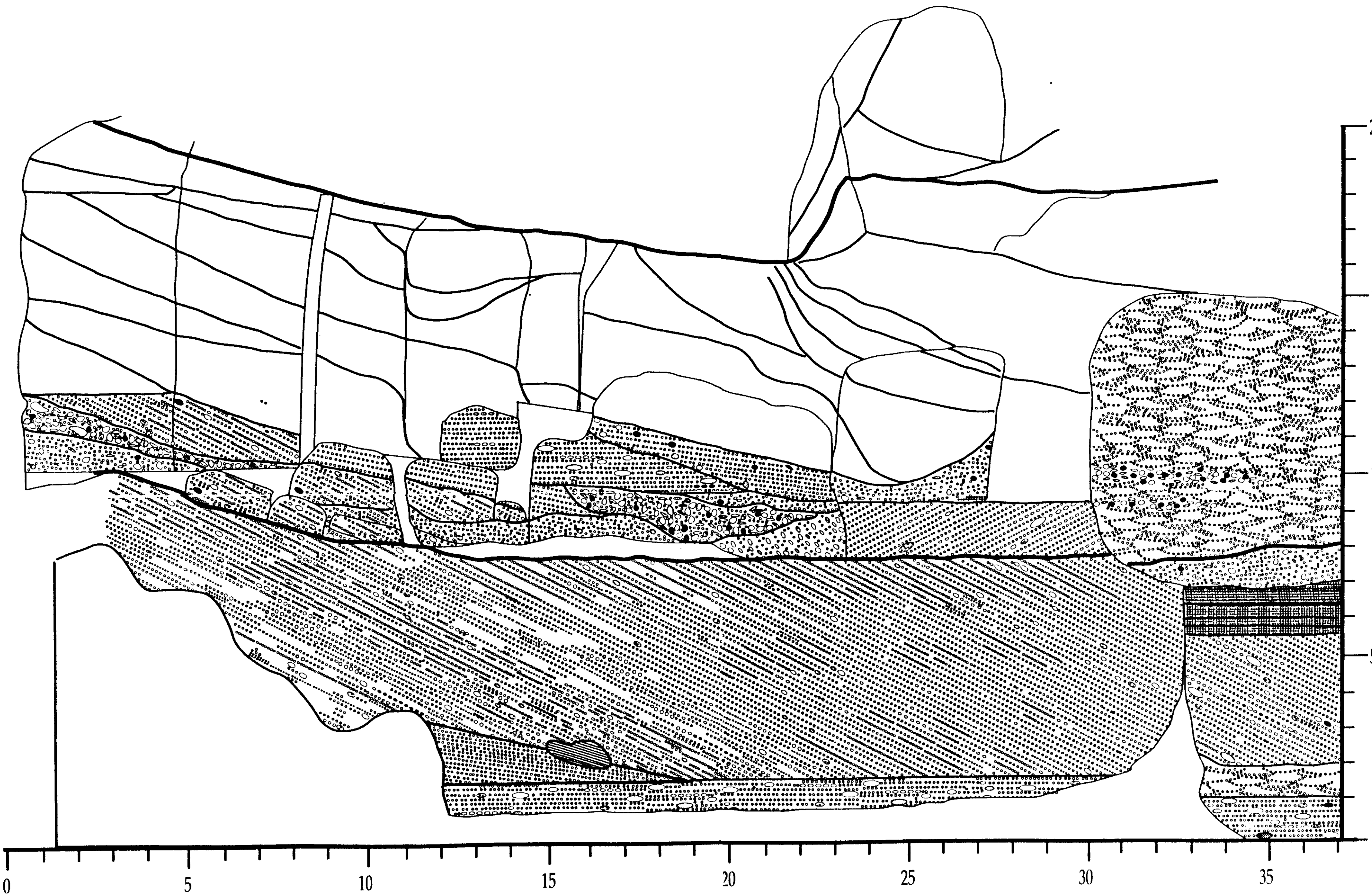
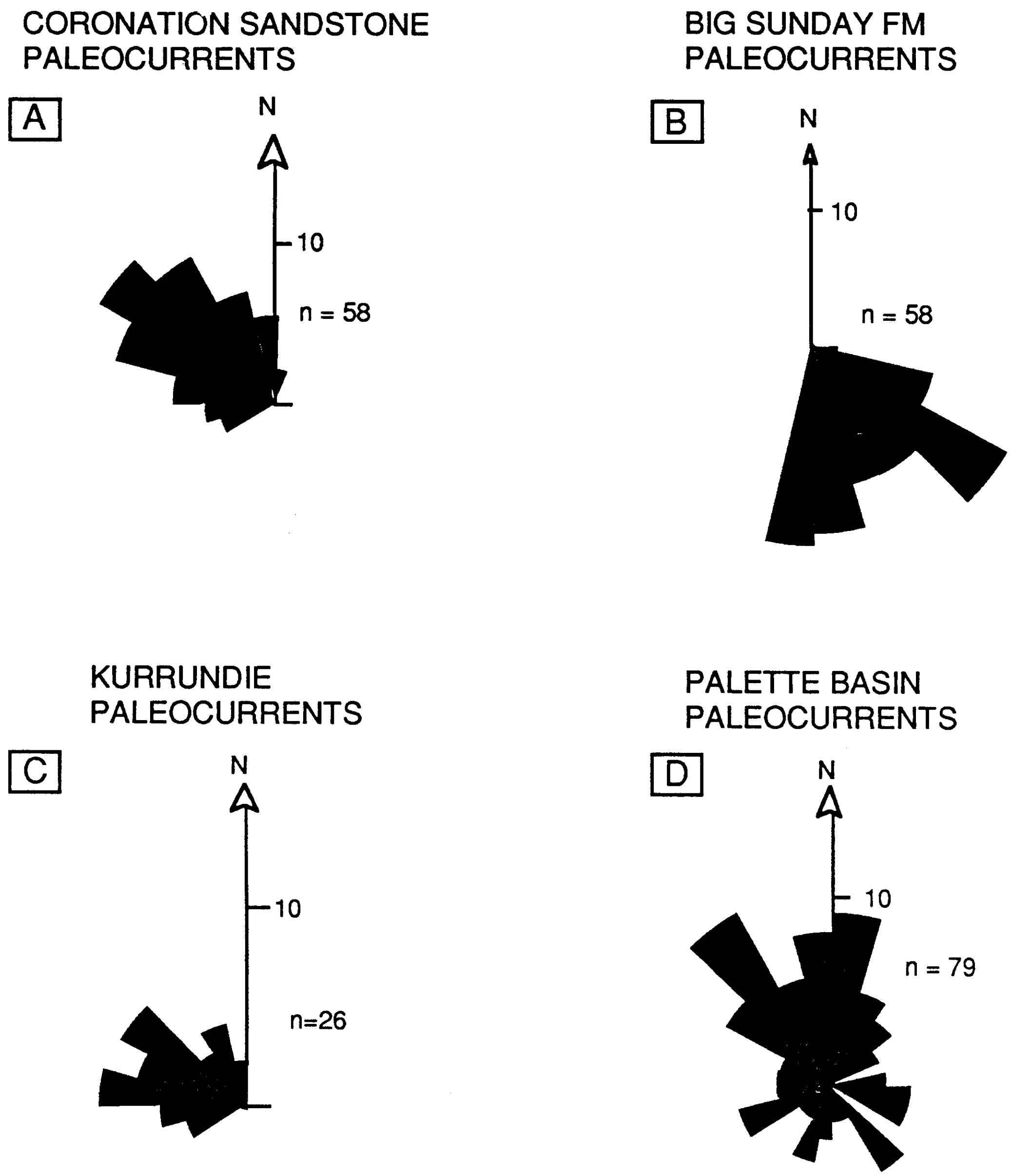


FIGURE 6


CORONATION SANDSTONE PALEOCURRENTS
A
N
10
n = 58
BIG SUNDAY FM PALEOCURRENTS
B
N
10
n = 58
KURRUNDIE PALEOCURRENTS
C
N
10
n=26
PALETTE BASIN PALEOCURRENTS
D
N
10
n = 79

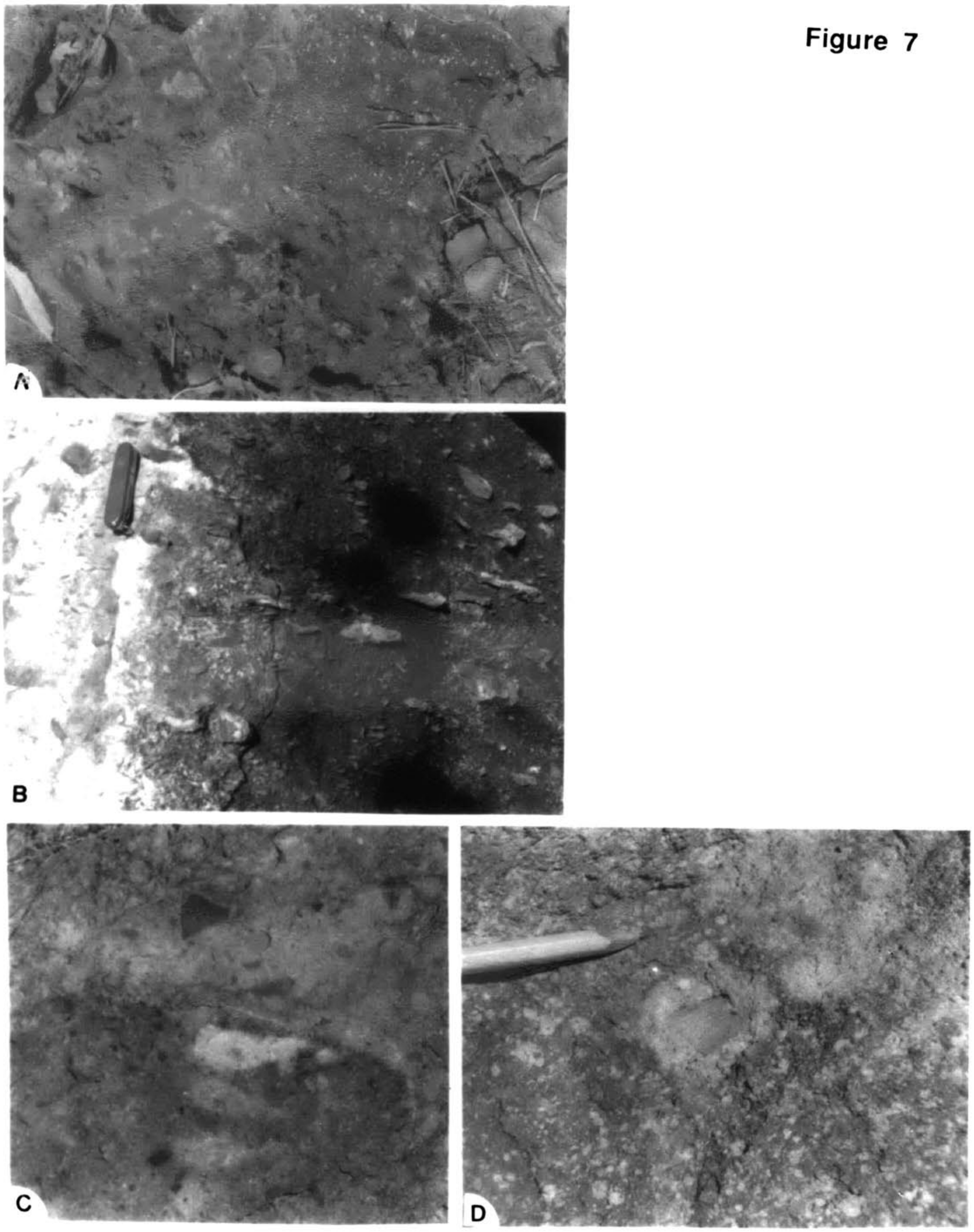
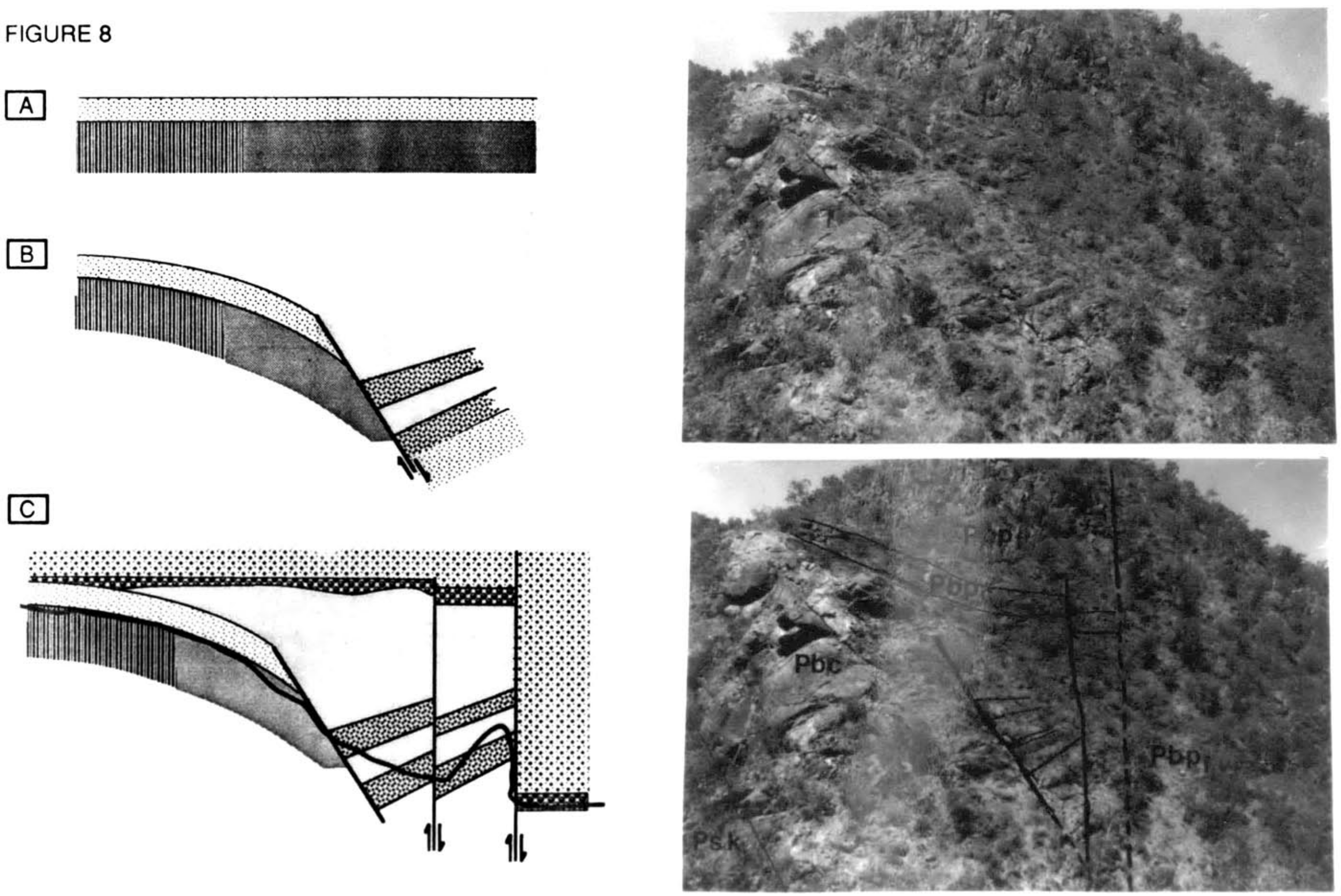


Figure 7

FIGURE 8



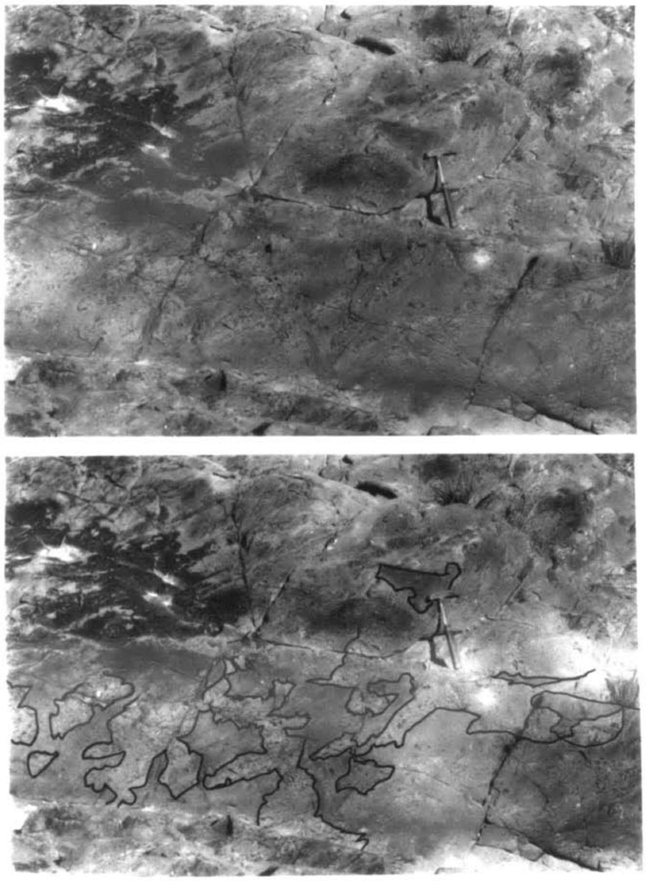
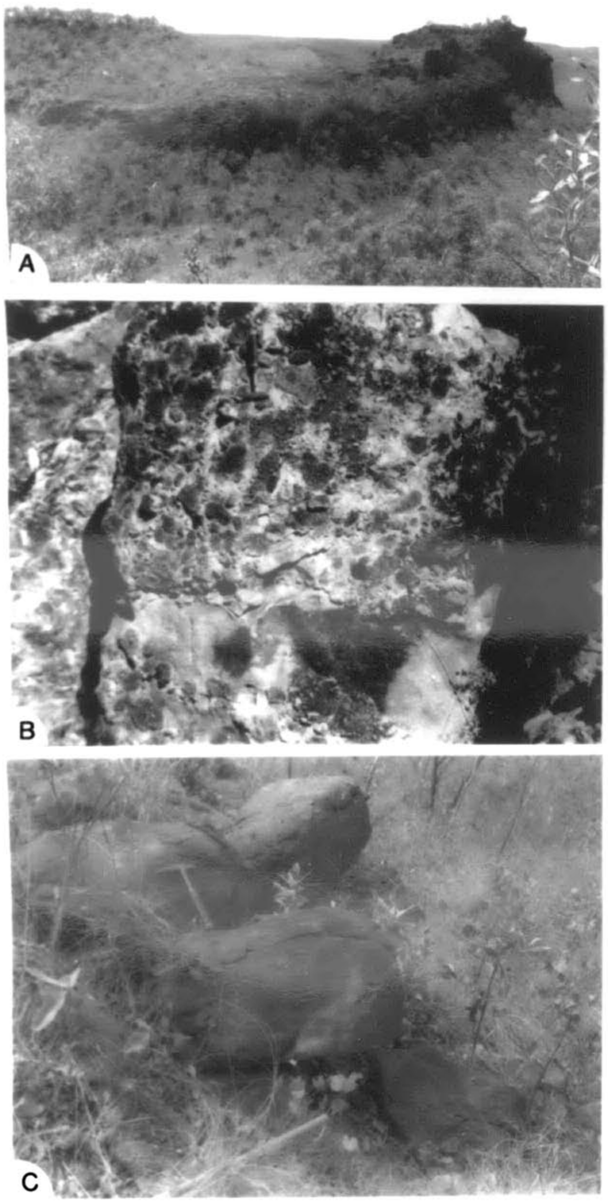


Figure 9

Figure 10



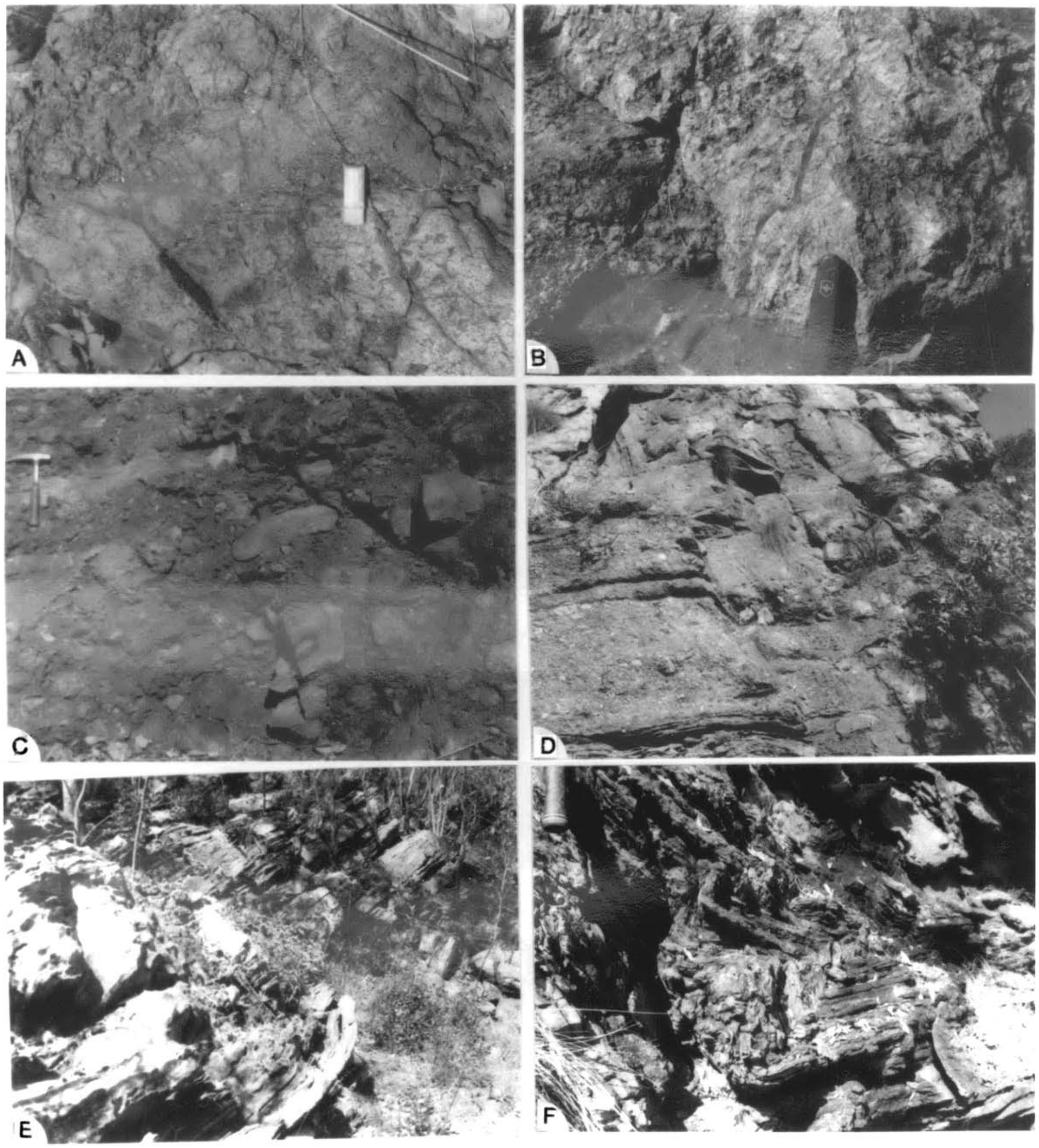


Figure 11

Figure 12

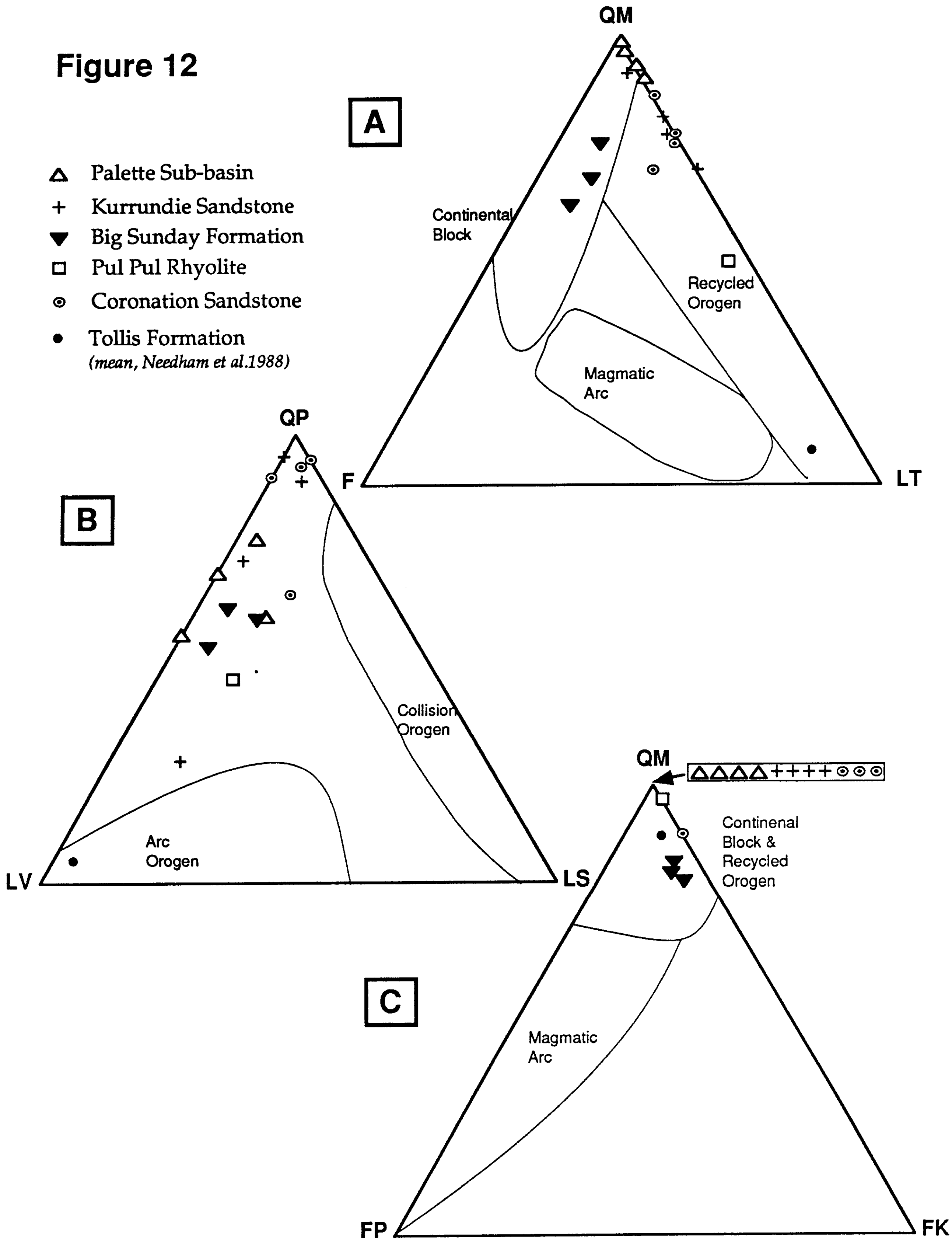
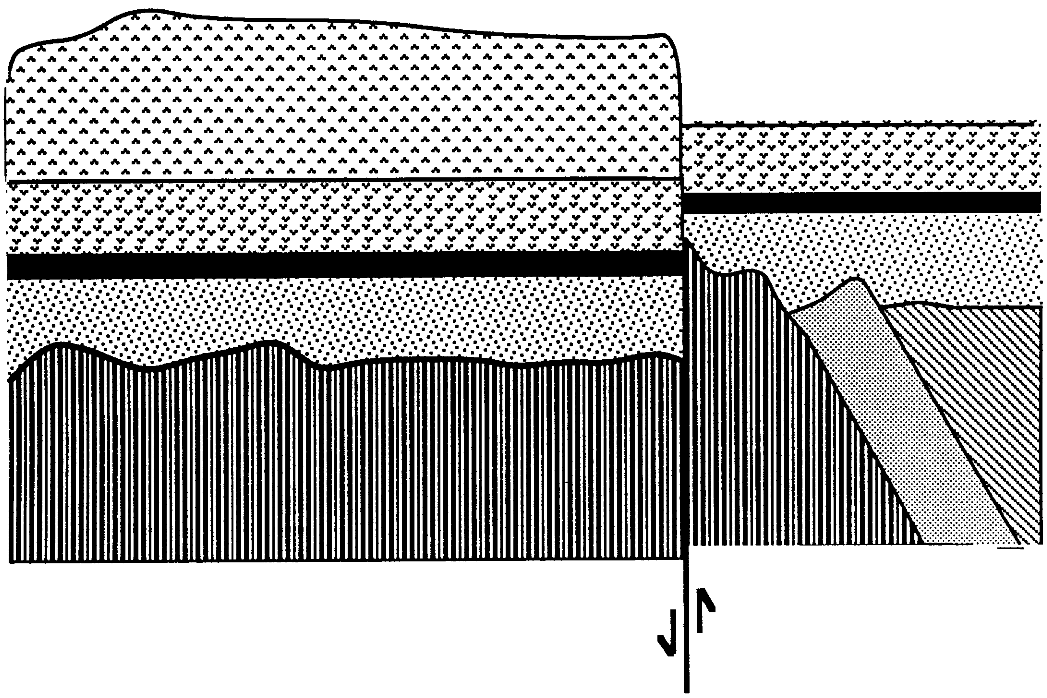
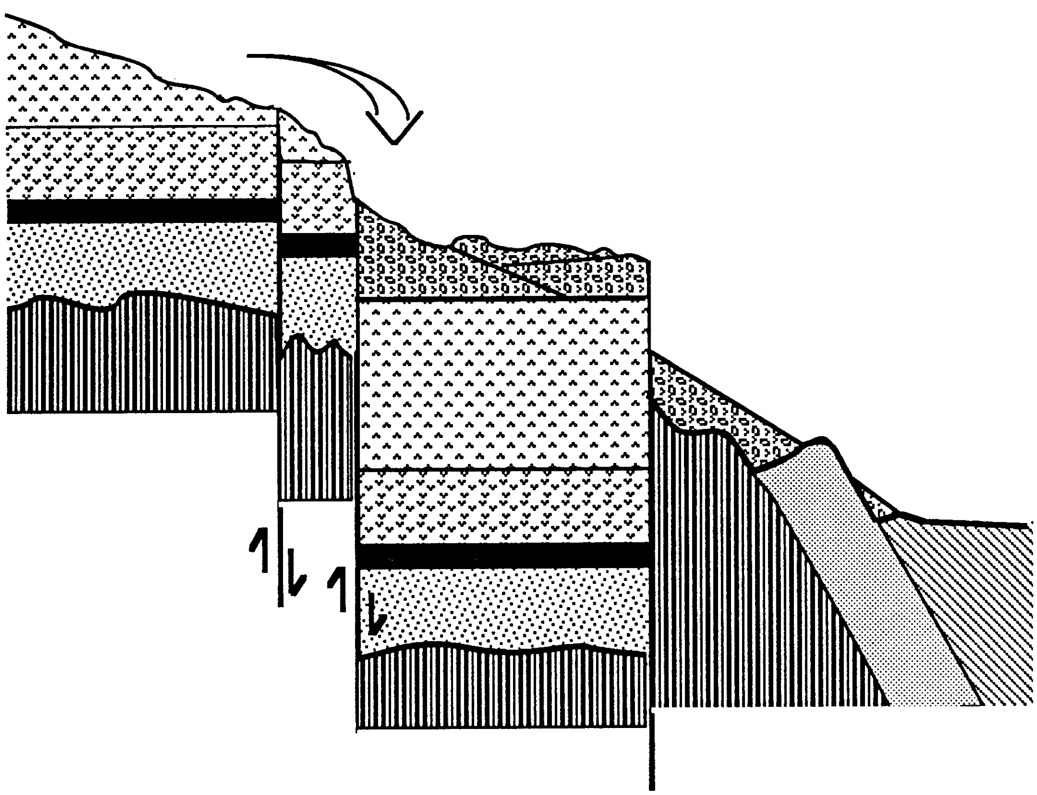

Δ Palette Sub-basin
+ Kurrundie Sandstone
▼ Big Sunday Formation
□ Pul Pul Rhyolite
⊙ Coronation Sandstone
● Tollis Formation
(mean, Needham et al.1988)
A
QM
F
LT
Continental Block
Recycled Orogen
Magmatic Arc
B
QP
LV
LS
Collision Orogen
Arc Orogen
C
QM
FP
FK
ΔΔΔΔ++++⊙⊙⊙
Continenal Block & Recycled Orogen
Magmatic Arc

FIGURE 13

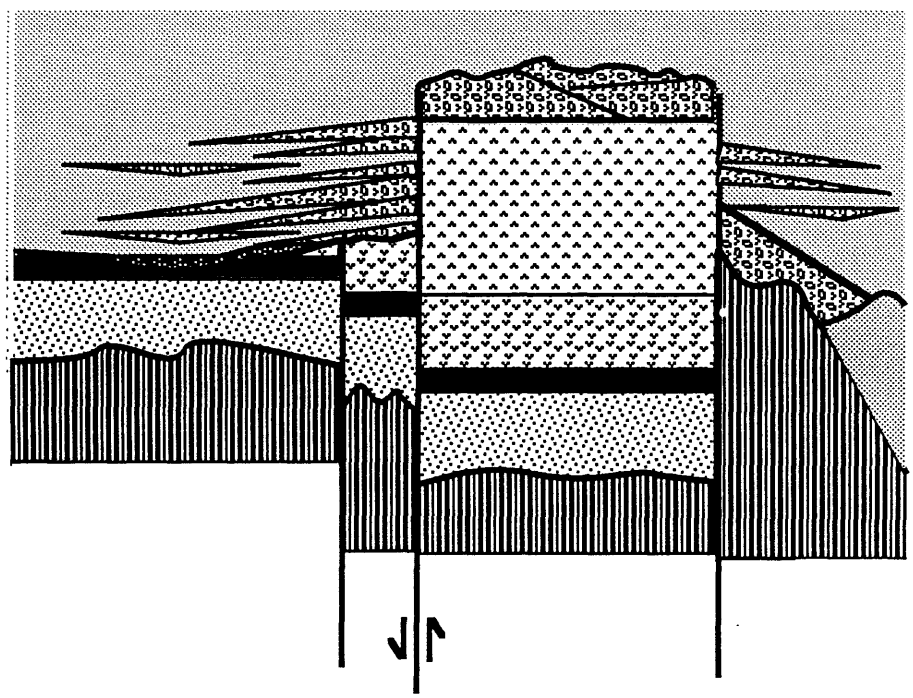
A



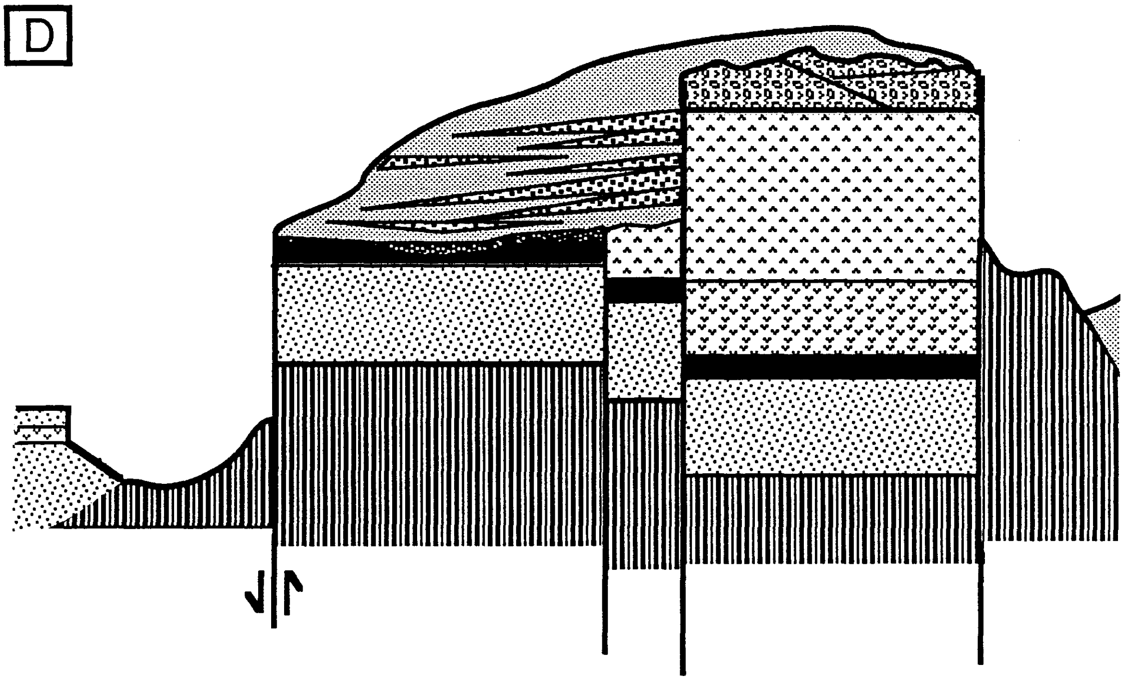
B



C



D



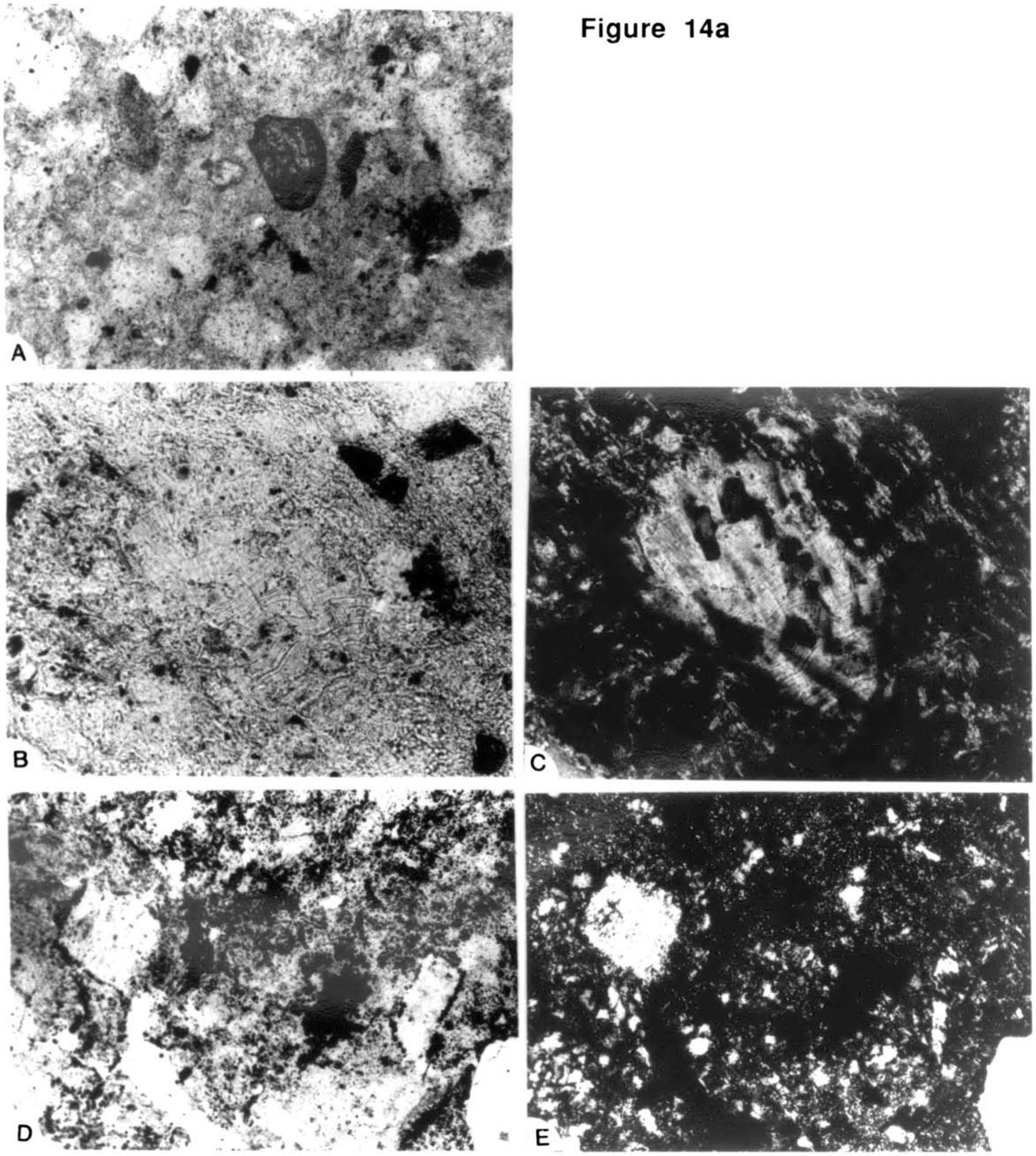


Figure 14a

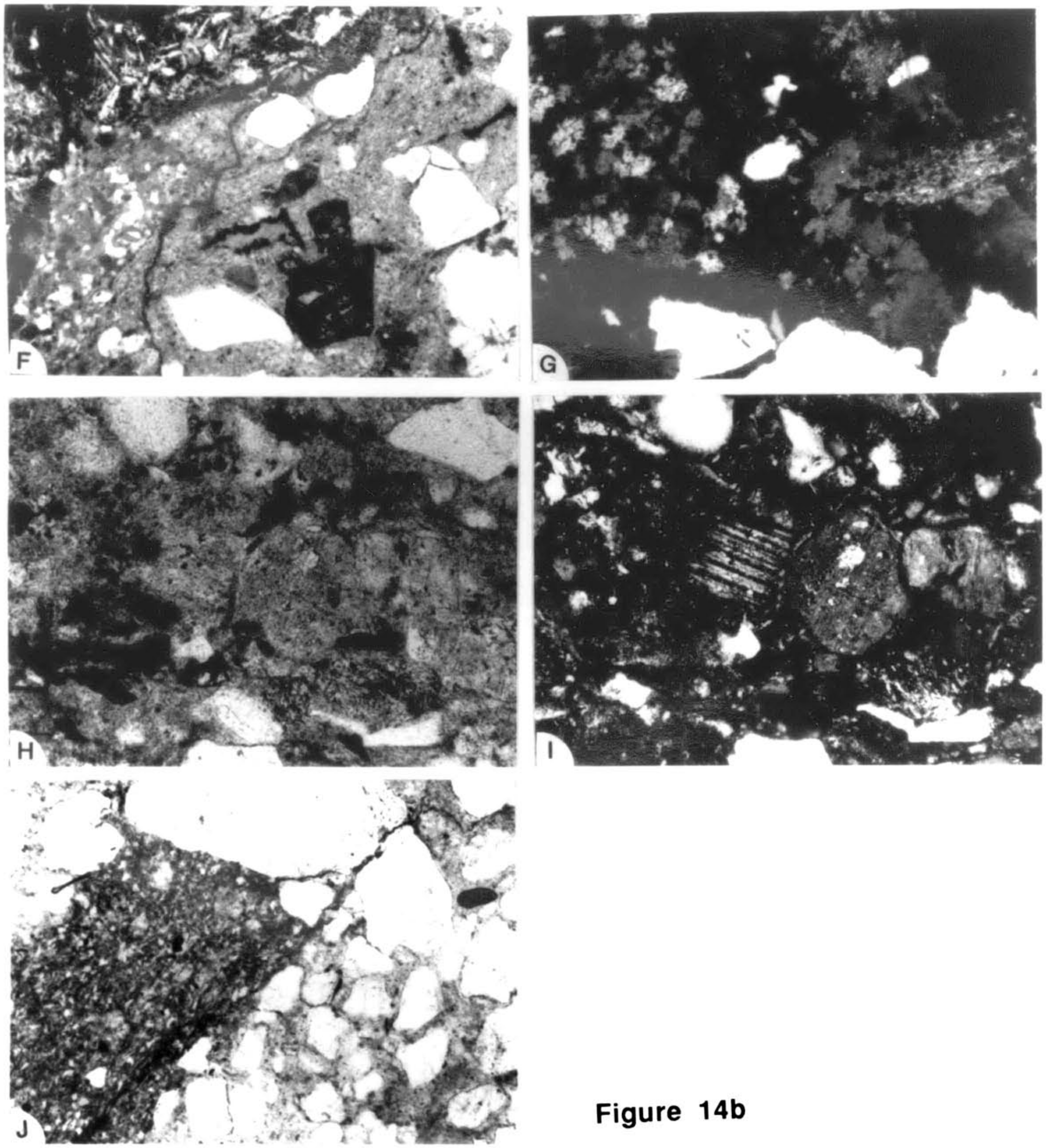


Figure 14b

Figure 15

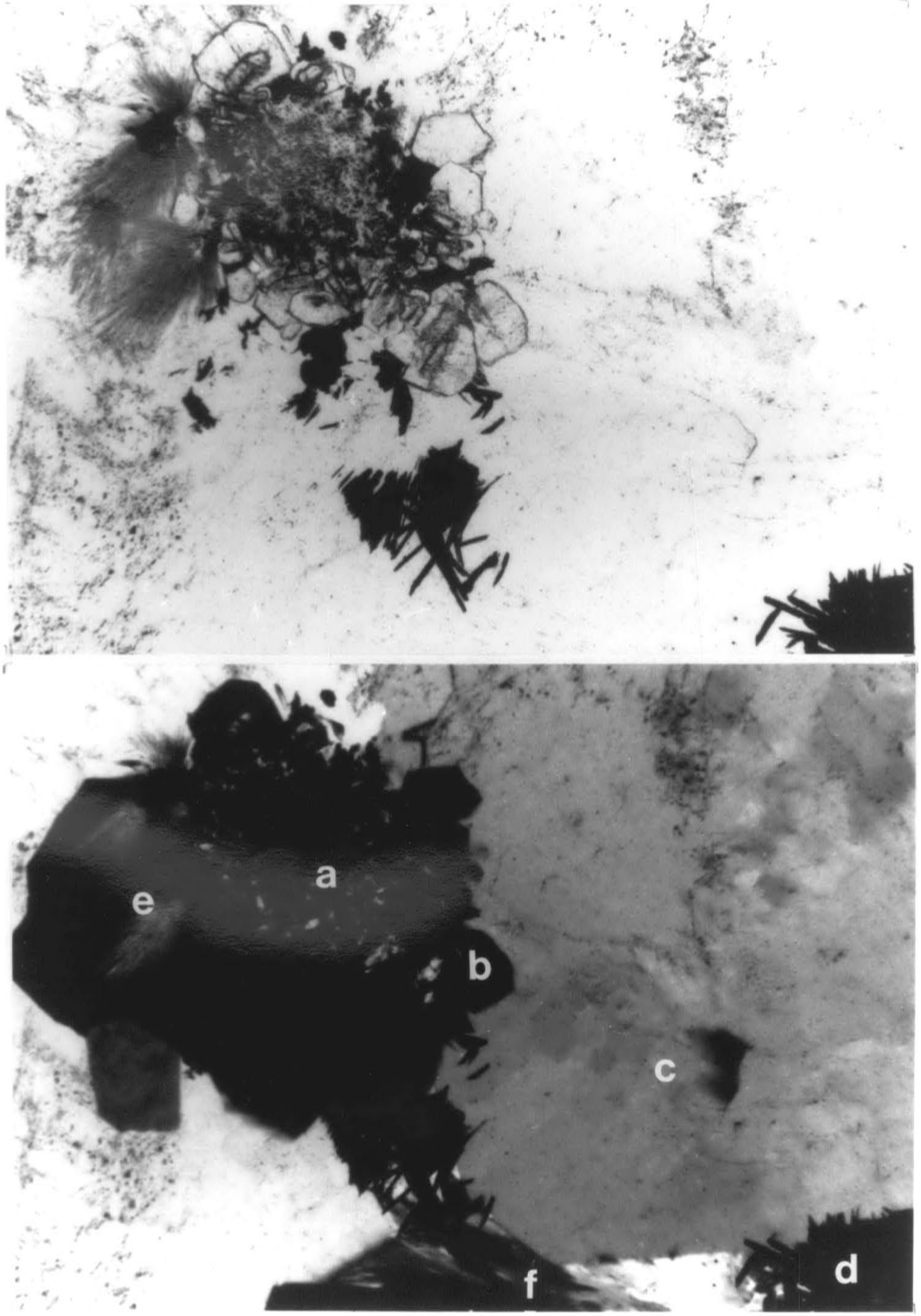
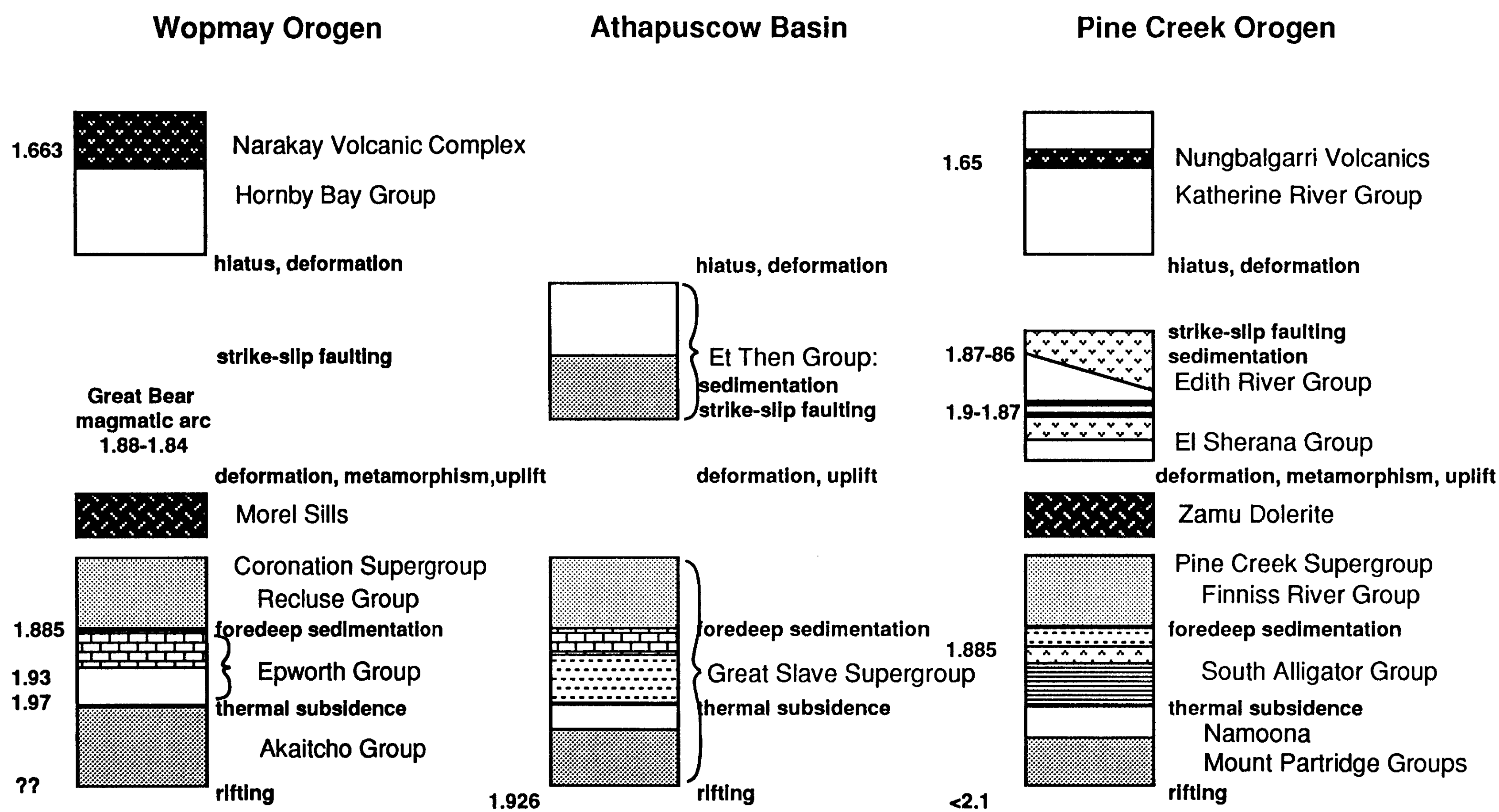


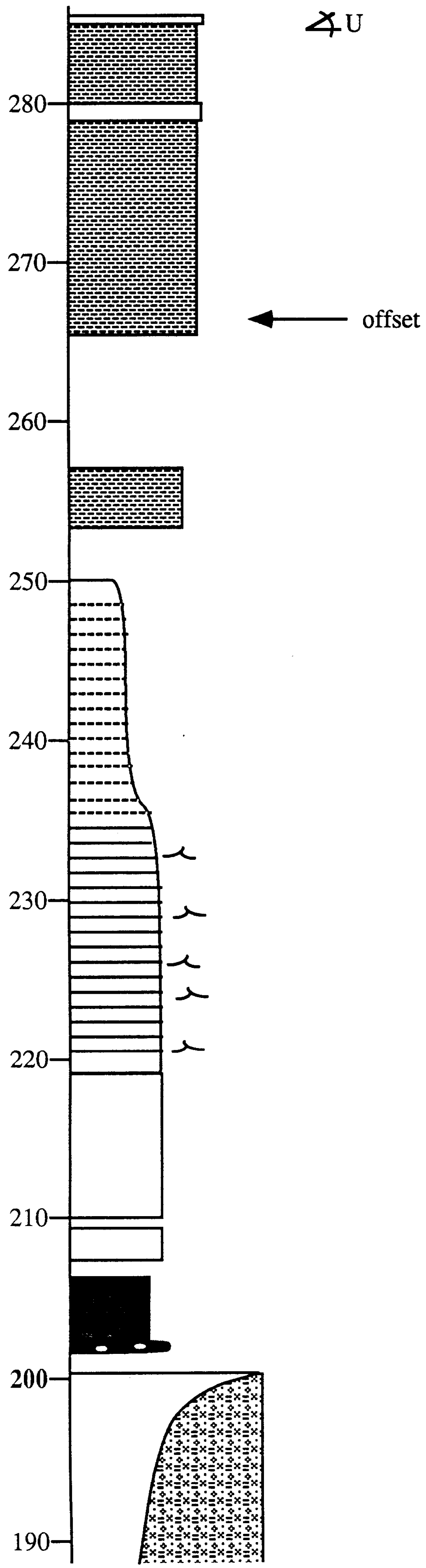
Figure 16

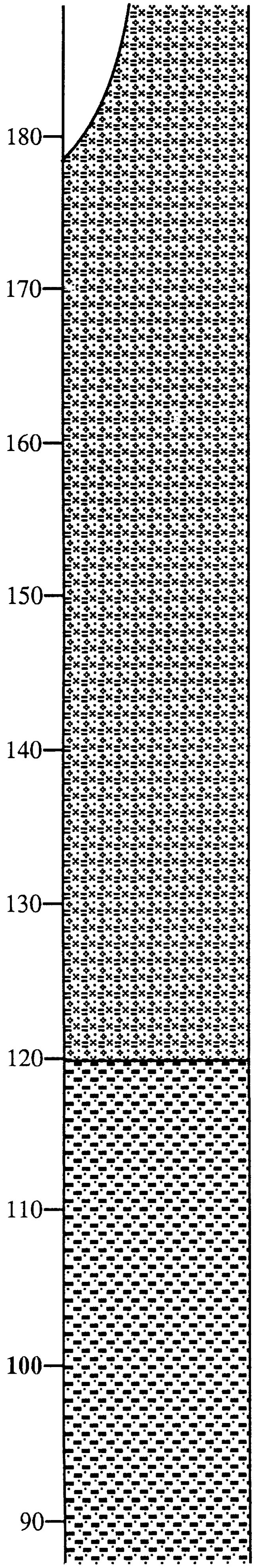


Wopmay Orogen
Athapuscow Basin
Pine Creek Orogen
1.663
Narakay Volcanic Complex
Hornby Bay Group
hiatus, deformation
strike-slip faulting
Great Bear
magmatic arc
1.88-1.84
deformation, metamorphism,uplift
Morel Sills
Coronation Supergroup
Recluse Group
1.885
foredeep sedimentation
1.93
Epworth Group
1.97
thermal subsidence
Akaitcho Group
??
rifting
hiatus, deformation
Et Then Group:
sedimentation
strike-slip faulting
deformation, uplift
foredeep sedimentation
Great Slave Supergroup
thermal subsidence
1.926
rifting
1.65
Nungbalgarri Volcanics
Katherine River Group
hiatus, deformation
strike-slip faulting
sedimentation
1.87-86
Edith River Group
1.9-1.87
El Sherana Group
deformation, metamorphism, uplift
Zamu Dolerite
Pine Creek Supergroup
Finniss River Group
foredeep sedimentation
1.885
South Alligator Group
thermal subsidence
Namoona
Mount Partridge Groups
<2.1
rifting

APPENDIX A: STRATIGRAPHIC COLUMNS

CORONATION SANDSTONE THROUGH KURRUNDIE SANDSTONE STAG CREEK

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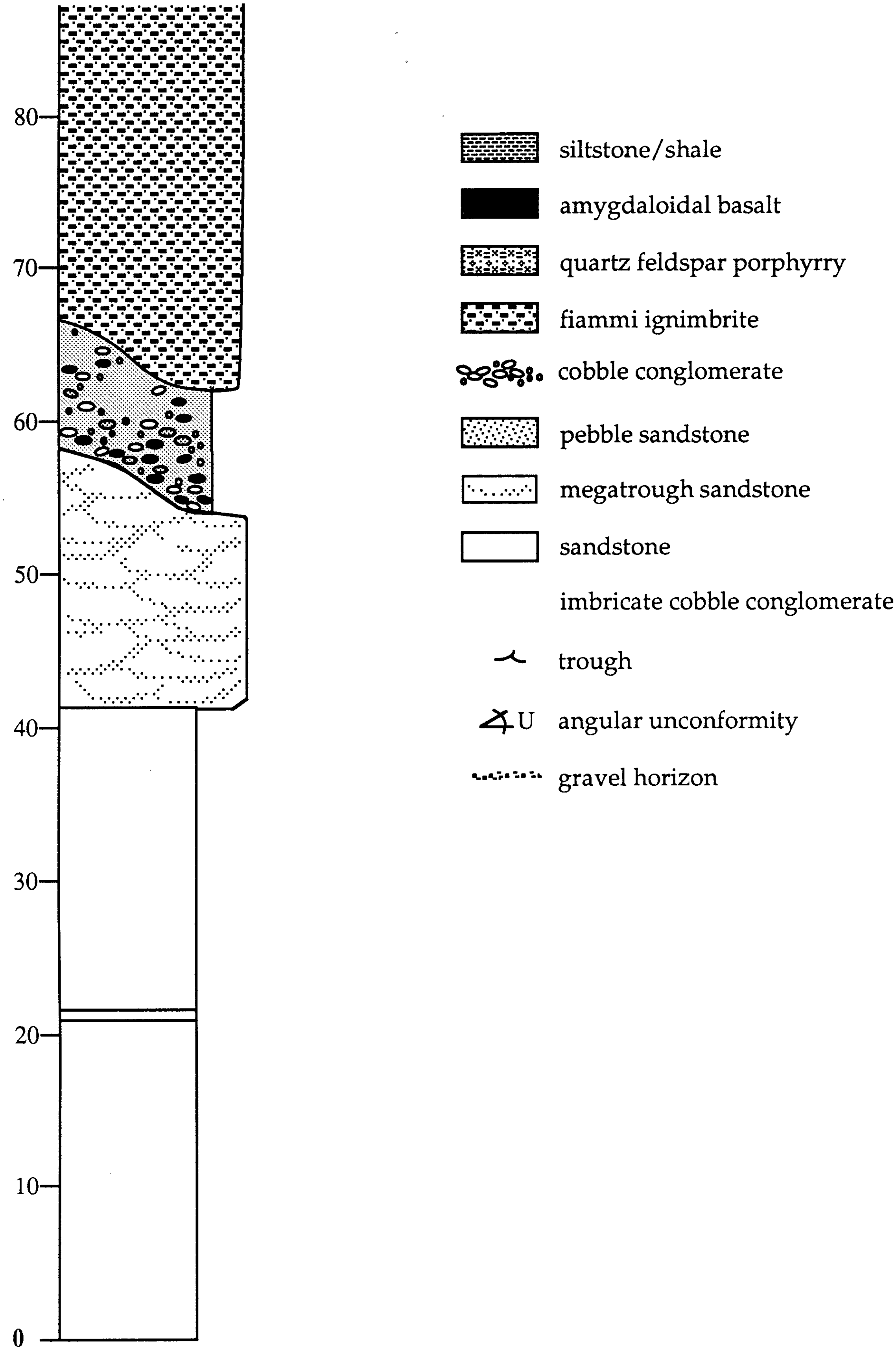
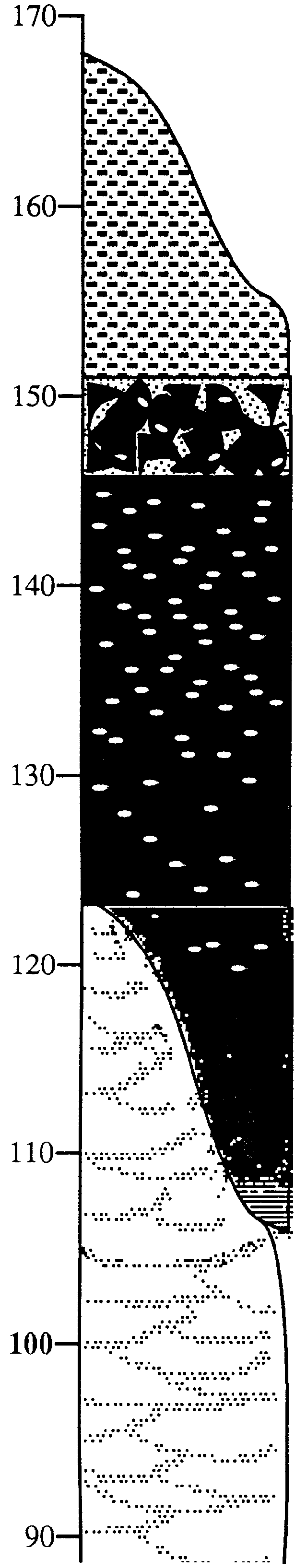
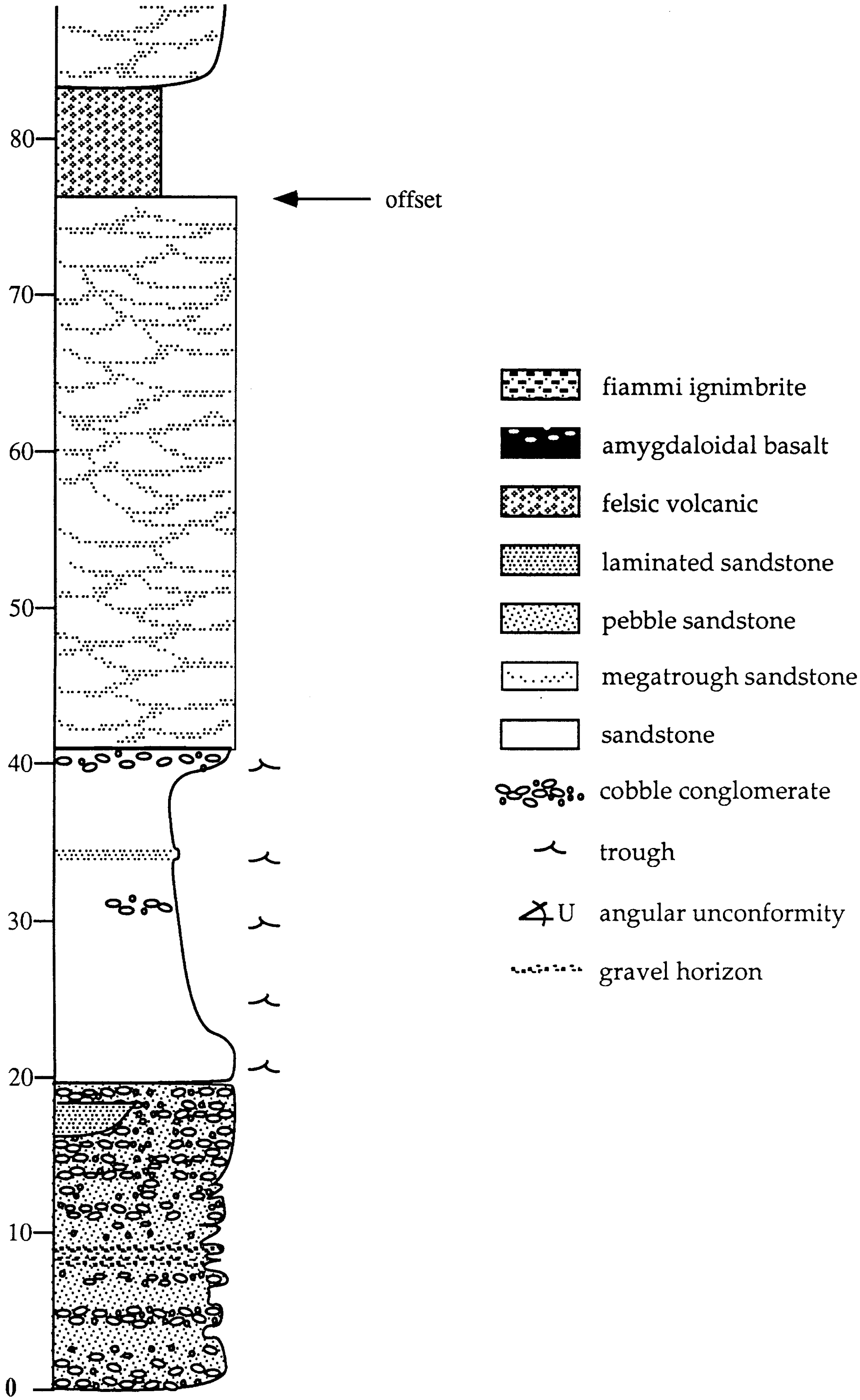
170
160
150
140
130
120
110
100
90

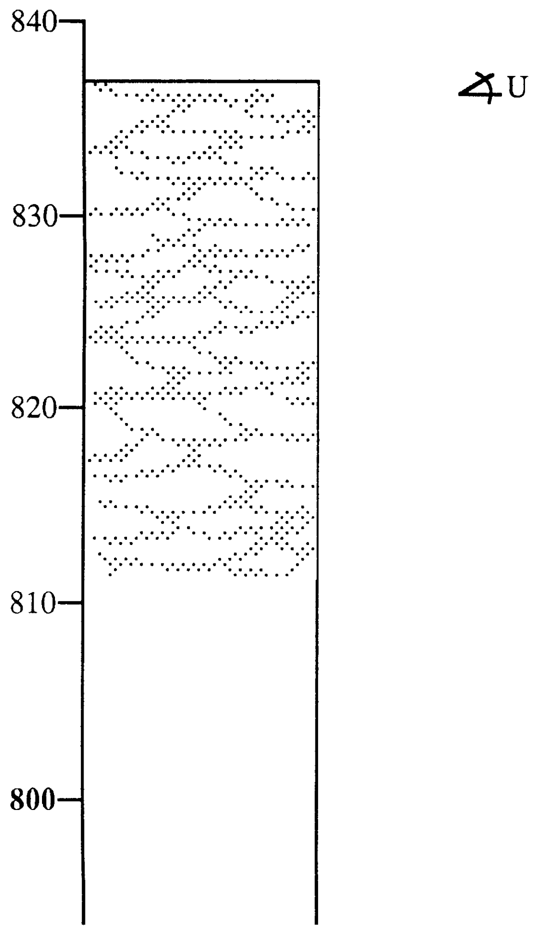

80
70
60
50
40
30
20
10
0
siltstone/shale
amygdaloidal basalt
quartz feldspar porphyrry
fiammi ignimbrite
cobble conglomerate
pebble sandstone
megatrough sandstone
sandstone
imbricate cobble conglomerate
trough
U angular unconformity
gravel horizon

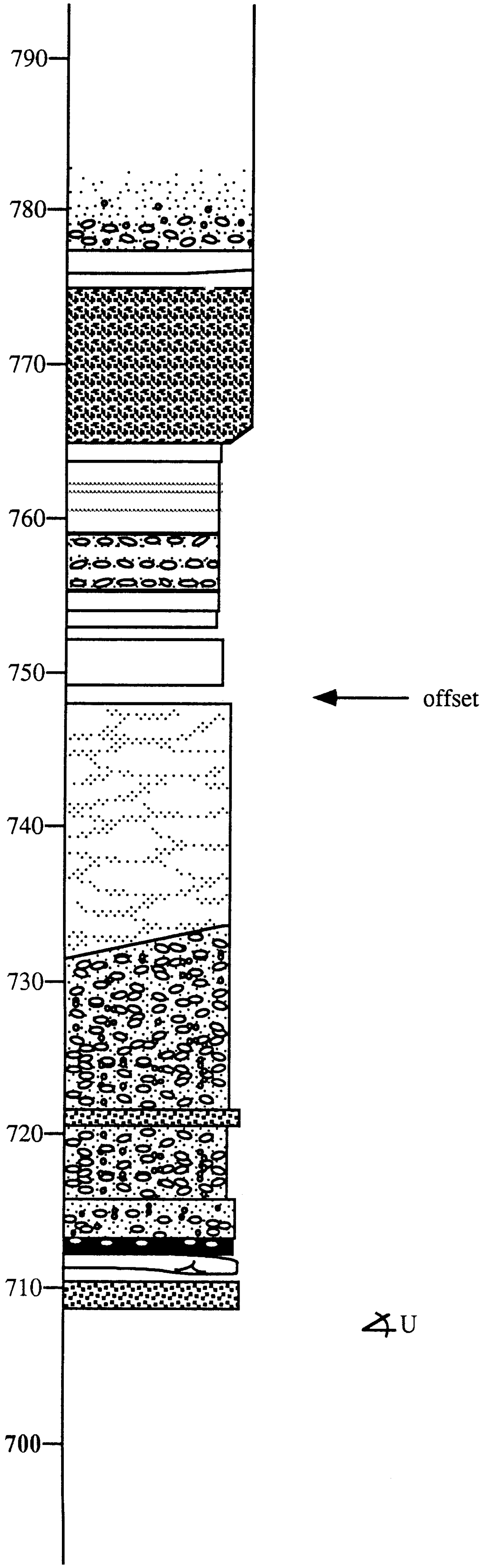
CORONATION SANDSTONE
SADDLE RIDGE

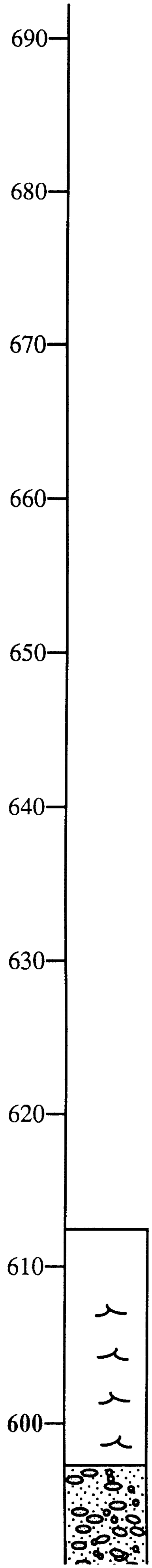


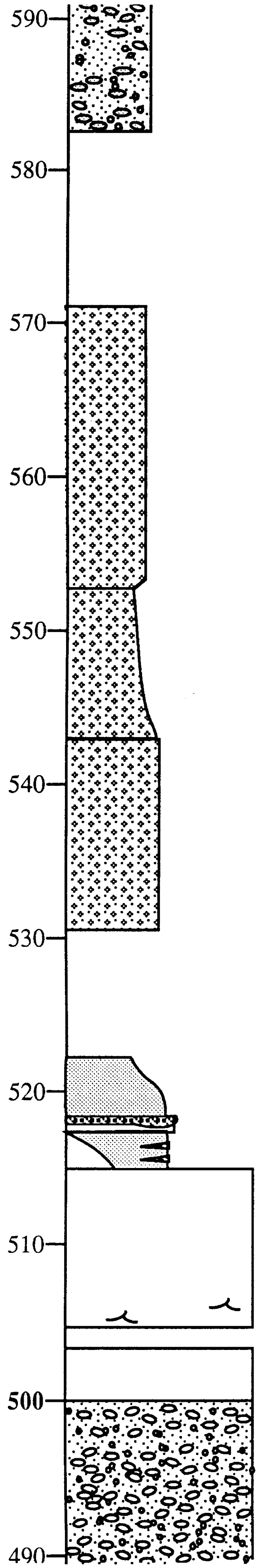

80
70
60
50
40
30
20
10
0
offset
fiammi ignimbrite
amygdaloidal basalt
felsic volcanic
laminated sandstone
pebble sandstone
megatrough sandstone
sandstone
cobble conglomerate
trough
U angular unconformity
gravel horizon

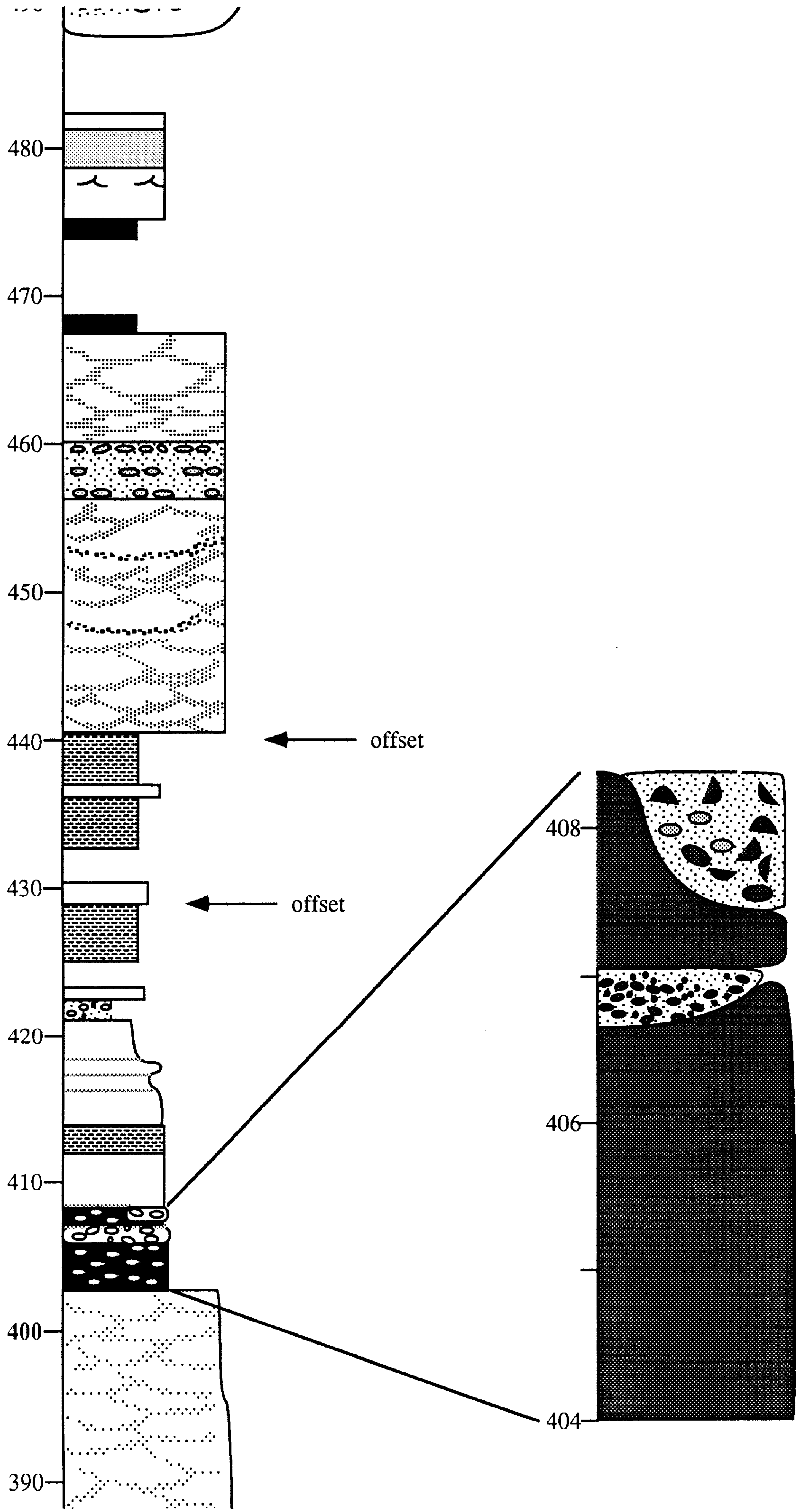
CORONATION SANDSTONE
THROUGH
KURRUNDIE SANDSTONE
"SYNCLINE"




790
780
770
760
750
offset
740
730
720
710
U
700


690
680
670
660
650
640
630
620
610
600


590
580
570
560
550
540
530
520
510
500
490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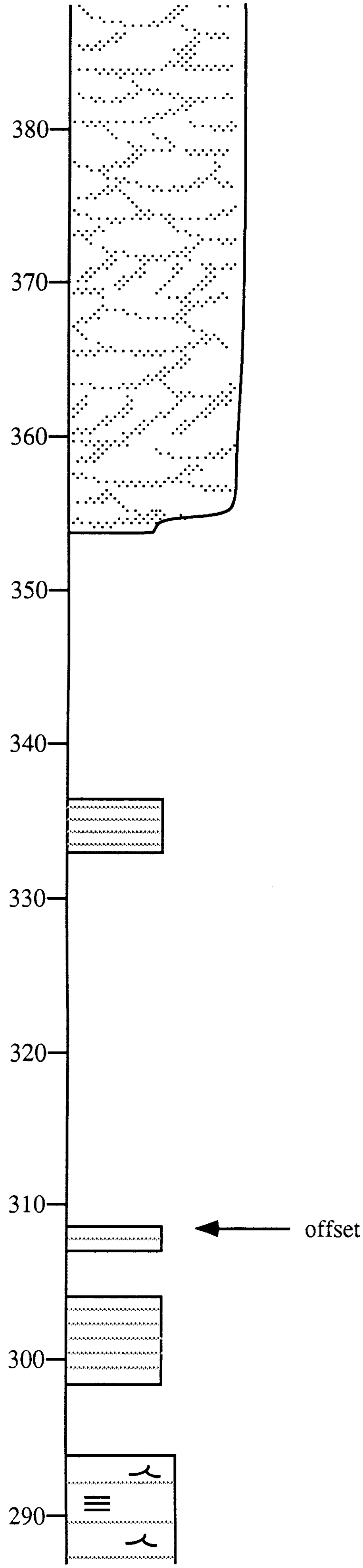
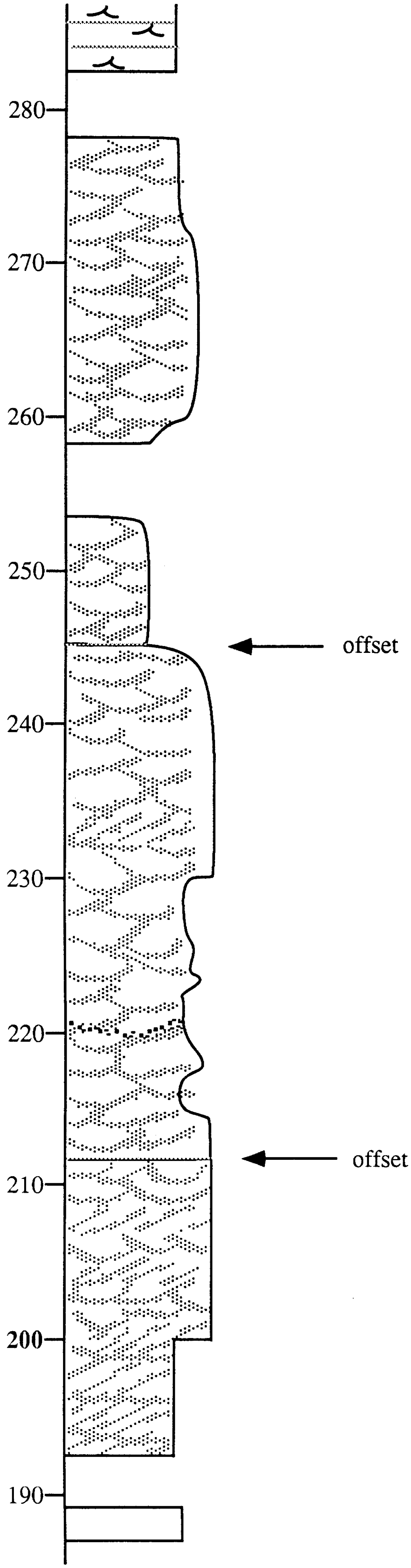
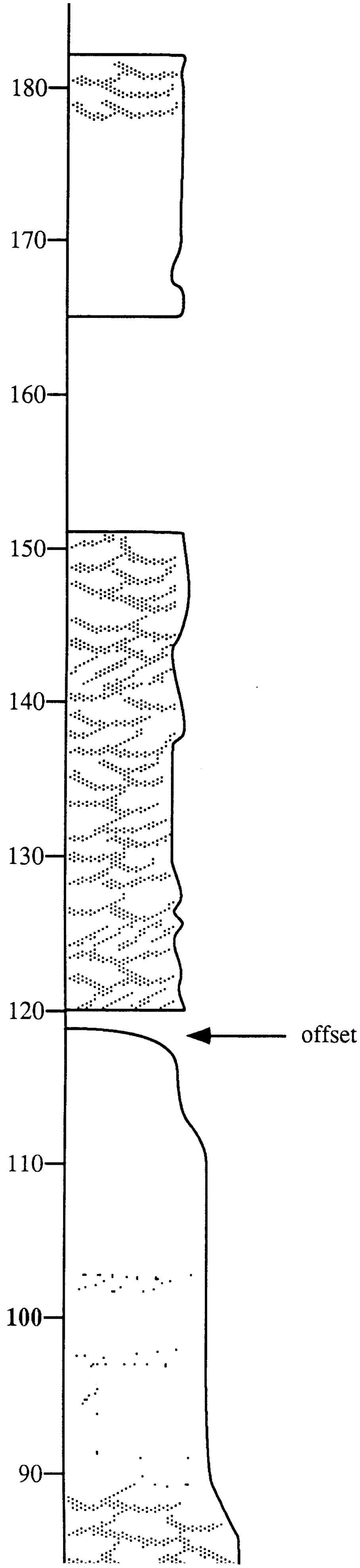
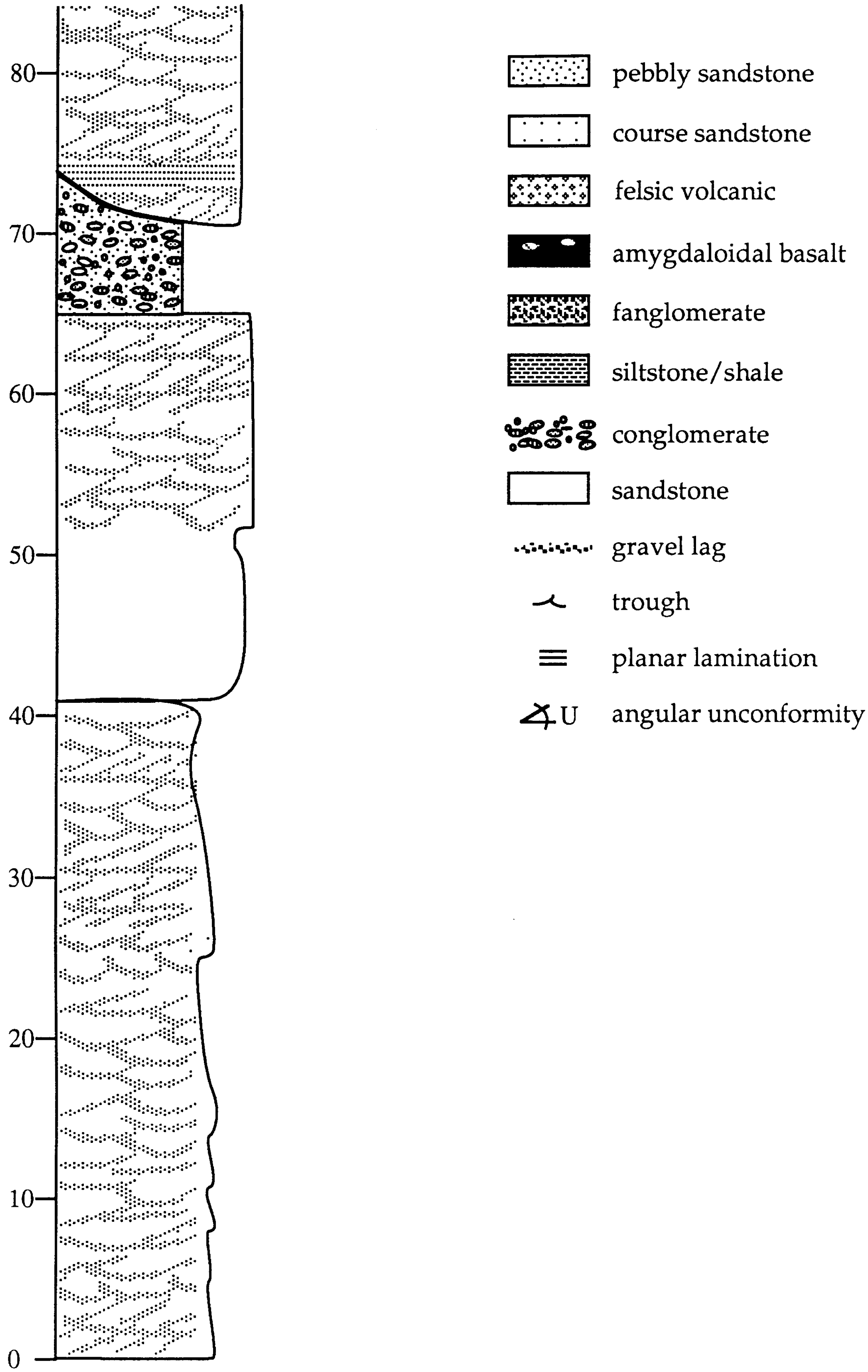
470
460
450
440
offset
430
offset
420
410
400
390
408
406
404

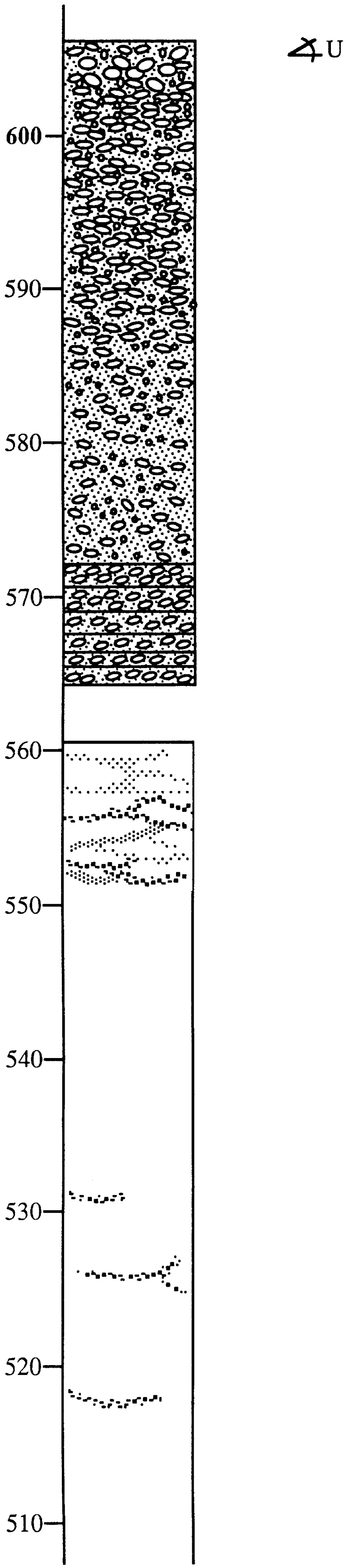

380
370
360
350
340
330
320
310
300
290
offset


280
270
260
250
offset
240
230
220
offset
210
200
190

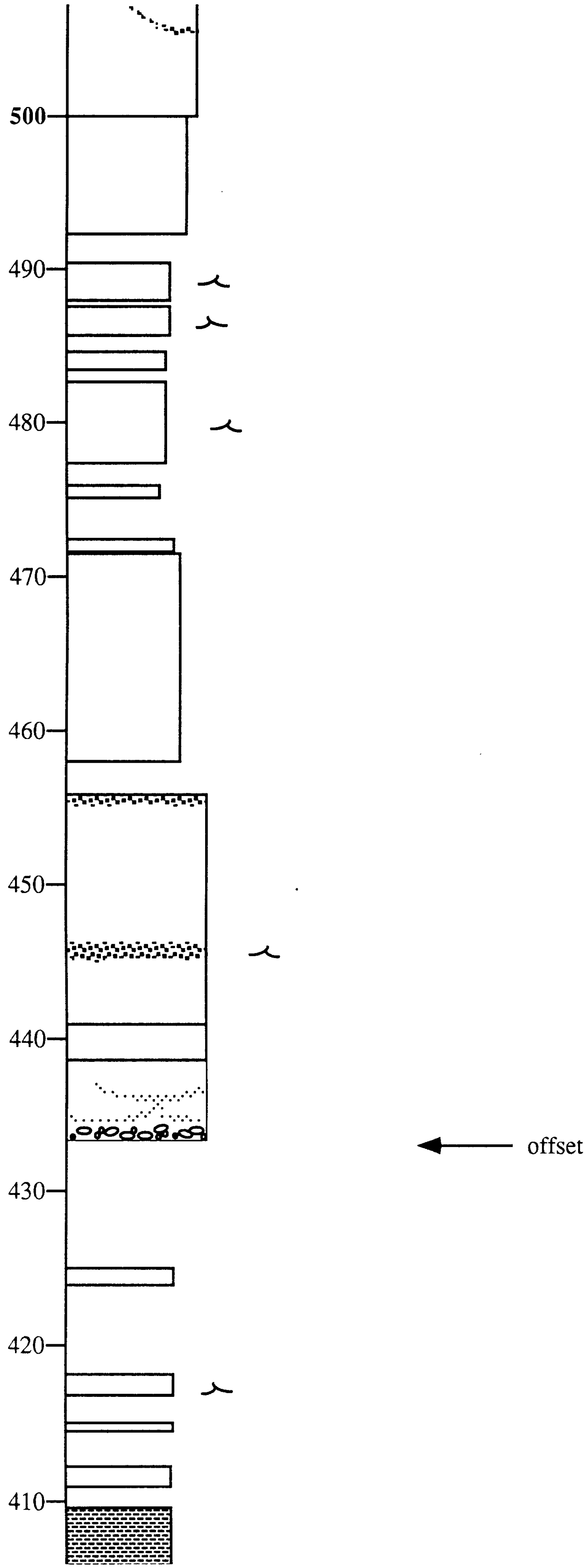

180
170
160
150
140
130
120
offset
110
100
90

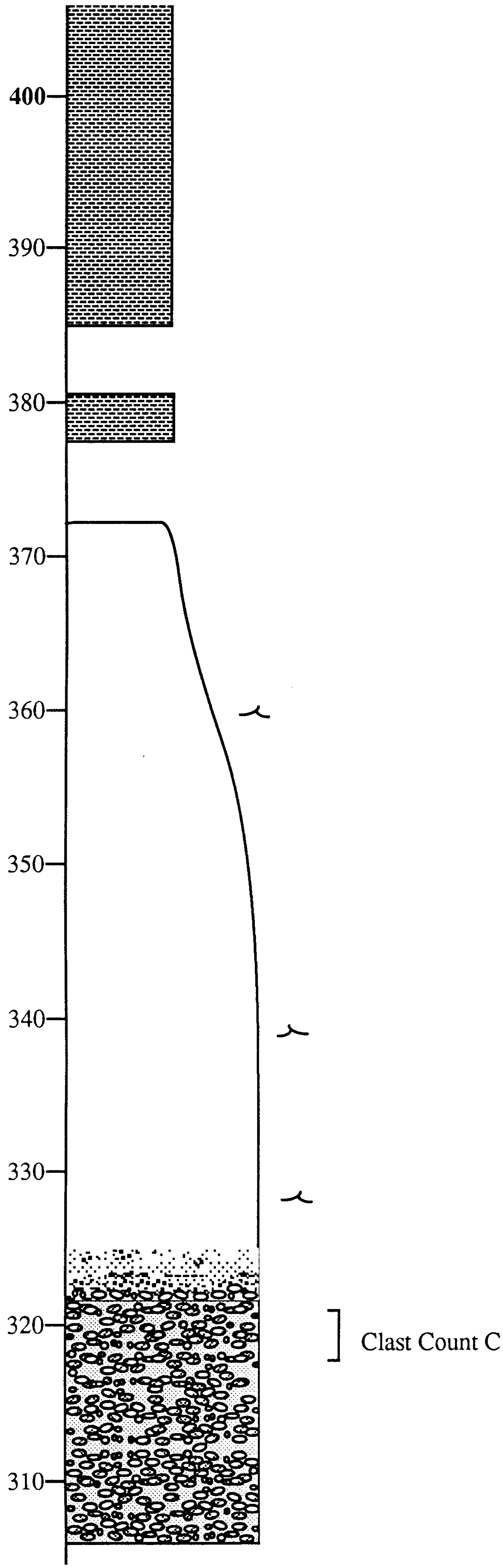


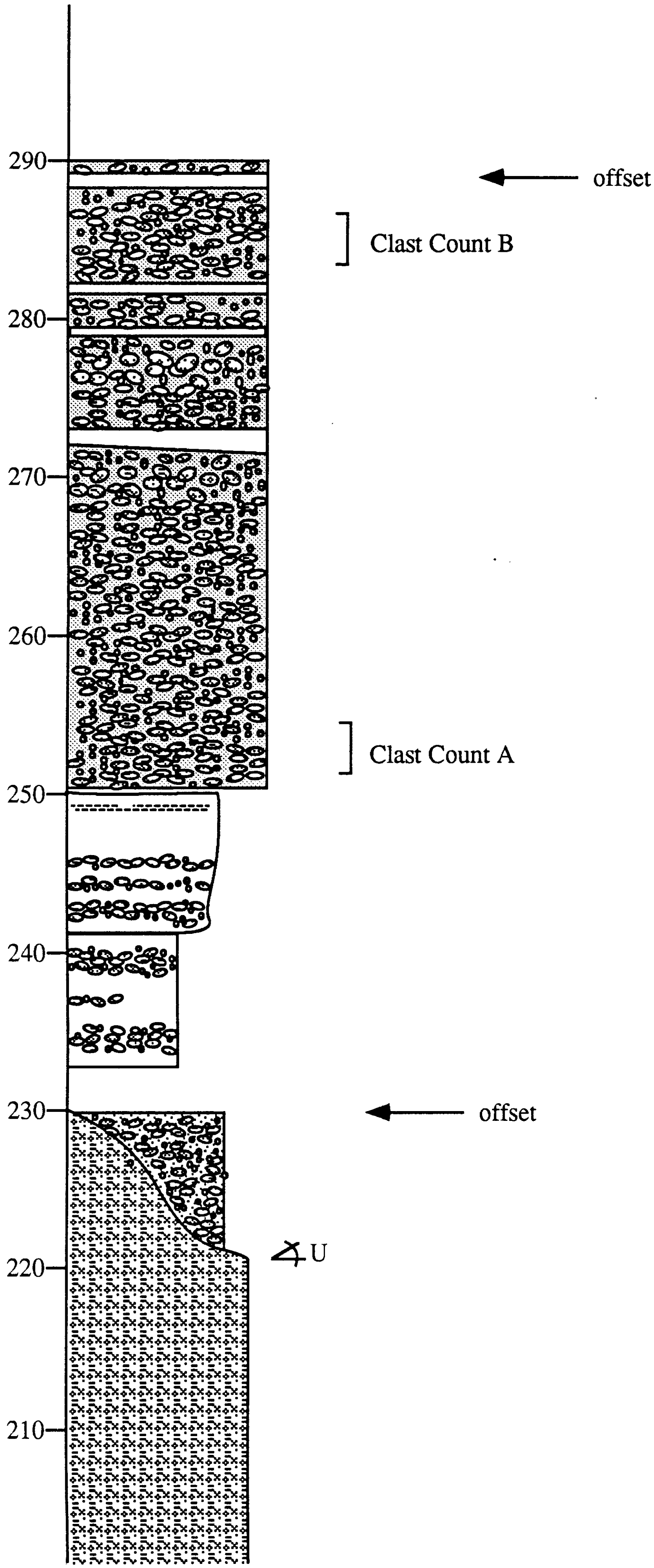
80
70
60
50
40
30
20
10
0
pebbly sandstone
course sandstone
felsic volcanic
amygdaloidal basalt
fanglomerate
siltstone/shale
conglomerate
sandstone
gravel lag
trough
planar lamination
U
angular unconformity

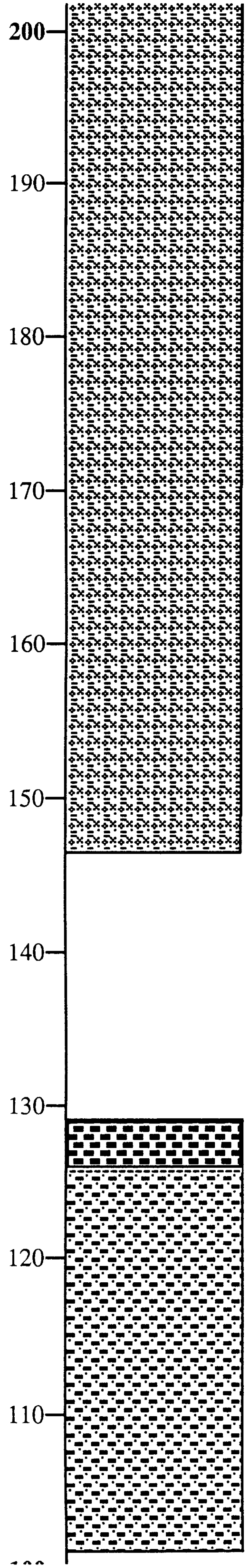


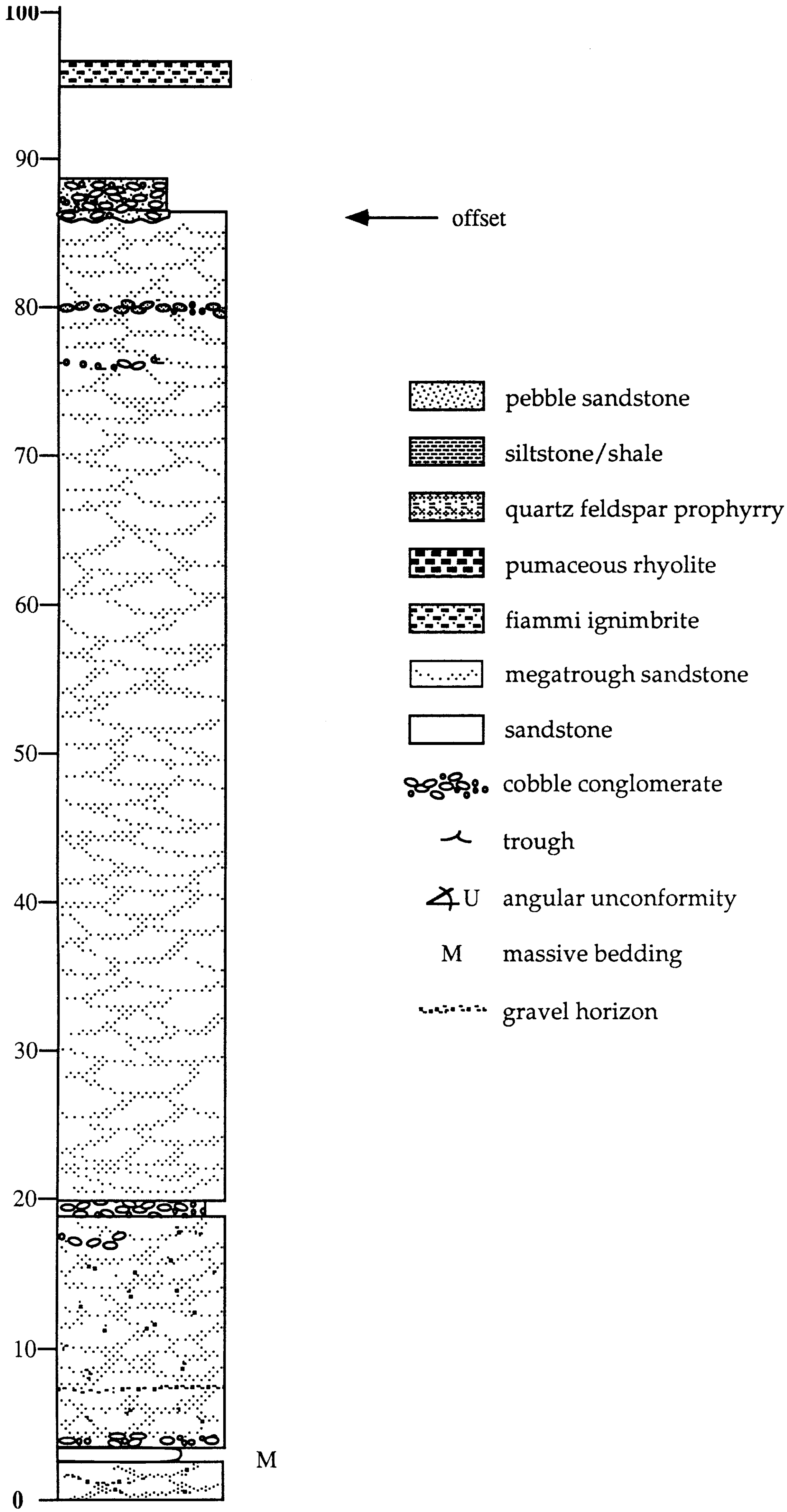
CORONATION SANDSTONE
THROUGH
KURRUNDIE SANDSTONE
"HOGBACKS"


500
490
480
470
460
450
440
430
420
410
offset

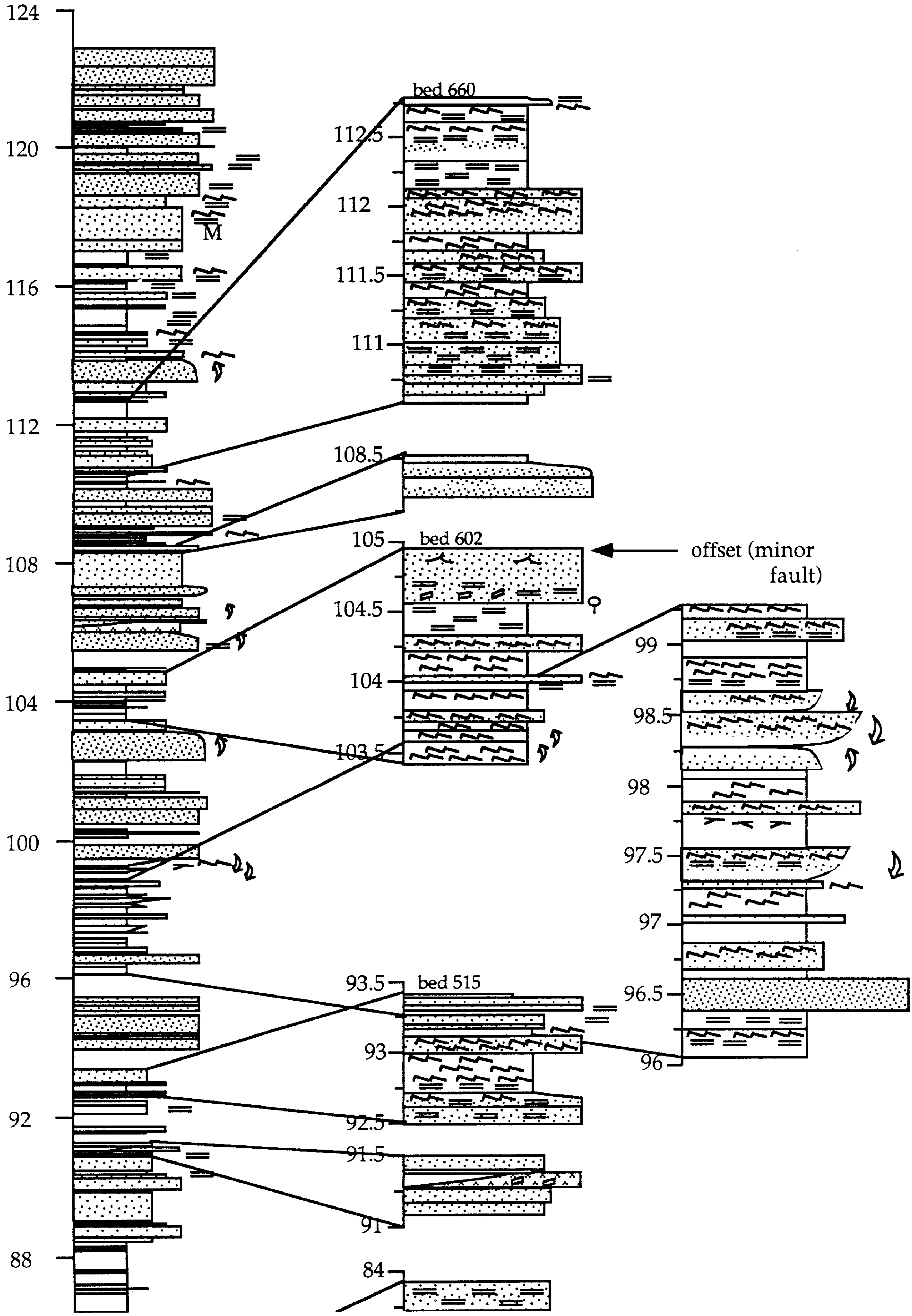

400
390
380
370
360
350
340
330
320
310
Clast Count C

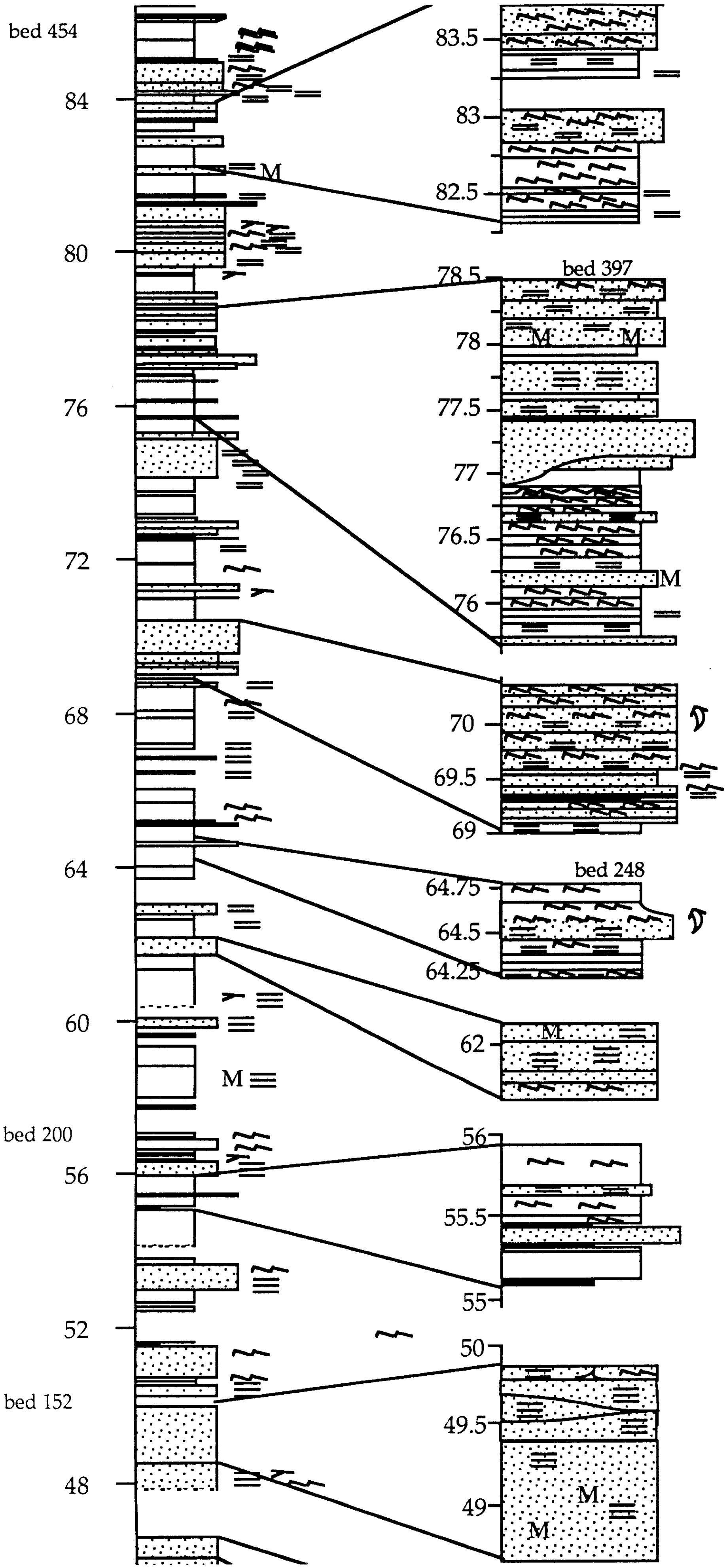

290
280
270
260
250
240
230
220
210
offset
Clast Count B
Clast Count A
offset
U

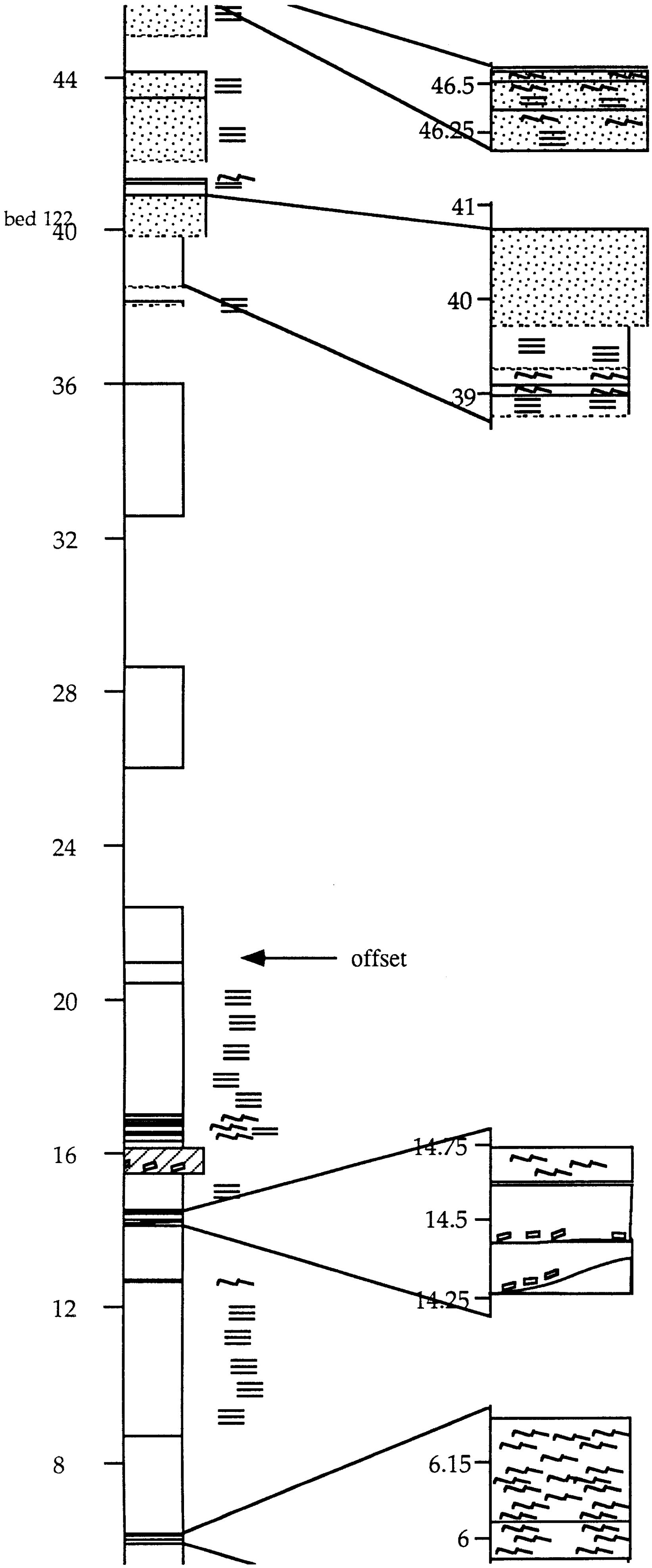

200
190
180
170
160
150
140
130
120
110

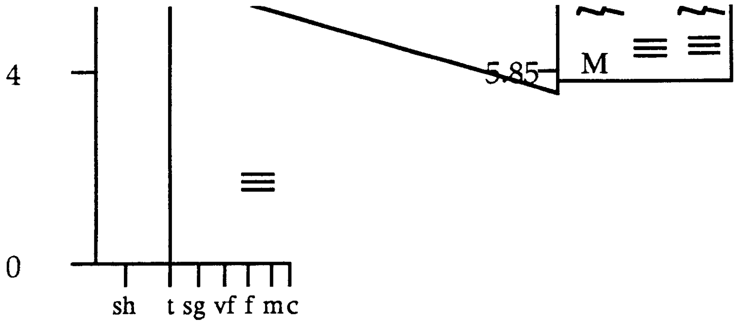

100
90
80
70
60
50
40
30
20
10
0
offset
M
pebble sandstone
siltstone/shale
quartz feldspar prophyrry
pumaceous rhyolite
fiammi ignimbrite
megatrough sandstone
sandstone
cobble conglomerate
trough
U angular unconformity
M massive bedding
gravel horizon

BIG SUNDAY FM.




bed 454
84
80
76
72
68
64
60
bed 200
56
52
bed 152
48
83.5
83
82.5
78.5
bed 397
78
77.5
77
76.5
76
70
69.5
69
bed 248
64.75
64.5
64.25
62
56
55.5
55
50
49.5
49
M


44
40
bed 122
36
32
28
24
20
16
12
8
46.5
46.25
41
40
39
offset
14.75
14.5
14.25
6.15
6



	fine-course greywacke/sandstone	M	massive bedding
	siltstone/very fine greywacke		fining upward
	tuff/tuffaceous siltstone		coursening upward
	felsic volcanic flow		parallel lamination
	felsic sill		low angle truncations
	intraclast/xenolith		climbing ripple
	trough		flute cast

Appendix B
Point Counts

sample	location	Q	F	L	Qm	Qp	Lv	Ls	Lt	Fp	Fk	Fund	D. mica	Matrix	Chl	Hem	HiClay	LoClay
11	p	299	3	3	295	4	2	1	7	1	1	1	0	20	0	0	14	2
62	k	196	1	58	177	19	47	11	77	0	0	1	0	63	0	1	9	51
13a	c	237	0	4	208	29	4	0	33	0	0	0	0	0	0	0	21	0
35a	c	265	0	4	210	55	0	4	59	0	0	0	0	46	0	0	45	0
79	b	113	37	7	104	9	5	2	16	12	17	8	13	99	4	1	3	19
40b	c	265	3	6	208	57	3	3	63	3	0	0	0	41	0	1	40	0
100	r	116	11	45	82	34	33	12	79	0	4	7	0	28	2	0	31	10
65	k	240	10	2	227	13	1	1	15	0	0	10	15	78	3	74	20	18
58	c	157	20	16	131	26	9	7	42	0	18	2	0	104	103	1	14	4
5	p	264	2	1	262	2	1	0	3	0	2	0	0	1	32	1	2	1
4a	p	315	2	9	305	10	9	0	19	0	2	0	0	7	0	7	4	3
31b	p	287	1	7	267	20	6	1	27	0	0	1	0	55	0	7	20	13
92	b	121	53	8	103	8	7	1	16	10	22	21	10	147	37	15	12	11
115	k	261	5	4	210	51	4	0	55	0	0	5	0	35	0	7	6	20
63	k	277	3	16	241	36	14	2	52	0	2	1	0	68	5	6	20	32

p	Coronation Sandstone	Lt=Qp+Lv+Ls
r	Pul Pul Rhyolite	Fund=feldspar undifferentiated
b	Big Sunday Formation	D. mica=demonstrably detrital mica
k	Kurrundie Sandstone	Matrix=not detrital grain or syntaxial overgrowth
		HiClay= High birefrinent clay minerals
		LoClay= Low birefringent clay minerals
		Chl, Hem, HiClay,. LoClay: only replacement or authigenic minerals

APPENDIX C: MAP

Key

Stratigraphic contact

Stratigraphic contact (approximate location)

Scinto Breccia (tectonic breccia)

Reverse Fault

Normal Fault

Fault, with ball on downside

Syncline

Anticline

Overturned syncline

Overturned anticline

Double-plunging syncline

Katherine River Group	Phk	*Trough and planar crossbedded course - fine quatz sandstone.*
	Phkc	*Boulder conglomerate, rounded to angular clasts of nearest underlying lithology*
	Pepv	*Basalt.*

Edith River Group	Palette Sub-Group	Pep	*Dominantly trough cross-bedded, planar-bedded, current-rippled medium-fine sandstone and interbedded matrix supported angular conglomerate lenses.*
		Pepc	*Cobble conglomerate, dominantly clast supported. Chief clast composition is Pul Pul Rhyolte.*
		PepΔ	*Sedimentary breccia of Pul Pul Rhyolite clasts interbedded with medium-fine quartz arenite, often hematite cemented.*
	Kurrundie Sandstone	Pek∴c	*Interbedded course pebbly trough sandstone and quartz pebble conglomerate.*
		Pek=∴	*Interbedded vey fine to medium quartz sandstone and shale.*
		Pek	*Pebble-medium trough cross bedded sandstone. Bedding typically 10-40 cm. thick. Pervasive liesegang banding common*
		Pekv	*Felsic and mafic exrtusives, typically altered to silica and hematite.*
		Pekc	*Bimodal, boulder-cobble conglomerate, often imbricate, and interbedded course - fine sandstone. Clasts are chiefly rhyolite. Pervasive liesegang banding common.*
	Rhyolite	Pbpp	*Quartz-feldspar porhpyr, often containing lithic fragments.*
		Pbpf	*Fiammi-rich ignimbrite, with abundant quartz phenocrysts and frequent feldspars.*

Group	Unit	Symbol	Description
El Sherana Group	Pul Pul	Pbpa	*Autobrecciated, lithic ignimbrite. Lithic fragments are sandstone and greywacke. Abundant unoriented fiammi.*
		Pbpc	*Cobble conglomerate, bimodal, with abundant mafic volcanic clasts.*
	Coronation Sandstone	Pbcv	*Rhyolite flow, qtz and feldspar phenocrysts.*
		Pbcb	*Basalt; locally amydaloidal, locally hematitic.*
		Pbc	*Pebbly , very course to course, planar cross-bedded, trough cross-bedded saandstone.*
		Pbcc	*Boulder to pebble, imbricated, planar cross-bedded or massive interbedded conglomerates and verycourse to fine sandstone.*
		Pbs	*Several unrelated units (see explainations), all siliceous and hematitic. Possible unconformity related, phosphatic breccia; tectonic gouge; hydrothermal breccia*
Zamu Dolerite		Pdz	*Course dolerite with plagioclase phenocrysts, typically expressed as surface cobbles.*
Finniss River Group		Pfb	*Greywackes, siltstones, and shales; well develped cleavage, occasional chevron folds.*
		Psb	*Altered mafic volcanic or hypabyssal intrussive*

		Psp	*Medium-very fine sandstones, greywackes, and shales; well developed cleavage.*
		Psg	*Devitrified felsic tuff, occasional quartz phenocrysys*
		Pskv	*Altered felsic volcanic, not a tuff. Possible mafic volcanics as well.*
South Alligator Group	Koolpin Formation	Psk8	*Dololutite and silicified grey to blue dolomite, often with microdigitate stromatolites.*
	Koolpin Formation	Psk=∴	*Interbedded fine-veryfine grained sandstones, siltstones, and shales.*
	Koolpin Formation	Pski	*Laminated hematitic siltstone and chert, occasionally jasper. Chert laminae may be centimeter or millimeter scale as well as nodular.*
	Koolpin Formation	Psk∴	*Medium-very fine sandstone, often penetratively fractured.*
Mount Partridge Group		Ppm	*Course, trough crossbedded sandstone and quartz pebble conglomerate, decimeter scale bedding*
Namoona Group		Pnm	*Red siltstone and shale*

R.F. 1:10,000

SOUTH ALLIGATOR RIVER

SHEET NO. 2