GEOLOGY AND PETROLOGY OF AN AREA INTERSECTED BY LATITUDE 28°40'N., LONGITUDE 102°30'W., COAHUILA, MEXICO

by

Elliott White Miller
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ABSTRACT

The area described is one of Lower and Upper Cretaceous (Comanche and Gulf series) sediments, and Tertiary and Quaternary intrusions and volcanic extrusives.

The dominant features affecting sedimentation were the Coahuila peninsula, upon the eastern flank of which this area is located, and the Mexican geosyncline. The area was a positive land mass for much of its pre-Albian history, being inundated by the great Cretaceous Transgression of Mexico and Southern United States. The formational units mapped are the Georgetown limestone, Del Rio shale, and Buda limestone of the Comanche series, and the Eagle Ford formation of the Gulf.

A study of the regional geology is made and areas of similar sedimentation, structure or igneous history are reviewed.

The geology and geomorphology are discussed and it is concluded that the Cuesta valley is essentially a large graben; that the folding probably predated the faulting; that there were three periods of igneous activity - the first during the Laramide Revolution of Lower Tertiary time when the volcanics associated with the Cuesta Peaks were erupted, a second period of activity in the Upper Tertiary with the intrusions at the Saddle Peaks and related volcanics, and a final minor period in the Quaternary.

A petrographic study of the igneous rocks is made and from thin section analysis it is concluded that the extrusive volcanics of the area are andesitic ash-flow tuffs.

A geologic map of the area is included with the paper.

Thesis Supervisor: Dr. Joseph L. Gillson
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure

Chapter I

Introduction

This thesis covers an area of forty-four square miles in the northwestern part of the state of Coahuila, Mexico. It lies approximately seventy miles due south of the border of the state of Texas, and forty miles southeast from Big Bend National Park at the Rio Grande River. Topographically, the area is within a range of mountains: at the southern extension of what is generally called Sierra del Carmen, and north of a group known as Sierra de los Guajes; and is located at the head of the Babia valley in an area known locally as the Cuesta.

It is a region of moderate to high temperatures, little rainfall and high evaporation.

The population of the region is sparse: the nearest town in the state of Coahuila being Melchor Muzquiz one hundred miles by unpaved road to the east. Locally there are small scattered settlements of the families of fluorite miners, perhaps totaling two hundred in a five hundred square mile region.

The area is of some economic interest due to the epithermal-mesothermal fluorite deposits first exploited by Fluorita de Mexico in 1951 (1) The prospects within the area studied were small scale tunneling operations mined by groups of local people without extensive modern equipment.

The topography of the region is one of high dissected plateaus and large intermontane basins characterized by confluent streams, thick valley fill, and sub-aerial deltas.

The paper presented describes the geology and petrology of this Cuesta region, that is, the nature of the rocks, tectonics, and geomorphology, and the evidence they give for the evolution of the region through geologic time.

Chapter 2

Stratigraphy

Regional Stratigraphic Setting The area described lies near the border of two physiographic provinces of Mexico: It falls along the east side of the Plateau Central and the western edge of the Sierra Madre Oriental provinces. While a division of this sort is somewhat arbitrary and even disputed by some authorities especially in view of the scant geologic knowledge of this region, still it is obvious that this area will have been subject to a variety of depositional environments as the two great ancient features: the Coahuila peninsula and the Mexican geosyncline extended and retreated. A summary of the paleogeography directly affecting this region is then helpful to appreciate the depositional forces encountered within the area studied.

Depositional history of region There has been no evidence found within the immediate region for extensive deposition before the Permian. Immediately north, the Sierra Del Carmen Mountains, early studies showed that the Cretaceous sedimentation overlies a mica schist of unknown, but presumed quite ancient age.

Three hundred miles west, in the northeast of the state of Sonora, one authority (see Taliaferro 1933) has reported a southward extension of the Balsa quartzite and Abrigo limestone from Arizona; these are of Cambrian age. Upper Ordovician strata have been mapped in two locations in central Sonora. No Silurian formations have ever been recognized in Mexico. Upper Devonian marine limestones, also an extension from Arizona, and lower Mississippian strata in three localities in Sonora have been established (Taliaferro 1933), but the Pennsylvanian seems to be the first Paleozoic of any considerable extent. A number of outcrops are found in Sonora, and King (1940) two hundred miles south in the Las Delicias region of southern Coahuila describes various shales and limestones of this age.

The Permian seas covered extensive areas in Mexico. Once again the Sonora region was affected, the entire state practically being covered. Studies of the fauna there and in West Texas and Las Delicias show that the western sea that invaded Sonora southward from Arizona apparently was separated from the eastern one covering western Texas and extending through the western part of the state of Coahula, covering San Luis Potosi and meeting the Gulf of Mexico.

Paleogeologic maps (See Kellum, 1944) show the eastern edge of this arm connecting western Texas seas with the Gulf of Mexico passing quite near the area studied. As the lowest member mapped or exposed within the area was middle Albian it was not possible to observe whether or not the Permian seas extended this far east. Studies in Sierra Del Carmen area as previously mentioned did not show Permian.

A general regression of the seas followed the Permian, leaving the state of Coahuila entirely and retreating to much the same position now occupied by the Gulf of Mexico; the Triassic eastern sea having only an embayment in central Mexico, and in Lower Jurassic retreating even further.

There was a general and extensive advance of the sea in Upper Jurassic and it is then that the main features that controlled deposition through the Cretaceous begin to emerge. The sea extended over the eastern portion of the state of Coahuila and short limbs of the sea went into the western half of the state. There was a positive area making a peninsula from West Texas through the Big Bend region and along the western half of Coahuila and eastern side of Chihuahua. The marginal seas on three sides of the Coahuila Peninsula during Upper Jurassic and Lower Cretaceous times contained coarse clastic derived from this high area. The extension of the sea on the western side of the peninsula came as far north as El Paso, and the sea to the east of it came as close as thirty miles from Del Rio, Texas with a limb from a major extension northwest into the Mississippi Valley embayment.

The Mexican Geosyncline (See figure #3, of Lower Cretaceous) had almost continuous deposition from this period through Upper Cretaceous.

From their beginning extension in Upper Jurassic, the seas continued the transgression that would reach the maximum extent over the North American continent in Turonian time. The Coahuila Peninsula was first inundated in upper Aptian time. By middle Albian at the latest, and perhaps sooner, the area studied was submerged, the Edwards limestone which outcrops just east of the mapped area was deposited then, and the region remained at sea level for a long period and lagoonal deposits accumulated at the borders of the former peninsula.

After Turonian times and the seas' regression, the beginning of the Laramide revolution in the Upper Cretaceous uplifted and folded much of the region, including the area studied. To the east the coal deposits of Nueva Rosita were being formed in a lagoonal embayment that marked the western edge of the Upper Cretaceous sea.

Stratigraphy of Lower and Upper Cretaceous (Albian, Cenomanian and Turonian) within the area studied. The section here described incompasses portions of the Comanche and Gulf series of which the European stages are known as the Albian, Cenomanian and Turonian; and those of Texas Imlay (1944) the Washita, Woodbine and Eagle Ford.

The Cretaceous and Quaternary systems are the only sediments represented by outcrops in the area mapped.

Comanche Series - Georgetown Member The Washita group composed of the Georgetown limestone, Del Rio shale and Buda limestone forms the highest stratigraphic division of the Comanche series.

Nomenclature The Georgetown limestone was first described by T.W. Vaughan in 1900 (See Lexicon of Geologic Names of United States, 1938) who states: "Georgetown limestone - name proposed by R.T. Hill for impure, yellow, argill. ls., forty or more ft. thick, characterized by Kingena wacoensis. Underlies Del Rio clay and overlies Edwards ls. Is equal in part to ls. formally called Fort Worth ls. Exposures very small." The formation was later traced and extended to include 7 well differentated and partly mappable members. It was named for Georgetown, Williamson County, Texas.

Stratigraphy and contacts The base of the Georgetown lies on the Edward limestone, the only immediate exposure was located in the Lead Road Canyon outside of the area studied. The contact is probably conformable.

The great majority of the area in the region mapped is capped by the Georgetown limestone which, along with the Buda limestone are the ridge forming formations. In nearly all of the major escarpments, the Georgetown limestone stands as the single cliff.

The Georgetown presents a massive face in many of its exposures, but when traced along its bedding plane most of the layering varies from a few to ten feet or more. One of its characteristic features in the region is the recrystalization of the exposed layers into single massive faces of forty to one hundred feet thick. This is especially prominant along canyons in the Cuesta escarpment, and along the raised edges of the Tea House syncline.

The Georgetown is fossiferous in its highest stratigraphic members, but the specimens found in the region were highly fragmental. Possibly, they are various rudistids and Gryphaeas, such as described by King (1937) in the Marathon region to the north. The fossiliferous zones did not seem to be everywhere uniform over the area, but in the pockets where they were found, they were especially prolific.

The highest layers also were marked by a brown chert which formed in 3 to 8 inch long wire-like concretions that stood up prominantly above the weathered tops of the Georgetown. The formation has an organic gray color that becomes slightly lighter toward the stratigraphic top.

Strat. #1 - Typical Outcrop of Georgetown limestone

<u>Del Rio shale and Buda limestone</u> The name Del Rio shale was first applied by Hill and Vaughan to the southward extension of what is called the Grayson in northern Texas. It is named after the town of Del Rio in the Rio Grande Valley.

Men familiar with the mining in the district state that the Del Rio in this region occurs in patches and is not everywhere present, a statement difficult to prove in the field due to the weathering characteristics of the outcrop. If it is missing in places, it would be hard to state if it was due to non-deposition and therefore is unconformable with the Georgetown, or was eroded before the Buda was deposited.

The Del Rio varies in thickness up to 15 or 20 feet and is buff to dark yellow color, in most outcrops it is friable and easily weathered, often highly calcareous. (See Strat #2) for example of outcrop with bedded calcareous feature.

Strat #2 Buda limestone overlying the Del Rio shale.
Note zone of leaching in the Buda

The Buda limestone was also first described by Vaughan in 1900 who named it after the town of Buda in Hays county. As contrasted with the Georgetown in this area it is non-cherty and non-fossiferous. Its primary distinctive feature is the way it weathers into spherical nodules, which often cover the sides of outcrops. It is a moderately weak ridgeformer - stronger than the Eagle Ford, inferior to the Georgetown. It has a light gray color, ranging to almost white in some of the weathered nodules. The thickness in the region is on the order of fifty to sixty feet.

Eagle Ford shale First named by Hill in 1887, it was described as overlying the Woodbine sand which is not present in the area. The name Boquillas flags is given by Udden in 1907 as the western equalivent which overlies the Buda limestone.

The Eagle Ford, which is the base member of the Gulf series of Upper Cretaceous, appear to overlie the Buda conformably, but others more familiar with the entire region state that there are examples of an unconformity at its base. The Eagle Ford is only found in certain protected locations in the region, such as under volcanic flows, in stable divides, and down faulted regions. The

Strat #3 Typical outcrop of Eagle Ford

formation is composed of an interbedding of thin shales and flat, flaggy, argillaceous limestones. The slabs of limestone vary from two or three inches in thickness on down to members a fraction of an inch thick. The formation is buff or cream colored. Some of the surfaces show imprints of fauna, probably small ammonoids and Inocerami. .

Other formations No stratigraphicly higher formations were found in the area studied, and from a review of the regional stratigraphy which has been briefly condensed above, it is doubtful that any were ever deposited.

Chapter 3

General Regional Geology

Introduction - Coahuila Peninsula

It has been shown from the review of the regional depositional patterns that the stratigraphic evidence strongly points to a positive landmass existing in western Coahuila during most of the pre-Aptian Mesozoic. It seemed generally to be of a peninsular nature, extending out into the Mexican geosyncline which surrounded it on the east, south and west. The landmass, then, was a pendant connected physically, and in many cases as we shall see, geologically bound to the history of the Big Bend - Trans-Pecos region of Texas. Studies by Imlay (1935) and others have shown that this stable area was largly formed by the intrusion of a large plutonic igneous rock injected sometime in the late Paleozoic. Evidence for this is found in the southern part of the state of Coahuila where part of the foreland is formed by Permian marine sediments and lavas and metamorphosed sediments of probable Permian and older Paleozoic age. In the Sierra

Del Carmen area the peninsula was formed at least in part by the Precambrian mica schist previously mentioned.

The Coahuila peninsula is further observed in the present distribution of the folded belts, a point that will be covered in the discussion of the structure patterns of the area.

Authorities who have done extensive work in the region, principally in southern Coahuila, have listed five periods of intrusive and extrusive igneous activity spanning from the late Paleozoic to the present time.

Outline of regional structural features and history

Marathon region

In his discussion of the regional relations of the structural features at Marathon, King (1937) points out that the Marathon folds were formed from rocks deposited in what he calls the Llanoria geosyncline, which covered an extensive area northeast and southwest of Marathon. The name Llanoria came from the landmass that was to have lain south of the Ouachita Mountains, and King mentions that the Nature of the geosynclinal sediments at Marathon gives evidence for this. He mentions the crystalline rocks in Sierra Del Carmen as possibly the eroded surface of this old land mass. Which, if true, would give this ancient mass an extensive area - all the way into southern Coahuila.

In a discussion of the post-Cretaceous structural features of southern trans-Pecos from the north end of the Sierra Madre Oriental, typically developed in northeastern Mexico. "(A) From this it can be inferred that much of the structural history in both regions may be similar in an analysis of the trend through Coahuila and eastern Chihuahua, from this time he notes, as have others that the Sierra

Madre folding bends around the ancient peninsula; going north-northwestward from Saltillo and continuing through Coahuila to eastern Trans-Pecos Texas, and part trending as far west as Torreon, as it bends around its southern extent, and then north-northwest through eastern Chihuahua into western trans-Pecos.

The western group of folds just mentioned follow closely the extent of the Jurassic sea mentioned in conjunction with the regional sedimentation, and are physically evident in the north-northwest trending folds in the Quit man and Eagle Mountains. The eastern branch of folding of the Sierra Madre is found in the Sierra Del Carmen near the Marathon region. This range is highly broken by normal faults and Baker (1917) states that a fault of great displacement downdrops the beds west of the Sierra Del Carmen.

King considers the Marathon dome as a broad swell on the eastern branch of the Sierra Madre foreland, with the Serrania del Burro across the border in Mexico to be a similar dome with approximately the same structural height as the Marathon, but with the Cretaceous cover still not eroded from its crest. Serrania del Burro parallels Sierra del Carman, which flanks it on the southwest.

Trans-Pecos region marks the end of the Sierra Madre Oriental of Mexico as it extends north into Texas. If it may be inferred that much of what has been discovered about this region is applicable to the Mexican extension, then a brief summary of the history of this region may be helpful.

It appears that some of the post-Cretaceous features are related to previous Paleozoic trend lines, rather then the northwestward direction of the Sierra Madre folding. This may be true for several arches of the Marathon dome on the east side. Also there seems to be some evidence in the rocks lying between the Marathon dome and those of Solitario.

At the end of Cretaceous time there was a period of diastrophism which brought strong folding and faulting to the western branch of the Sierra Madre. This was followed by a period of deep erosion, and in early Tertiary, lava flows and tuffs spread over much of the foreland, some resting on the folded higher Cretaceous.

Further movements after the period of early Tertiary lavas folded these extrusives, primarily along the trends of the previous deformation.

There is some disagreement between authorities as to the time of folding and faulting. Baker (1928) suggests that the faulting and folding went together, with the trends of the faults being roughly parallel to that of the anticlines. King, however, believes that the faulting is a later feature than the folds and were produced during a time of regional tension following the compression. He gives the time of earliest movement of normal faults as late Tertiary.

It is interesting that the faults of the trans-Pecos have two general trends. There is one system which extends north and south, but is highly irregular in detail with some members extending north-northeast or north-northwest. There is a second system found in the Van Horn region where the first system is crossed by a second trending west-northwest, with less displacement than the first, but far more regular. Many of these, states King, show clear evidence of recurrent movement. He further states: "The recurrent movements along the west northwestward trending faults suggests that they coincide with persistent lines of weakness in the basement rocks of the region."

In southern trans-Pecos Texas, Baker has worked out a system en echelon faulting of general north - south trend. Most of the rocks being downthrown to the west. The rocks capping the upthrown blocks are rather non-resistant tuffs and lavas suggesting a rather recent age for the faulting.

Southern Coahuila

It is interesting that as far south as southern Coahuila, the two trends of faulting seem to continue, Kellum states: "Where best exposed, the grain of the basement rocks, which comprise the foreland block in southern Coahuila appears to have two principal trends - approximately N 12 to 20 E and N 75 E. The trends of folds in the overlying Cretaceous rocks varies from about N 25W to slightly east of due north.

It seems to be agreed by all authorities that the Coahuila Peninsula is the cause of the prominant cross folding in southern Coahuila and northern Zacatecas.

Igneous Activity

As has been stated in the introduction, there is generally believed to be five stages of igneous activity in the region. The first two being Permian, and late or post-Permian and pre-Cretaceous. The last three being Jurassic, post-Cretaceous and late Tertiary. (See Kellum, 1936)

The post-Cretaceous igneous activities are represented in southern Coahuila in four regions, and are believed by those who studied them to have occured in the Laramide, along with the many others throughout the Rocky Mountain Cordillera.

The later Tertiary intrusives seem to have taken place in Durango, Chihuahua, and in the central part of southern Coahuila, many of these seem to have featured basalt flows. Bose in Durango noted rhyolite resting on Tutonian sediments which in turn was overlain by basalts.

Only one locality has been found, Ojo de Agua, in Sierra de Tlahualilo, where Tertiary tuffs and breccias are found in western Coahuila where the pre-Aptian peninsula was once located. It is stated that these are probably remnants of extrusives blown from volcanoes west and south of the peninsula. It is stated by Kellum that: "during the later three periods (Jurassic and Tertiary) it (the igneous activity) was confined to the geosynclinal area bordering the peninsula." This does not appear to be true in the area studied.

Ordonez (1900) in a comprehensive study of the igneous activity of N. Mexico places the rhyolite extrusions at the end of the Miocene to the middle of the Pliocene, and lists the succession of Tertiary igneous as:

6. Basalts
5. Dacites
4. Rhyolites
3. Andesites-dacites
2. Diorites - diabases
1. Granites-granulites

Chapter 4

Introduction

This thesis reports on the results of geologic mapping in an area consisting mostly of Cretaceous sediments broken into large fault blocks. Interpretation of the structure resulting from the intensive faulting which is the principal contribution of this study, required an analysis of the geomorphology. The principal features described in detail in subsequent pages are:

The *Cuesta Valley* - a graben with different characteristic features in both its northern and southern extent. The north portion of the graben is bounded by long continuous faults: to the west, the main *Cuesta Valley fault* and the minor paralleling *Seco faults*; to the east it is bordered by the *Saddle Peaks fault* and the accompaning *Uva Brandy fault*. The *Saddle Peaks*, an intrusive which followed the fault zone, and its related volcanics are the principal igneous features of the north Cuesta Valley.

The center of the graben is itself cut by the *Tea House fault* which marks the change in features between the two halves of the graben. The southern portion is bounded on the west by the large *Cuesta Peaks*, two intrusive bodies accompanied by extrusive volcanics, which follow the zone of the Cuesta Valley fault. The eastern side of the graben features the complex faulting of the *Tea House syncline*. The Cuesta graben ends in the small individual *Quien Sabe* and *Sabe Nunca grabens*.

The high *Cuesta* west of the valley is characterized by flat lying sediments and two major east-west trending faults. In the northern portion of the area studied is the *Camp fault* which marks the drainage change between the area further to the north and that of the Cuesta mapped. On the Cuesta and perhaps aligned with the Tea

House fault in the Cuesta Valley graben below is the *Las Mujeres fault*. The deep *Lead Mine canyon* is a major drainage feature of the Cuesta. A second intrusive, the *Fluorita Plug*, is found aligned with the Cuesta Valley fault and the Cuesta Peaks and is located in the southern portion of the Cuesta.

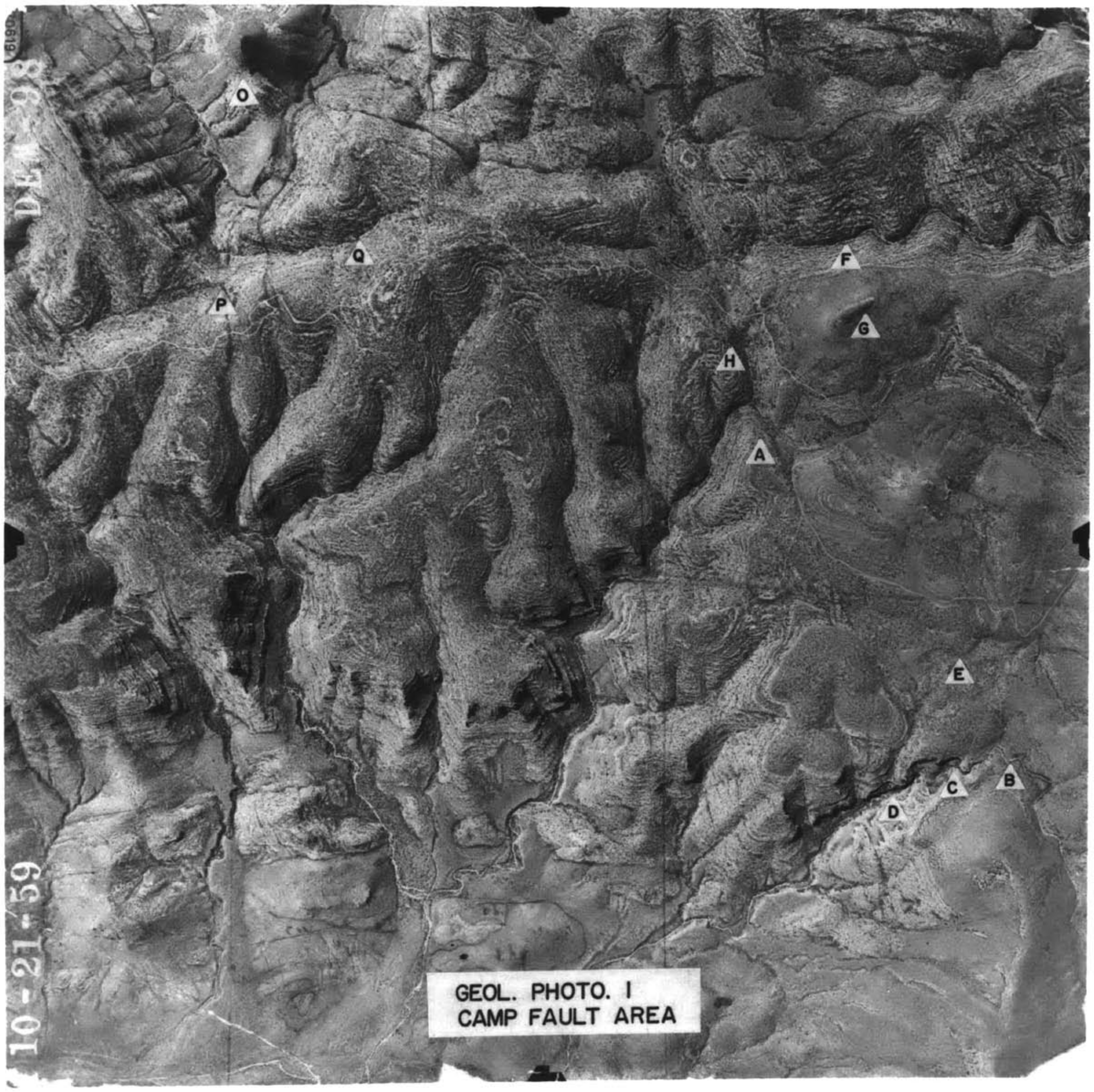
Discussion of the Geology - Geomorphology of the Area Mapped

The Camp Fault Region

The camp fault is located in the northwestern part of the area mapped and is one of the major faults of the region, running for 1.7 miles along a east-northeastwardly strike. The linear topographic expression would suggest that it has a steep dip (see point A Figure geol. photo. #1). The sediments north of the fault are folded into a syncline; those to the south, as with most of the sediments on the Cuesta, are flatlying. It is probably a scissors fault with the north side down thrown to the west and up-thrown to the east.

Note at point B the exceedingly small head stream leading into what becomes a canyon as it proceeds on further, its lack of tributaries as it passes over the flow, and how quickly the main stream disappears. It might be significant that the point where the canyon deepens an and widens is the point where the Camp fault intersects it. It would be probable that the fault collects surface water which follows along its course at some depth; this would account for a large part of the water needed to form a canyon of this order. Note also how very suddenly it steepens, (point D is at almost valley level) It is also interesting that the drainage patterns to northeast of the Camp Dulce fault are just beginning to form (point E) contrasted with the area to the south.

Another feature associated with the fault is the path of the deeply dissected stream in the northwest corner of the photograph. North of the fault it first meanders, then becomes linear at point F. It meanders again as it crosses fault and becomes shallow, then deepens again and becomes linear. The linear part is probably due to



GEOL. PHOTO. I
CAMP FAULT AREA

joint control. It seems likely as it parallels joints to the west that are outlined by the growth of cedars. Poor downcutting in fault region would indicate difficulty of streams to transverse this permeable region, as was inferred from the solution of the limestone at the end of the fault that it was a water carrier. Note though, that streams concordant with the Camp Dulce fault are not adversely affected and possibly deepened by this effect (point H).

It is unlikely that the Buda should be preserved at the valley edge of the Cuesta escarpment, because here stream dissection begins and works headward. It would seem more logical to find the Buda near the stream divides - the sediments being flat lying as they are in this area - where stream erosion would be the weakest. But was noticed, the area to the north of the fault is not drained well in this northeast region, it was supposed, because the drainage patterns have not had time to form after the erosion of the volcanics. This raises an interesting speculation. It would almost appear as if the fault itself forms a drainage divide. The area to the north of the Camp fault is drained by streams traversing principally north, and becoming more deeply dissected toward the west end of the fault, away from the main body of the volcanic flow. The area to the south of the fault drains principally east. And for the area along the fault from point C to A there is no noticable drainage across the fault. This has probably been a feature of the region for a geologically long period of time. It has enabled the land to the north of the Camp Dulce fault to develop a separate drainage pattern and direction of its own by not allowing significant passage of water across it for the cuesta escarpment to impose its drainage upon it, even though with its tremendous gradient, it must be a rapidly eroding system of streams. This would be another reason why high areas such as G have not been destroyed. The Buda to the south of the Camp Dulce fault would then be preserved because it represents a water divide between that of the Cuesta escarpment drainage to the south and east and the water carrying fault directly to the north.

Relying upon the geomorphic considerations of the effect of stream erosion with time, which will unfortunately in many cases be the most accurate guide, the possibility is great as shown by the arguments above the case of the anomilous preservation of the Buda; the deepness of the valley at P; the totally different drainage patterns to either side of the fault, with the ones to the northwest well intrenched; that the Camp fault must have formed early. It is probably related to the time of the formation of the cuesta escarpment in the Laramide or soon after when the drainage patterns were being impressed upon the land.

In the Camp fault region the divide is far from the east Cuesta escarpment. It becomes obvious that the escarpment appeared soon after emergence of the sediments and that the drainage, becoming deep and entrenched, moved the divide far back from the face of the escarpment.

East of the Camp fault in the region of the volcanic cone (point 0), there seems to be an instance of stream capture-the stream once following the course from point Q to P, Now the upper part drains into the valley surrounding the cone after being captured by the radial drainage of the volcanic, and the head of the previous stream is a hanging valley.

The Cuesta Peaks area

The north and south Cuesta Peaks are the highest topographic features in the area rising about 200 feet above the Cuesta itself. The south Cuesta Peak is the larger of the two, being a little over one half mile in diameter; the north peak is slightly more than a third of a mile in diameter. Unconsolidate volcanic ash beds, small obsidian lenses, and volcanic debris and talus are especially prevalent along the north side of the north Cuesta Peak.

Figure geol. slide #1. South Cuesta Peaks viewed toward the north. This illustrates the character of the volcanics described as fluted, or jointed. In the background on the hill is part of the extrusives thought by examination of thin section to be ash-flow tuffs.

GEOL. PHOTO. 2
CUESTA PEAKS AREA

The fluted volcanics visable in the preceeding slide may also be seen in Figure geol. photo. #2 at point A. This may be a remnant of a spine of the Pelee type; it could be the exposed volcanic neck of the vent for the extrusives found in the region. It could also be volcanic tuffs downfaulted from a position over the cone.

Figure geol. slide #2. A closeup view of the volcanics seen in the preceeding slide.

The large caldera AT F which may be seen to the south of the south Cuesta Peak in the air photograph appears to be a more recent feature than much of what is associated with the Cuesta Peaks. The drainage within the caldera is just forming and the streams on the cuesta appear to have recently drawined from a topographic feature. There is certainly not enough debris in the area to account for a feature of a magnitude that could have lately filled this caldera. Papers by Williams (1941) and others suggest that explosion calderas are rare, and what usually happens is a collapse of the feature due to withdrawal of magma from below causing a form of graben fault within the caldera. It seems quite likely that this is what took place.

Thin section studies show that what appear to be normal volcanic flows are in reality ash-flow tuffs of intermediate composition. This was found in samples collected throughout the region mapped and will be covered more fully in the chapter on thin sections. One consequence of this would be that for a period of time much of the area would have to be covered by a considerable thickness of volcanic ash to enable the extrusives to weld.

Drainage

It was noted, in the Camp Dulce fault region, to the north that the dissection of the Cuesta by the streams cutting the escarpment face had pushed the divide far back from the valley. It was argued that, by their deep incisions, it was quite likely that the escarpment had formed early, giving the streams time for extended erosion. However, in the Cuesta Peaks area the situation abruptly changes. Where once the divide occupied the center of the Cuesta, it now shifts abruptly to the tops of the volcanic flows on the edge of the escarpment and along the north Cuesta Peak, the Eagle Ford between the Peaks, and goes along the very edge of the escarpment on the west of the Cuesta displacement. (See photograph #2) As an indication of the continuous runoff in this direction note the depth of the Old Lead Road canyon at E. It is the deepest canyon on the Cuesta-due to its extensive drainage area, over what must have been a long period of time.

It seems probable that the drainage from the Cuesta Peaks area never extended in any other direction. There are no remnants of any drainage system in an eastern direction. The fact that there is Eagle Ford preserved on the divide between the Cuesta Peaks would indicate that this must have always been in a position where it could not easily be eroded. It quite possibly was covered by flows for periods as are remnants of Eagle Ford to the north. (See geologic map) But like the other preserved remnants of the easily eroded Eagle Ford, it is found at the far extent of the drainage system where the processes of stream erosion are the weakest.

It is probable that just as the cuesta escarpment must have come soon after the emergence of the Cretaceous sediments (so as to have determined the present drainage), so the Cuesta Peaks must have first intruded at an early date, making a topographic high in the region and draining the waters to the west. Reason seems to indicate that the intrusion and valley escarpment came together. The region could be pictured as underlain by a huge batholith, stoping from below. The entire wide Cuesta valley, from north to south, in the mapped region five miles long and a mile wide, is, in essence, a huge graben valley bordered by long extensive continuous faults to the north and ending in shorter length faults and individual graben valleys to the south. At the time of faulting of the huge valley the region had just recently emerged; The valley began to sink and simultaneously the volcanic masses began to push up along the western escarpment weaknesses, fracturing the sediments directly overhead concentrically. The igneous feature emerged forming the topographic high that would shape the drainage pattern as dramatically as the escarpment to the north. Then, early in the history of the region, the broad features were already evident: the cuesta valley graben, the escarpments, the Cuesta Peaks intrusion - all probably formed in the Laramide in Upper Cretaceous and Lower Tertiary.

Extrusives. It is difficult to say when the extrusives associated with the Cuesta Peaks first advanced. The volcanics to the north of the north Cuesta Peak which cap the hill at the edge of the escarpment were most likely early, and preserved this portion of the cuesta from erosion. It seems likely that it is old, as the divide passes through the middle of the extrusive as it moves laterally from the center of the cuesta to the edge. The fact that the volcanics rest almost entirely on Eagle Ford is another point in favor of their early appearence.

Further to the west of the Cuesta Peaks are two small patches of igneous flow (see geologic map) located not far from Las Mujeres fault. It is interesting that remnants of the flow should be preserved this far from the main volcanics. They probably owe their existence to the Las Mujeres fault which reversed the drainage over a short area causing the streams to flow east in the immediate region, creating a divide from the streams to the west upon which the flow remnants rest. Both patches rest on Buda which is interesting in itself.

The assumption has been that the drainage has always been to the west in this region which implies that the features further to the west are attached first as the streams cut headward. Here we see the Eagle Ford removed from over the Buda before introduction of the flow to the area. We may also see Eagle Ford downthrown in a splinter of the Las Mujeres fault a short distance from it. It would seem to follow that the fault was a very early former downfaulting the Eagle Ford before it eroded even here, and that the flow came sometime afterward when the Eagle Ford in this small area had been eroded. The same idea is perhaps strengthened at the eastern end of the Las Mujeres fault where it seems to disappear under the north Cuesta Peak flow, but due to the flaggy, shaley nature of the Eagle Ford it is difficult to determine positively where the fault actually goes, or whether it simply plays out. The Las Mujeres fault lines up with the Tea House fault a mile and a half away in the Cuesta valley. The Tea House fault which will be discussed later is known to exist by purely structural considerations, and must run along the Tea House valley perpendicular to the Cuesta Valley, and is covered by alluvium and older Quaternary hill talus. It cuts the Saddle Peaks fault, the major fault in the area, and is itself of major magnitude. Whether the Tea House and Las Mujeres faults actually join is perhaps academic, however, it should be stated that both mark a major division in the region. Within the Cuesta valley, the Tea House fault seems to mark the change from the long continuous faults of the north and the short fault, valley syncline, small graben area to the south where the Cuesta Valley ends. Just as to the north, the Las Mujeres fault parallels the divide change and immediately to its south is the first of the twin peaks.

Lineations

A few comments might be made about the long lineations that appear in photograph #2. Field examination of these features reveals that they are marked by growths of a small cedar-like bush that are easily missed in the field, but show up well from the air because of their dark outline, which contrasts well with the other lighter vegetation. In examining the total region it was found that these growths and larger conifers were found in other scattered areas (such as point G) along certain stream beds which seem sure to collect water in the wet seasons. It is probable that these plants can exist only under certain conditions and possibly the critical requirement is an amount of water above that normally supplied to the entire region. It may well be that the intense evaporation on the surface of the land tends to penetrate these zones of weakness perhaps causing slightly increased humidity near the openings, due to moisture at depth, which the desert plants can use to their advantage. In any case, where found apart from the jointing, the plants are in areas associated with an anomalous supply of moisture.

The joints themselves rarely have any displacement although to some few cases observed they definitely do. Faults too, often have these plants outlining their course. (See point H for Las Mujeres fault).

The origin of the lineations is not sure. In a minority of cases they seem to radiate from the igneous intrusives. One speculation is that they might be the fault pattern of some lower underlying system which has impressed itself on the sediments above due to reactivation of older faults or joints by the later tectonic and igneous activity of the region. Similar ones are found in the trans-Pecos area and are described in the chapter on regional geology.

It has been mentioned that the lineations never cross the Buda formation. A more accurate statement would be that the cedar-like markers do not seem to grow readily on the Buda; they do grow, however, on the Del Rio shale and are a good marker for the formation, especially in the southern region. The implication that the lineations appeared before the deposition of the Buda, evidently within the Cretaceous seas, does not seem at all reasonable. There are scattered instances where the lineations do cross the Buda (point I).

The Saddle Peaks Area

The Saddle Peaks stand perhaps 250 feet above the valley floor, the sides rising almost vertically out of the talus slopes surrounding them. The south Saddle Peak is .36 miles long and .07 miles wide and is extended in a north east-southwestwardly direction, and it is crudly saddle shaped. The north Saddle Peak has approximately the same dimensions as the south peak. Their attitude and form suggests that they are intrusives.

West of the south Saddle Peak,volcanics rest against its flank at an attitude of 68° showing that this and probably a number of the many extrusives in the area are related to this feature (See Figure geol. photo. #~~4~~3, point A). Examination of samples from both north and south Saddle Peaks show no dissimilarities, and there can be little doubt that their histories are the same.

One indication of their genesis is the long linear shape of these features; each is four or five times as long as it is wide, and north and south Saddle Peaks, further, are themselves aligned. Point B on photograph #~~4~~3, is an approximate point on the line along the valley where the external drainage of the talus cover on the Georgetown gives way to the internal drainage of the valley, marking the edge of the underlying limestone and the position of the Saddle Peaks Fault. It seems highly probable that at a time after the placement of the Saddle Peaks fault, perhaps well after it, a second period of volcanic activity in the region injected magma up through the Saddle Peaks fault giving the present topographic feature its long linear shape. The fact that the Saddle Peaks are located at the intersection of the Saddle Peaks fault and the Uva Brandy fault would further insure it being a zone of weakness. The patches of Eagle Ford were probably carried up from their downfaulted position below by the new tectonic and igneous activity. Note also how north Saddle Peak curves to keep parallel with the edge of the faulted sediments as the Saddle Peaks fault changes direction, a further indication that the Saddle Peaks are fault-controlled also.

It is interesting to note that the volcanics at A, previously mentioned, extend down to the creek level, showing that the relationship between the topography when the extrusive was formed and the change since by the downcutting of the creek has been slight. Also once more we are concerned with a divide in the watershed. The divide in the valley occurs just to the north of the South Saddle Peak and extends through the volcanic cone C. Much that could be said and inferred by this point is lost by the fact that there must have been a divide here long before the igneous intrusion and the intrusions may have changed the drainage pattern little. Note to the east in the Georgetown that the entrenched streams of long standing make a divide that would naturally extend through the valley here. The assumption that the intrusion in this case, contributed to a new pattern of water shed would be unfounded.

The volcanic cone at C with its accumulation of superficial volcanic ash can be assumed to be of relatively recent origin. Other small pockets of ash are found to the east of the north Saddle Peak and are perhaps associated with it. The Saddle Peaks post-date the Saddle Peaks fault, and while it is impossible to tell anything but relative ages in this case, it is probable from the study of the volcanics of Northern Mexico mentioned in conjunction with the regional geology that the age is Miocene to middle Pliocene.

Another feature of interest in the Saddle Peaks area is the large extrusive at point D. This is a portion of the one found in the Camp fault area. It stands well above the valley at about the same height as the cuesta to the west, and lies principally outside the mapped area, there is the chance that it may have flowed down the Cuesta Valley (assuming it is younger than the valley) leaving many of the remanent patches of volcanics.

Figure geol. slide #3. View of the dipping Georgetown and valley east of the Tea House syncline.

GEOL. PHOTO. 3
SADDLE PEAKS AREA

GEOL. PHOTO. 4
TEA HOUSE SYNCLINE

The Tea House Syncline

The Tea House Syncline is the most complexly faulted block in the mapped region. Actually the block contains two synclines, the broad Tea House Syncline (marked A in Figure geol. photo. #~~3~~4) and a tightly folded one to the north, bounded by faults, on the side of a steep hill, which this is most easily seen at point B on photograph.

The probably history of the Tea House syncline is as follows; Before the major faulting took place there was a gentle syncline extending from the north east dipping limb, now at the edge of the Quien Sabe graben, to a south west dipping limb, a portion of which is still preserved at point C on the photograph. It also extended northwestward, probably plunging in that direction; the remnants of which are still visable across the south valley creek. (See the geologic map for the total syncline) At the beginning of the era of the major valley faulting, in the Laramide, the Saddle Peaks and Uva Brandy faults cut the syncline, upending the block between them in much the same manner as they did in the north Cuesta Valley. The Uva Brandy fault curves into the Saddle Peaks fault, narrowing the upended block between much in the manner the block narrows in the north end. A second fault principally strike slip cut the upended block separating the two parts (see blocks D and E on photograph). Finally the Esperanza Suerte fault, (visible at F) uplifted the north limb of the Tea House syncline to its present steep attitude and the drag on the down-thrown side formed the second tight syncline high on the slope (mentioned at point B). The complete view may be seen on the geologic map accompaning this paper. An interesting feature of the Tea House syncline is the deep cleft down its center separating the gently from the steeply dipping limbs, (cleft visible at point A on photograph). Field observations show that there is no displacement along the cleft; it apparently represents a type of structural hinge formed under the stress of the upthrown side of the Esparanza Suerte fault. The stream now seem deeply entrenched in the cleft; and there is apparent stream capture (point G on photograph). The abandoned high valley probably represents an early zone of weakness the stream followed, as it parallels the faults bordering the Quien Sabe graben.

There are a number of fluorite mines within the Tea House syncline, a rather unexpected occurence, although they are stratigraphicly located within and below the Del Rio shale, as are the vast majority of mines in the area upon the cuesta.

Figure geol. slide #4. View of the fault on the west of the Quien Sabe graben. Georgetown is on the hill and Eagle Ford is in the valley. Line of trees shows that the fault plane dips to the east.

The Quien Sabe Graben

The Quien Sabe Graben and the Sabe Nunca graben to the west, mark the southern end of the Cuesta Valley faulting. The Quien Sabe graben has an interesting drainage pattern; two member streams of the same system encircle the Tea House Syncline block and divide the drainage of the graben in the middle of the valley(#B). At first appearences it seems to be a very unstable condition. The southern stream has not only cut up into the Quien Sabe graben, but also through the Georgetown and drains the Sabe Nunca as well (point H on photo). With the head of the southern stream in the Sabe Nunca graben perhaps it will not capture the other part of the graben. The graben is poorly drained, being in the upper reaches of two streams, certainly a help in preserving the Eagle Ford. The history of both grabens are probably quite similar, both forming with the major cuesta valley faulting.

Cuesta Valley Escarpment

The western edge of the Cuesta Valley is marked by the shear Georgetown cliffs, and within the near edge of the valley, the long continuous Seco faults. The western margin of the Cuesta Valley probably went through two different periods of instability. The first was with the formation of the Cuesta Escarpment at the time of the earliest tectonic and igneous activity in the Laramide. The escarpment represents a zone of weakness, principally exhibited by the escarpment fault, but also with the parallel Seco faults, along which the downward movement of the cuesta valley graben took place, along which recurrent movement occurred together with the tectonic activity that followed in the Upper Tertiary.

The cuesta escarpment ends to the north at the cliff capped by the North volcanics. To the south,the edge of the escarpment is intruded by the Cuesta Peaks, while the downthrown features of the Cuesta valley continue past the peaks to Quien Sabe graben.

The sediments at the base of the escarpment, in the region of the southern end of the Seco faults, are folded into a anticline which is faulted but easily recognizable.

The block between the two Seco faults is downfaulted and contains two patches of volcanics that have been preserved. Portions of it are still visible in the unfaulted portion overlying the Eagle Ford to the west. It might be questioned whether these volcanics are the same age as those further up the valley to the north, the volcanics in this area having time to become faulted and weathered in volcanics talus slopes where as, with those to the north this was not the case. The question, too, might arise, just as with the North volcanics, whether any of the extrusives from the Cuesta Peaks ever covered the valley. The case for a later pulsation of activity, not long after the large cuesta graben had formed with flows through the valley, and an accompaning minor tectonic disturbance shown in the Seco faulting, is good considering the extensive erosion of the volcanics near the Cuesta Peaks.

There is much minor faulting to the east of the Seco faults especially in the Buda and Georgetown which form little hills above the valley fill.

The Saddle Peaks, Uva Brandy and Tea House Faults

In contrast to the multiple faulting in the Cuesta Valley across from it, the eastern side is bordered by one continuous fault line, the Saddle Peaks fault. The sediments behind it in the hills to the east of the fault make a gentle anticline, which had its westward dipping limb faulted with the formation of the cuesta graben. The limb broke, forming the Uva Brandy fault, under the drag of the tremendous Cuesta graben and presently dips steeply toward the valley (#A). (see Figure geol. photo. #4) The drainage with a divide along the Uva Brandy fault and old entrenched streams, on the slopes, once more points to the early formation of features associated with the Cuesta Valley graben.

The Tea House fault is younger than the Saddle Peaks and Uva Brandy faults, although it too, must have been formed early in the region's history. It is probably connected with the intense faulting of the Tea House Syncline to the south and represents faulting connected with the settling of theCuesta Graben. South of the Tea House fault, the side of the graben that rests against the Cuesta Peaks has the greatest displacement while the area of the Tea House syncline took the downward movement with a deep buckling, leaving the Tea House syncline plunging steeply into the valley where large patches of Eagle Ford are preserved within the valley graben. The area south of the Tea House fault is a region of short faults of considerable displacement and much folding.

The Fluorita Plug

The Fluorita Plug is in the far south of the region, in a line with the Cuesta Peaks. It is quite likely that it is of the same age as the Cuesta Peaks, although the forces of erosion do not seem to have effected it as greatly, undoubtedly because there is no great fault valley to either side to aid the erosional process. The extraordinary number of fluorite mines in the vicinity lead to the speculation that the mineralizing waters were especially prevalent near this intrusive. Thin section studies show that this body is from the same magma source as the other intrusive volcanics in the region.

Chapter 5

A discussion of the volcanics within the area studied

Microscopic studies of thin sections from the samples collected from the consolidated volcanics show a number of features not generally expected of normal flow rocks. These features will be covered in detail in the subsequent discussion, but briefly they may be summarized as follows.

Megascopicly the volcanics in the region would be classified as aphanites, having well below 50% of the component material large enough to be recognized by the unaided eye. Further, they all fall into the color range associated with felsites, being almost cream through yellow, light brown and red. Microscopic examination shows that the feldspar phenocrysts are entirely plagioclase - hence a rock is of intermediate composition, but generally without the andesite's expected association of hornblende, biotite and pryoxene. The groundmass was not that expected of a flow rock, containing examples of shards, and being largely composed of devitrified glass. The devitrification products formed two minerals of widely differing indices of refraction too fine grained to be identifiable under the microscope, but covered in the literature discussed in the following chapter.

It will develop that, at least by microscopic criteria, the volcanics are ash-flow tuffs, the concepts and implications of which have only recently been put forward in the geologic literature, with the first attempt to compile the divergent studies into a paper covering the field coming only two years ago. For this reason a short background was included giving the concept of ash-flow tuffs along with the criteria for recognition which have been evaluated point by point in the light of what was found-in thin section study and also briefly, where it is pertinent, in the field.

Difficulty of distinguishing ash-flow tuffs from rock flows

In a conclusion based on an intensive study of the literature dating back to the 1860's, Ross and Smith (1961) state: "Many rocks have been described that show peculiar "flow" structures or 'ash' structures, or what has been considered normal 'rhyolitic' structures, Many of these rocks, from their descriptions, illustrations, or by reexamination, are now known to be welded tuffs." Going back over 800 thin sections from the U.S. Geological Exploration of the 40th Parallel under Clarence King in 1867-73, the authors found that almost 200 of them were of welded rhyolitic tuffs. In their conclusion on the recognition of ashflow tuffs they point out that not only are the welded tuffs often confused with lava flows, but that this is especially true when the tuffs are devitrified.

The concept of the ash-flow tuff

Modern studies of active volcanos, chiefly at Pelee and the Valley of Ten Thousand Smokes in Alaska, have greatly helped in the understanding of the dispersal of pyroclastic materials. From his study of Pelee, Perret concluded that the particles were carried along in a form of gaseous avalanche, exceedingly dense, swift, hot and moble, which supported and separated each particle by a cushion made of its own gasous nature. The rapid discharge of gas converts the volcanic material into ash rather than hurling it into the air as volcanic bombs or related debris. Most welded tuffs found around the world seem to be closer related to the deposits at the Valley of Ten Thousand Smokes. Discovered by a National Geographic Society Expedition in 1917, it has proved to have been formed by a volcanic dust and gas mixture, virtually dry upon emplacement, supported in the same manner as the Pelée deposits with the gas eliminating the friction between particles.

Recent work, both in the field and laboratory, has added greatly to our fund of knowledge on the subject. From studies of other deposits it has been concluded that deposits erupted from domes seem to have less volume and extent then those emitted from open craters. The former, being highly dependent on the location of the vent, has a more asymmetrical distribution of material around the opening.

Experimental data has placed the temperature of the parent magma from which rhyolitic tuffs are derived as not greater than 1000°C, and andesitic magmas at not more than 1,150°C.

The speed at which the ash flows move has been estimated in a number of instances, they are all extremely rapid varying from 60 to 100 miles per hour. It is easy to see that the time between emission and deposition leaves little chance for extensive cooling. Despite the great speed the gas-volcanic mixture has a certain density and moves near the gound unlike ash falls and related forms. Although the volume of gas in quite large its actual mass is small another factor in conserving heat in the deposited tuffs.

After the volcanics become emplaced welding and devitrification often occur. Ross and Smith list the factors pertinent in welding as: "(a) The initial heat of the magma; (b) dispersal by flowage; (c) insulation in thick ash flows (d) the effect of volatiles." And the factors controlling devitrification as: "(a) Chemical composition of the tuff; (b) chemical composition of the accessory volitiles; (c) rate of cooling; (d) temperature of devitrification; (e) identity of the minerals formed; and (f) stability relations of these minerals."

As to the relations of these two processes to the experimental data and the factors listed above, the picture is developed by the authors as follows: "The tuffs come to rest in a heated condition, with welding initiated at about 650° to 700°C, and perhaps reaching about 900°C in the hotter tuffs. This provides them with a plastic yield, although the viscosity is high in glasses of rhyolitic composition. They contain small amounts of dissolved volatiles that have an important effect in reducing viscosity. After coming to rest the tuffs are under a static load, depending on the thickness of the overlying material. Porous glassy tuffs are exceedingly poor conductors of heat and remain hot probably for years." And on devitrification: "The temperature of devitrification has a wide range, probably beginning immediately after welding and continuing to some problematical minimum temperature. However, once crystallization starts, it probably proceeds rapidly."

Intermediate Composition Ash-Flow Tuffs

The main body of the literature concerning ash-flow tuffs deals with those of the Western United States which are largely of rhyolitic composition. Intermediate types have been studied in Costa Rica, Argentina, Russian Armenia, El Salvador, and Japan, and it was found that the physical characteristics are nearly the same.

In the cases of intermediate composition studied by the authors, devitrification seemed to be rare - certainly not the story in the area studied. The study also indicated that intermediate shard tend to be platelike with some almost shredlike, and that few of the forms seemed to be derived from the shattering of rounded bubbles, which was very much the case in the specimens examined.

Studies show a much lower viscosity for andesitic type glass than for rhyolitic, a definite contributing factor to the collapse of shard and pumice forms and subsequent welding.

It is also interesting to note that preliminary studies have shown that the more andesitic welded-tuff deposits are especially traceable to definite volcanic centers.

Identification of ash-flow tuffs - field criteria

Ross and Smith (1961) list twelve characteristics for field identification of ash-flow tuffs. Each of these will be briefly discussed as a background to the entire picture of their formation and will enable a more intelligent conclusion as to the meaning of the microscopic characteristics.

Pyroclastic character Pumice fragments are listed as the most diagnostic feature for field recognition of ash-flow tuffs. They state that they are found in nearly all ash-flow tuffs even though there has been extreme welding and vapor-phase mineralization; only when "extreme devitrification follows extreme welding" are they obscured. Unfortunately a further limitation is stated: "In very fine grained tuffs the pumice fragments are too small or too few to be of much aid in field studies and other field or microscopic criteria must be used." This will be covered presently in the microscopic discussion.

No systematic field search was made for pumice fragments in the volcanics as it was not suspected until later microscopic study that they could differ much from rhyolite flows which they are locally called. It is evident from microscopic studies that the groundmass is extremely fine grained and devitrified. From a general field examination, pumice was not readily noticable in the red volcanics with which we are concerned, although it was found in quantity with the volcanic ash, tuff and volcanic debis on the north slope of the Cuesta peaks and to a lesser extent at the Saddle Peaks.

Sorting In conjunction with sorting the main characteristics are that ash-flow tuffs are found in units measured in tens of feet, and the materials are typically nonsorted or nonbedded. They stated that the size range is commonly great, but ash or fine ash constitute the major portion. Foreign rock fragments are typically of one inch diameter or less and generally constitute less then 5 percent of the whole. Examples of inclusions are shown in the illustrations of photomicrographs. The characteristics for sorting in ash flows do not differ greatly from those encountered in the field.

Thickness Examples of thicknesses up to 500 feet are found throughout the world. Generally 50 to 200 feet seem to be the most common. Red volcanics in the area went to 60 feet, with perhaps 20 feet being the average.

Layering Characteristics of layering in ash-flow tuffs include any examples of zones of differing consolidation even within single flow units. Columnar structures are common, forming in zones often of differing color from the rest of the units. These effects combine to give a layered look that may be confused with individual flows. Vegetation growth, and weathering may contribute to this effect. A statement made by Ross and Smith that is perhaps pertinent concerning sorting at the ends of ash flows: "Probably a great many ash flows would show these features. However, as the ends of the flows are in general thinner and have lost more heat during emplacement than the thicker parts of the ash sheet, they show less intense welding and vapor-phase crystallization or none at all and are more readily eroded, and thus are less often preserved in older deposits."

Zones of different consolidation are not always apparent in the red volcanics. Between E and F on Camp Fault area photo is an example however, also observable in the right hand corner in larger flow. area is the bottom consolidated unit of a much thicker original deposit, since eroded. The fluting previously mentioned in conjunction with the Cuesta Peaks is quite similar to columnar structure. It was concluded that this feature probably represented the zone between extrusive and intrusive. It may be as also suggested that this is a collapse caldera with what is now seen being the down dropped portion of what once overlay the neck; explaining the difficulty of proving in thin section a more intrusive nature of this feature.

Areal extent. The extent depends upon the amount of ash erupted and the topography of the area. Many examples are given in tens of miles. The uniformity over extended areas is especially characteristic-not to be found in flow rocks.

Dip. Generally the dips are very gentle with even upper surfaces and do not have the steep dip found in many lava flows. In the area the volcanics are flat lying where the underlying sediments are, however at Cuesta peaks and Saddle peaks they dip steeply as they follow the slope of the topographic high.

Welding and deformation of pumice. A welded zone according to Ross and Smith either at the base or intermediate zones within the flow. Without further burial by other flows it is most likely that the tops remained unwelded and may be removed by erosion. They do state that: "However, in some areas the emplacement of flows in rapid succession results in a complex of flows welded in their entirity, especially near the source areas." And in another place: "Some densely welded tuffs have been found to occur in very thin units of a few feet or tens of feet in thickness. No detailed studies of such rocks have been published." A high temperature of emplacement is suggested as one reason for these units.

Other characteristics. Devitrification and vapor phase minerals will be discussed in conjunction with the microscopic characteristics. Jointing which has been mentioned is often found, many times in rectangular or square columns. Erosional forms are highly diverse. The authors state that: "A few hard compact devitrified crystal-rich welded tuffs may superficially resemble intrusive rocks. These welded tuffs are usually dacitic or quartz latitic in composition." It is interesting to speculate on this sentence, not only in conjunction with the Cuesta peaks, but whether dacitic type tuffs have a tendency to become hard compact and devitrified.

Microscopic characteristics of ash-flow tuffs

There are five microscopic characteristic headings listed by Ross and Smith. They state that the field characteristics are usually adequate for identification, as are the microscopic. In some cases a coordination between the two will be needed. A summary of the evidence relating to the genesis of the red volcanics follows the discussion of the microscopic characteristics of ash-flow tuffs and illustrations of what is present in volcanics of the area.

Pyroclastic character Studies show that the physical forms of the materials, that is the shard forms, are not especially influenced by the magma composition from which they came. Little variation through geologic time or from specimens from different locations have been found, although after emplacement many changes develop.

Common types encompass fragments of crude bubble shape, or cusp and lune-shapes, Y shaped fragments formed by portions of intersecting bubbles, and U shapes. Variations and distortions of these forms are common. A dustlike material possibly caused by attrition during flowage which fillsthe spaces between shards is often found.

Intense devitrification has largely destroyed the original forms in the specimens examined. Figures, micro. 1, 2, and 3 however seem to display shards of the elongated circular, flattened and cusp forms.

Contrast these with many of the others showing complete divitrification and dust-like groundmass.

Pumice fragments As was mentioned in conjunction with the field characteristics, pumice is extremely common in ash-flow tuffs. The authors state that they found pumice of at least ash size in nearly all the ash-flow tuffs examined. It is normally associated with the shards, but greatly exceeds them in size. In most cases the pumice fragments are composed of elongated tubular pore spaces making a fibrous structure. Collapse of the pumice structure occurs in some cases and subsequent rewelding obliterates the internal structure. The features may be further obscured by vapor-phase alteration or devitrification. In commenting upon this effect Ross and Smith state: "Pumice fragments are subject to the same devitrification effects as are shards and the resulting minerals - feldspar and cristobalite - are the same. However, pumice fragments tend to be more readily devitrified, and to develop a much coarser grained aggregate of devitrification products than the associated shard minerals."

Pumice fragments were apparent in thin section. Figure micro. 4, illustrates collapsed pumice structure with welding together of the fibers. Note abrupt line between pumice and welded shards on the right. This is very similar to Figure 44 in Ross and Smith.

Figure micro. 5, illustrates how devitrification effects the pumice. Note the coarse grained devitrification mentioned as typical in pumice. This compares closely with Figures 55 and 57 of Ross and Smith.

Welding, distortion, and stretching These have been covered in a general way in the discussion of the other characteristics which they tend to hide. Welding and distortion are listed as outstanding characteristic of ash-flow materials. Regarding the identification of welded tuffs and lava flows the authors state: "Welded tuffs usually have a foliate structure (eutaxitic) due to a parallel arrangement of originally flattened plates, or to compaction and flattening of glass shards and pumice fragments into more or less platelike units. The planar arrangement of these platelike units imparts a foliation which has, in many occurrences, been mistaken for liniation due to flowage.. ....The discontinuity of the flow lines in the welded tuff, may be contrasted with the more continuous flow lines (of flow rocks)."

Figure micro. 6, is an example of the platelike, but discontinuous units.

Phenocrysts and foreign materials The authors divide the crystalline material, asside from devitrification products, into two categories: phenocrysts which developed as part of the genetic history of the rock, and alien mineral fragments.

Quartz grains are listed as commonly being subhedral with a few euhedral types in some tuffs. Rounded and irregular embayments are common (see Figure micro. 7 & 8 for examples) Fracturing of grains is also typical in many instances (see Figure micro. 9, note also relatively undevitrified shards in lower left hand corner)

Alien inclusions of some type are nearly always present in ash-flow tuffs, and of these by far the most common are those of andesitic rocks. Indeed the statement is made that: "andesitic minerals and rock fragments are so ubiquitous in tuffs from the United States and other countries that their absence seems a rare exception." Plagioclase is the feldspar phenocryst in the specimens examined from the area; augite, biotite and hornblende - minerals almost always present in andesite, however, were not generally found. One crystal of hornblende contained in a specimen from the Las Mujeres fault area presented as well defined exception; the others being resorbed remnants now containing iron and manganese oxides of uncertain origin rather than the pyroxene, amphibole, and biotite members of the ferromagnesian group.

Examples of these remnants may be seen in Figure micro. 2 where there is an excellent outline of an alien inclusion. Figure micro. 10 gives an example of hematite stained shards from a specimen taken at a prospect pit near the Lead Mine canyon. Figure micro. 11 demonstrates emplacement after resorbtion of a plagioclase crystal; the opaque hematite forms the dark portion of the photomicrograph Figures micro 12 & 13 are from a sample near the lone intrusive in the northeast corner of the mapped area; the inclusions are probably Eagle Ford. Figure micro. 14 is of a specimen from the base of the Cuesta escarpment the dark portion is iron oxide; the specimen is highly silicified.

While many examples of inclusions can be given still it should be pointed out that in the vast percentage of the slides examined, the rock was composed of simply devitrified glass. A typical example of the samples examined would be something approximating Figure micro 15.

Devitrification and vapor phase minerals

Ash-flow tuffs are commonly affected by post-depositional changes-namely devitrification and the development of vapor phase minerals. Ross and Smith make the distinction as follows: "Devitrification and vapor phase mineralization are distinct episodes, even though they are related processes in the cooling history of many ash-flow tuffs. The distinction made by the authors is that in devitrification the formation of crystals takes place within the boundaries of the glass shards or glass mass. In vapor phase crystallization the formation of crystals takes place in open spaces under the influence of a vapor phase."

In distinguishing ash-flow from a lava they say: "Devitrification imposed on zones of intense welding and flattening of the structure results in a rock that closely resembles a flow lava. However, silicic flow rocks nearly always shown flow banding. This means that if linear elements (exclusive of horizontal jointing) in unmetamorphorphosed rock extend over several feet, the rock almost surely is not a welded tuff." In thin section, while there are many examples of distortion and stretching-especially near phenocrysts - there did not seem to be any continuous well-defined elements traceable the width of the slide. This seems a definite point in favor of the volcanics been of ash-flow tuff origin.

Devitrification and the coalescence of the vesicle walls during welding have a strong tendency to obliterate the pumice structure completely, turning the fragment into crystalline material without form. The formation of vapor phase minerals also has the effect of obscuring the pumice structure by their growth into discrete crystals or aggregates of crystals within the open spaces.

Devitrification products are listed as cristobalite and feldspar. Vapor-phase crystallization products are tridymite, alkalic feldspar, and crystobalite. There minerals provide good indicators of ash-flow tuff origin.

Regarding the identification of the minerals in the devitrification products Ross and Smith state: "The slender parallel intergrowths of the devitrification products (axiolitic structures) vary greatly in size, but are normally too fine grained to be identifiable under the microscope. ... the materials (viewed microscopicly) have a rough surface, indicating a parallel aggregate of minerals of greatly differing indices of refraction, as shown..(in micrographs of shards), or as in the spherulites illustrated... The mineral aggregates within the shards can not be definitely identified by means of the microscope. However, many tests of devitrified glass shards and pumice fragments of rhyolitic ash-flow tuffs from many localities have been made by means of X-rays, and these have invariably shown that the products are cristobalite and feldspar."

An illustration of this may be seen in Figure micro. 16 & 17. In micro 16 there is a well defined spherulite with the intergrowths radiating out from the center and the effect from the contrasting indices somewhat visable. Micro. 17 is the same feature under crossed nicols showing the coarse aggregates of feldspar and crystobalite. Micro. 18 is another example of the same feature. Spherulitic structures found in ash-flow tuffs do not differ from those seen in rhyolitic extrusives.

A number of authorities have mentioned the possibility that 'devitrification could destroy all direct evidence of the original ash structure.

Photomicrographs of thin sections from specimens collected

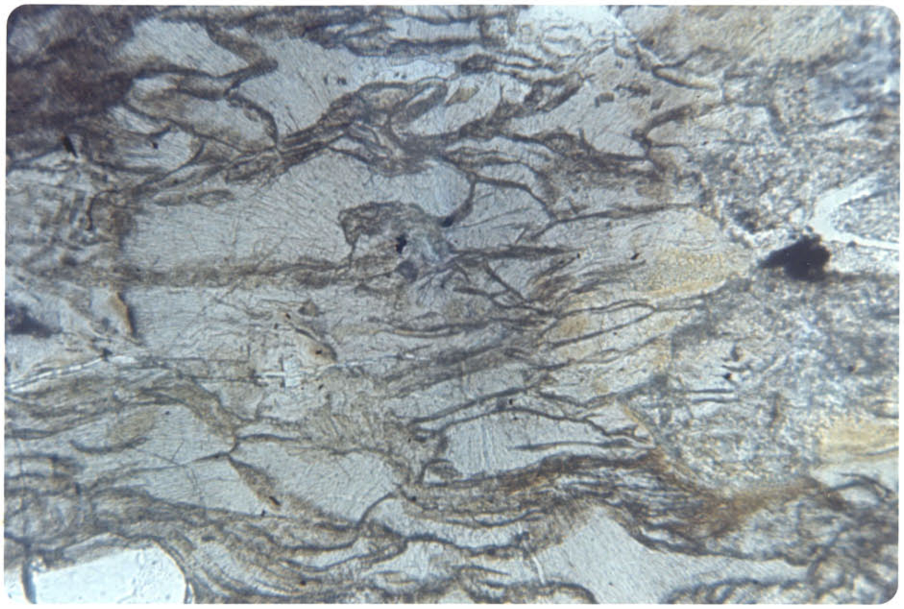


Figure micro. 1

A portion of an elongated shard bubble is observable on the right. Platelike and shredlike shards are a tendency in intermediate composition ash-flow tuffs.

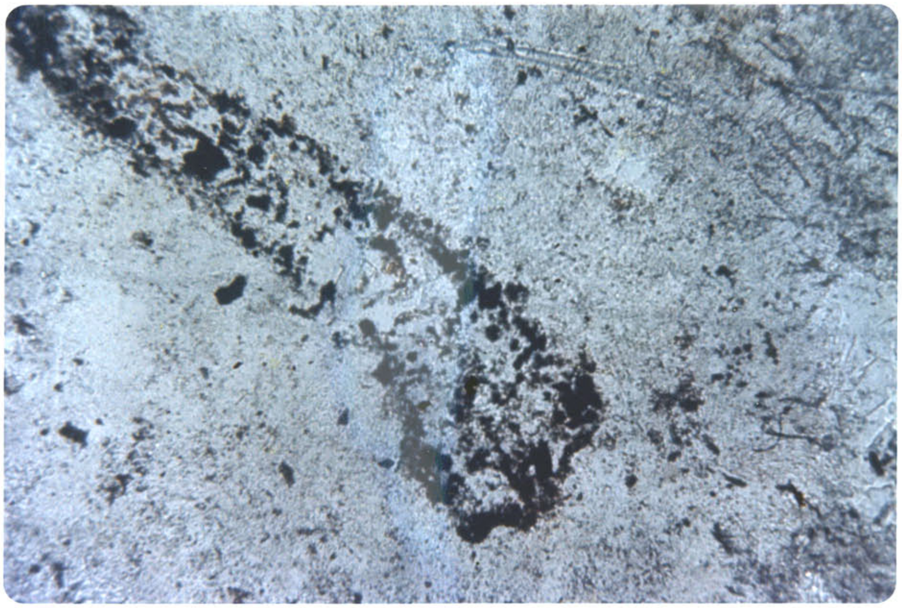


Figure micro. 2.

The slightly curved form of the flattened bubble may be followed in the dark inner line of the shard in the top right of photomicrograph. The rest of groundmass is almost entirely devitrified. The outline of a resorbed ferromagnesium mineral forms the dark diagional feature.

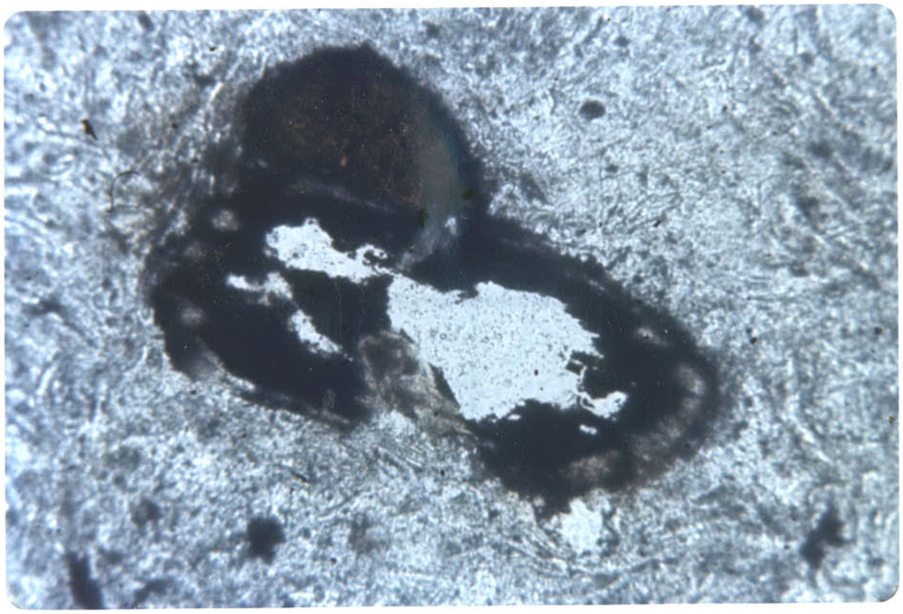


Figure micro. 3

This specimen has escaped devitrification to a greater extent then micro. 2. The cusp pattern visable to the right of the ferromagnesium mineral is a quite common shard feature.

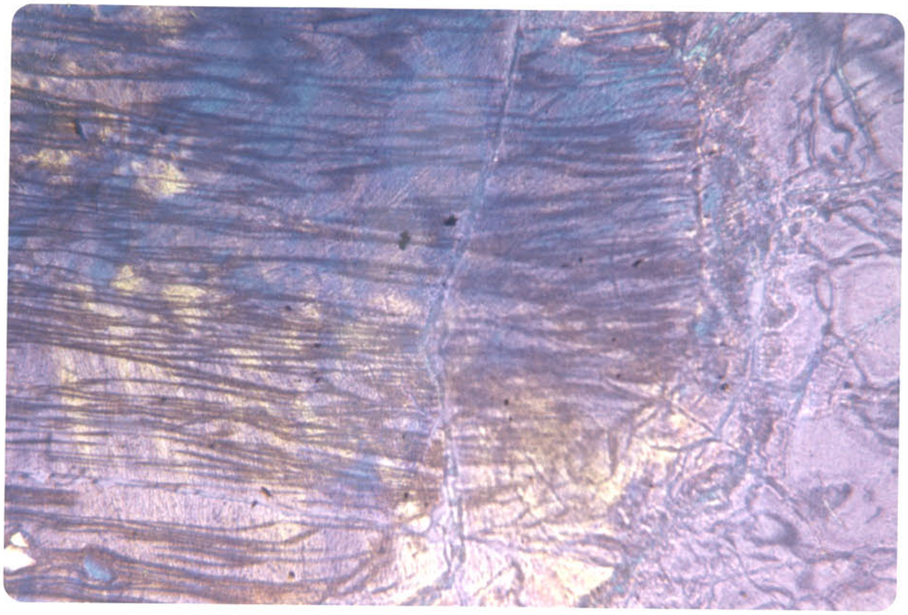


Figure micro. 4

The structure on the left is a completely collapsed and welded pumice fragment; on the right arewelded platey shards of the type seen in micro 1. Gypsum plate has been inserted to further show structural contrast. This is from the Seco faults area.

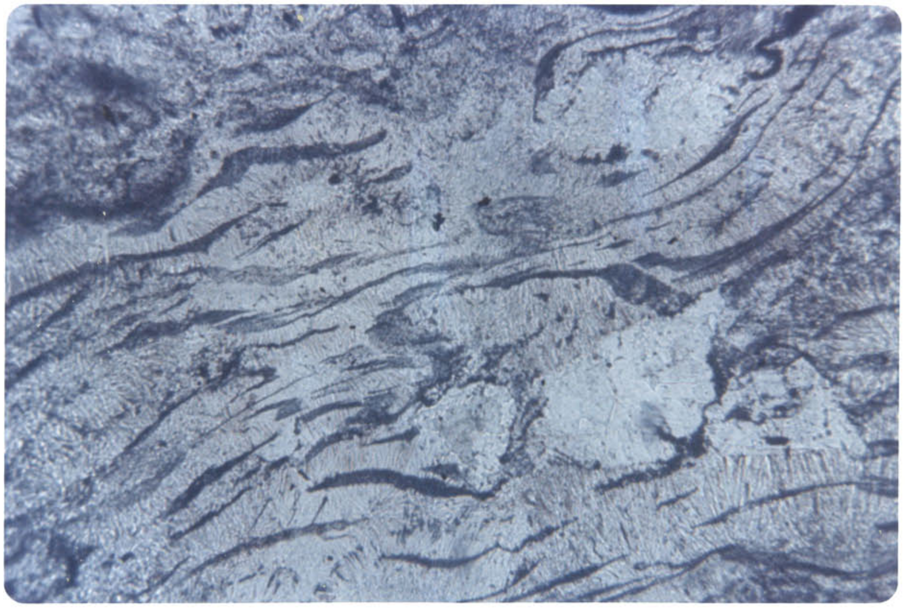


Figure micro. 5

An illustration of the devitrification effects on pumice. Note how well the contrasting indices of refraction stand out in the devitrification mineral products.

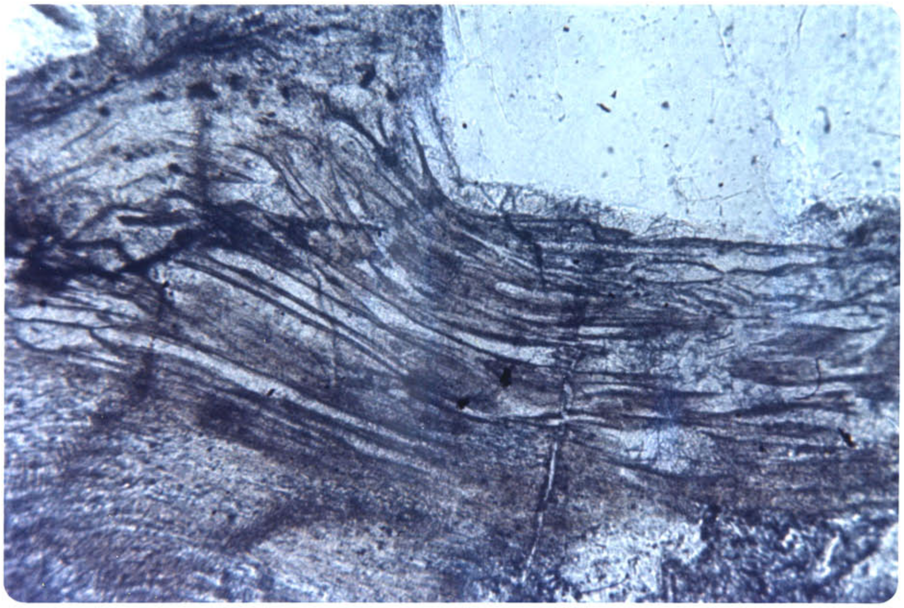


Figure micro. 6

An illustration of the platelike shards of the type seen in micro. 1 & 4 but seen in cross section. This plate of a plane perpendicular to horizon of deposition. As characterized from a flow rock, it is not possible to follow the individual lens-like units.

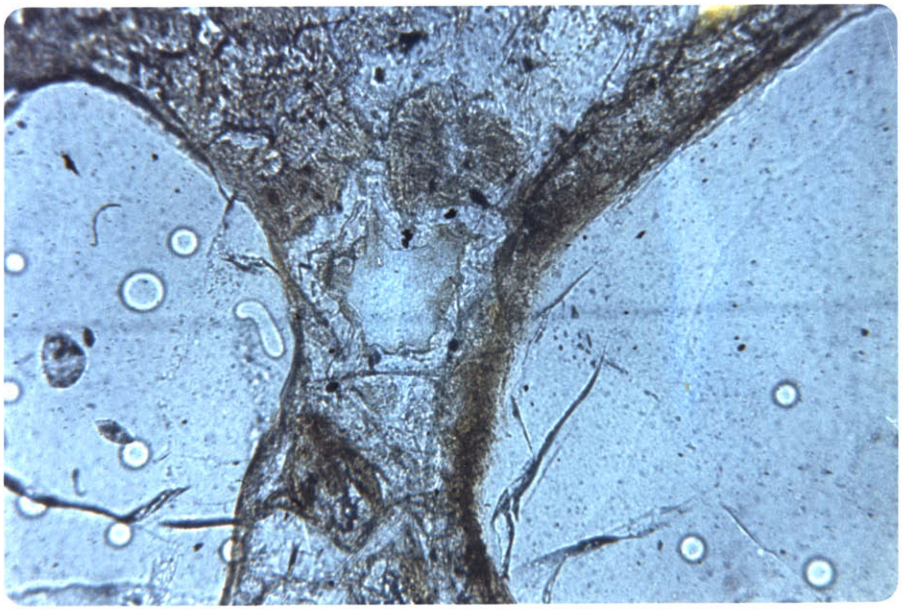


Figure micro. 7

Rounding of Quartz grains is quite common.

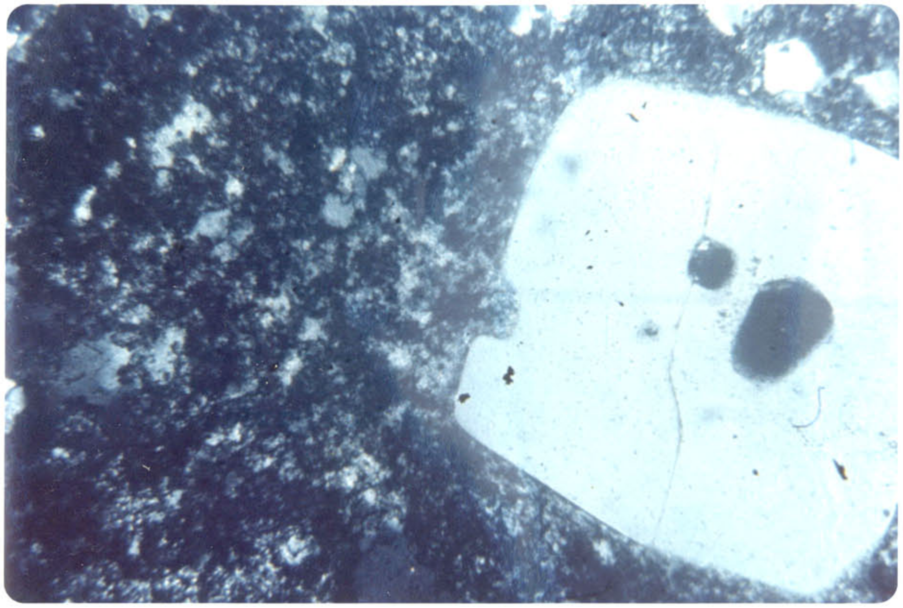


Figure micro. 8

Embayments in Quartz grains are also common. The groundmass is especially coarsely devitrified in this specimen.

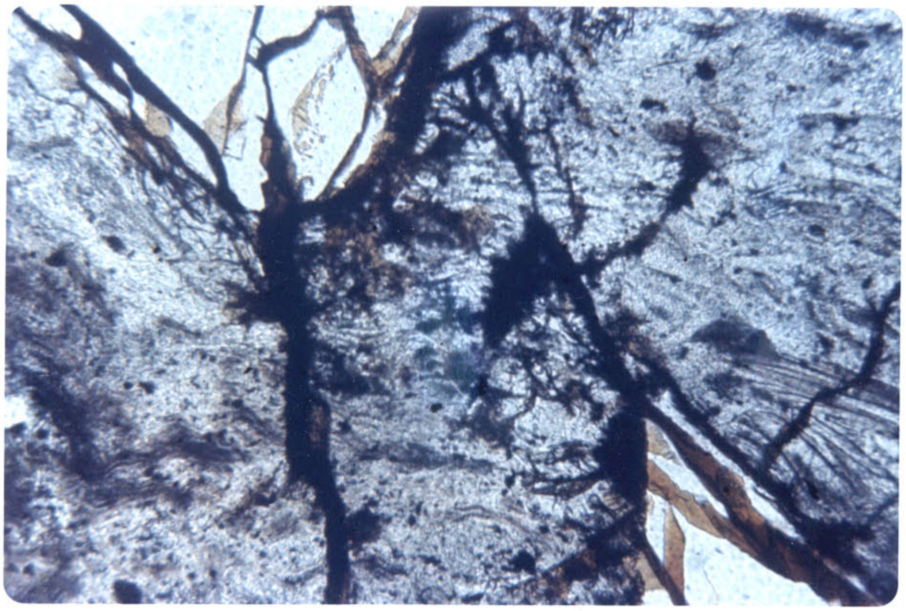


Figure micro. 9

The fracturing in this sample seems to have taken place well after time of formation. In the left hand bottom there is a good example of an undevitrified shard bubble.

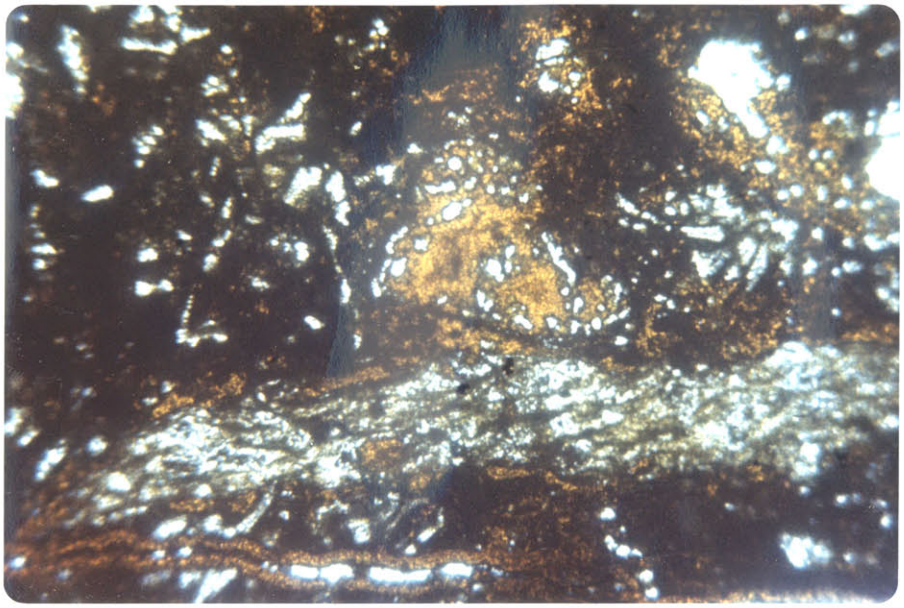


Figure micro. 10

This is not atypical sample of the volcanics of the area. The dark and light brown represent hematite stains.

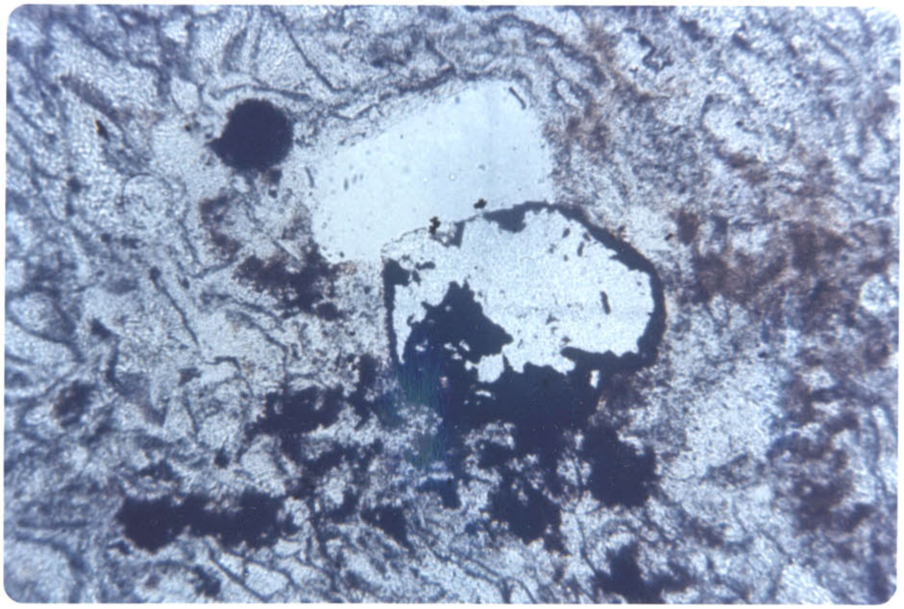


Figure micro. 11

A further example of more common opaque hematite that has not stained the shards as in micro 10, but seems to have replaced the feldspar.

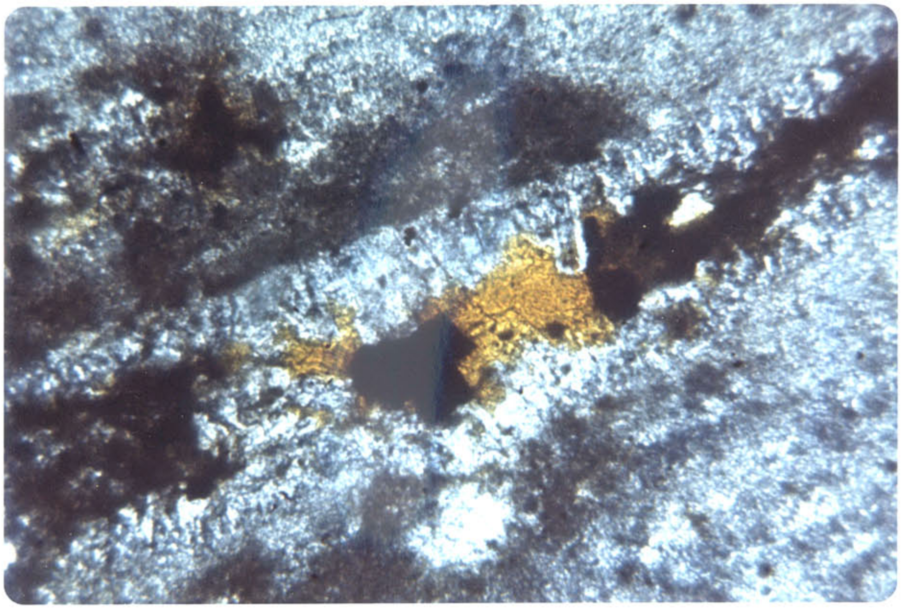


Figure micro. 12

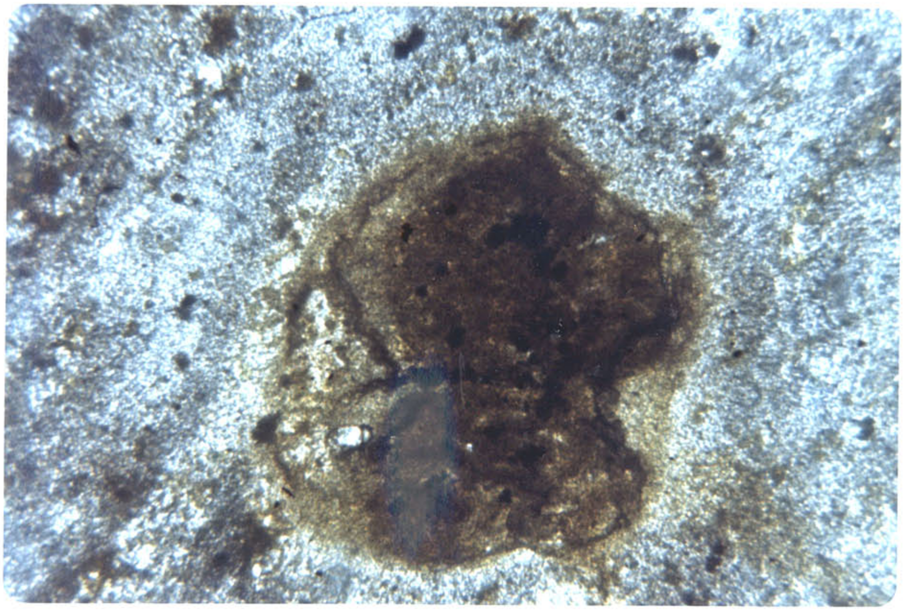


Figure micro. 13

Two more examples of resorbtion, probably of the Eagle Ford limestone. Note quite intense devitrification.

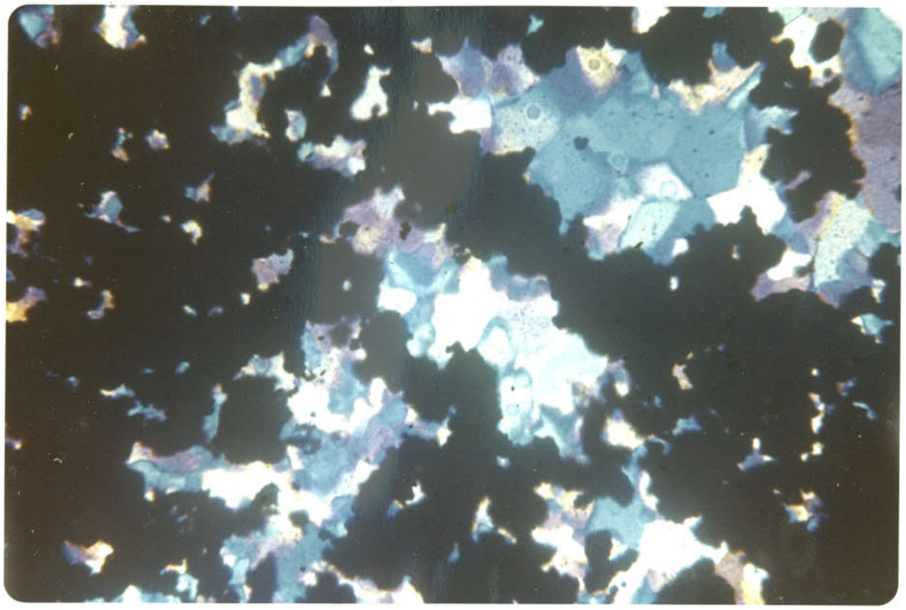


Figure micro. 14

Iron oxide from a rather rich specimen taken at base of the Cuesta in the Seco fault region.

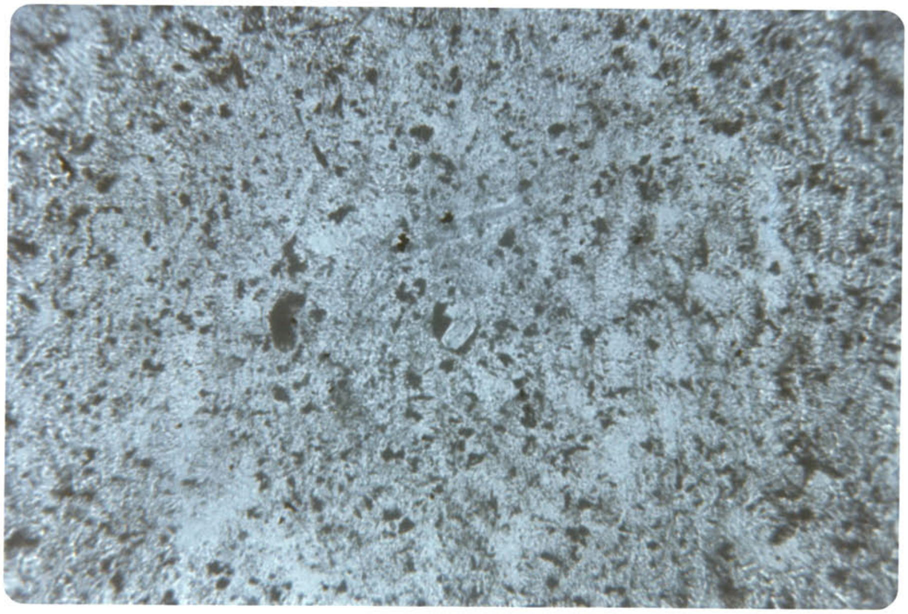


Figure micro 15

A highly typical specimen of the majority of what was seen in an examination of the thin sections.

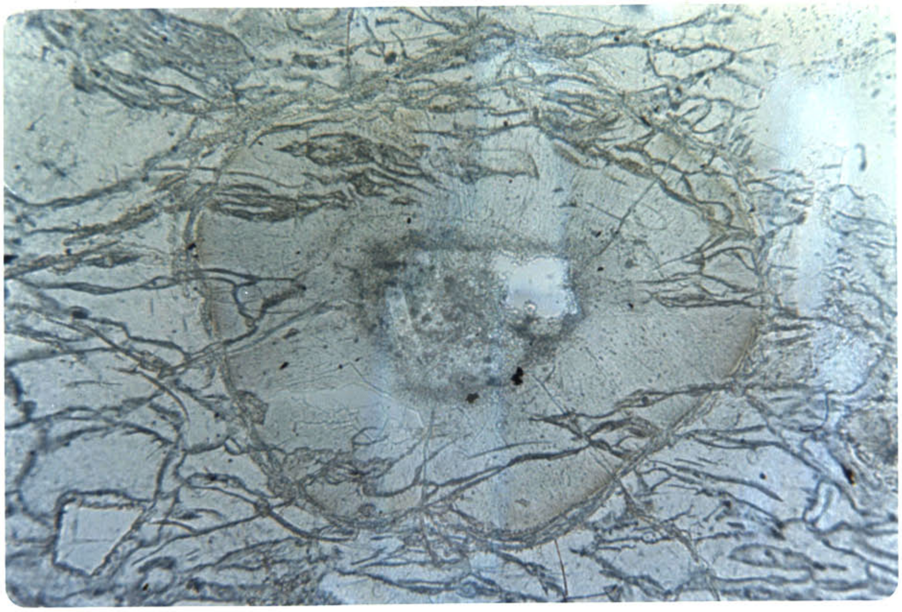


Figure micro. 16

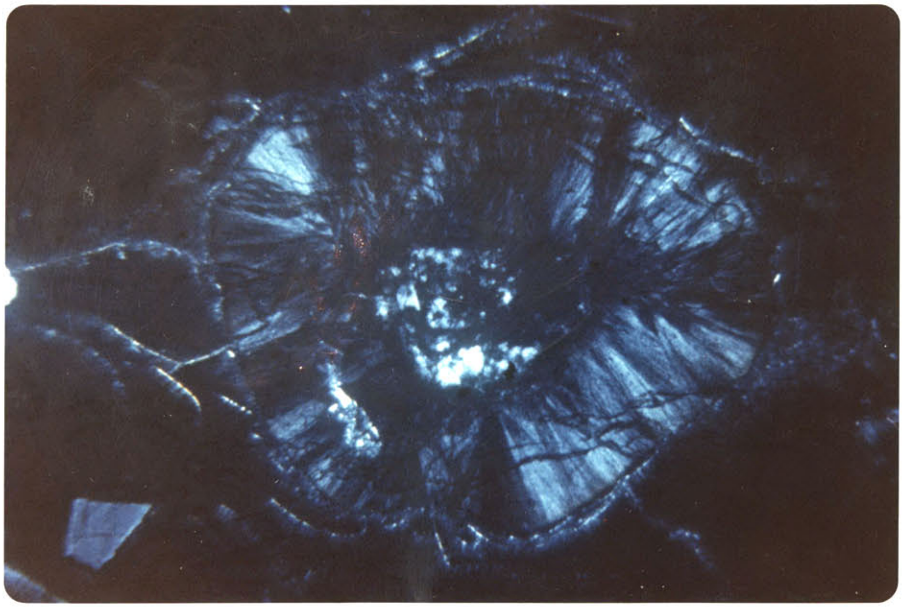


Figure micro. 17

The same spherulite as seen above and under crossed nicols in micro. 17. The devitrification products seen so well in this view and in the other photomicrographs of shard structure are cristobalite and feldspar.

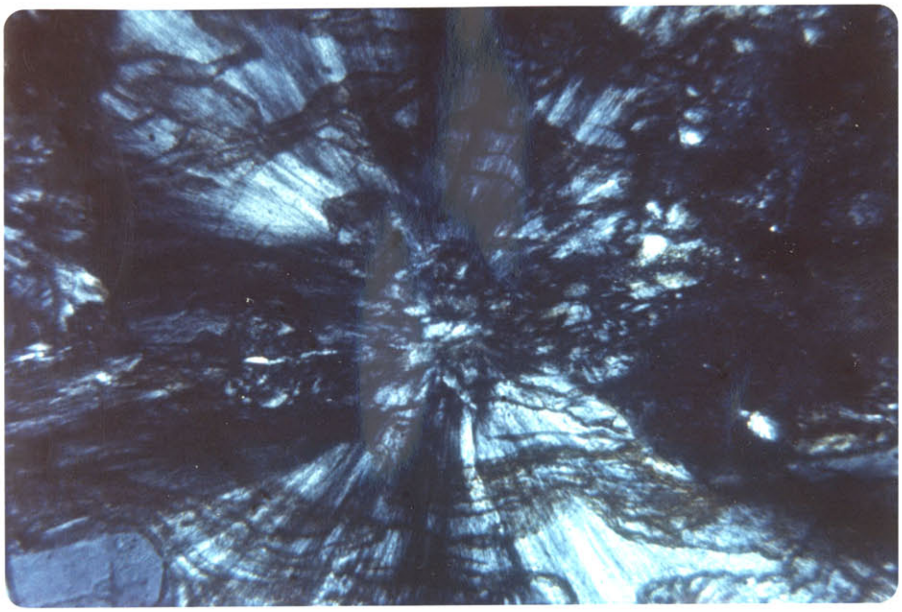


Figure micro. 18

A second example of spherolite under crossed nicols

Summary and Conclusion

In the foregoing discussion the problem has seemed to resolve itself into one with the field criteria presenting difficulties for the volcanics being of ash-flow tuff origin, and the microscopic work pointing strongly to evidence that they were formed in this manner.

The principal field objection is that it doesn't have the layering of zones of different consolidation that are to be expected. A secondary point is that the thickness of the volcanics is not as great as those usually associated with ash-flow tuffs. Much could be at least partially resolved by the supposition that at one time the area was covered by a great thickness of ash-flow tuff. It is true that the intense welding found in the thin sections goes well with the fact that the observed volcanics are compacted. Also little has been studied about intermediate composition ash-flow tuffs, but from the experimental findings that the viscosity of these volcanics is far less then those studied of rhyolitic composition (the order of difference being 104 poises) the chance of collapse and welding of ahard materials under load is proportionally greater. It may well be that after more data is compiled, it will be found intermediate composition ash-flow tuffs require less ash load to weld then now assumed for the rhyolitic tuffs. In any case it may be then, with the volcanics appearing in the Laramide there were higher units of ash over lying what is now seen causing compaction, consolidation, and intense welding at its base - and subsequently removed by erosion.

The results of the microscopic study were highly favorable to the volcanics being ash-flow tuffs. The analysis of the shards, pumice fragments, devitrification, devitrification product minerals, and the numerous other criteria covered seemed to show conclusively that the materials were ash-flow tuffs. Some of the minor discrepancies will undoubtedly be resolved as further progress in this opening field is compiled.

In conclusion then, it seems almost certain that the extrusives in the area studied are intermediate composition volcanics of ash-flow tuff origin.

Chapter 6

The Geological History of the Area

After the quiescent depositional conditions associated with the transgressing seas of upper Jurassic through to the upper Cretaceous, the sea receded from this region. The Coahuila peninsula, upon who's eastern flank this area is located, and the Mexican geosyncline were the dominant features of its depositional history.

With the retreat of the sea in Upper Cretaceous and the diastrophism of the Laramide Revolution, the region began the uplift that would take it almost a mile above the level of the present day ocean. As the land rose, and the sea drained off, the streams coalesced into the consequent drainage patterns that were imprinted increasingly deeper.

The Eagle Ford formation was rapidly eroded, and stress differences during uplift and this time of Laramide diastrophism at the end of the Cretaceous and early Tertiary, warped the region into gentle synclines and anticlines. Long vertical joints, trending westwardly, much like those described for the trans-Pecos region to the north, probably indicate widespread, and recurrent zones of weakness in the basement complex. There is much in the entire history of the area that appears similar to that of the Sierra del Carmen, trans-Pecos, Big Bend regions which lie within the same belt of folded mountains to the north.

Not long after the area emerged, before the stream patterns became impressed upon the Georgetown, there was a period of igneous activity, probably coinciding with the Laramide, in which a single igneous source, probably a huge batholith, broke through the sediments and intruded at the Cuesta Peaks and Fluorita Plug. At the same time, probably aided by magmatic stoping from below, the large Cuesta Valley graben downfaulted. In the northern part of the valley it was bounded by the Saddle

Peaks fault to the east, and the Cuesta Escarpment and Seco fault belt to the west. In the southern half of the valley, the Cuesta Peaks had intruded along the western zone of weakness just mentioned; across the valley formed by the graben was the downfaulted western edge of the Tea House syncline, indicating, but not conclusively, that the regional folding predated the faulting and intrusions. The Cuesta Valley graben plays out in this southern region. Along the eastern side of the valley, the Saddle Peak and Uva Brandy faults intersect and end within the deeply downwarped Tea House syncline which plunges into the Cuesta Valley. The valley itself ends with the individual Quien Sabe and Sabe Nunca grabens in the far south.

There is further tectonic adjustment at the end of the Laramide in lower Tertiary, and it is then that the complex faulting north of the Tea House syncline takes place. Las Mujeres fault and the Camp fault on the cuesta are of this period. During the time of Laramide tectonics the volcanics associated with the Cuesta Peaks were erupted. Thin section studies show that they are ash-flow tuffs of intermediate composition. A blanket of considerable thickness, deposited by this erruption of hot gas and suspended ash must have covered the area. The bottom layers were welded into the remnants now seen, with the higher more poorly consolidated units being eroded.

After the end of the Laramide there was a period of tectonic and igneous quiescence. Streams downcut well into the Georgetown limestone as they flowed westward along the cuesta from the high divide created by the igneous Cuesta Peaks. North of here, streams cut their way headward from the Cuesta Valley into the escarpment, forming deep canyons and pushing the divide to the west. The solution of limestone, especially the Georgetown, is a prevalent feature of the region. The deepest canyon in the region, the Lead Road canyon, is directly west of the Cuesta Peaks and is caused by the large watershed due to the early formed, topographically high igneous peaks.

The Cuesta Valley drained to the east through the pass created by the Tea House fault, part of the fault series north of the Tea House syncline.

Probably during this period of extensive erosion within the area or perhaps before, volcanics from a distant place covered the area north of the Camp fault, preserving it.

At a later time, work in other areas suggests from the end of Miocene to middle Pliocene, there was a renewal of tectonic and igneous activity. In the north end of the Cuesta Valley, magma followed along the zone of weakness of the Saddle Peaks fault plane and extruded more ash-flow tuffs of similar composition to those from the Cuesta Peaks formed earlier along the valley and the Saddle Peaks neck. The border weaknesses along western edge of the Cuesta valley were rejuvinated, and there was downfaulting along the Seco faults. The Cuesta Peaks along this same zone also had renewed activity, and deposited immense quantities of volcanic ash along its northern slope, along with minor obsidian flows, tuffs, tuff breccias, volcanic talus, and interbedded with erosional fragments of Eagle Ford, perhaps by moving down the steep volcanic slopes much in the manner of mud flows.

In Pleistocene, probably, there was a final minor time of igneous activity. Within the Cuesta Valley, not far from the Saddle Peaks there is a small cone with ash beds still in primary depositional positions. The volcanic cone of the Camp Fault area and the associated Cross Camp faults appear to also be of this time.

In Recent times we have the youthful, steep stream cuts of the elevated Cuesta contrasting with the wide, alluvium-filled bolson valleys of interior drainage below. The Cuesta Valley is now being rapidly filled by sediments from the cliffs to either side, which are quickly eroded despite the small amount of rain, due to the lack of protective vegetation in this desert region.

BIBLIOGRAPHY

Adkins, W.S. and Lozo, F.E., Stratigraphy of the Woodbine and Eagle Ford, Waco area, Texas, p. 101 - 164: Southern Methodist University Fondren Science Series 4. (1951)

Bose, E. and Cavins, O.A., 1927, The Cretaceous and Tertiary of southern Texas and northern Mexico: Univ. Texas Bull. 2748, p. 7 - 142.

Burrows, R.H. 1909, Geology in northern Mexico: Mining and Scientific Press, v. 99 p. 290 - 294, 324 - 327.

________ 1910, Geology of northern Mexico: Soc. Geol. Mexicana, Bol., v. 7 p. 85 - 103.

Eardley, A.J., 1942, Aerial Photographs; their use and application: N.Y. Harper and Bros., 203p.

Hill, R.T. 1923, Further contributions to the knowledge of the Cretaceous of Texas and northern Mexico (Abstract): Geol. Soc. America Bull., v. 34. p 72, 73.

Humphrey, W.E., 1949, Geology of the Sierra de Las Muertas area, Mexico with description of Aptian cephalopods from La Pena formation: Geol. Soc. America Bull., v 60, p. 89 - 176.

Imlay, R.W., 1944, Correlation of the Cretaceous formations of the Greater Antilles, Central America, and Mexico: Geol. Soc. America Bull., v. 55, p. 1005 - 1046

Jones, T.S. 1938, Geology of the Sierra de la Pena and paleontology of the Indidura formation, Coahuila, Mexico: Geol. Soc. America Bull., v. 49, p. 69 - 150

Kellum, L.B., 1944, Geologic history of northern Mexico and its bearing on petroleum exploration: American Assoc. Petroleum Geologists Bull., 28, no. 3, p. 301 - 325

________ 1954, Geology of the Villareal uplift, Sierra de Tlahualilo, Coahuila, Mexico (Abstract): Geol. Soc. America Bull., v 65 p. 1273

Kellum, L. B. Imlay, R. W., and Kane, W. G., 1936, Evolution of the Coahuila Peninsula, Mexico; Part 1, Relation of structure, stratigraphy, and igneous activity to an early continental margin: GSA Bull. v. 47 p. 969 - 1008

Kelly, W. A., 1936, Evolution of the Coahuila Peninsula, Mexico; Part 2, Geology of the mountains bordering the valleys of Acatita and las Delicias: Geol Soc. America Bull., v. 47, p.

Ross C. S. and Smith R. L. 1961, Ash Flow Tuffs: Thier Origin Geologic Relations and Identification: U. S. G. S. Prof. Paper 366.

Williams, Howel, 1941, Calderas and their Origin: California University Pub., Dept. Geol. Sci. Bull., v. 25, no. 6 p. 239 - 346

King, P. B., 1948, Geology of the Southern Guadalupe Mountains Texas: U. S. G. S. Prof. Paper 214

King, R. E., and Adkins, W. S., 1946, Geology of a part of the lower Conchos Valley, Chihuahua, Mexico Geol. Soc. of America Bull., v 57, p. 275 - 294

Muller, C. H., 1947, Vegetation and climate of Coahuila, Mexico: Madrono, v. 9, no. 2, p. 33 -57.

Wilson, I. F. and Rocha, V. S., 1948, Managanese deposits of the Talamates district near Parral, Chihuahua, Mexico: U. S. Geol. Survey Bull. 954-E, p. 181 - 208

Ordonez, Ezeuiel, Las riolitas de Mexico: Inst. geol. Mexico Bol. 14, 75 pp. 1800; Bol. 15, 76 pp., 1901

Scott, G. 1933, The Cretaceous of Texas, p. 46 - 61 in Wrather, W. E., Editor, Oklahoma and Texas: 16th Internat. Geol. Cong., U. S. 1933., Guidebook 6, Excursion A-6, 91 p.

Sellards, E. H., Adkins, W. S. and Plummer, F. B., 1932, The Geology of Texas, Vol I, Stratigraphy, Univ. of Texas Bull. 3232.

Sellards, E. H. and Baker, C. L., 1934, The Geology of Texas, Vol II, Structural and Economic Geology: Univ. of Texas Bull. 3401.

Shreve, F. 1942, The desert vegetation of North America: Biotanical Review, v. 8, p. 195 - 246.

Stanton, T. W., 1928, The Lower Cretaceous or Comanche series: Am. Jour. Sci., 5th ser., v 16, p 399 - 409

Stephenson, L. W., King, P. B., Watson, H. M., and Imlay, R. W., 1942, Correlation of the outcroping Cretaceous formations of the Atlantic and Gulf Coastal Plain and Trans-Pecos Texas: Geol. Soc. of America Bull., v. 53, p. 435 - 448

Stose, G. W., Compiler, 1946, Geologic map of North America: Geol. Soc. of America

King, P. B. (1937) Geology of the Marathon region, Texas: U. S. Geol. Survey Prof. Paper 187, 148 pp.

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States: U. S. G. S. Bull. 896

King, P. B. 1940, Tectonics of Northern Mexico: Proceedings of the Eigth American Scientific Congress, Vol. IV p 395 - 398

GEOLOGICAL MAP
of the
Cuesta Peaks Region

LAT. 28° 40'N. LONG. 102° 30' W.
COAHUILA, MEXICO

SCALE
0 MILES 1

SPECIAL SYMBOLS

Contact, showing dip
Dashed where approximately located

Indefinite contact

Fault, showing dip
Dashed where approximately located
U, *upthrown side*; D, *downthrown side*

Vertical fault

Concealed fault

Fault, showing relative movement

Axis of anticline

Axis of syncline

Strike of vertical beds

Horizontal beds

Strike and dip of beds

Prospect