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Geology of the Central Peloncillo Mountains, the North Third of the Pratt Quadrangle, Hidalgo County, New Mexico

Dennis J. Gebben

GEOLOGY OF THE CENTRAL PELONCILLO MOUNTAINS,
THE NORTH THIRD OF THE PRATT QUADRANGLE,
HIDALGO COUNTY, NEW MEXICO

by

Dennis J. Gebben

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INTRODUCTION

Purpose and Scope

In the summer of 1970, with partial support from the New Mexico Bureau of Mines and Mineral Resources, Dr. Richard McGehee, John Yellich and I undertook detailed mapping of the Pratt Quadrangle in the Peloncillo Mountains of southwestern New Mexico. The Peloncillo Mountains, south of 32° latitude, have never been mapped in detail. Reconnaissance maps compiled by Dane and Bachman (1961) indicate that the 45 miles from 32° latitude to the Mexican border are almost entirely Tertiary volcanics, which range in composition from basalts to rhyolites.

The quadrangle was divided into two major areas of responsibility. This report covers the area from the 32° latitude southward to a line delineated by the southern boundary of T 27S, R 21W. This area encompasses approximately 80 square miles of which approximately 20 square miles are mountains and low hills. The rest of the area consists of valley alluvium and basalt flows.

This report includes a geologic map, description of stratigraphic units, petrographic descriptions, structural interpretation and a geologic history. When possible, correlations are made or suggested with units mapped by others in neighboring ranges.

Methods

Mapping in the field was done on aerial photographs which have a scale of approximately 3 inches to the mile. The Pratt Quadrangle was photographically enlarged to serve as the base for the geologic map. The Pratt Quadrangle was published in 1919, and lacks detail that can be seen on the aerial photographs. Consequently, a certain amount of accuracy was lost in the transfer of information from the aerial photographs to the enlarged quadrangle map.

Representative rock samples of all the stratigraphic units were collected. From these, fifty-one thin sections were made and analyzed using flat stage methods. Petrographic descriptions of all the thin sections are appended.

Geography

Figure 1 is an index map of the Peloncillo Range and the surrounding ranges in New Mexico and Arizona. The Peloncillo Mountains lie along the New Mexico-Arizona border. From the southwest corner of New Mexico they extend roughly 45 miles northward in New Mexico's Hidalgo County before striking northwest across the border into Arizona. In Arizona they trend north-northwest an additional 45 miles before terminating at the Gila River. The neighboring ranges to the west are the Chiricahua and Dos Cabezas Mountains which are separated from the Peloncillo Range by the San Simon Valley. To the east lie the Animas and the

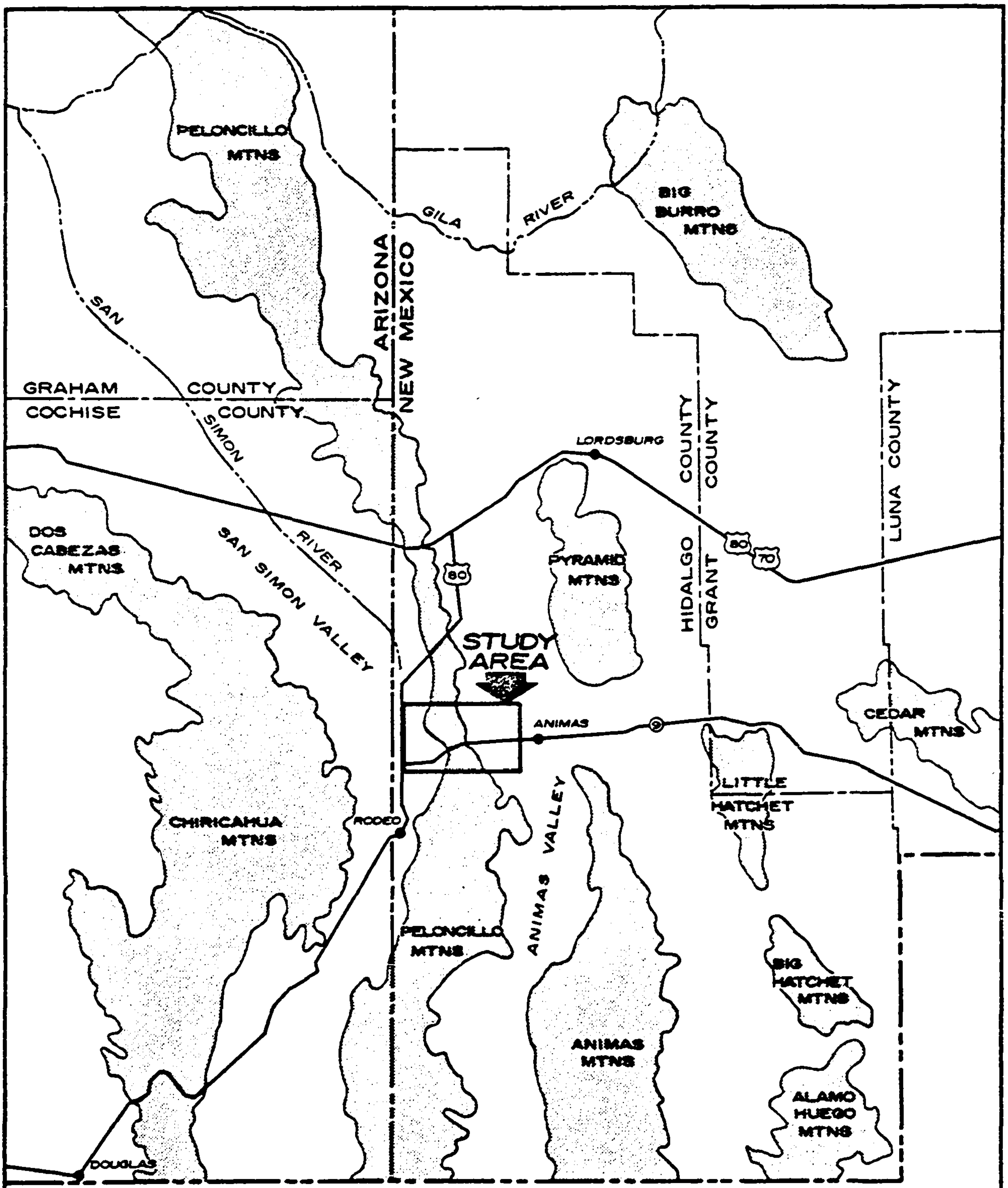

FIGURE I

INDEX MAP OF THE STUDY AREA

Pyramid Mountains, separated from the Peloncillo range by the Animas Valley.

The area mapped in this report lies within the Pratt Quadrangle and a small segment of the Portal Quadrangle. Specifically, the borders of the mapped area are as follows:

1) North border is the 32° latitude.
2) South border is the south boundary of T 27S, R 21W.
3) West border is New Mexico Highway 80.
4) East border is the east boundary of T 27S, R 20W.

New Mexico Highway 9 runs east and west through the area, crossing the Peloncillo Mountains through Antelope Pass. An abandoned railroad bed parallels Highway 9 through Antelope Pass, then heads southwest toward Rodeo, New Mexico.

Physiography

Physiographically, the area is typical of the semi-arid southwest. The Peloncillo Mountains are flanked on the east and west, respectively, by the alluvium filled Animas and San Simon Valleys. The San Simon Valley is lower than the Animas Valley. Within the area covered in this report there is approximately 300 feet difference between the lowest elevation in the Animas Valley (approx. 4,300 feet, U.S.G.S. datum) and the lowest elevation in the San Simon Valley (approx. 4,000 feet, U.S.G.S. datum).

The highest peak in the area mapped has an elevation of 5,971 feet (U.S.G.S. datum); therefore, the maximum relief is about 2,000 feet.

Drainage in the area is intermittent. Arroyos and shallow gullies braid the alluvial fans transporting runoff to the valleys. Drainage within the Animas Valley is all internal, and playa lakes form during the wet season north of the map area. In the San Simon Valley, San Simon Creek flows northward to the Gila River, but in the area mapped, the creek is dry except after a heavy rainfall.

The vegetation in the area is typical for the semi-arid region. Desert grasses, low shrubs and cactus cover the uncultivated portions of the valleys and extend up the generally bare slopes. Scrub-oak and low juniper are scattered on the mountains and provide the only shade.

Some lands in both the Animas and San Simon Valleys are cultivated, made possible by irrigation wells in the valley sediments.

Previous Work

The area mapped was previously included in an unpublished, undated, reconnaissance map by Zeller. That map is now part of a compilation reconnaissance map by Dane and Bachman (1961). Within the area mapped by the writer, Zeller correctly identified Paleozoic and Cretaceous strata, but he left the Tertiary volcanics almost entirely undifferentiated.

The Peloncillo Range, from south of the Pratt Quadrangle to the Mexican border, was mapped by Wrucke and Bromfield (1961) who produced a broad reconnaissance map.

The most detailed mapping in the central Peloncillo Mountains was done by Gillerman (1958). He mapped the 15 minute quadrangle directly north of this study area. In Gillerman's area, a northwest trending arch has exposed Precambrian granite, a thick Paleozoic and Cretaceous sedimentary sequence, and a late Cretaceous to late Tertiary sequence of volcanics.

Zeller and Alper (1965) did extensive work to the southeast in the Animas Range mapping the Walnut Wells Quadrangle.

Across the San Simon Valley, portions of the Chiricahua and Dos Cabezas Ranges have been mapped by Enlows (1955), Sabins (1957a, 1957b), Fernandez and Enlows (1966) and Marjaniemi (1968, 1969).

STRATIGRAPHY

Table 1 presents a stratigraphic column and summary of rocks mapped in the area of this study. The oldest rocks are Pennsylvanian-Permian limestones that occur along the eastern side of the range. Uplift and erosion characterized the area in the Triassic and Jurassic and left no record of these periods. In the Cretaceous the Johnny Bull Sandstone was deposited and was followed in the Late Cretaceous by the Laramide Orogeny. Deformation resulting from the Laramide Orogeny is evident in the Cretaceous and Paleozoic rocks.

The main mass of the Peloncillo Mountains in the area mapped, is composed primarily of Tertiary volcanic ash flows with smaller interbedded units of epiclastic volcanic deposits. Three unique periods of volcanic activity occurred during the Tertiary, and the depositional record of these periods are separated by unconformities. During the first period, Unit T1 and the Bobcat Hill Conglomerate were emplaced. This was followed by emplacement of Units T2 and T3 during the second period, and in the third period, by Unit T4 and the Weatherby Canyon Ignimbrite. In the Late Tertiary, basin and range block faulting and subsequent erosion occurred. This activity continued into the Quaternary and is evidenced by a small fault scarp in the Recent alluvial. Also during the Quaternary, basalt flows occurred in the Animas Valley.

TABLE 1: ROCKS OF THE CENTRAL PELONCILLO MOUNTAINS

AGE		ROCK UNIT		LITHOLOGIC DESCRIPTION
QUATERNARY		Quaternary Alluvium		A heterogeneous mixture of sand, gravel and clayey sediments.
				interbedded
QUATERNARY		Animas Valley Basalt		A vesicular olivine basalt. Probably more than one lava flow based on two distinct textural differences.
		UNCONFORMITY - BASIN & RANGE FAULTING		
TERTIARY	MIOCENE-OLIGOCENE	WEATHERBY CANYON IGNIMBRITE	Upper Member	A sequence of variegated gray, flow-banded, rhyolitic, vitrophyres, both devitrified and perlitic. Spherulites, axiolites and lithophysae are texturally prominant. Total exposed thickness is approximately 1600 feet.
TERTIARY	MIOCENE-OLIGOCENE	WEATHERBY CANYON IGNIMBRITE	Middle Member	A thick sequence of partially to highly welded ash flows with some interbedded layers of non-welded tuff and pumice flows. The unit is predominantly a rhyolite with lesser amounts of trachyte. The rock has only 6 to 8 percent phenocrysts, usually less than 5 percent rock fragments and is pale red to light gray. Textural variation (welding) accounts for most of the diversity within this member. Andesite porphyries intrude this unit.
TERTIARY	MIOCENE-OLIGOCENE	WEATHERBY CANYON IGNIMBRITE	Basal Member	A partially to highly welded lithic tuff of rhyolitic to trachytic composition. Rock has a distinctive white color. Phenocrysts comprise only about 6 percent of the rock and volcanic rock fragments vary from 5 to 20 percent and are mainly pumice fragments. Unit is approximately 100 feet thick.
TERTIARY	MIOCENE-OLIGOCENE	UNIT T4	Upper Member	A sequence of pumiceous ash flows, each flow 10 to 30 feet thick and grayish yellow to pale orange in color. Volcanic rock fragments are abundant in the flows and lahars occur occasionally in the unit. Approximate thickness of the unit is 700 feet.
TERTIARY	MIOCENE-OLIGOCENE	UNIT T4	Lower Member	A volcanic sandstone and conglomerate with thin interbedded layers of airfall ash, lithic pumiceous tuffs, and partially welded ash flows. Mainly an alluvial fan deposit typified by scour and fill marks, poor sorting and rapid vertical change in grain size. Compositional variation is high reflecting a lithologically varied source area.
		UNCONFORMITY		
TERTIARY		Unit T3		A rhyolite sequence of phenocryst rich welded ash flows with thin beds (2 to 3 feet) of perlitic vitrophyre.
TERTIARY		Unit T2		An epiclastic volcanic deposit that is soft, clayey, pale greenish-yellow and grains of quartz, sanidine, and plagioclase comprise greater than 50 percent of the rock.
		UNCONFORMITY		
TERTIARY		Bobcat Hill Conglomerate		An epiclastic volcanic unit comprised of sandstones and conglomerates. The sandstones are immature litharenites comprised primarily of quartz and volcanic rock fragments. The conglomerates are comprised primarily of andesite and limestone clasts.
				interbedded
TERTIARY		Unit T1		A sequence of ash flows and possibly some lava flows ranging in composition from quartz latite to andesite. Rocks of this unit are highly altered, and lie on Cretaceous and Pennsylvanian-Permian strata.
		UNCONFORMITY - LARAMIDE OROGENY		
CRETACEOUS		Johnny Bull Sandstone		A light gray to pale red fine sandstone with some slightly argillaceous beds. The texturally mature beds are more resistant and form ridges. Unit shows textural signs of deformation and some outcrops have dips near 90 degrees. The greatest thickness exposed is approximately 1600 feet.
		UNCONFORMITY		
PENNSYLVANIAN-PERMIAN		Horquilla and other Limestone		Medium grained, grayish blue limestones with beds 1 to 10 feet thick. Chert beds often occur with these limestones. Fossiliferous beds contain fusulinids, crinoid fragments and bryozoa.

Pennsylvanian - Permian Limestone

Along the east side of the Peloncillo Range, in the area mapped, Pennsylvanian-Permian limestone crops out in scattered outlying hills and mounds. These limestones are the oldest rocks within the map area and are separated from all younger rocks by erosional unconformity. The limestone is grayish-blue, medium grained, and occurs in beds 1 to 10 feet thick. Some beds are fossiliferous containing, notably; fusilinids, crinoid fragments, and bryozoa. Associated with almost every limestone outcrop are beds of chert, the larger of which are mapped on Plate I. The chert is presumably replacement chert although some may represent silicification along fault zones. In many of the limestone outcrops signs of structural deformation, such as brecciation, and steep dips up to 61 degrees, have been observed. Mineralization has also occurred, and a number of abandoned prospect pits are evidence of earlier attempts to explore veins filled with vein quartz and other gangue minerals.

Strikes trend generally in a west by northwest direction and dips are to the south ranging generally from 40 to 60 degrees. An exception is the limestone hill in Sections 34 and 35, T 27S, R 20W, where strikes are scattered in east and northeast directions and northward dips range from 12 to 42 degrees.

The lower contact of the limestone is not exposed within the report area. The upper contact of the limestone with overlying Cretaceous sandstones and Tertiary volcanics is an erosional unconformity. The greatest thickness of limestone within the mapped area crops out in Section 17, T 27S, R 20W (Pl. I) where approximately 3,400 feet are exposed.

A definite correlation of these limestones with similar rocks mapped in nearby areas has not been made. Gillerman (1958) who mapped the quadrangle directly north of this area, found the Horquilla Formation to be the most widespread of the Pennsylvanian-Permian Limestones. It is identified most easily by its abundance of fusilinids. Undoubtedly the Horquilla Formation is also well represented in the area mapped by this writer, but it is also quite probable that some of the limestone outcrops belong to other Permian formations.

Johnny Bull Sandstone

The Johnny Bull Sandstone crops out in four localities - Sections 19, 20, 29 and 32, T 27W, R 20W. All four outcrops lie on the east side of the range within the south half of the map area.

In terms of Folk's (1968, p. 149-152) sandstone classification, outcrops of this formation are predominantly light gray to pale red fine sandstone: silica and/or calcite cemented mature to supermature quartzarenites. Other beds are slightly argillaceous, contain some rock fragments and are composed of silica-cemented immature sublitharenite. A summary of thin section descriptions from this formation is given in Table 2.

Table 2

Petrographic summary of thin sections from the Johnny Bull Sandstone (Based on 4 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Quartz	90-95	0.1-0.4	rounded to well-rounded; overgrowth; some abraded; some composite grains.
Metamorphic Rock Fragments	tr.-4	0.1-0.4	rounded; foliated; sericitic.
Chert	tr.-2	0.1-0.2	rounded to well-rounded.
Zircon	tr.		
Muscovite	0-tr.		
Apatite	0-tr.		pale green.
Matrix	tr.-10		cement, silica and/or calcite; some hematite staining.

Metamorphic rock fragments, squeezed and contorted between quartz grains, indicate that deformation of the rock has occurred.

The Johnny Bull Sandstone was first mapped by Gillerman (1958, p. 52 and 53) two townships north of the area mapped. Based on stratigraphic position, Gillerman assigns the unit to the Early Cretaceous, acknowledging that this age is conjectural since no fossils were found or other age determinations made. According to Gillerman, most of the formation is sandstone with some interbedded shale beds. In his description of the sandstone he states:

> "Many of the beds are well undurated and thick and form resistant ledges. Others are thin, soft, and argillaceous, and are less resistant to erosion. Colors range from white to gray, pink and brown. The light-colored sandstone is a medium to fine-grained, well-sorted orthoquartzite.....a typical example showed more than 95 per cent of well-rounded clear quartz grains, many with overgrowth, 1 to 2 per cent of sericitized feldspar and 1 to 2 per cent of clay and metamorphic rock fragments."

In the area mapped, the unit shares unconformable contacts with the younger Bobcat Hill Conglomerate and Unit Tl. An unconformable lower contact with the Pennsylvanian-Permian limestone also occurs in Sections 19 and 32.

Most outcrops of the formation are poorly exposed and the location of contacts with other units are often inferred. The two large outcrops in Sections 19, 20 and 29 offer the best exposures. Here sandstone beds of varying resistance dip from 30 to near 90 degrees to the southwest and the more resistant beds form ridges which parallel the strike across the outcrops. In each of these two outcrops an estimated 1,600 feet of sandstone is exposed with alluvium covering both upper and lower parts of the sections.

Unit Tl

This mapping unit consists primarily of a series of ash flows and possibly some lava flows which range in composition from quartz latite to andesite. The unit covers much of the lower area in Antelope Pass. North of State Highway 9 it crops out in the NE¼ of Section 24, T 27S, R 21W. South of State Highway 9 it is found on the lower slopes of the hills and in the flats surrounding the hills. The unit defies accurate mapping of all the variations in texture and composition because only about 5-10 percent of outcrop occurs in the low areas between the prominent hills. Secondly, the only possible correlation that can be made between different outcrops of the unit has to be based solely on phenocryst composition and abundance. Textures and colors vary so much and so rapidly that they are useless except in some cases where they indicate the mode of emplacement (i.e. ash flow versus lava flow).

The rocks are highly altered. Where alteration is most severe; devitrification, silicification, and clay alteration have all played a part. Most feldspar phenocrysts have been altered to clay, but are still visible as obscure pseudomorphs of the original mineral. They often lie in a matrix of microcrystalline secondary minerals which have completely destroyed any original volcanic features. Silicification and clay alteration are most severe in the portion of the unit found north of State Highway 9. In two thin sections from rocks within this area, only quartz phenocrysts survived the alteration (Appendix I, samples 97 and 109). The feldspars are totally kaolinized and their former presence is only hinted at by pseudomorphic ghosts.

The majority of the rocks mapped within this unit are andesites. Quartz latites and rhyodacites comprise a minor fraction. The location of these different rock types is not completely random for the quartz-rich rocks tend to occur north of State Highway 9.

This is also the area of most intense alteration, and changes in the mineral percentages within the rock undoubtedly occurred when the rock was subjected to severe alteration. A strict mineralogical correlation between outcrops of this unit exposed north of State Highway 9 and those exposed on the south side would not be conclusive. The reasons for mapping these rocks as one unit are: (1) the similarity in the degree and type of alteration, (2) the fact that both have thin spotty occurrences of pyroclastic beds and epiclastic volcanic sediment interbedded within and overlying them and (3) they both appear to rest on the underlying Paleozoic and Cretaceous strata along their eastern margin.

Nine thin sections were cut from representative samples of Unit Tl. Table 3 presents a summary of the thin section descriptions.

Table 3

Petrographic summary of thin sections from Unit Tl
(Based on 9 thin sections)

Part I: Andesites			
Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Plagioclase	5-26	0.2-5.0	euhedral; zoned; selective corrosion of zones; pseudomorphs.
Biotite	tr.-7	0.1-1.0	euhedral; greenish red-brown.
Pyroxene & Amphibole	0-tr.	0.5	pseudomorphs replaced by calcite, serpentine, and opaques.

Table 3 Continued on Next Page

Table 3 Cont'd.

Petrographic summary of thin sections from Unit Tl
(Based on 9 thin sections)

Part I: Andesites

Composition	Volume (%) Range	Size (mm) Range	Character
Accessory & Secondary Minerals:			
Opaques	1	<0.1-0.5	finely disseminated; exsolved out of biotite; filling pseudomorphs.
Zircon	0-tr.	0.1	euhedral; found with opaques.
Serpentine	0-tr.		filling pseudomorphs.
Quartz	0-3	<0.1-0.5	vein filling.
Calcite	0-2		pseudomorphic after plagioclase and pyroxene.
Sericite	0-2		pseudomorphic after plagioclase.
Matrix & Texture:			
	66-83		Devitrification products; spherulites; microlites of plagioclase (?).

Comment: No trace of pumice or shards. Devitrification has obscured any flow textures which might indicate the mode of emplacement. There is no conclusive evidence to indicate whether emplacement was as an ash flow or a lava flow.

Table 3 Continued on Next Page

Table 3 Cont'd.

Petrographic summary of thin sections from Unit Tl
(Based on 9 thin sections)

Composition	Part II: Volume (%) Range	Quartz Latite & Rhyodacite Size (mm) Range	Character
Phenocrysts:			
Plagioclase	4-7	<0.5-2.0	subhedral; zoned.
Sanadine	4-5	<0.5-2.0	euhedral-subhedral; resorbed.
Quartz	3-11	<0.5-2.0	subhedral; resorbed.
Biotite	tr.	0.5-1.0	red-brown.
Accessories:			
Opaques	tr.-1	<0.5	form rims around spherulites.
Volcanic Rock Fragments	0-tr.	1.0	andesite fragments (?).
Matrix & Textures:			
	77-86		Mostly devitrification products, but some glass, relic shards, flattened pumice, axiolites, and spherulites can be recognized.

Comment: Ash flow textures are more recognizable in these rocks than in the andesites. Slightly flattened clusters of spherulites, shards, and axiolites indicate varying degrees of welding occurred.

As stated before, the color of Unit Tl is quite variable. It ranges through grays, yellows, reddish-browns and shades of off-white.

Flows within Unit Tl probably record volcanic eruptions in Early Tertiary. These appear to be the oldest volcanic rocks in the area mapped and were extruded over a surface of moderate relief cut in Cretaceous sandstones and Paleozoic limestones.

The thickness of the unit is not known, although it is probably quite variable since it was deposited over a surface of moderate relief. On the eastern side of the range, small limestone and sandstone outcrops protrude through the volcanics of Unit Tl. Two such limestone exposures are mapped in Section 30, T 27S, R 21W.

Andesites and quartz latites described by Gillerman (1958, p. 53-55, p. 58-65) are probably contemporaneous with Unit Tl. Approximately fourteen square miles of andesite and associated dacite were mapped by Gillerman. These andesites are located approximately fifteen miles north of Antelope Pass. Gillerman (1958, p. 58) describes an andesite that:

> "... is not uniform in composition, texture, or general appearance, a condition which is reflected in its response to erosion and effect upon the topography."

He also says that:

> "... later tectonism and alteration which profoundly affected the rocks has imparted a corresponding difficulty to the mapping and to the correlation and interpretation of these rocks."

It is doubtful that Unit Tl is part of the same sequence of andesite flows mapped by Gillerman, but they probably are contemporaneous, and were produced by the same period of volcanic activity.

Fernandez and Enlows (1966, p. 1018-1019) described andesites unconformably underlying the early Tertiary Faraway Ranch Formation in the Chiricahua National Monument. There also the andesites are highly silicified and altered. Fernandez and Enlows are not sure if the andesites are intrusive or extrusive, but they interpreted the age of the andesites as Laramide.

To the east in the Animas Mountains, Zeller and Alper (1965, p. 46-47) have mapped an andesite which is petrographically similar to the andesites in Tl, but there the andesite unconformably overlies pyroclastic rocks instead of Cretaceous sandstones. Zeller and Alper date the andesite as mid-Tertiary. No correlation is suggested here with the andesite mapped by Zeller and Alper.

Bobcat Hill Conglomerate

The type location of the Bobcat Hill Conglomerate, as mapped by Gillerman (1958, p. 55-58) is eighteen miles north of similar outcrops mapped by the writer. In the type area Gillerman describes the formation as "... alternating beds of sandstone and conglomerate...", which are overlain by a vast area of andesite extrusives, and are underlain by a quartz latite extrusive. It is Gillerman's contention, with some reservations, that the correct sequence of events is: emplacement of the quartz latite, followed by erosion and subsequent deposition of the conglomerate, followed by extrusion of the andesite. He states that the conglomerate lies unconformably on the quartz latite, but that the overlying andesite is conformably on the conglomerate and probably interbedded with it.

The Bobcat Hill Conglomerate trends east-west across the range in Gillerman's area, and he notes variations in composition from east to west. In the east the conglomerate beds are predominantly pebbles and cobbles of andesite and limestone, with andesite constituting 80-90 percent of the fragments in the upper most beds. In the west the conglomerate beds are predominantly pebbles and cobbles of quartzite, sandstone, or Paleozoic limestone. Volcanic rock fragments are also present but in fewer numbers.

In the area of this study, on the east side of the range in Sections 19, 29, 32 and 33, T 27S, R 20W (Pl. I), there are a number of localized outcrops which are mapped as Bobcat Hill Conglomerate. Rocks from these outcrops vary appreciably with regard to their texture and the relative percentages of constituent minerals and rock fragments. Both sandstones and conglomerates comprise the formation. The sandstones are generally pinkish-gray to olive-gray immature litharenites, composed mainly of quartz and volcanic rock fragments. The framework grains are bound in a matrix of calcite and authigenic clay minerals. The clay minerals probably are the result of devitrification of volcanic ash. A small pit has been developed in Section 32 for recovery of this clay. The conglomerates are composed primarily of andesite and limestone clasts. Less abundant than these rock fragments, and not occurring in all samples, are grains of quartz, chert, microcline, perthite, plagioclase, metamorphic rock fragments and trace amounts of zircon and apatite. Five thin sections were cut from representative samples. Table 4 summarizes the thin section descriptions.

The formation crops out in the low hills and mounds which characterize the Antelope Pass area (Pl. I). Surrounding and bordering many of the outcrops are the andesite and quartz latite extrusives of Unit Tl which are similar to those described by Gillerman (1958, p. 53-55, 58-65). From the spatial relationship with Unit Tl, it appears that the conglomerate is an epiclastic volcanic unit deposited during interim lulls in the eruptive activity which produced Unit Tl. This is supported by the fact that most of the volcanic rock fragments within the conglomerate appear to be from Unit Tl.

Gillerman makes the distinction of placing the conglomerate stratigraphically between the quartz latite and the andesite. Within the area mapped, no indication was found to verify this relationship. Mapable distinctions between quartz latite and andesite flows are not as apparent as in the area mapped and described by Gillerman. Moreover, outcrops of the conglomerate typically occur in isolated low relief areas adjacent to the andesite and quartz latite extrusives, which give no clear cut indication as to the correct stratigraphic relationship between them. Therefore, the Bobcat Hill Conglomerate, is here considered contemporaneous with the andesite and quartz latite flows.

Table 4

Petrographic summary of thin sections
from the Bobcat Hill Conglomerate
(Based on 5 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Sandstone:			
Quartz	22-80	0.2-0.4	subangular to rounded, abraded overgrowth, some volcanic quartz.
Chert	5-19	0.2-0.4	subrounded to rounded, some may be fine-grained volcanic rock fragments
Volcanic Rock Fragments	5-20	0.2-0.4	subrounded to rounded, andesite & spherulite fragments.
Plagioclase	1	0.2-0.4	subangular to subrounded.
Metamorphic Rock Fragments	0-1	0.2-0.4	quartzite fragments & fine-grained foliated fragments.
Zircon, Microcline, Chlorite, Muscovite	0-tr.		
Cement	9-36		both argillaceous calcite and silica.
Conglomerate:			
Limestone Fragments	0-30	0-5-40-0	subrounded, fusilinids, brachiopods.
Volcanic Rock Fragments	15-99	0.5-10.0	subangular to rounded, andesitic.

Table 4 Continued on Next Page

Table 4 Cont'd.

Petrographic summary of thin sections
from the Bobcat Hill Conglomerate
(Based on 5 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Conglomerate Cont'd:			
Quartz	0-10	0.5-1.0	angular to rounded, single & composite grains.
Perthite	0-10	0.5-20.0	angular.
Microcline	0-5	0.5-20.0	angular.
Plagioclase	tr.-1	0.5	angular.
Zircon	0-tr.		
Apatite	0-tr.		
Hematite	0-tr.		
Chlorite	0-tr.		
Cement	0-53		Clay minerals & calcite.

Unit T2

Unit T2 crops out only in the lower half of the hill located at the intersection of Sections 29, 30, 31 and 32, T 27S, R 20W. It consists of approximately 250 feet of what appears to be epiclastic volcanic sediment which is thickest in the southeast side of the hill and thins to the north and west. Bedding structures are evident only in the lower part of the unit, which is cause for some doubt that the entire unit is epiclastic. The upper part of the unit is more massive and lacks visible sedimentary structures, which may be obscured by the high percentage of secondary clay and matrix material. However, the entire unit is interpreted to be epiclastic because: (1) the lower part is definitely fluvially deposited, and (2) grains (or crystals) make up a high percentage (55%) of the rock throughout the unit. Crystal-rich ash flows have been reported (Hay, 1959), but they seem to be relatively rare.

The unit is pale greenish-yellow, soft, clayey, and the upper massive part forms steep irregular slopes similar in appearance to those formed by the pumice flows in Unit T4. The petrography of the unit is summarized in Table 5.

Although the lower contact of Unit T2 is poorly exposed, it appears that Unit T2 unconformably overlies both Unit T1 and the Pennsylvanian-Permian limestone. The upper contact is conformable with the overlying Unit T3.

Unit T3

Unit T3 is composed of a sequence of welded ash flows that cap the hills south of State Highway 9. The unit conformably overlies Unit T2 but where Unit T2 is missing, Unit T3 directly overlies Unit T1. Capping isolated hills in antelope Pass, Unit T3 appears as an erosional remnant in the subdued topography of the area.

Table 5

Petrographic description of Unit T2
(Based on 1 thin section)

Composition	Volume (%) Range	Size (mm) Range	Character
Quartz	28	<0.5-5.0	subhedral; angular fractured; resorbed.
Sanidine	10	<0.5-5.0	subhedral; angular fractured; resorbed.
Plagioclase	25	<0.5-5.0	subhedral; angular; fractured; zoned; resorbed.
Biotite	2	<0.5	euhedral.
Sphene	tr.	0.1	euhedral.
Volcanic Rock Fragments	tr.	20.1	fine-grained; red (in hand specimen).
Matrix	35	micro.	clay, no relics of shards or pumice can be seen.

The color of the unit varies between pale red, brownish-gray, black, grayish-pink and white. It is best described as a "textbook" ignimbrite with obvious eutaxitic texture. The rock is somewhat devitrified, shows selective corrosion of portions of sanidine crystals, and appears locally bleached. The selective corrosion of the sanidine is probably due to the presence of very thin albite lamellae within the sanidine crystals.

Compositionally the unit is a rhyolite, and, by comparison to the younger rhyolites, it is rich in phenocrysts (22 percent phenocrysts compared to 5 to 10 percent for the Weatherby Canyon Ignimbrite). Figures 2 and 3 show photomicrographs of this phenocryst-rich unit, and Table 6 summarizes the petrology of the unit based on six thin sections. Five of the thin sections are from welded tuffs with varying degrees of devitrification and the sixth thin section is from a vitrophyre that is 52 percent glass. The hornblende, augite (?) and sphene are found only in the vitrophyre (Table 6). Four beds of perlitic vitrophyre were found. They are all relatively thin on the order of 2 to 3 feet, and probably represent the basal part of individual ash flows.

Both Unit T3 and Unit T2 record early to middle Tertiary volcanism. In the quadrangle north of this map area, Gillerman (1958, p. 55-70) reported four volcanic units of similar age (i.e. younger than the andesite flows, yet older than the Weatherby Canyon Ignimbrite). These four units range in composition from rhyolite to basalt. The largest and oldest is the Quarry Peak Rhyolite complex. This is the only unit reported by Gillerman which would be correlated with Unit T3, and this correlation is very tenuous because, other than their compositional similarity and their common stratigraphic positions with regard to the underlying andesite flows, there are no other similarities. The rhyolite described by Gillerman is texturally more varied and includes flows, breccias, and tuffs. Also Gillerman described most

Figure 2. Rhyolite from Unit T3, which is a phenocryst-rich sequence of welded ash flows. Note the flow lines and/or flattened shards around the phenocrysts and the volcanic rock fragment.

Figure 3. An example of a resorbed quartz crystal in a rhyolite from Unit T3.

Table 6

Petrographic summary of thin sections from Unit T3
(Based on 6 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
<u>Phenocrysts</u>:			
Quartz	6-12	<0.5-2.0	anhedral-subhedral; fractured; embayed.
Sanidine	8-16	<0.5-2.0	anhedral-subhedral; carlsbad twinning; resorbed; selective corrosion of lamellae.
Plagioclase	0-8	<0.5-1.0	anhedral-subhedral; zoned; fractured.
Biotite	0-1	<0.5-1.0	brown; greenish.
Hornblende	0-tr.	0.8	euhedral-anhedral.
Augite (?)	0-tr.	0.8	anhedral.
<u>Accessories</u>:			
Sphene	0-tr.	0.3	anhedral.
Zircon	0-tr.	0.2	
Opaques	tr.	0.1	finely disseminated; concentrated around volcanic rock fragments.
Volcanic Rock Fragments	0-25	0.5-10.0	fine grained; reddish; andesite fragments; pumice fragments.
<u>Matrix</u>:			
	55-84	Micro.	devitrification products; relic shards; eutaxitic texture; flattened pumice; glass; spherulites.

of the unit as a:

> "... white or light-gray rhyolite which contains a few small inconspicuous phenocrysts of quartz and feldspar."

This is not at all like the phenocryst-rich Unit T3.

Unit T4

Unit T4 is best seen in Sections 24 and 12, T 27S, R 11W. In these two sections the unit forms two prominent hills with approximately 600-850 feet of section exposed. Numerous other exposures occur on lower slopes of the hills, but Quaternary alluvium covers most of the lower section. All outcrops of Unit T4 are found north of State Highway 9.

Unit T4 can be divided into lower and upper members. The lower member is predominantly fluvial volcanic sandstone and conglomerate. Where the lower contact is exposed, Unit T4 lies unconformably on Unit T1, Cretaceous sandstone, and Paleozoic limestone. These older rocks formed a surface of low to moderate relief at the time of deposition of the lower member. Figure 4 is a photomicrograph showing the unconformable contact between Unit T1 and the lower member. The upper member is predominantly a sequence of pumice flows, and is conformable with the lower member and the overlying Weatherby Canyon Ignimbrite.

The total thickness of the entire unit is not known, because nowhere is a complete section visible. The upper member is completely exposed in Section 12, T 27S, R 21W and is more than 700 feet thick. Here the upper member overlies approximately 175 feet of the lower member. The basal part of the lower member is covered by Quaternary alluvium.

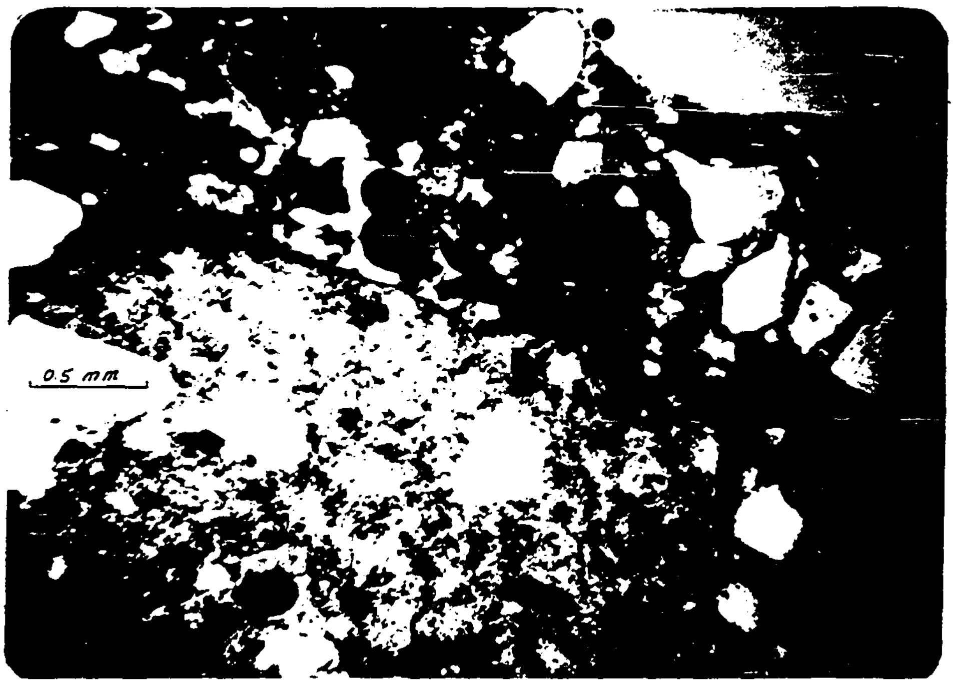

Figure 4. Photomicrograph showing unconformable contact between andesite of Unit Tl (bottom) and the lower member of Unit T4.

Lower Member

A petrographic summary of the lower member is given in Table 7, and is based on three representative thin sections. Two of these thin sections are from fluvial sediments, and the third is from a thin, partially welded tuff which is interbedded in the fluvial sediments and represents a minor portion of the member. Compositional variation is high between samples from different locations because the sediments were deposited on alluvial fans that bordered a lithologically variable source area. Figures 5 and

Table 7

Petrographic summary of thin sections from the lower member of Unit T4. (Based on 3 thin sections)

Part I: Fluvial Volcanic Sediment

Composition	Volume (%) Range	Size (mm) Range	Character
Quartz	3-9	<0.1-2.0	angular to well-rounded abraded overgrowths.
Plagioclase	6-30	<0.1-2.0	angular to rounded; some zoned & sericitized.
Sanidine	0-3	0.1	angular.
Biotite	0-1	<0.1-0.2	red-brown; highly altered.
Opaques	1-8	<0.1	magnetite.
Zircon	tr.		
Volcanic Rock Fragments	17-38	0.2-16.0	devitrified; sericite; perlitic fractures; some andesite fragments.
Matrix	39-42		clay; chalcedony; sericite; calcite; hematite.

Part II: Rhyolitic, Partially Welded Tuff

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Quartz	16	0.2-1.0	anhedral; fractured; re-sorbed.
Sanidine	8	0.2-1.0	subhedral; fractured.
Plagioclase	3	0.2-1.0	anhedral.

Table 7 Continued on Next Page

Table 7 Cont'd.

Petrographic summary of thin sections from the lower member of Unit T4. (Based on 3 thin sections)

Part II: Rhyolitic, Partially Welded Tuff Cont'd.

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts Cont'd.:			
Biotite	3	0.5	light brown.
Accessories:			
Opaques	tr.	<0.1	concentrated in porous clasts & finely disseminated.
Volcanic Rock Fragments	10	1.0	devitrified; relic shards; spherulite fragments; sedimentary rock fragments.
Matrix:			
	60	micro.	devitrification products; relic shards & flow lines around phenocrysts.

6 show a typical outcrop of the lower member. Note the scour and fill, poor sorting, and the rapid vertical change in grain size typical of alluvial fan deposition.

In some samples andesite fragments are present which were derived from the underlying Unit T1. Quartz, with abraded overgrowths, was derived from the Cretaceous Johnny Bull Sandstone which also formed part of the underlying erosional surface. Some of the volcanic rock fragments may have been derived from Unit T3.

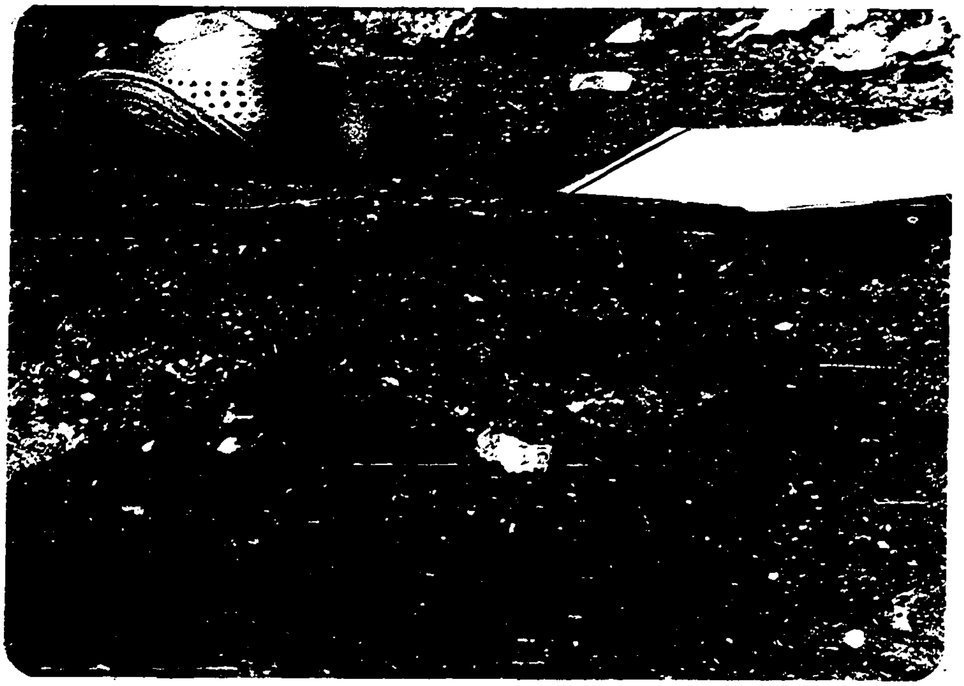

Figure 5. Typical outcrop of the lower member of Unit T4. Note the scour and fill, poor sorting, and rapid vertical change in grain size.

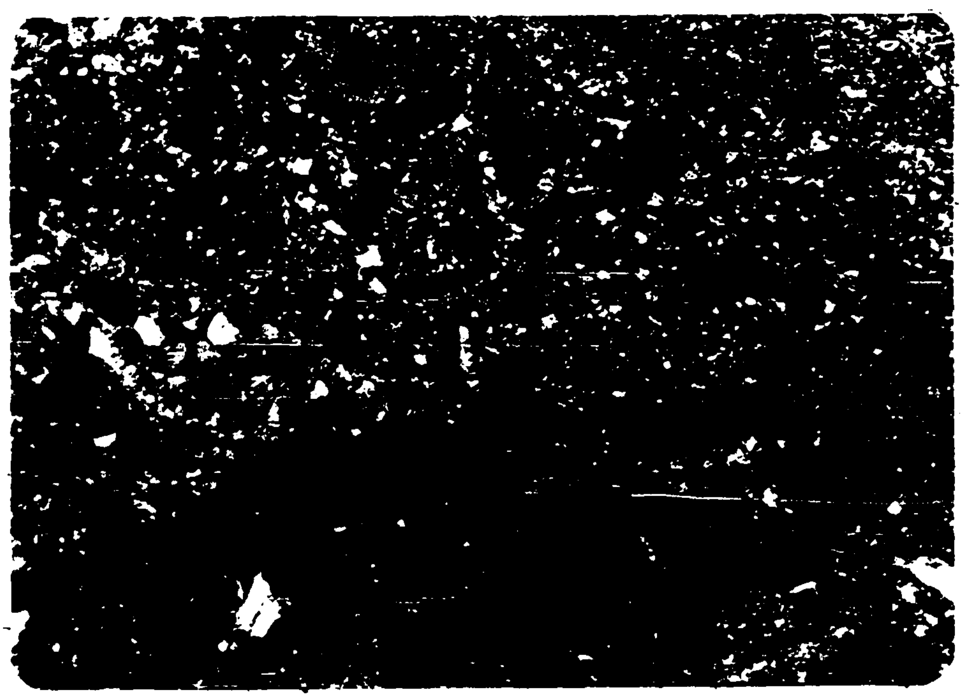

Figure 6. Fluvial volcanic sediment from the lower member of Unit T4. This photo is a close-up of an area in Figure 5 that is to the left and slightly above the lens cap.

Although the volcanic fluvial deposits form the major part of the lower member, there are also some interbedded air-fall ash layers and lithic pumiceous tuffs. These interbedded layers are thin. The thickest is about 15 to 20 feet.

The color of the lower member is generally reddish-brown because of the hematite staining, but shades of brown, yellow, gray-green and purple also occur. The assorted colors result from different pyroclastic material and differences in the degree of alteration.

Upper Member

The contact between the lower member and the upper member is gradational, and is arbitrarily placed where pumiceous ash flows predominate over the fluvial sediments.

A petrographic summary of the upper member is given in Table 8 based on thin sections of the pumiceous flows and does not include information based on any of the interbedded fluvial deposits.

The color of the upper member is grayish-yellow to very pale orange, and stands out in striking contrast to the surrounding hills. Most of the pumice flows which comprise the upper member are 10 to 30 feet thick (Figure 7) and the main compositional difference between the flows is in the amount of rock fragments. Figure 8 shows the texture of a typical pumice flow which contains approximately 25 per cent volcanic rock fragments. Interbedded within the pumice flows are beds of fluvially reworked volcanic sediment, accretionary lapilli (?), and an occasional lahar. Figure 9 shows the texture of a lahar which is approximately 50 per cent volcanic rock fragments in a clayey matrix.

Table 8

Petrographic summary of thin sections from the upper member of Unit T4. (Based on 3 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Quartz	0-2	<0.5-2.0	anhedral-subhedral; fractured; embayed;
Sanidine	0-3	0.2-1.0	anhedral-subhedral; fractured.
Plagioclase	0-7	0.2-1.0	anhedral-euhedral; fractured; zoned.
Biotite	0-tr.	<0.3-0.5	red and brown.
Accessories:			
Volcanic Rock Fragments	12-25	0.2-8.0	fine-grained; devitrified; red; brown; gray; spherulite & andesite fragments.
Zircon	0-tr.	0.2	
Matrix:			
	63-88	micro.	devitrified to clay minerals; relict pumice balls.

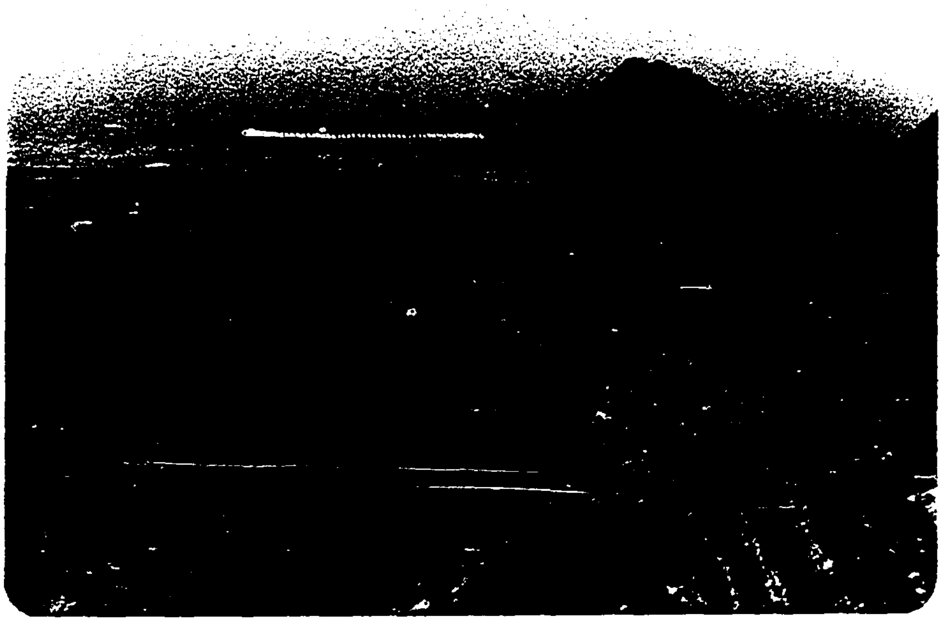

Figure 7. Sequences of pumice flows which comprise the upper member of Unit T4. Most of the flows are 10 to 30 feet thick.

Figure 8. The texture of one of the pumice flows shown in Figure 7. This flow contains about 25 per cent volcanic rock fragments.

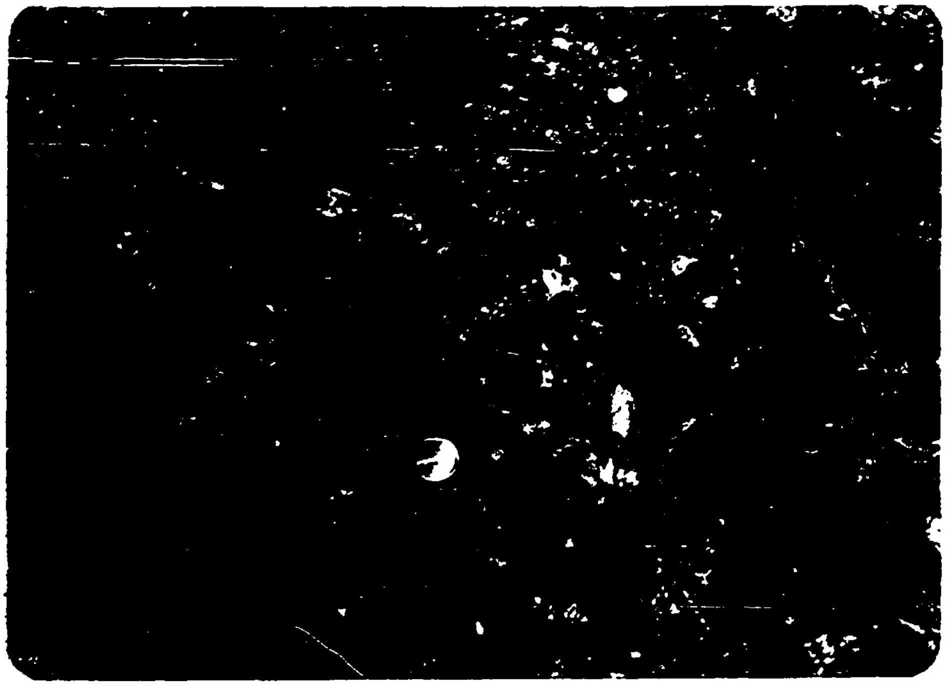

Figure 9. A lahar that is interbedded with the pumice flows of the upper member of Unit T4. Volcanic rock fragments compose approximately fifty percent of the rock.

Weatherby Canyon Ignimbrite

The Weatherby Canyon Ignimbrite is by far the most voluminous of all the volcanic rock units mapped. Rocks belonging to this unit comprise a seven-mile stretch of the Peloncillo Mountains. Approximately three and one-half of the seven miles extend out of the map area and were mapped earlier by Gillerman (1958). It was Gillerman who originally named this unit after a major canyon which is developed in the rock unit. Gillerman (1968, p. 223) described Weatherby Canyon Ignimbrite as tuffs and ignimbrites of rhyolite and trachytic composition. He further stated that non-welded tuffs occur in minor amounts compared to welded ignimbrites and that rhyolitic rocks greatly predominate over trachytic rocks. Using the eutaxitic texture of the ignimbrite to measure strike and dip, Gillerman (1968, p. 223) concluded that the rocks dip uniformly to the east at about fifteen degrees for a horizontal distance of three miles normal to the strike, with no apparent break in continuity. Assuming no break in continuity, Gillerman calculated that at least 3,000 feet of ignimbrite occur in the highest peak ("1117 Mountain") and the ridges to the west.

In the area mapped, the Weatherby Canyon Ignimbrite dips generally to the north-northeast at roughly twenty degrees. Using this dip and measuring the longest horizontal exposure of the ignimbrite in the dip direction (1.3 miles) the calculated thickness is about 2,300 feet.

Because of the way ash flows are deposited, horizontal and vertical continuity is seldom found over any extended distance. The Weatherby Canyon Ignimbrite is a thick sequence of volcanic flows, generally rhyolitic to trachytic in composition, but displaying many textural variations resulting from differences in intensity of welding, relative variations in the amount of glass and rock fragments in individual flows, mode of emplacement (nuēe ardente versus lava flow), and the degree of alteration. Reliable marker units within the ignimbrite are rare, which makes faults within the unit extremely difficult to recognize. Evidence of faulting such as slickensides and brecciation can be found but seldom in a conclusive linear pattern which would indicate a fault zone. If faulting within the ignimbrite has gone unnoticed and repetition and displacement of beds occur on a large scale, the actual thickness could be greater or less than 2,300 feet.

Within the area mapped three texturally distinct members have been delineated.

Basal Member

The basal member is the best marker unit in the Weatherby Canyon Ignimbrite. It is relatively thin with a thickness of approximately 100 feet, but it is distinctive because of its white color. Lithologically it varies from a highly-welded to partially-welded lithic tuff of rhyolitic to trachytic composition. Phenocrysts make up only about six percent of the rock (Table 9).

Table 9

Petrographic summary of thin sections
from the basal member of the Weatherby Canyon Ignimbrite
(Based on 2 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Sanidine	0-6	0.5-1.0	anhedral-euhedral; resorbed; fractured.
Orthoclase (?)	0-4	0.5-1.0	anhedral-subhedral; slightly kaolinized.
Quartz	0-1	0.5-1.0	anhedral; resorbed; fractured.
Biotite	tr.	<0.5	red-brown.
Accessories:			
Opaques	0-1	0.1	finely disseminated.
Zircon	tr.	0.2	inclusions in quartz.
Volcanic Rock Fragments	5-20	<0.5-20.0	fine-grained; red; gray; pale yellow; pumice fragments; relic spherulites in holocrystalline groundmass.
Flattened Pumice	0-50	0.5-20.0	devitrified into microspherulites.
Matrix:			
	37-76	micro.	highly devitrified; good shard preservation both flattened and unflattened.

Sanidine appears in hand specimen as tiny clear crystals. The orthoclase (?) is elusive in hand specimen, but can be seen with a hand lens as tiny pink crystals. The matrix is white to light pink and the volcanic rock fragments are angular, dark gray to red, and dispersed evenly throughout the rock. Volcanic rock fragments vary from 5 to 20 percent of the rock, and ninety percent of these are pumice fragments.

The lower contact of the basal member of the Weatherby Canyon Ignimbrite with the upper member of Unit T4 is gradational. It is arbitrarily placed where white color becomes dominant over yellowish gray and where partial welding becomes apparent by imparting to the rock a higher resistance to weathering than displayed by the underlying pumiceous flows of Unit T4.

The upper contact of the basal member is usually marked by a sharp color change from white to red and a decrease in the amount of volcanic rock fragments incorporated in the rock. In places where the color change is gradational the upper contact is set where the volcanic rock fragments cease to be a dominant characteristic of the rock. Figure 10 shows the basal member and the units both above (Twcm) and below (T4u).

The degree of welding is generally less in the basal member than in the overlying red ignimbrite; therefore, the weathering profile is often a slope covered with talus from the overlying massive, red ignimbrite. In many places the basal member can be seen only in the gullies where it stands out as linear traces

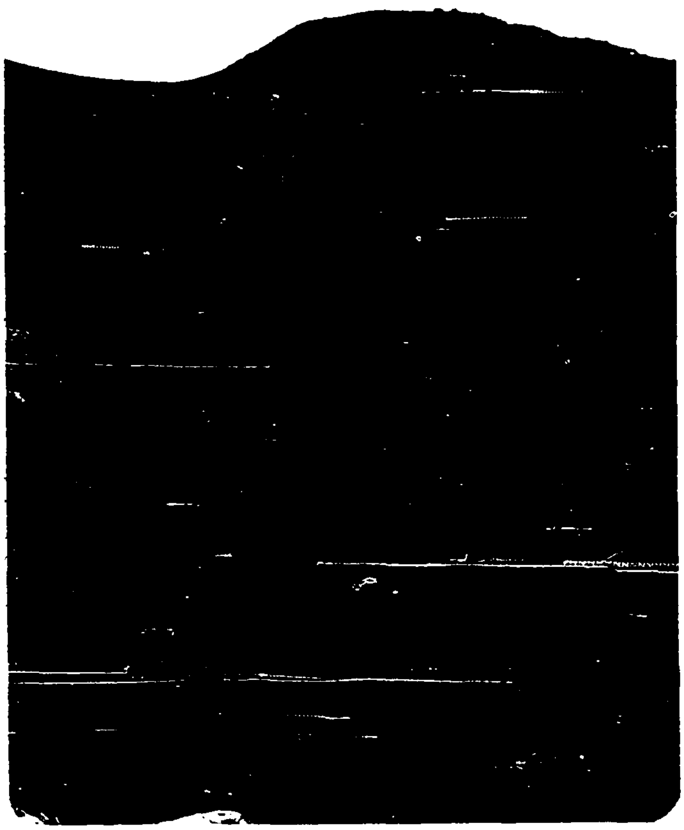

Figure 10. A section showing pumice flows of Unit T4 overlain by the white basal member of the Weatherby Canyon Ignimbrite and capped by the red highly welded middle member of the Weatherby Canyon Ignimbrite.

running down the sides of the slopes. "1117 Mountain", which is located just north of the map area, gets its name from the white gullies which emblaze "1117" on its eastern flank.

Middle Member

The middle member forms the peaks of many of the hills north of State Highway 9. For the most part it is a partially to highly welded tuff with all the textural characteristics of an ignimbrite (Figures 11 and 12). Within the ignimbrite, lenses of non-welded possibly air-fall tuff occur which range from 50 to 300 feet thick; however, these tuffs constitute a minor portion of this predominantly welded member and will be described in more detail later.

The middle member is predominantly rhyolite with lesser amounts of trachyte. Table 10 gives a summary of the petrography of the member based on six thin sections. Five of the thin sectioned rocks are classified as rhyolites and the remaining one as trachyte. Phenocrysts comprise only 6 to 8 percent of the rock, and the main diversity within the member results from textural variation. The following are the main textural variations within this member.

1. Partially to highly-welded tuffs: Partially to highly-welded tuffs account for the largest volume of the middle member and are generally pale red to light gray. Compositionally, rhyolites predominate; however, on the southern flank of "1117 Mountain" and

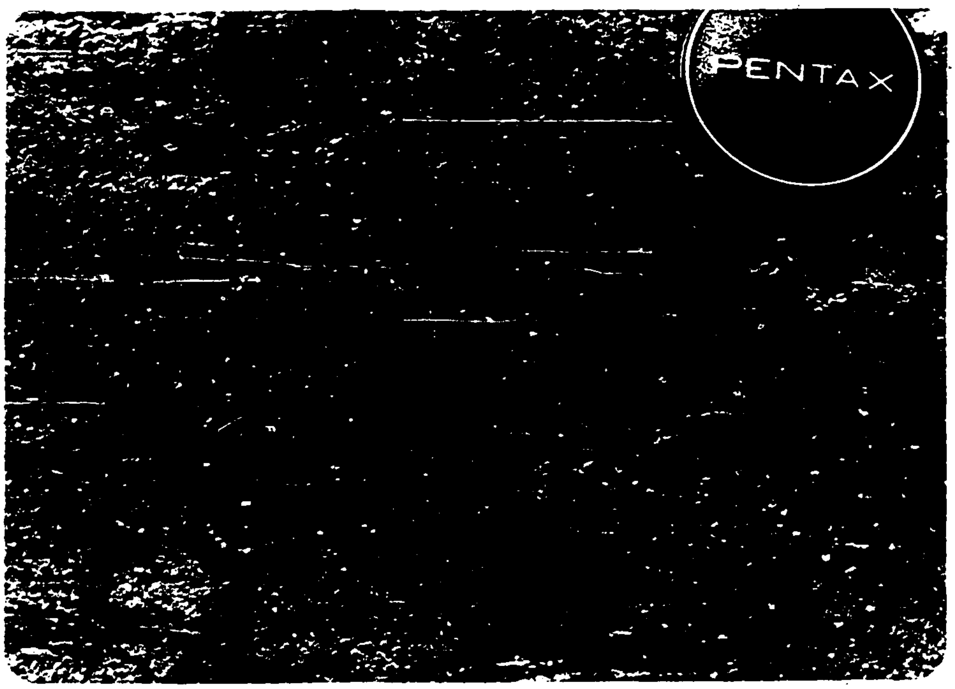

Figure 11. Example of eutaxitic texture in highly welded flows within the middle member of the Weatherby Canyon Ignimbrite.

Figure 12. Photomicrograph of a welded tuff from the middle member of Weatherby Canyon Ignimbrite. Notice how the shards are flattened around the phenocrysts.

Table 10

Petrographic summary of thin sections from the middle member of the Weatherby Canyon Ignimbrite (Based on 6 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Quartz	0-4	<0.5-2.0	anhedral-subhedral resorbed; fractured.
Sanidine	3-12	<0.5-2.0	anhedral-euhedral; resorbed chatoyant; fractured; carlsbad twinning; kaolinized.
Plagioclase	0-4	0.5-2.0	euhedral; fractured; plagioclase found in sample #147 only.
Biotite	0-tr.	0.5	red-brown.
Pyroxene (?)	0-tr.	0.2	sample #147 only.
Accessories:			
Opaques	0-tr.	0.2-0.5	Magnetite & Hematite staining.
Zircon	0-tr.	0.2	Biotite inclusions.
Apatite	0-tr.	0.2	
Volcanic Rock Fragments	0-5	0.5-20.0	fine-grained; spherulites.
Pumice	0-50	0.5-40.0	devitrified; flattened & unflattened; spherulites
Matrix:	40-94	Micro.	

Comment: All samples are partially to completely devitrified. Some samples have good eutaxitic texture, shards, spherulites, axiolites and miarolitic cavities with secondary quartz, tridymite and alkalic feldspar.

the hills in Sections 11 and 12, T 27S, R 21W, the middle member of the Weatherby Canyon Ignimbrite is a trachyte lying conformably on top of the white lithic basal member.

These partially to highly-welded tuffs are resistant to weathering and often stand out as cliffs as shown in Figures 13 and 14. Megascopically the rock is a hard, indurated, red to gray, aphanitic-porphyritic, ignimbrite with fiamme up to several centimeters long. The flattened pumice imparts a characteristic eutaxitic texture to the rock, which is generally more prevalent in the red than in the gray ignimbrite. Fine-grained rock fragments are present although not abundant. The dominant phenocrysts are sanidine and quartz. The quartz-poor trachytes tend to be reddish in color, whereas the rhyolites are both red and gray. The grayish rocks are usually not as highly welded as the red, show corrosion of feldspar, and often have miarolitic cavities where trapped gasses and devitrification have lined the cavities with quartz, tridymite (?) and alkalic feldspar. Both the red and gray ignimbrites are highly devitrified. Shards and pumice structures are still recognizable but not in their original glassy state. No perlitic layers were found anywhere within the member.

2. Non-welded Tuffs: Non-welded tuffs are found throughout the middle member but predominantly in the upper half where they occur interbedded with layers of welded and pumiceous tuff. Non-welded tuffs typically represent the upper part of individual ash flows, and their occurrence indicates that the Weatherby Canyon Ignimbrite

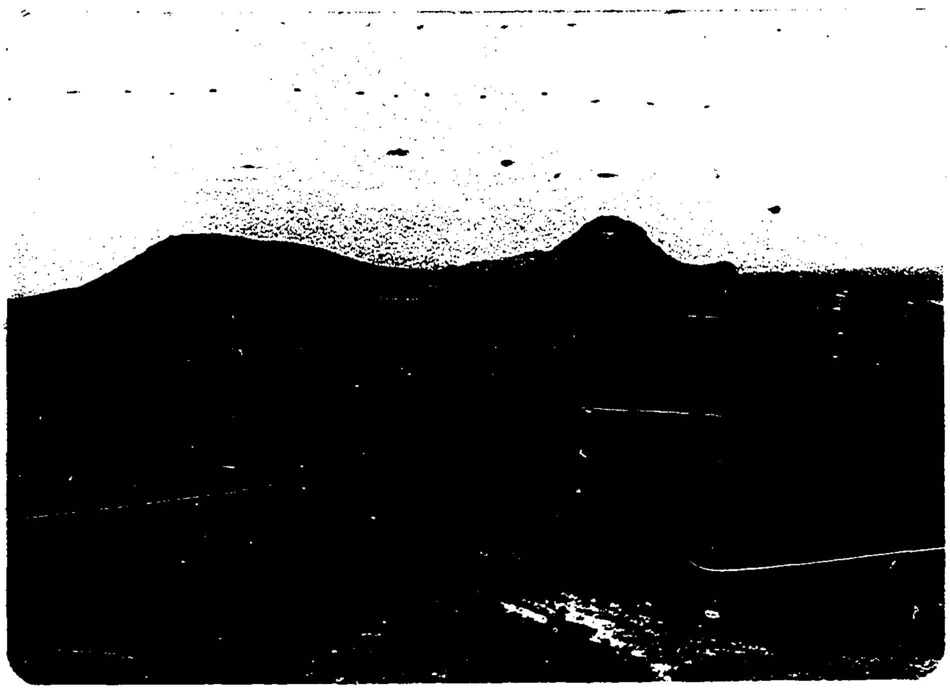

Figure 13. The peak on the right is "1117 Mountain". Cliffs midway up the slope expose highly-welded tuffs of the middle member of the Weatherby Canyon Ignimbrite. The view of the photo is to the north.

Figure 14. The east side of "1117 Mountain" showing poorly formed columnar jointing of the welded tuff of the middle member of the Weatherby Canyon Ignimbrite.

consists of many individual flows. Because of their position, they were not subjected to the compaction and welding which occurs in the lower parts of an ash flow. Often these non-welded lenses of tuff occur directly below beds of perlitic glass or a vitrophyre which belong to the upper member. Beneath the non-welded tuffs lie massive layers of welded ignimbrite, but the contact between the two types of tuff is gradational as would be expected.

These non-welded tuffs are generally light gray and less commonly reddish-gray. They are all rhyolites and their density is noticeably less than the highly-welded tuffs. In Figures 15 and 16 undeformed shards can be seen in random orientations in photomicrographs of non-welded tuffs.

3. Pumiceous Flows: Incorporated within the main body of the Weatherby Canyon Ignimbrite and mapped separately on Plate I, are interbedded lenses of pumiceous flows and epiclastic volcanic deposits. The lenses vary from 50 to 300 feet thick and are made up of several individual flows which vary in percent of lithic fragments and in the size and preservation of the pumice fragments. The thickest and best preserved sequence is found in sections 10 and 11, T 27S, R 21W. Here, the basal 30 feet of the sequence is composed of epiclastic volcanic sandstones. Bedding planes can be recognized and the size of the grains are generally in the fine to coarse sand range. These grains make up about 45 percent of the rock; the remaining 55 percent is a matrix of white clay which is fairly well indurated, but originally was probably composed of glass shards,

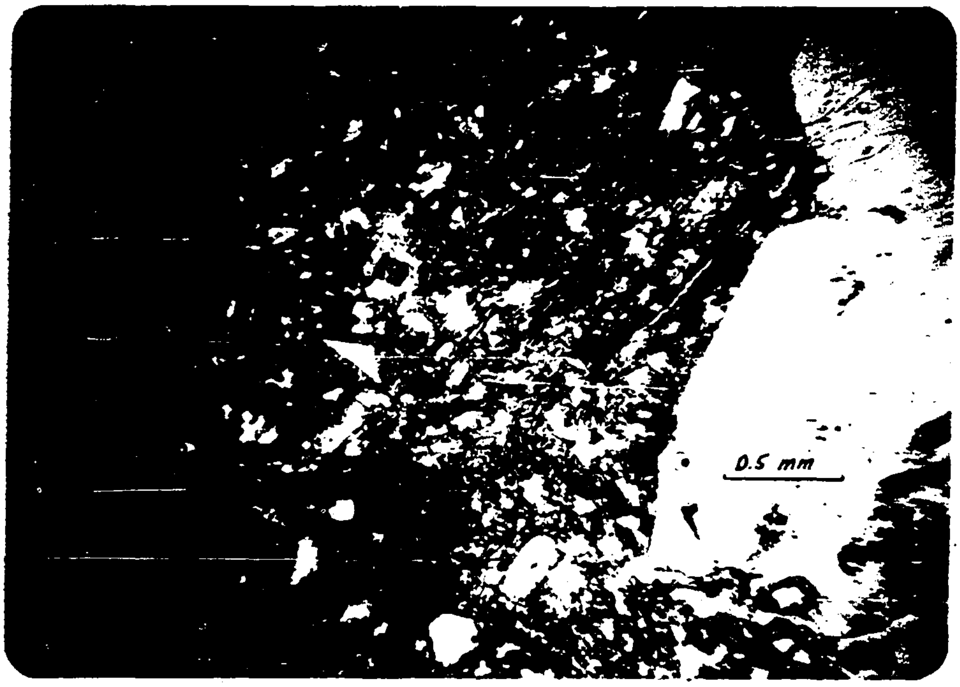

Figure 15. Photomicrograph of non-welded tuff from the middle member of the Weatherby Canyon Ignimbrite. Note the random orientation and generally unflattened nature of the shards.

Figure 16. Photomicrograph of non-welded tuff from the middle member of the Weatherby Canyon Ignimbrite. Note the random orientation and generally unflattened nature of the shards.

ash, and pumice fragments. Half of the grains are red and dark gray volcanic rock fragments, while the other half are clear fragments of quartz and alkali feldspar. The general appearance of the rock is white with linear concentrations of dark grains giving it the bedded appearance.

Immediately above the epiclastic volcanic sandstone is a layer of pale red, well indurated pumiceous tuff. The induration is probably due to secondary silification. Pumice fragments in the rock are not flattened as would be expected if induration was due to welding. Phenocrysts make up 5 percent of the rock and with the hand lens appear as tiny (.5-1 mm) clear anhedral crystals. Volcanic rock fragments account for 4 percent of the rock, are 1 to 5 mm in length, and are generally medium gray in color. Pumice fragments, which are 0.5 to 6 mm long, are well preserved so that their vesicular texture is still apparent. They account for 50 percent of the rock. The remaining 40 percent is matrix which is very-fine grained and has a pinkish-red cherty appearance. The total thickness of this well-indurated pumice flow is approximately 70 feet.

The remainder of the sequence consists of a pale pink pumice flow, or possibly a series of pumice flows, which is approximately 200 feet thick and composed of 75 percent pumice fragments. Although the rock was originally mostly glass, it has since been completely altered to clay, but the original pumiceous textures are well preserved. There are only traces of phenocrysts in the rock and they appear to be clear sanidine crystals with an average size of 0.5 mm. Volcanic rock fragments account for roughly 1 percent of the rock and are up to 1 cm in size. The rest of the rock is matrix, which is a porous ash or finely ground pumice.

In other locations within the middle member, interbedded pumiceous flows were also noted and are mapped on Plate I as a variation within the middle member. They are not all identical to the flow just described, but vary in thickness, degree of alteration, lateral extent, and in phenocryst and volcanic rock fragment percentages. The pumiceous flows are all included as one unit because genetically and lithologically they are all very similar to the thick sequence described in detail. Stratigraphic correlation between different exposures of these pumiceous flows did not prove reliable. With lateral discontinuity characteristic of ash flow emplacement, and the possibility of numerous source vents, as suggested by Gillerman (1968, p. 225), these individual exposures could represent minor eruptions localized around different vents and need not be contemporaneous or occupy similar stratigraphic positions.

Upper Member

The upper member of the Weatherby Canyon Ignimbrite is a variegated gray, flow-banded rhyolite. The rocks in this member are generally vitrophyres, both devitrified and perlitic, and are not found in other members of the Weatherby Canyon Ignimbrite. Most of the vitrophyres are totally devitrified and are composed of very fine-grained crystalline material in the shape of spherulites, axiolites and lithophysae. The axiolites are a prominent feature which parallel the flow lamination in the rocks as shown in Figure 17. Spherulites are also well developed in the perlitic layers as shown in Figure 18. A petrographic summary of the upper member is given in Table 11 based on four representative thin sections.

As in other members of the Weatherby Canyon Ignimbrite, phenocrysts are not abundant and comprise only 4 to 7 percent in rocks from the upper member. The uniqueness of this member is the laminar flow-banded texture which is very obvious in hand specimen. The laminar texture raises the question as to whether these rocks were emplaced as ash flows or lava flows. Christiansen (1966) described a rhyolitic lava flow with flow foliation similar to the vitrophyres described above. He described the flow lines as resulting from lava flowing around obstacles and into depressions. Rutten (1963) described examples of acid lava flows in both the United States and Europe which have this highly contorted laminar texture. He visualized acid lava flowing horizontally near the base of the flow and becoming more turbulant near the top where a surface crust is repeatedly broken up causing the lava to surge over and slowly swirl around the solidified fragments of crust. Rutten (1963, p. 121) made the distinction between lavas and ignimbrites based on these flow lines, claiming that:

> "...ignimbrites, in contrast, are deposits of low viscosity flows, and characterized by uniform texture and only the faintest of subhorizontal flow lines."

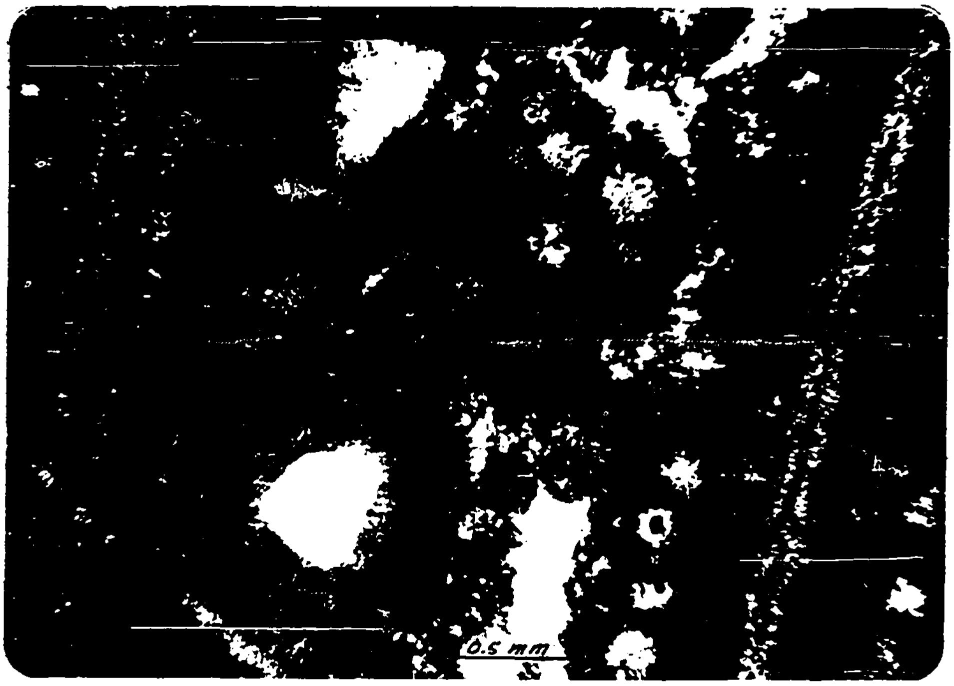

Figure 17. Photomicrograph from the upper member of the Weatherby Canyon Ignimbrite. The round radiating forms are spherulites and the light colored parallel bands are axiolites.

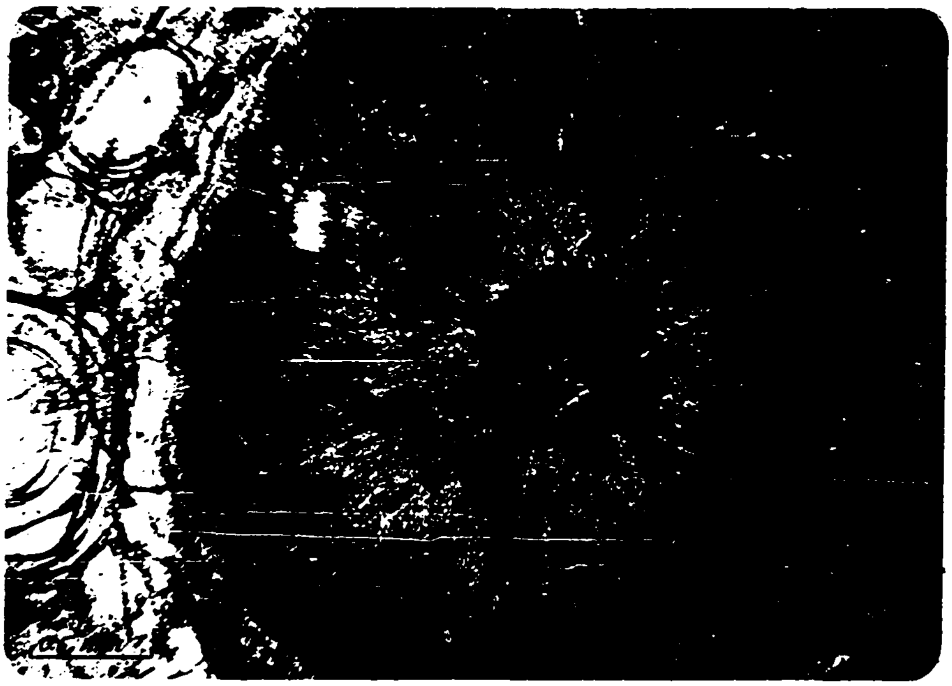

Figure 18. Photomicrcgraph of a well-developed spherulite within perlitic glass from the upper member of the Weatherby Canyon Ignimbrite.

Table 11

Petrographic summary of thin sections
from the upper member of the Weatherby Canyon Ignimbrite
(Based on 4 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Quartz	1-3	0.5-1.0	anhedral-euhedral.
Sanidine	2-3	0.5-1.0	anhedral-euhedral.
Plagioclase	0-1	0.5-1.5	anhedral-euhedral; cumulophyric.
Pyroxene	0-tr.	<0.5-1.5	subhedral-euhedral; reaction rims.
Accessories:			
Opaques	0-1.0	<0.2-0.5	finely disseminated.
Zircon	0-tr.	0.2	
Vein Quartz	0-5		
Matrix:	90-96		spherulites; axiolites; lithophysae; perlitic glass; miarolitic cavities between flow bands; laminar texture.

Schmincke and Swanson (1967) took the other view and described the laminar flowage structure as a primary end phase of movement of a pyroclastic flow. Schmincke and Swanson (1967, p. 663) suggested that as the gases escape from the flow, there is a "process of continued collapse". The collapsing ash flow creeps en masse before halting, perhaps at times totally obliterating relic pyroclastic texture even though remaining glassy.

Elston (1965) who has done extensive work in the ash flow volcanics of southwestern New Mexico, particularly in the Mogollon Plateau area, considered "flow-banded rhyolites" to be part of "intrusive-extrusive rhyolite complexes". He (Elston, 1965, p. 173) stated:

> "...dikes and elongated domal intrusive bodies of flow-banded rhyolite were emplaced at various times along major faults. Some of the intrusives broke through to the surface and formed lava flows and pumiceous tuffs. Because of their high viscosity, none of the flows spread more than a few miles, but around vents they may reach thicknesses of thousands of feet."

In more detail Elston continued:

> "In and around them, hydrothermal alteration is common.... Spherulites and lithophysae are common. Alternate flow bands tend to be light gray and pink or dark gray. Characteristically, the bands are intensely contorted.... The bottom of flows and the margin of intrusive bodies locally consist of perlite glass, which grades into a stony rock via a spherulitic zone."

Elston has found these flows close to vents and since vents are controlled by major faults, he considers them excellent guides to the regional geologic structure.

The opinion of the writer is that the laminar textured vitrophyres in the upper member of the Weatherby Canyon Ignimbrite were emplaced as lava. Three reasons tentatively support this opinion:

1. Perlitic glass found at the bottom of the member has no evidence of shards. If emplaced as an ash flow flattened shards should be visible in this section.

2. The total exposed thickness of the member is approximately 1,600 feet. A thickness of volcanic glass of that magnitude on top of a pyroclastic section is more reasonable, if it were emplaced as a lava, for then it would not necessitate the over-burden pressure to fuse it into a solid glass.

3. Rocks within this member very closely match the description given by Elston (1965), with the exception that rhyolite intrusives and source vents were not identified. It is not surprising that rhyolite intrusives or source vents were not found, since Basin and Range faulting has added considerable complexity to the regional structure of this area as compared to that of the Mogollon Plateau.

Animas Valley Basalt

A late Pleistocene or Recent basalt flow (Figure 19) covers much of Animas Valley in the area covered by this study. The flow begins about two miles south of the map area and extends northward down the valley for about twelve miles, with a maximum width of three and one-half miles just north of State Highway 9.

The rock is a vesicular olivine basalt. Olivine crystals account for 4 percent of the rock, and are rimmed with opaque reaction rims, presumably magnetite. Pyroxenes account for 14 to 18 percent, plagioclase 58 percent, and opaques 4 to 14 percent. Although the mineral composition is nearly uniform throughout the basalt, two distinct textural differences were noted.

North of State Highway 9 and on the west side of the flow the basalt is dark gray and very fine grained. All the plagioclase occurs in euhedral laths roughly 0.3 mm in size. Subhedral olivine crystals, which range from 0.5 to 2.0 mm, are the only grains larger than the plagioclase, and the pyroxene is pigeonite.

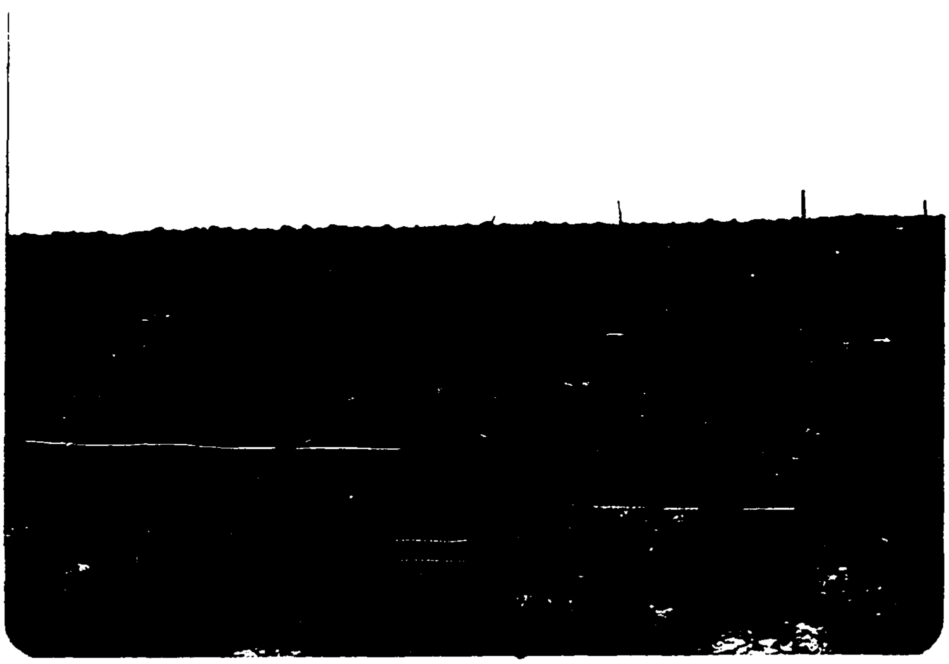

Figure 19. A view of the Animas Valley Basalt flow.

The other textural variation is found largely south of State Highway 9, and may represent a younger flow. This rock is light gray, very vesicular, with an abundance of large plagioclase laths visible in hand specimen. The random orientation of these plagioclase crystals results in many closely spaced, minute, angular cavities giving the rock a diktytaxitic texture. The olivine is similar to that described previously, but the pyroxene ranges up to 2.0 mm and is augite. Opaques are also more numerous composing 14 percent of the rock.

According to well log information gathered by Gillerman (1958, p. 77-78), part of the lava is now covered with valley alluvium, and although the thickness of the basalt is not uniform, about 60 feet of basalt was encountered in a well drilled in the SW¼ of Section 26, T 27S, R 20W (Plate I).

Alluvium

Quaternary alluvium, consisting of heterogeneous debris eroded from the mountains, forms bajadas on both sides of the range. This poorly sorted sediment spreads far out in both the Animas and San Simon Valleys, even overlying some of the Animas Valley basalt. A rough zonation of grain size exists, with the coarser particles nearer the mountains grading to finer material near the valley bottom. Lacustrine deposits found in both the Animas and San Simon Valleys are described by Schwennesen (1917, 1918).

Above the bajadas, arroyos and fingers of alluvium extend higher into the range, and in the low relief areas of Antelope Pass, alluvium is continuous across the range between the San Simon and Animas Valleys. The thickness of the alluvium is unknown. Well log information gathered by Gillerman (1958, p.77) indicated wells were still in alluvium after 500 feet in the Animas Valley and after 7,560 feet in the San Simon Valley.

Intrusives

Basalt Dikes

Two small exposures of basalt occur near the Phelps Dodge clay pit. One is in Section 32 and the other in Section 33 of T 27S, R 20W. Both outcrops are highly altered, but the exposure nearest the clay pit (in Section 33) is the most severely altered. In Section 32 a five foot wide dike crosses the bottom of a stream bed. In Section 33, the dimensions of the dike are not known, because the outcrop is poorly exposed among the rubble on the side of a low mound. It is thought to be a dike because of the limited outcrop and the compositional similarity and nearness to the known dike in Section 32.

The dike in Section 33 is grayish red. Phenocrysts account for 30 percent of the rock and are all calcite pseudomorphs of plagioclase, pyroxene, and olivine (?). Fine plagioclase laths, displaying trachytic texture, account for 60 percent and the opaques that make up the remaining 10 percent give the rock a red iron oxide color.

The dike in Section 32 is dark gray. Phenocrysts total 4 percent of the rock and are pseudomorphs of pyroxene and olivine. Replacement is by chlorite, serpentine, calcite, and chalcedony. Plagioclase laths account for 54 percent of the rock and exhibit a trachytic texture. Calcite is also found subophitic with respect to placioclase, and has probably replaced pyroxene. The replacement calcite accounts for 38 percent of the rock. Vein quartz accounts for the remaining 3 percent. Andesite clasts occur in the dike along the contact.

The age of the dikes is not known. In Section 32 the dike intrudes Unit Tl, incorporating some andesite clasts along the contact. In Section 33 the overlying unit is the Bobcat Hill Conglomerate, but the contact is not visible. From these field relationships and the high degree of alteration a conjectural age of early Tertiary is suggested.

Andesite Porphyries

Two irregular masses of andesite porphyry are located on the eastern side of the range north of State Highway 9. One outcrop is located in Section 1, T 27S, R 21W, and the largest part of the other is located in Section 7, T 27S, R 20W. The outcrops occur as low mounds at the base of larger hills.

The porphyries range in color from gray, grayish-red, to pale red-purple. They are holocrystalline, highly altered, contain 10 percent plagioclase phenocrysts, 1 to 3 percent amphibole pseudomorphs, and fine plagioclase laths in the matrix exhibit a trachytic texture where flow lines can be seen around the phenocrysts. A petrographic summary of the porphyries is given in Table 12 based on three thin sections.

Table 12

Petrographic summary of thin sections
from the Andesite Porphyries
(Based on 3 thin sections)

Composition	Volume (%) Range	Size (mm) Range	Character
Phenocrysts:			
Plagioclase	10	0.5-5.0	euhedral; cumulophyric; kaolinized.
Amphibole Pseudomorphs	1-3	0.5-2.0	voids; some replaced with serpentine, chlorite, clay minerals; opaque reaction rims; some cumulophyric.
Accessory & Secondary Minerals:			
Opaques	1-8	micro.-0.5	magnetite & hematite; exsolved out of mafics; forms reaction rims & fills some pseudomorphs.
Serpentine	tr.		alteration of amphiboles.
Quartz	0-tr.		vein quartz.
Matrix:	79-88	<0.5	¼ plagioclase laths, remainder to fine to resolve; trachytic texture.

Texturally the rocks could be classified either extrusive or intrusive. The small plagioclase laths flow around the larger plagioclase phenocrysts. The two sizes of plagioclase and the pseudomorphs of amphibole indicate that the temperature and pressure of the magma were changing rapidly as would be expected for both a lava and also for an intrusive which was injected as a small body close to the surface.

Clues to their intrusive nature are found at the contacts with adjoining rock units. The location and description of these contacts is as follows:

1. The largest body of andesite porphyry lies in the NW¼ of Section 12, T 27S, R 21W where it is in contact with Unit T4 on the west and north. In the gully on the west side of the andesite body the contact between the lower fluvial member of Unit T4 and the porphyry can be seen. The fluvial deposits are baked to a brown color adjacent to the contact. On the north side of the porphyry a small andesite porphyry dike intrudes the volcanic sandstone of the lower member of Unit T4. Here also the sandstone has a definite baked zone along the contact with the porphyry.

2. In the NW¼ of the SE¼ of Section 1, T 27S, R 21W, an andesite porphyry protrudes from the base of the hill. This outcrop appears to overlie the Pennsylvanian-Permian limestone, and, in turn, to be overlain by the Weatherby Canyon Ignimbrite. The contacts with both the limestone and the ignimbrite are not visible, but in the small saddle where the contact between the porphyry and ignimbrite must lie; the partially exposed ignimbrite is brecciated and ignimbrite float has an off-white altered appearance, presumably caused by the intruding andesite.

It should also be noted that rock fragments were not found as part of the porphyries, neither in hand specimen nor thin section. An extrusive is more likely to incorporate rock fragment during emplacement than an intrusive. Indeed, all extrusive rock units within the area mapped include some rock fragments.

The field evidence described above not only supports the intrusive nature of the andesite porphyries but it also indicates an age younger than the lower part of the middle member of the Weatherby Canyon Ignimbrite for at least one of the outcrops; and it is probable that both are the same age because of their compositional and textural similarities.

STRUCTURE

The discussion of the structure within the mapped area is aided by reference to Figure 20, which is a tectonic sketch map of the southwest New Mexico area.

In southwest New Mexico the dominant tectonic features are the result of the Laramide orogeny, Tertiary volcanism, and Basin and Range faulting. All Paleozoic strata within the study area was deposited in the Pedregosa Basin during Pennsylvanian and Permian time. Greenwood and others (1970) reported that no Triassic or Jurassic deposits are known from Hidalgo, Luma, and Grant Counties, New Mexico or from eastern Cochise County, Arizona; and that:

> "...southwest New Mexico appear to have been a low broad uplifted source of early and middle Mesozoic clastic rocks deposited to the north in central New Mexico and central Arizona."

During the early Cretaceous the area was on the north flank of the Mexican geosyncline and during the Cretaceous received both marine and terrestrial deposits as evidenced by the Hell-To-Finish and U-Bar Formations mapped by Zeller (1965) in the Big Hatchet Mountains. The north border of the Mexican Geosyncline is defined by the Deming Axis (Turner, 1962), which is a lineament running from Texas to Arizona and includes the Burro and Florida Uplifts in the southwest New Mexico area. Elston (1958) also recognized the Burro Uplift and the Florida Mountains as the northeastern limit of the Mexican Geosyncline.

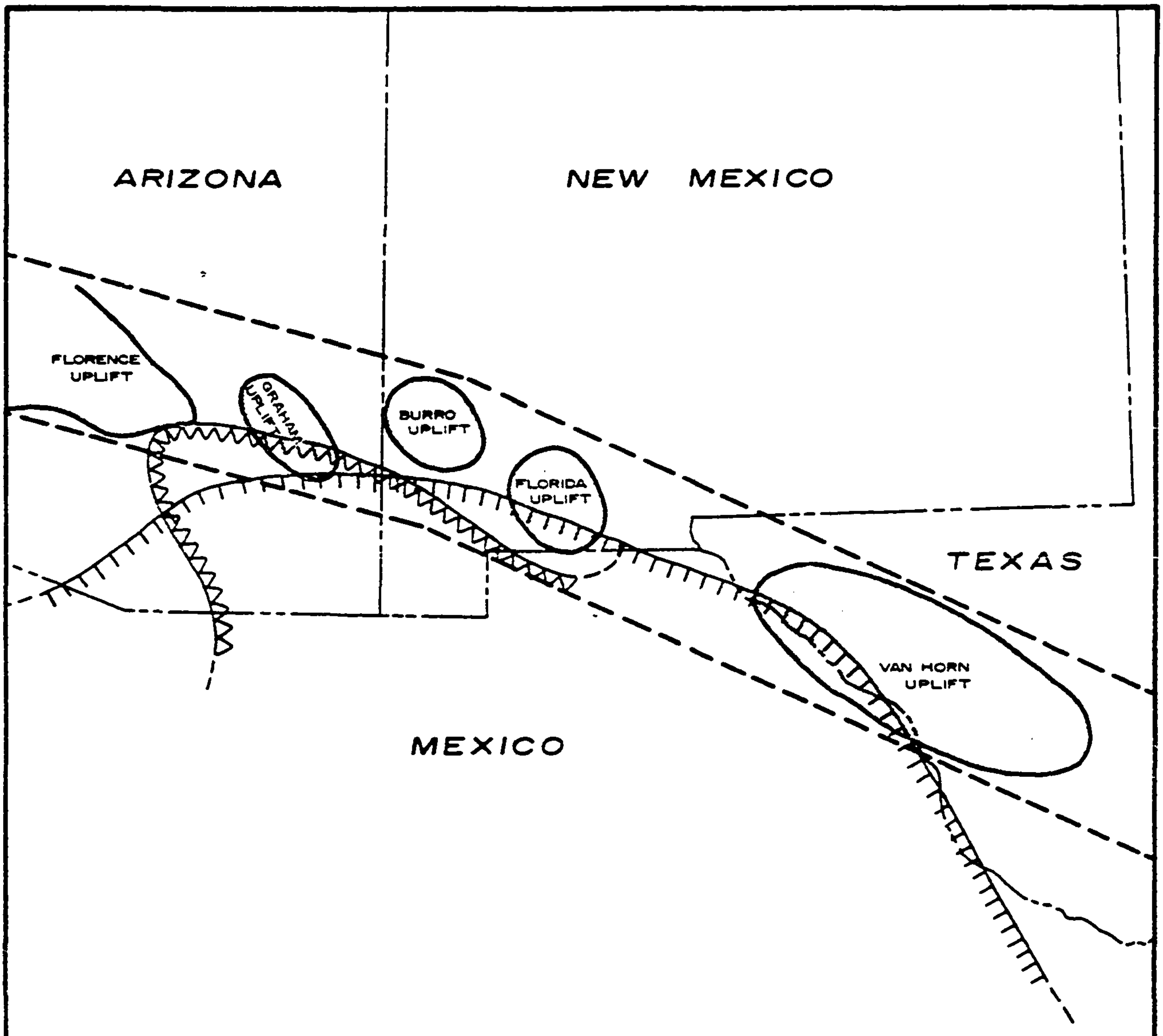

Figure 20

A REGIONAL SKETCH MAP OF SIGNIFICANT TECTONIC FEATURES

- LEGEND -

PEDROGOSA BASIN (PENNSYLVANIAN-PERMIAN)

MEXICAN GEOSYNCLINE (MESOZOIC)

DEMING AXIS

N

NO SCALE

MAP ADAPTED FROM TURNER (1962)

Evidence of pre-Laramide Mesozoic tectonism is not widespread in southwest New Mexico. Zeller and Alper (1965) reported that the Winkler Anticline in the Animas Range was the first recognized evidence of pre-Early Cretaceous deformation in southwest New Mexico. Perhaps some folding in the area coincided with the Nevadian Orogeny.

The Laramide Orogeny occurred from the Late Cretaceous to the Late Eocene (75 m.y.b.p. to 45 m.y.b.p., Elston, 1970) and during that time intense folding and northeast thrusting occurred in a belt south of and parallel to the Deming Axis. Discussion and reference to these Laramide structures can be found in papers by Wengerd (1970), Corbitt and Woodward (1970 & 1973), Trauger (1965), Turner (1962), and Elston (1970). After Laramide thrust faulting, volcano-tectonic structures developed concurrently with the extrusion of vast quantities of andesitic to rhyolitic volcanic rocks, and the emplacement of many of the "Laramide" mineralized porphyries. Basin and Range faulting accompanied by basaltic volcanism followed mainly during the time span of 20 m.y.b.p. to 6 m.y.b.p. (Elston and others, 1970). However, in some areas Basin and Range faulting is still active.

The Peloncillo Mountains, along with neighboring ranges both to the east and west, are typical Basin and Range fault block mountains, where the parallel ranges and valleys represent "horst and graben" structures. In the area mapped, Paleozoic and Cretaceous rocks are found along the east side of the horst block.

To the west are successively younger Tertiary volcanics presumably down faulted in a step-like series of normal faults some of which have not been located. Laramide structures within the pre-Tertiary rocks are not well defined, because many of the outcrops are small and poorly exposed, but with the information available some interesting hypotheses can be made.

In the quadrangle north of this map area Gillerman (1958) mapped the southern 3½ miles of the range as Weatherby Canyon Ignimbrite, with the ignimbrite overlying southwesterly dipping Pennsylvanian-Permian limestone. In the area of this study, all the Paleozoic and Cretaceous strata dip moderately to steeply to the south-southwest, with the exception of the outlying limestone hill in Sections 34 and 35, T 27S, R 20W. The reoccurrence of southwesterly dipping Pennsylvanian-Permian limestone north of the area of this study suggests repetition of beds by northeast thrust faulting and/or truncated folds overturned to the northeast. Normal faulting could also produce the structure, but is is considered an unlikely mechanism since the structure in question is Laramide.

The only pre-Tertiary formations identified in the area mapped are Horquilla Limestone and the Johnny Bull Sandstone. Whether other Permian and Lower to Middle Cretaceous rocks are also represented has not been determined. It is conceivable that some of the limestone mapped as Pennsylvanian-Permian could be Cretaceous, although sandy Cretaceous limestones described by Gillerman (1958) were not noted by the writer. Faulting and extensive covered intervals may explain the absence of these other formations. Another explanation for the absence of other Cretaceous formations is that the Antelope Pass area was a structural high on the shelf of the Mexican Geosyncline throughout the Early and Middle Cretaceous, and in the Late Cretaceous the Johnny Bull Sandstone was deposited in a near-shore environment.

In the quadrangle to the north, Gillerman (1958) did not report any thrust faults, and his interpretation of structure in the Paleozoic and Cretaceous rocks is primarily a broad northwest trending arch, broken parallel to the axial plane by high-angle faults. A.K. Armstrong has remapped the area and in a personal communication to Corbitt and Woodward (1973, p. 2214) he reported thrust faulting and "....many bedding plane faults with tectonic elimination and repetition of strata".

All faults shown on Plate I are normal and high-angle reverse faults and are part of the Basin and Range structure. The major fault trend is northwest paralleling the direction of the border faults which define the horst and graben blocks. A major northwest trending fault, downthrown on the west, is mapped cutting across the Weatherby Canyon Ignimbrite for about three miles. Similar northwest trending faults probably occur to the west, thereby exposing only the upper member of the Weatherby Canyon Ignimbrite in the outlying hills to the west.

East to northeast trending faults also are mapped. Many of these cross or intersect with the major northwest fault and represent minor movements and adjustments within the major rock masses.

All the high-angle faults discussed previously have been mapped in Unit T4 or younger units. A fault trace in contact with older rocks was found in Section 1, T 27S, R 21W and Section 7, T 27S, R 20W. Here an intensely brecciated low ridge of chert and fault mylonite is exposed. This fault trends northwest and the downthrown side is presumably to the west. On the west side of the fault the volcanic sediments of the lower member of Unit T4 are exposed. On the east side of the fault trace is the Pennsylvanian-Permian limestone and interbedded chert outcrops. A small outcrop of trachytic welded tuff also occurs east of the fault and has been mapped as Weatherby Canyon Ignimbrite.

Recent movement along the border fault on the east side of the range has left a small (4 to 10 foot) scarp in the alluvium and it is also visible where it crosses the Animas Valley Basalt (Plate I).

GEOLOGIC HISTORY AND SUMMARY

The early Paleozoic geologic history of the region is not well known. During early Paleozoic time (Cambrian through Devonian) the area was covered by shallow seas interrupted by several cycles of uplift and erosion. A strong uplift occurred in Late Devonian. During this time the Transcontinental Arch was raised across northern New Mexico and central Arizona, and in the area of this report a broad upwarped belt occurred along the area of the New Mexico-Arizona boundary (Turner, 1962).

During the Missippian, the Pedregosa Basin began to form. This basin covered most of Hidalgo County, New Mexico, Cochise County, Arizona, and extended southeast into Mexico, with the center of the basin about in southeastern-most Hidalgo County (Wengerd, 1970). During the Pennsylvanian and Permian, a thick, predominantly carbonate, section was deposited in the basin. The most widespread formation (and oldest within this study area) is the Horquilla Limestone, which was deposited in the basin throughout the Pennsylvanian and Early Permian. Younger carbonate formations, with interbedded siltstone and sandstone, complete the Permian section.

The absence of Triassic and Jurassic sediments in southwest New Mexico and Cochise County, Arizona, plus the widespread regional occurrence of the Glance conglomerate, and its homotaxial equivalents at the base of the Cretaceous section, indicate a post-Paleozoic period of uplift, deformation (?), and erosion. Turner (1962) concluded that the Deming Axis was a positive area throughout the Mesozoic. Sediments of Triassic and Jurassic age are found on either side of the Deming Axis; however, if these sediments were continuous over the axis they were eroded off during pre-Cretaceous uplift (Nevadian). During the Nevadian orogeny the Burro uplift occurred, and throughout the Early Cretaceous the Deming Axis formed the northern limit of the Mexican Geosyncline (Turner, 1962).

In the quadrangle north of the area mapped, Gillerman (1958) mapped four Cretaceous formations - McGhee Peak Formation, Carbonate Hill Limestone, Still Ridge Formation, and Johnny Bull Sandstone. The succession represented by the older three of these formations begins with alternating beds of conglomerate, shale, sandstone and limestone, which are succeeded by beds of sandy limestone, and capped by sandstone, limestone pebble conglomerate and interbedded volcanic rocks. This succession is overlain by the Johnny Bull Sandstone which is mainly a silica cemented sandstone or orthoquartzite, with some interbedded shale beds. According to Gillerman (1958, Table 1, p. 10), the Johnny Bull Sandstone is 1,047+ feet thick, and the maximum combined thickness of the lower three formations is 1,400+ feet.

In the area of this study, only the Johnny Bull Sandstone was found, and although contact relationships are not clear it appears that the sandstone was deposited directly on an eroded Pennsylvanian-Permian limestone surface. The deposition of older Cretaceous formations may have never occurred in the area of Antelope Pass. It was suggested earlier that this may reflect localized uplift of the Antelope Pass area contemporaneous with other nearby tectonic activity attributed to the Nevadian Orogeny, such as the Burro Uplift and the Winkler Anticline.

The Laramide Orogeny began in the Late Cretaceous and ended in the Early Tertiary. Its beginning marks the end of Cretaceous sedimentation within the study area. During the time span of this orogeny upwarping, folding, thrust faulting, volcanism and igneous intrusions have all occurred within southwest New Mexico. Within the area mapped all Laramide structures are found in rocks older than Unit T2, and it is probable that thrust faults and/or overturned folds account for the older structures found in Cretaceous and Paleozoic strata.

In the area mapped, the volcanic rocks can be divided into three unconformable groups. The oldest group is the andesite flows (Unit T1) and the Bobcat Hill Conglomerate. The andesite flows were deposited on an erosion surface that truncated deformed Cretaceous and Paleozoic strata. The Bobcat Hill Conglomerate is interbedded with the andesite flows indicating that volcanism was interrupted by periods of erosion and deposition of conglomerates and sandstones. The conglomerates and sandstones contain not only volcanic detritus but also quartz sands and limestone fragments derived from the older Cretaceous and Paleozoic strata. Thus either the andesite flows were not sufficiently extensive or thick enough to bury the moderate relief surface exposing the older sedimentary strata, or faulting contemporaneous with volcanism exposed the older rocks to erosion. It is probable that the andesite flows (Tl) and the interbedded conglomerates and sandstones of the Bobcat Hill Conglomerate accumulated during late stages of the Laramide Orogeny.

The second group of volcanic rocks consists of Unit T2 and Unit T3. Unit T2 is a fluvially deposited volcanic sequence which possibly includes some interbedded pumice flows. Unit T3, which conformably overlies Unit T2, is composed of a series of rhyolitic ash flows. The occurrence of these units within the area mapped is limited to the few, somewhat isolated hills within Antelope Pass. An undeterminable section of Unit T3 has been removed by erosion. Because the third and youngest group of volcanic rocks locally overlies Unit Tl and the Paleozoic limestone, it is probable that erosion removed much of the second volcanic group (Units T2 and T3) before the third was deposited. Since Antelope Pass seems to have been a structural high since pre-Cretaceous time, it is probable that early volcanics (Units Tl, T2 and T3) never did accumulate in great thickness over the area; however, tectonic-volcanic subsidence structures may have become active north and south of the Pass after the emplacement of Unit T3, so that down-faulted areas north and south of the Pass filled with the third group of volcanic rocks which now dominate the topography.

The third group of volcanic rocks consists of Unit T4 and the Weatherby Canyon Ignimbrite. Where the lower unconformable contact is exposed, the fluvial member of Unit T4 overlies Unit Tl and

Paleozoic limestone. The fluvial lower member of Unit T4 is succeeded by the pumice flows of the upper member and these in turn are overlain by the thick, extensive ash flows and lavas of the Weatherby Canyon Ignimbrite.

The present Basin and Range structure of the area is predated by the volcanism which produced the Weatherby Canyon Ignimbrite and older volcanic rocks. The topography which influenced the direction of flow, areal extent, and thickness of these ash flows and lavas must have been in part the result of both older Laramide structures and subsequent erosion, and the volcanic-tectonic structures which formed during the time of active volcanism. Volcanic-tectonic structures are calderas, ring dikes, vents, and all the assorted faults, subsidences, and localized flexures which are contemporaneous with or result from the extrusion and deposition of large quantities of volcanic material.

It is significant that the older Cretaceous and Paleozoic strata crop out only along the eastern side of the range and that the Weatherby Canyon Ignimbrite, the youngest Tertiary unit, occurs in contact with these older strata. The indication is that when the Weatherby Canyon Ignimbrite was extruded, the Paleozoic strata formed a topographic high along the east side of the flow. This may have resulted from faulting which occurred during the period of active volcanism, or from erosion of the older volcanic units before accumulation of Unit T4 and the Weatherby Canyon Ignimbrite.

Elston and others (1970) concluded from their work in the Mogollon Plateau volcanic province that at least three major eruptive cycles occurred, with K-Ar ages established at 29 to 38 m.y.b.p., 23 to 27.5 m.y.b.p.and 20.6 to 22.4 m.y.b.p. Elston and others (1973) concluded that mid-Tertiary volcanism ceased about 20 m.y. ago, coincident with the beginning of Basin and Range faulting.

To the writer's knowledge there are no known radiometric dates from rocks within the area mapped. Marjaniemi (1969) worked in the Chiricahua Mountains of southeast Arizona and attempted to correlate ash flow volcanic rocks found in the Chiricahuas with similar ash flows found in the Peloncillo Mountains. He obtained a K-Ar age of 26.3± 0.8 m.y.b.p. from a sample of the Weatherby Canyon Ignimbrite collected near "1117 Mountain", just north of the study area.

Elston and others (1970) place the main phase of Basin and Range faulting between 20 m.y. and 6 m.y. before present. During this time the Peloncillo Mountains were formed by normal faults which dropped the Animas and San Simon Valleys to form the horst and graben structure typical of the region. The border fault which defines the range on the east side may still be active. Recent movement along this fault is evidenced by a small but distinct scarp visible in the alluvium and Recent basalt flow.

During the Pleistocene, both the Animas and San Simon Valleys were occupied by lakes in response to the climatic change concurrent with continental glaciations (Schwennesen, 1917 & 1918).

In the late Pleistocene or Recent the Animas Valley Basalt flowed north down the Animas Valley. Continued transport of alluvium into the valley has covered fringes of the basalt flow along the western side of the valley.

MINERALIZATION

Hidalgo County is near the top among counties in New Mexico in production of non-radioactive metals. Most of this production is from the Lordsburg mining district which produced 94.1 percent of the county's total through 1958 (Elston, 1965). The San Simon mining district is second in production with 3.2 percent of the County's total production. The San Simon district is located in the Peloncillo Mountains north of the study area, and was described by Gillerman (1958). Mines in this district produced silver, gold, lead, zinc, copper and tungsten worth $1,442,000 through 1958 (Elston, 1965).

Within the area mapped, there are numerous small prospect pits, a few of which produced a little manganese ore from World War II to the early 1950's as reported by a local rancher. Phelps Dodge Corporation owns and periodically extracts fire clay from a pit in Section 32, T 27S, R 20W. This fire clay deposit is included in the Animas mining district as described by Elston (1965).

According to Elston (1965) three periods of mineralization can be recognized in Hidalgo County. The first is associated with Laramide tectonism and is most important commercially. During this period high-temperature base-metal veins and contact metasomatic deposits formed around porphyritic intrusive bodies. The second period occurred in the middle Tertiary during which low-temperature gold, silver, and lead-bearing veins were emplaced in volcanic rocks and their fine-grained intrusive equivalents. In the Late

Tertiary to Quaternary, the third period of mineralization produced low-temperature psilomelane and fluorite veins.

Within the area mapped, alteration and mineralization has affected in varying degrees all the rock units older than the Animas Valley Basalt. Rubble from old prospect pits seldom show anything other than vein quartz, but psilomelane was found in the tailings from a couple of pits, and black calcite associated with fluorite was found in another.

The Johnny Bull Sandstone shows textural signs of deformation. Thin sections from the steeply dipping beds showed metamorphic rock fragments squeezed and contorted between quartz grains. These fabric features probably resulted from Laramide tectonic activity.

The degree of alteration within the volcanic rocks is variable. Unit Tl is highly altered, especially north of Highway 9 in Section 19, T 27S, R 20W and Section 24, T 27S, R21W. Here original minerals and textures have been completely destroyed by silicification and hydrothermal (?) alteration of the rock. All of the intrusive rocks are also highly altered, with many of the phenocrysts replaced, or visible only as pseudomorphic voids of the original mineral. It is probable that the alteration experienced by Unit Tl and the intrusive dikes coincide with Laramide activity and the high-temperature mineralization that occurred during that period.

The other periods of mineralization had a less pronounced effect. Localized alteration zones occur throughout the Tertiary volcanic section, mainly as bleached zones with phenocrysts partially or totally altered to clay.

Many of the prospect pits are in the Paleozoic limestone, and associated chert beds. Some are also in the Cretaceous sandstone. The Phelps Dodge fire clay pit is excavated in a low mound of clay and andesite-rich sandstone which has been mapped as Bobcat Hill Conglomerate. All of the ore extracted from the area mapped, was probably emplaced during the Late Tertiary period of low-temperature mineralization, with the exception of the fire-clay which is a high-temperature alteration product formed from the andesite and volcanic sediment in the Bobcat Hill Conglomerate. This alteration probably coincides with Laramide tectonism and mineralization.

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APPENDIX I

THIN SECTION DESCRIPTIONS

Johnny Bull Sandstone

Sample #216
Fine sand, silica cemented, mature, quartzarenite.
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Quartz	90	0.1-0.2	subangular to sub-rounded; abraded overgrowths; composite-quartz.
Metamorphic Rock Fragments	tr.	0.1-0.2	subrounded; foliated.
Chert	tr.	0.1-0.2	subrounded.
Zircon	tr.		
Muscovite	tr.		
Chalcedony	10	micro.	cement.

* * *

Sample # 115
Fine sand, silica and calcite cemented, supermature, quartzarenite.
Color: Pale red (10R6/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	95	0.1-0.2	rounded to well-rounded; composite grains; overgrowths.
Chert	1	0.1-0.2	well-rounded.
Metamorphic Rock Fragments	tr.	0.1-0.2	rounded; foliated; micaceous.
Apatite	tr.	0.1-0.2	pale green.
Zircon	tr.		

Sample # 115 Continued on Next Page

Sample # 115 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Calcite	4	micro.	interstitial; secondary; cement.
Hematite staining	tr.		authigenic

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Sample # 173
Fine-medium sand, silica & calcite cemented, supermature, quartz-arenite.
Color: Very light gray (N8)

Composition	Volume (%)	Size (mm)	Character
Quartz	95	0.2-0.4	rounded to well-rounded; overgrowths; composite-grains.
Metamorphic Rock Fragments	4	0.2-0.4	rounded; sericitic.
Chert	1	0.1-0.2	rounded.
Zircon	tr.		
Calcite	tr.	micro.	Secondary; interstitial; cement.

Comments: Rock appears slightly metamorphosed. The quartz grains have crenulated boundaries in places and the metamorphic rock fragments are squeezed and contorted between the quartz grains.

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Sample # 128
Fine sand, silica cemented, immature, sublitharenite.
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Quartz	90	0.1-0.2	rounded to well-rounded; overgrowths; composite grains.
Chert	2	0.1-0.2	well-rounded.
Metamorphic Rock Fragments	2	0.1-0.2	foliated; sericitic.
Clay & Silt	6		stringers parallel to bedding.
Zircon	tr.		
Hematite	tr.		fracture filling; stains.
Muscovite	tr.		

Comments: Specimen has a textural inversion; the well-rounded and well sorted quartz, chert, and metamorphic rock fragments are interbedded with stringers of clay. Is an indication of a changing depositional environment.

*   *   *

Unit T1

Sample # 161B
Quartz Latite
Color: Pale red (5R6/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	11	< 0.5-2.0	subhedral; fractured; resorbed.
Sanidine	5	< 0.5-2.0	subhedral; fractured; resorbed.
Plagioclase	7	< 0.5-2.0	subhedral; fractured; zoned.
Biotite	tr.	1.0	brown.
Accessories:			
Opaques	tr.	0.1	magnetite & hematite.
Axiolites	8	7.0	devitrified flatten pumice.
Volcanic Rock Fragments	tr.	1.0	andesite fragments (?).
Matrix:	69	micro.	Devitrification products & glass. Glassy patches are partially isotropic.

Comment: Rock is a vitrophyre that is almost totally devitrified. Sample has good eutaxitic texture.

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Sample # 179B
Andesite
Color: Medium light gray (N6)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase pseudomorph	5	0.2-1.0	replaced by sericite and calcite.
Pyroxene (?) pseudomorph	tr.	0.5	replaced by calcite and opaques.
Accessories:			
Biotite	tr.	0.1	partially resorbed.
Opaques	1	< 0.1	finely disseminated.
Sericite			pseudomorphic after plagioclase.
Calcite			pseudomorphic after plagioclase and pyroxene.
Quartz	3	0.5	vein filling.
Matrix:	81	micro.	clay & chalcedony.

Comment: Rock was hydrothermally altered leaving only relics of the primary minerals.

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Sample # 162
Andesite
Color: Grayish red (5R4/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	15	0.5	highly altered; zoned.

Sample # 162 Continued on Next Page

Sample # 162 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Biotite	tr.	0.1	highly altered.
Pyroxene (?) pseudomorph	tr.	1.0	replaced with calcite.
Accessories:			
Opaques	1	< 0.1	finely disseminated magnetite and hematite.
Quartz	1	< 0.1-0.5	vein filling.
Calcite	tr.		pseudomorphic after pyroxene.
Matrix:	83	micro.	clay & chalcedony.

Comment: Rock has been hydrothermally silicified resulting in resorbtion and alteration of most of the primary minerals.

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Sample # 97
(Too altered to classify)
Color: Very light gray (N8)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	7	< 0.5-2.0	subhedral; fractured; resorbed.
Textural Features:			
White clay clasts	25	0.5-8.0	clay is probably an alteration of pumice fragments and feldspar.

Sample # 97 Continued on Next Page

Sample # 97 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Matrix:	68	micro.	clay & chalcedony; no relics of primary minerals.

Comment: The quartz is the only recognizable primary mineral. The rock is very hard presumably from hydrothermal silicification. The unflatten white clasts and the lack of any eutaxitic texture indicate this rock was probably an unwelded tuff.

* * *

Sample # 109
(Too altered to classify)
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	5	1.0	anhedral; resorbed; overgrowths (?).
Secondary Minerals:			
Hematite	tr.		fracture filling.
Matrix:	95	micro.	chalcedony and a small percentage of clay minerals.

Comment: This sample has been completely silicified by hydrothermal activity, replacing almost completely the entire rock. The quartz, with questionable overgrowths, might be from the Johnny Bull sandstone. Brecciation is evident in the hand specimen.

* * *

Sample # 85
Quartz Latite
Color: Very light gray (N8)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	3	<0.5-2.0	subhedral; resorbed.
Sanidine	4	<0.5-2.0	euhedral; resorbed.
Plagioclase	4	<0.5-2.0	subhedral; zoned.
Biotite	tr.	0.5-1.0	red-brown.
Accessories:			
Opaques	1		rims around sperulite clusters.
Spherulites	11	2.0-3.0	clusters; partially filled with calcite.
Matrix:	77	micro.	devitrification products; relic shards.

Comment: Devitrification has obscured any welding, but based on the slightly flattened spherulite clusters this rock could have been slightly welded. The contact with the overlying lower member of Unit T4 can be seen on this thin section. In this thin section, the overlying unit is a medium-coarse, silica cemented, immature, volcanic lithic arkose, and the composition is described below:

Quartz	20	0.3-1.0	angular.
Sanidine	20	0.3-1.0	angular.
Plagioclase	5	0.3-1.0	angular.
Opaques	15	0.1	hematite & magnetite; interstitial.
Volcanic Rock Fragments	15	0.3-1.0	spherulite & andesite fragments.
Matrix	15	micro.	clay & chalcedony.

* * *

Sample # 192
Andesite
Color: Light brownish gray (5YR6/1)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	19	0.5-3.0	euhedral; zoned; selective corrosion of zones.
Biotite	2	0.5-1.0	euhedral; red-brown.
Accessories:			
Opaques	1	0.1	magnetite & hematite; finely disseminated; exsolved out of biotite; filling amphibole pseudomorphs.
Matrix:	78	micro.	clay, chalcedony, and microlites of plagioclase (?).

Comment: Subtrachytic texture shown by the microlites. Devitrification and hydrothermal activity obscure any evidence of pumice or shards. In hand specimen a flow texture is evident. This specimen could be from a lava or ash flow.

* * *

Sample # 160
Andesite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	26	< 0.5-4.0	euhedral; zoned; resorbed; fractured; selective corrosion of zones.

Sample # 160 Continued on Next Page

Sample # 160 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Biotite	7	1.0	euhedral; greenish-red-brown.
Amphibole pseudomorph	tr.	1.0	replaced with serpentine.
Accessories:			
Opaques	1	< 0.5	exsolution from biotite.
Zircon	tr.	0.1	euhedral, found with opaques.
Serpentine	tr.		replacement in amphibole pseudomorphs.
Matrix:	66	micro.	clay and chalcedony.

* * *

Sample # 170
Andesite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	23	< 0.5-3.0	euhedral; fractured; zoned; selective corrosion of zones.
Biotite	4	1.0	enhedral; greenish-red-brown.
Accessories:			
Zircon	tr.	0.1	euhedral
Opaques	1	0.5	exsolved from biotite and pseudomorphic after amphibole (?).

Sample # 170 Continued on Next Page

Sample # 170 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Spherulites	62	0.5-2.0	
Matrix:	10	micro.	devitrification products, chalcedony, and vein quartz.

Comment: Specimen is a devitrified vitrophyre. Hydrothermal activity promoted the spherulite development and the secondary crystallization of the quartz and chalcedony.

* * *

Bobcat Hill Conglomerate

Sample # 198C
Medium sand, silica & calcite cemented, submature, sublitharenite.
Color: Pinkish gray (5YR8/1)

Composition	Volume (%)	Size (mm)	Character
Quartz	80	0.2-0.4	subangular to sub-rounded; abraded overgrowths.
Chert	5	0.2-0.4	sub-rounded.
Volcanic Rock Fragments	5	0.2-0.4	sub-rounded.
Plagioclase	1	0.2-0.4	sub-rounded.
Chalcedony	4	micro.	cement.
Calcite	5	micro.	cement.
Chlorite	tr.		
Muscovite	tr.		

* * *

Sample # 199B
Conglomerate
Color: Grayish red (10R4/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	3	0.5-1.0	angular to rounded.
Limestone Fragments	30	<0.5-15.0	sub-rounded; brachiopods; fusulinids.
Volcanic Rock Fragments	30	<0.5-4.0	rounded; trachytic andesite fragments.

Sample # 199B Continued on Next Page

Sample # 199B Cont'd.

Composition	Volume (%)	Size (mm)	Character
Sedimentary Rock Fragments	1	4.0	dirty volcanic sandstone.
Plagioclase	tr.		
Calcite & Clay	36		interstitial; secondary; fragments of sparite.

Comments: Fusulinids in limestone identify it as probably from the nearby Horquilla formation.

* * *

Sample # 207B
Conglomerate
Color: Light olive gray (5Y5/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	10	< 0.5-8.0	angular; both single grains & composite grains with undulatory extinction.
Perthite	10	< 0.5-20.0	angular; pink in hand specimen.
Volcanic Rock Fragments	15	< 0.5-5.0	fine-grained matrix with fine trachytic plagioclase laths.
Limestone Fragments	5	1.0-40.0	sub-rounded; fusulinids; brachiopods.
Calcite	53	0.5	secondary; interstitial; some are fragments of sparite.
Microcline	5	< 0.5-20.0	angular.

Sample # 207B Continued on Next Page

Sample # 207B Cont'd.

Composition	Volume (%)	Size (mm)	Character
Plagioclase	1	< 0.5	angular
Zircon	tr.		concentrated together.
Apatite	tr.		
Hematite	tr.		
Chlorite	tr.		

* * *

Sample # 165
Fine-medium sand, calcite cemented, immature, chert-rich, volcanic arenite.
Color: Light olive gray (5Y5/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	22	0.2-0.4	sub-rounded to rounded; abraded overgrowths; 2% volcanic quartz.
Chert	19	0.2-0.4	sub-rounded to rounded; some may be fine-grained Volcanic Rock Fragements.
Volcanic Rock Fragments	20	0.2-0.4	sub-rounded to rounded; andesite fragments; spheruiite fragments.
Metamorphic Rock Fragments	2	0.2-0.4	quartzite fragments; fine-grained foliated fragments.
Plagioclase	1	0.2-0.4	subangular.
Zircon	tr.		
Microcline	tr.		

Sample # 165 Continued on Next Page

Sample # 165 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Argillaceous calcite	36	micro.	cement.

Comments: Most of the quartz is derived from the Johnny Bull sandstone. The chert could have come from the replacement chert associated with the nearby limestone.

* * *

Sample # 167
Andesite conglomerate
Color: Dark greenish gray (5GY4/1)

Composition	Volume (%)	Size (mm)	Character
Andesite Fragments	99	0.5-10.0	rounded & subangular; plagioclase phenocrysts; chlorite replaced px. pseudomorphs.
Opaques	1		magnetite & hematite; authigenic.

* * *

Unit T2

Sample # 176
(Questionable whether igneous or sedimentary).
Color: Pale greenish yellow (10Y8/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	28	< 0.5-5.0	subhedral; angular; fractured; resorbed.
Sanidine	10	< 0.5-5.0	subhedral; angular; fractured; resorbed.
Plagioclase	25	< 0.5-5.0	subhedral; angular; fractured; zoned, resorbed.
Biotite	2	< 0.5	euhedral
Sphene	tr.	0.1	euhedral
Volcanic Rock Fragment	tr.	2.0 cm	(in hand specimen) fine-grained, red.
<u>Matrix</u>:	35	micro.	clay, soft.

<u>Comment</u>: No relics can be seen in the matrix. Bedding in the lower part of this unit indicates this rock is sedimentary. From the thin section alone it could be a crystal-rich tuff.

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Unit T3

S·mple # 187
Rhyolite
Color: Light brownish gray (5YR6/1)

Composition	Volume (%)	Size (mm)	Character
<u>Phenocrysts</u>:			
Quartz	6	< 0.5-2.0	anhedral-subhedral; embayed; fractured.
Sanidine	10	< 0.5-2.5	anhedral-subhedral; carlsbad twinning; resorbed.
Plagioclase	4	< 0.5-1.0	anhedral; zoned; fractured.
Biotite	1	0.5	brown.
<u>Accessories</u>:			
Opaques	tr.	0.1	hematite.
Volcanic Rock Fragments	6	1.0-3.0	fine-grained with plagioclase laths and opaques; fragments of volcanic sediment similar to Unit T2.
<u>Matrix</u>:	73	micro.	devitrification products; relic shards; relic flattened pumice up to 3.0 cm. long.

<u>Comment</u>: Rock has a eutaxitic texture; is a welded tuff.

* * *

Sample # 190
Rhyolite
Color: Black (N1) with brown spots

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	12	0.5-2.0	anhedral-subhedral; embayed; fractured.
Sanidine	16	0.5-2.0	anhedral-subhedral; fractured.
Plagioclase	8	<0.5-1.0	anhedral-subhedral; fractured; zoned.
Biotite	tr.	<0.5-1.0	brown & greenish.
Oxyhorn-blende	tr.	0.8	euhedral-anhedral.
Augite (?)	tr.	0.8	anhedral.
Accessories:			
Sphene	tr.	0.3	anhedral.
Volcanic Rock Fragments	2	1.0-8.0	fine grained andesite fragments.
Opaques	tr.	0.1	concentrated around Volcanic Rock Fragments.
Matrix:	62		glass; eutaxitic, relic shards; relic pumice fragments; slight devit-rification.

Comment: Rock is so highly welded it is perlitic.

* * *

Sample # 182
Rhyolite
Color: White (N9)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	12	< 0.5-1.0	anhedral-subhedral; embayed; fractured.
Sanidine	8	< 0.5-1.0	anhedral-subhedral; carlsbad twinning; selective corrosion of albite (?) lamellae.
Matrix:	80	micro.	devitrification products; relic shards; and flattened pumice fragments.

Comment: The pumice fragments are very porous with voids weathered into many of the fragments. Rock has a eutaxitic texture. The unique bleached white color, corroded sanidine and weathered pumice fragments indicate the rock has experienced some hydrothermal (?) alteration.

* * *

Sample # 180
Rhyolite
Color: Grayish pink (5R8/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	10	< 0.5-2.0	anhedral-subhedral; embayed; fractured.
Sanidine	12	< 0.5-1.0	anhedral-subhedral; carlsbad twinning; selective corrosion of albite (?) lamellae.

Sample # 180 Continued on Next Page

Sample # 180 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Plagioclase	1	< 0.5-1.0	anhedral.
Biotite	tr.	< 0.5	
Accessories:			
Opaques	tr.	0.1	
Volcanic Rock Fragments	1	2.0	fine-grained; rich in feldspar laths and opaques.
Matrix:	76	micro.	devitrification products; relic flattened pumice fragments and shards; some spherulites.

*   *   *

Sample # 177
Rhyolite
Color: Grayish red (10R4/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	8	0.5-2.0	anhedral-subhedral; fractured; selective corrosion of albite (?) lamellae.
Quartz	8	0.5-2.0	anhedral-subhedral; fractured; embayed.
Biotite	tr.	< 0.5	red-brown.

Sample # 177 Continued on Next Page

Sample # 177 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Accessories:			
Opaques	tr.	0.1	hematite; finely disseminated.
Volcanic Rock Fragments	tr.	2.0-7.0	fine-grained; reddish.
Spherulites	30		found in elongated fiamme-like features.
Matrix:	54	micro.	devitrification products.

* * *

Sample # 157B
Rhyolite
Color: Pale red (10R6/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	7	0.5-2.0	anhedral-euhedral; fractured; embayed.
Sanidine	9	0.5-2.0	anhedral-subhedral; selective corrosion of albite (?) lamellae.
Plagioclase	4	0.5-1.0	anhedral-subhedral; fractured.
Biotite	tr.	< 0.5	brown.
Accessories:			
Zircon	tr.	0.2	

Sample # 157B Continued on Next Page

Sample # 157B Cont'd.

Composition	Volume (%)	Size (mm)	Character
Opaques	tr.	0.1	hematite.
Volcanic Rock Fragments	25	0.5-10	flattened pumice fragments with spherulites.
Matrix:	55	micro.	devitrification products; relic shards.

Comment: Good eutaxitic texture.

* * *

Unit T4

Lower Member

Sample # 83
Rhyolite
Color: Varigated pale red (10R6/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	16	0.2-1.0	anhedral; fractured; resorbed.
Sanidine	8	0.2-1.0	subhedral; fractured.
Plagioclase	3	0.2-1.0	anhedral.
Biotite	3	0.5	light brown.
Accessories:			
Opaque	tr.	< 0.1	magnetite & hematite; concentrated in porous clasts and finely disseminated.
Volcanic Rock Fragments	10	1.0	devitrified texture; shard relics; spherulite fragments; epiclastic rock fragments.
Matrix:	60	micro.	Devitrification products; chalcedony & clay; relic shards and flow lines around phenocrysts.

Comment: This sample is from a thin welded tuff. The epiclastic volcanic rock fragments are from the same Lower Member.

* * *

Sample # 68
Clayey, fine sand, SiO_2 cemented, immature, volcanic litharenite.
Color: Grayish orange pink (5YR7/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	9	0.1-0.2	angular-rounded; abraded overgrowths.
Plagioclase	6	0.1-0.2	sub-rounded; zoned.
Sanidine	3	0.1-0.2	angular.
Biotite	1	0.1-0.2	highly altered; red-brown & brown.
Opaques	1		hematite; exsolved from biotite.
Volcanic Rock Fragments.	38	0.1-0.2	sub-rounded; fine-grained; some sericitic.
Matrix:	42	micro.	clay, sericite & chalcedony.

Comment: The source rocks are the Johnny Bull sandstone and the underlying volcanics.

* * *

Sample # 4B
Very fine sand, SiO_2 cemented, immature, volcanic lithicarkose.
Color: Grayish red (5R4/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	9	< 0.1	subangular to well-rounded; abraded overgrowths.
Plagioclase	30	< 0.1	rounded; sericitized.
Opaques	1	< 0.1	magnetite & hematite.

Sample # 4B Continued on Next Page

Sample # 4B Cont'd.

Composition	Volume (%)	Size (mm)	Character
Volcanic Rock Fragments	17	0.1-0.5	fine-grain devitrified texture; andesite fragments.
Matrix:	43	micro.	clay, sericite, calcite & chalcedony.

Comment: The source is from both the Johnny Bull sandstone and the underlying volcanics.

* * *

Sample # 11
Fine sand with some granules, silica cemented, immature, volcanic, feldspathic litharenite.
Color: Grayish red (5R4/2)

Composition	Volume (%)	Size (mm)	Character
Quartz	3	0.2-2.0	angular.
Plagioclase	22	0.2-2.0	angular; zoned.
Opaques	8	< 0.1	magnetite & hematite.
Volcanic Rock Fragments	28	0.2-10	devitrified; perlitic; red; flow texture; andesite fragments.
Biotite	tr.	< 0.1	red-brown.
Zircon	tr.		
Matrix:	39	micro.	sericite, chalcedony, and hematite.

Comment: The principle source for this sample is the andesite flows of Unit T1. Much of the matrix is devitrified shards and pumice fragments.

* * *

Upper Member

Sample # 7
Lithic Tuff (Lahar?)
Color: Grayish yellow green (5GY7/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	2	2.0	anhedral.
Biotite	tr.	< 0.3	
Accessories:			
Volcanic Rock Fragments	20	0.2-5.0	fine grained; devitrified; spherulite fragments; plagioclase phenocrysts; brown & brownish-red.
Matrix:	78	micro.	Relic pumice balls; devitrification products.

* * *

Sample # 10
Rhyodacite
Color: Very pale orange (10YR8/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	2	< 0.5-1.0	anhedral-subhedral; fractured; embayed.
Sanidine	3	< 0.5-1.0	anhedral-subhedral; fractured.
Plagioclase	7	< 0.5-1.0	anhedral-subhedral; fractured; zoned.
Biotite	tr.	< 0.5	red & brown.

Sample # 10 Continued on Next Page

Sample # 10 Cont'd.

Composition	Volume (%)	Size (mm)	Character
<u>Accessories</u>:			
Zircon	tr.	0.2	
Volcanic Rock Fragments	25	0.5-8.0	red & gray; plagioclase phenocrysts; spherulite fragments; biotite.
Matrix:	63	micro.	totally altered to clay; relic pumice balls.

<u>Comment</u>: This specimen is representative of a series of individual pumice flows which vary in thickness from 3 to 30 feet and have a weathered profile that defines the individual flows. In some flows volcanic rock fragments are 25% of the volume and the clasts are 3 inches in size.

* * *

Sample # 93
Accretionary Ash (?)
Color: Grayish yellow (5Y8/4)

Composition	Volume (%)	Size (mm)	Character
<u>Phenocrysts</u>:			
Sanidine	1	0.2-1.0	subhedral.
Plagioclase	tr.	0.2-1.0	anhedral.
<u>Accessories</u>:			
Volcanic Rock Fragments	12	0.2-1.0	fine grained; gray.
<u>Matrix</u>:	87	micro.	clay; totally devitrified ash & pumice fragments.

Sample # 93 Continued on Next Page

Sample # 93 Cont'd.

Comment: In hand specimen, clayey spheres about 2 mm. in diameter stand out in relief on the weathered surface. Although the size of the spheres are less than 4 mm. it is suggested that the rock formed by the same mechanism as accretionary lapilli.

*   *   *

Weatherby Canyon Ignimbrite

Basal Member

Sample # 90
Rhyolite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	6	< 0.5-1.0	anhedral-euhedral; resorbed; fractured.
Quartz	1	< 0.5-1.0	anhedral; resorbed; fractured.
Biotite	tr.	< 0.5	red-brown.
Accessories:			
Opaques	1	0.1	finely disseminated.
Zircon	tr.	0.2	inclusions in quartz.
Volcanic Rock Fragments	5	< 0.5-10.0	reddish-gray; fine grained.
Pumice	50	< 0.5-20.0	flattened; devitrified into spherulites.
Matrix:	37	micro.	devitrification products; relic shards.

Comment: Good eutaxitic texture; a partially welded tuff.

* * *

Sample # 234
Trachyte
Color: Very light gray (N8)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	4	0.5-1.0	anhedral-subhedral; selective alteration of laminae.
Biotite	tr.	< 0.5	
Accessories:			
Zircon	tr.	0.2	
Volcanic Rock Fragments	20	0.5-20.0	light gray & pale yellow; relic spherulites; concentrations of opaques.
Matrix:	76	micro.	highly devitrified; relic unflattened shards.

Comment: Most of the volcanic rock fragments probably came from the underlying pumice flows of the Upper Member of Unit T4. The unflattened shards indicate little welding occurred.

* * *

Middle Member

Sample # 25
Trachyte
Color: Pale red (10R6/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	8	0.5-2.0	subhedral-euhedral; selective alteration of albite (?) lamellae.
Biotite	tr.	< 0.5	red-brown.

Sample # 25 Continued on Next Page

Sample # 25 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Accessories:			
Zircon	tr.	0.2	
Apatite	tr.	0.2	
Opaques	tr.	0.2	hematite.
Volcanic Rock Fragments	5	0.5-20.0	very fine grained; pale red.
Pumice	25	0.5-5.0	flattened; devitrified.
Matrix:	62	micro.	Devitrified iron-stained shards; good eutaxitic textures; densely welded.

* * *

Sample # 1B
Rhyolite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	4	1.0	anhedral-euhedral; resorbed.
Sanidine	3	1.0-2.0	subhedral-euhedral; kaolinized.
Biotite	tr.	<0.5	red-brown.
Accessories:			
Pumice	15	1.0-40.0	devitrified to spherulites surrounded by drusy crystals which are probably tridymite and alkalic feldspar.

Sample # 1B Continued on Next Page

Sample # 1B Cont'd.

Composition	Volume (%)	Size (mm)	Character
Matrix:	78	micro.	partially devitrified; unflattened shards.

Comment: The unflattened shards indicate rock is non-welded. The spherulites in the pumice are in the advance stages of devitrification. The specimen is nearly holocrystalline.

* * *

Sample # 58
Rhyolite
Color: Pale red (5R6/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	3	1.0	subhedral.
Sanidine	3	1.0	subhedral.
Accessories:			
Zircon	tr.	0.2	inclusions in sanidine.
Opaques	tr.	0.5	hematite and/or magnetite.
Matrix:	94		Spherulites & axiolites; occur in bands approx. 0.5 mm. wide; brown in plain light. Probable minerals are tridymite, cristobalite, and alkali feldspar.

Comment: Rock is highly devitrified. It could have been emplaced as a glassy lava or a densely welded tuff.

Sample # 140B
Rhyolite
Color: Pinkish grayish (5YR8/1)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	2	< 0.5-1.0	anhedral-subhedral; embayed; fractured.
Sanidine	4	< 0.5-1.0	anhedral; carlsbad twinning; biotite inclusions.
Accessories:			
Volcanic Rock Fragments	4	1.0-5.0	fine-grained; spherulites; feldspar laths & opaques.
Pumice	50	0.5-6.0	unflattened; devitrified; outlines of vesicles and shards preserved.
Matrix:	40		devitrification products; no textural features.

Comment: Rock was not welded, but secondary hydrothermal silicification has made it very hard.

* * *

Sample # 147
Rhyolite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	12	0.5-2.0	euhedral-subhedral; fractured.
Quartz	4	0.5-2.0	euhedral-subhedral; resorbed.

Sample # 147 Continued on Next Page

Sample # 147 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Plagioclase	4	0.5-2.0	subhedral; fractured.
Biotite	tr.	< 0.5	
Pyroxene (?)	tr.	0.2	Opaque reaction rims; exsolution laminae; probably augite and pigeonite.
Accessories:			
Zircon	tr.	0.2	biotite inclusions.
Opaques	tr.	< 0.5	exsolution from biotite.
Matrix:	80		Highly devitrified; spherulites scattered throughout; miarolitic cavities with quartz, tridymite (?), and alkali feldspar.

Comment: Hand specimen has eutaxitic texture. Rock was partially to densely welded with trapped gases forming the miarolitic cavities.

* * *

Sample # 137
Rhyolite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	6	0.5-2.0	anhedral; resorbed; chatoyant.
Quartz	2	0.5-2.0	anhedral.
Biotite	tr.	0.5	anhedral; red-brown.

Sample # 137 Continued on Next Page

Sample # 137 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Accessories:			
Volcanic Rock Fragments	tr.	8.0	fragments with sanidine, calcite, and spherulites.
Matrix:	92		Fifty per cent is still glass, the rest is crystalline. Unflattened shards visible.

Comment: Very good shard preservation. Rock was never welded.

* * *

Upper Membe·

Sample # 148
Rhyolite
Color: Medium light gray (N6)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	2	1.0	anhedral.
Sanidine	2	1.0	anhedral.
Pyroxene (?)	tr.	< 0.5	altered; reaction rims.
Accessories:			
Opaques	1	< 0.2	hematite.
Zircon	tr.	0.2	
Matrix:	95		Highly devitrified 0.4 mm. wide laminations with spherulites and axiolites arranged in parallel bands. Between the laminations are secondary quartz crystals and lath-shaped crystals, probably tridymite.

* * *

Sample # 139C
Rhyolite
Color: Brownish gray (5YR4/1)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	3	1.0	subhedral.
Quartz	1	1.0	anhedral.
Plagioclase (?)	1	1.0	anhedral; untwinned.
Pyroxene	tr.	< 0.5	euhedral-subhedral.
Accessories:			
Zircon	tr.	0.2	
Opaques	tr.	0.5	finely disseminated.
Spherulites	35	1.0-2.0	
Lithophysae	55	0.5-1.0	developed in a slightly devitrified glassy matrix.
Quartz	5		vein quartz.

Comment: Trapped gases in a densely welded tuff promoted the formation of lithophysae. In hand specimen the space surrounding the lithophysae is filled with a very porous clayey material in which fine vesicles are preserved. Presumably the trapped gases prevented the collapse of these shards and vesicles.

* * *

Sample # 139
Rhyolite
Color: Light gray (N7)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Quartz	3	0.5-1.0	subhedral-euhedral.
Sanidine	3	0.5-1.0	subhedral-euhedral.
Plagioclase	1	0.5-1.5	euhedral; cumlophyric.
Diopside (?)	tr.	0.5	reaction rims.
Accessories:			
Zircon	tr.	0.2	
Matrix:	93		Spherulites arranged in swirls and axiolitic bands. Miarolitic cavities between the bands filled with drusy crystals of tridymite (?) and alkali feldspar.

Comment: Trapped gases and devitrification account for the present texture of the matrix. Rock was emplaced as a glassy lava or as an ash flow that was densely welded.

* * *

Sample # 139B
Rhyolite
Color: Brownish black (5YR2/1)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Sanidine	2	0.5	anhedral-subhedral.
Quartz	2	0.5	anhedral-subhedral.

Sample # 139B Continued on Next Page

Sample # 139B Cont'd.

Composition	Volume (%)	Size (mm)	Character
Matrix:			
Perlitic Glass	63		concentric fractures.
Spherulites	23	0.5-2.0	some with colorless centers surrounded by an outer brown layer.
Devitrification Products	10	micro.	

Comment: Rock is a black vitrophyre or perlite. No shard relics in the glass, possibly because it is a lava.

* * *

Animas Valley Basalt

Sample # 229
Basalt
Color: Dark gray

Composition	Volume (%)	Size (mm)	Character
Plagioclase	68	0.3	euhedral laths.
Pigeonite (?)	18	0.1	anhedral.
Olivine	4	0.5-2.0	subhedral; thin reaction rims.
Opaques	4	0.1	anhedral; magnetite & hematite.
Calcite	6		secondary alteration of plagioclase and pyroxene.

* * *

Sample # 223
Basalt
Color: Light gray

Composition	Volume (%)	Size (mm)	Character
Plagioclase	68	0.2-2.0	euhedral laths.
Augite (?)	14	0.2-1.0	anhedral.
Olivine	4	0.2-2.0	anhedral-euhedral; reaction rims; resorbed.
Opaques	14	0.2	anhedral; hematite & magnetite.

Comments: Rock has a diktytaxitic texture. The large (2 mm) olivine & plagioclase phenocrysts were formed first and the olivine reacted with the melt as evidenced by the resorbed phenocrysts. The smaller plagioclase, augite, and magnetite crystals crystalized last, filling space between the larger plagioclase crystals and assuming the anhedral-subhedral shapes.

* * *

Intrusives

Andesite Porphyry

Sample # 5B
Andesite
Color: Grayish red (5R4/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	10	0.5-5.0	euhedral; partially kaolinized.
Amphibole pseudomorphs	1	0.5	appear as vacant holes with the amphibole habit or as pseudomorphic secondary minerals.
Accessories:			
Opaques	1	micro.-0.5	magnetite, some pseudomorphic after amphibole.
Serpentine	tr.		pseudomorphic after amphibole.
Matrix:	88	< 0.5	Mainly plagioclase laths, also some quartz and clay minerals. Many crystals are too small to resolve.

Comment: There is no strong trachytic texture, although some localized flow lines can be seen around some phenocrysts.

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Sample # 6
Andesite
Color: Pale red purple (5RP6/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	10	0.5-2.0	euhedral; cumulophyric; kaolinized.
Biotite	1	< 0.5	fragments surrounded by opaques.
Amphibole pseudomorph	1	0.5-1.0	void or clay filled; opaque reaction rims; some are cumulophyric.
Accessories:			
Opaques	2	< 0.5	exsolved out of the biotite and other mafics.
Serpentine and/or chlorite	tr.	micro.	alteration product.
Quartz	tr.		vein filling.
Matrix:	86	< 0.5	Twenty percent are plagioclase laths showing localized flow lines around phenocrysts. Eighty per cent of matrix is too small to resolve.

* * *

Sample # 8
Andesite
Color: Medium Light Gray (N6)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Plagioclase	10	0.5-2.0	euhedral.
Amphibole pseudomorphs	3	1.0-2.0	reaction rims; serpentine replacement.
Accessories:			
Opaques	8	0.2-0.5	hematite and magnetite exsolved out of mafics.
Serpentine	tr.		pseudomorphic after amphibole.
Matrix:	79	< 0.5-micro.	Twenty-three per cent of the matrix is fine plagioclase laths which are trachytic, seritized and kaolinized.

Comment: Rock exhibits very good trachytic texture.

* * *

Basalt Dikes

Sample # 200
Basalt (?)
Color: Grayish red (5R4/2)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Pseudomorphs of plagioclase pyroxene & olivine	30	<0.5-2.0	all pseudomorphs are replaced by calcite.

Sample # 200 Continued on Next Page

Sample # 200 Cont'd.

Composition	Volume (%)	Size (mm)	Character
Accessories:			
Opaques	10	0.1	hematite & magnetite; secondary exsolution from ferro-magnesium silicates.
Calcite			pseudomorphic replacement.
Matrix:			
Plagioclase	60	< 0.1	fine trachytic laths

Comment: Rock was hydrothermally altered promoting the formation of iron oxides and giving the rock a reddish color. Specimen is probably from a dike. The outcrops contacts are buried beneath Quaternary sediment, but the sample is similar to # 207 which is from a dike.

* * *

Sample # 207
Basalt
Color: Medium dark gray (N4)

Composition	Volume (%)	Size (mm)	Character
Phenocrysts:			
Pseudomorphs of pyroxene & olivine	4	0.2-0.5	replaced by chlorite, serpentine, calcite, and chalcedony.
Accessories:			
Calcite	38	< 0.1	anhedral; subophitic with respect to the plagioclase; probably replacing pyroxene.

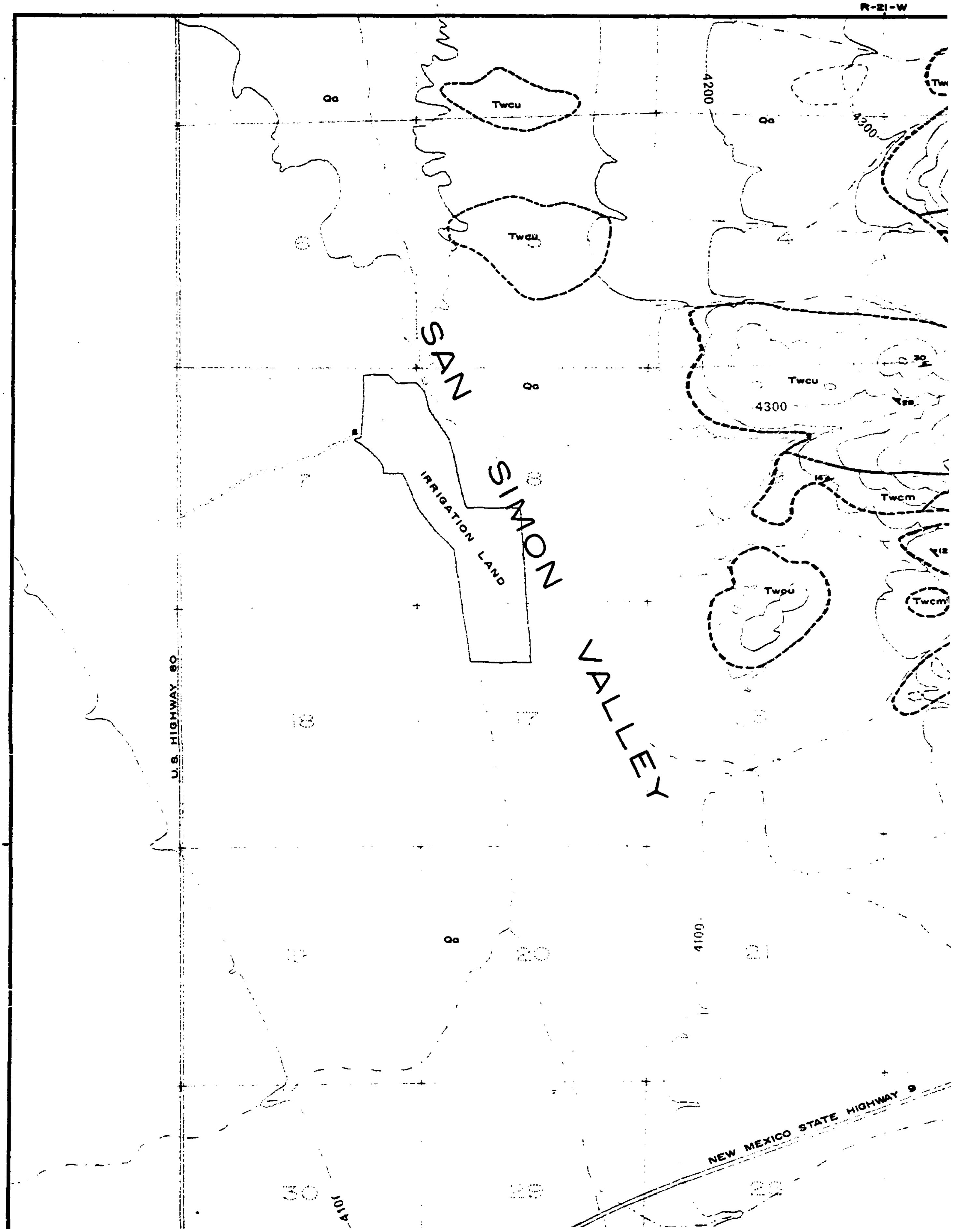
Sample # 207 Continued on Next Page

Sample # 207 Cont'd.

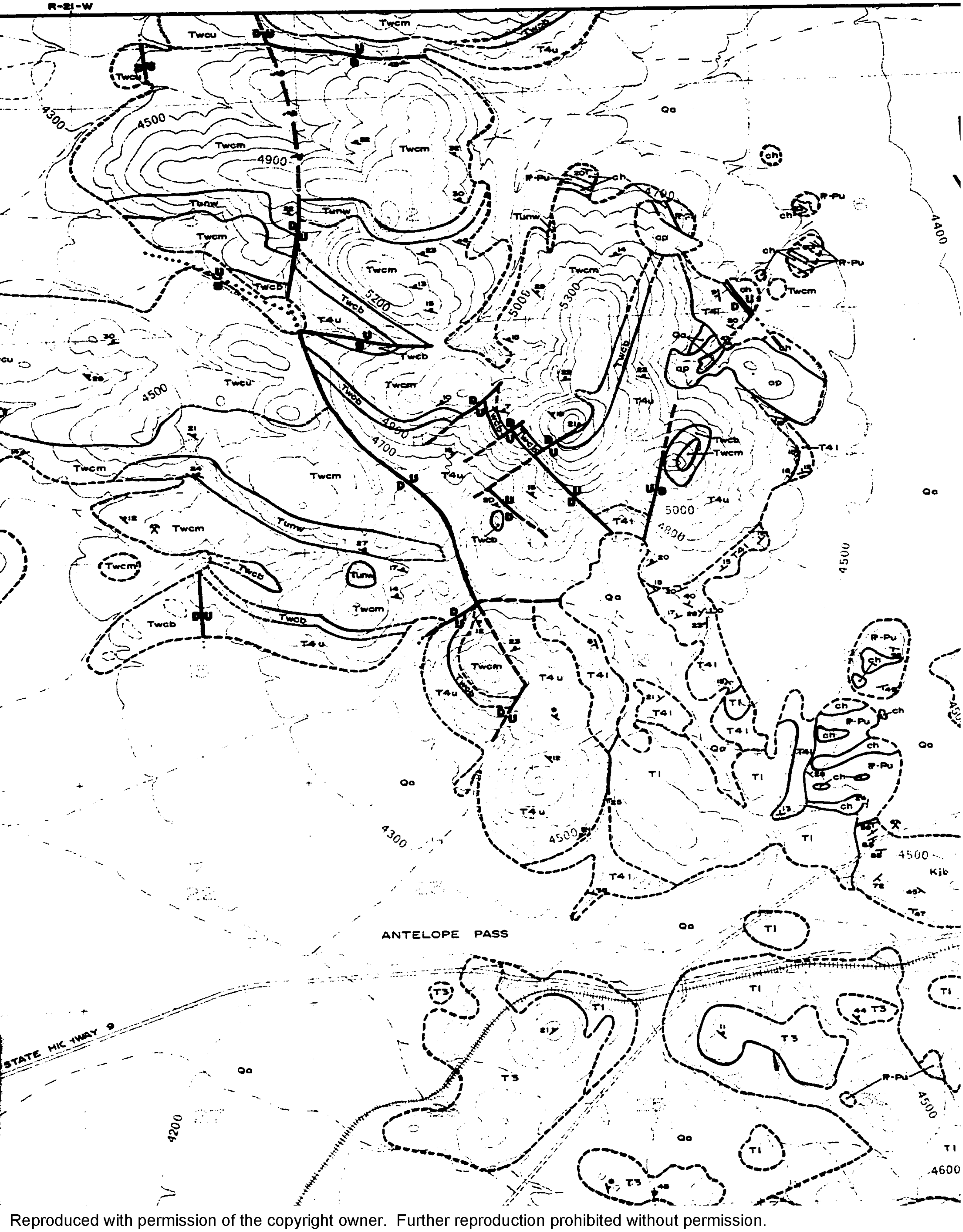
Composition	Volume (%)	Size (mm)	Character
Quartz	3	2.0	vein filling
Chlorite Serpentine Chalcedony }			replacement minerals in pyroxene and olivine pseudomorphs.
Matrix:			
Plagioclase	54	0.1	euhedral; trachytic; flow lines around pseudomorphs.

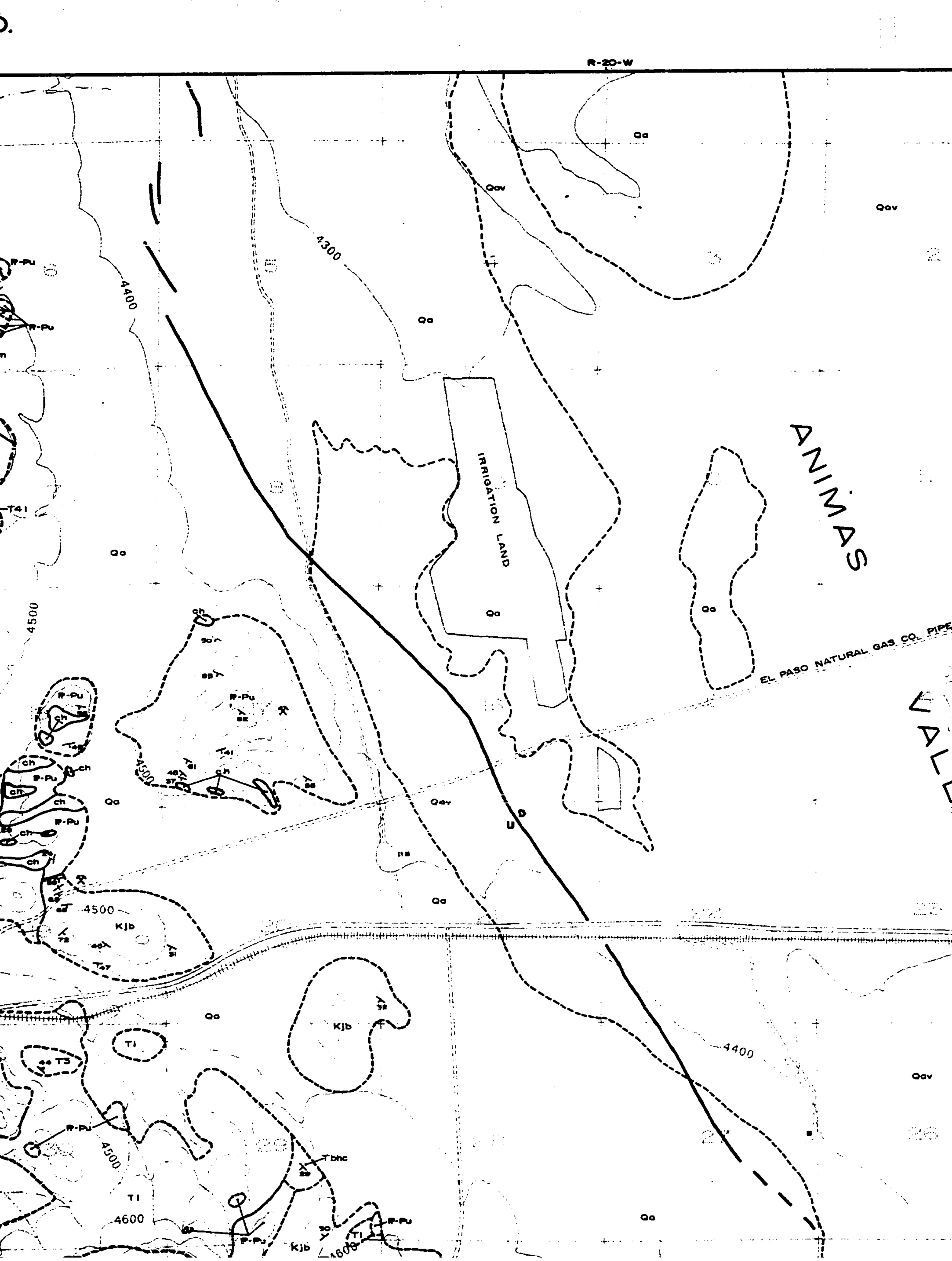
* * *

PLATE I: GEOLOGIC MAP OF THE CENTRAL PELONC
THE NORTH THIRD OF THE PRATT QUADF



PELONCILLO MOUNTAINS,
T QUADRANGLE, HIDALGO COUNTY, NEW MEXICO.

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ANIMAS
VALL
IRRIGATION LAND
EL PASO NATURAL GAS CO. PIPE
Qa
Qav
Kjb
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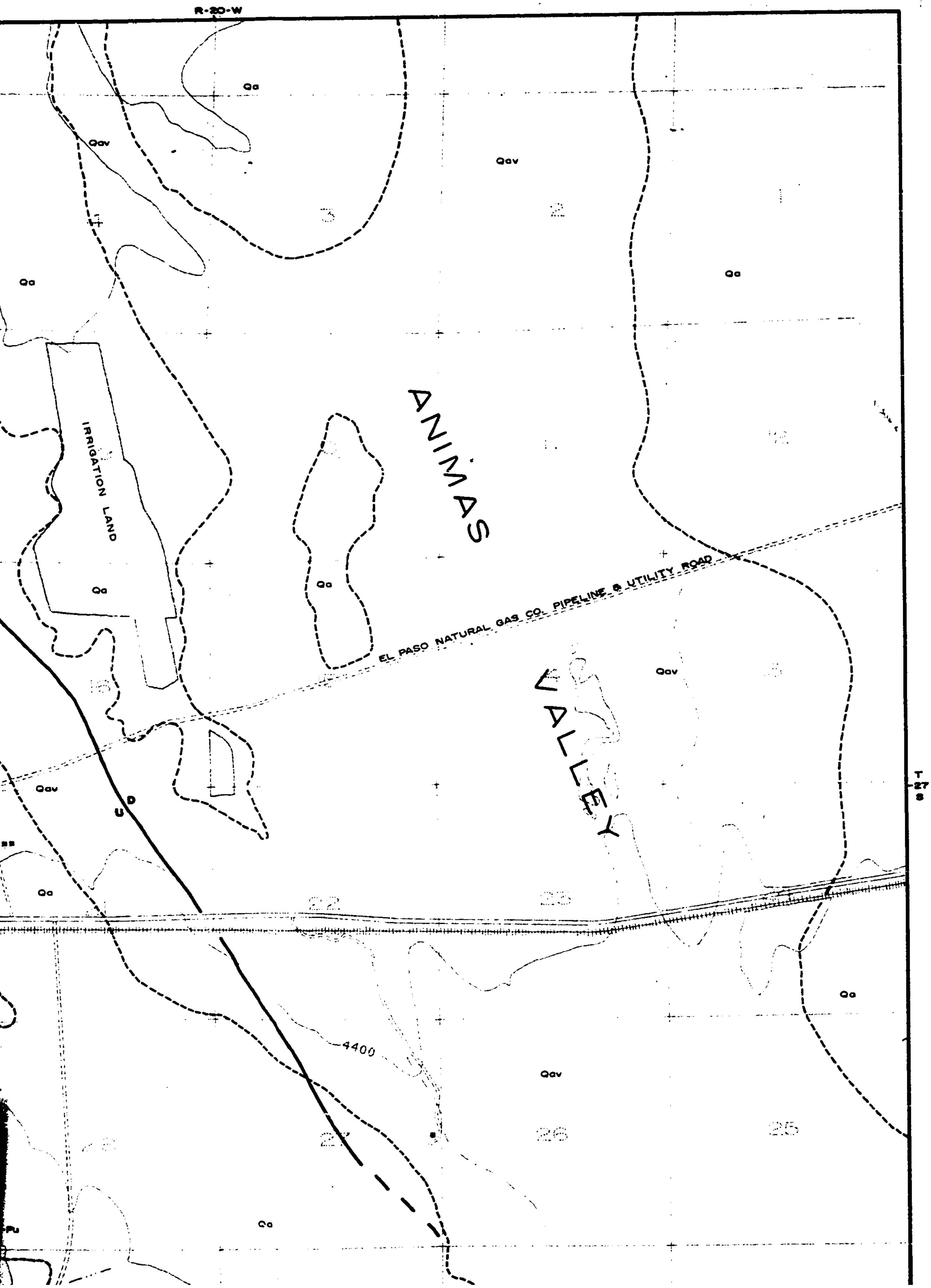
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VALLEY
IRRIGATION LAND
Qa
Qa
EL PASO NATURAL GAS CO. PIPELINE & UTILITY ROAD
Qav
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Qav
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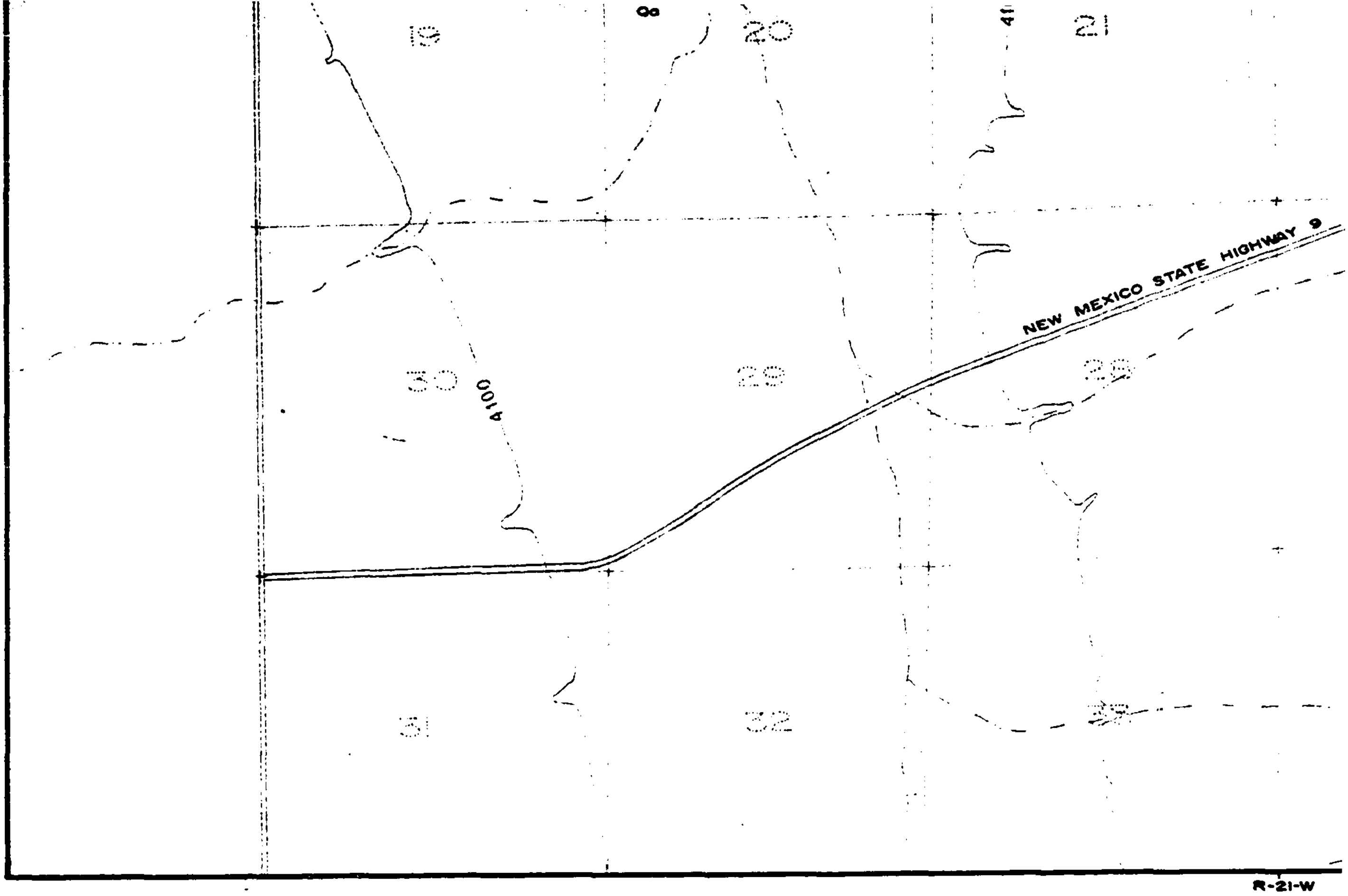
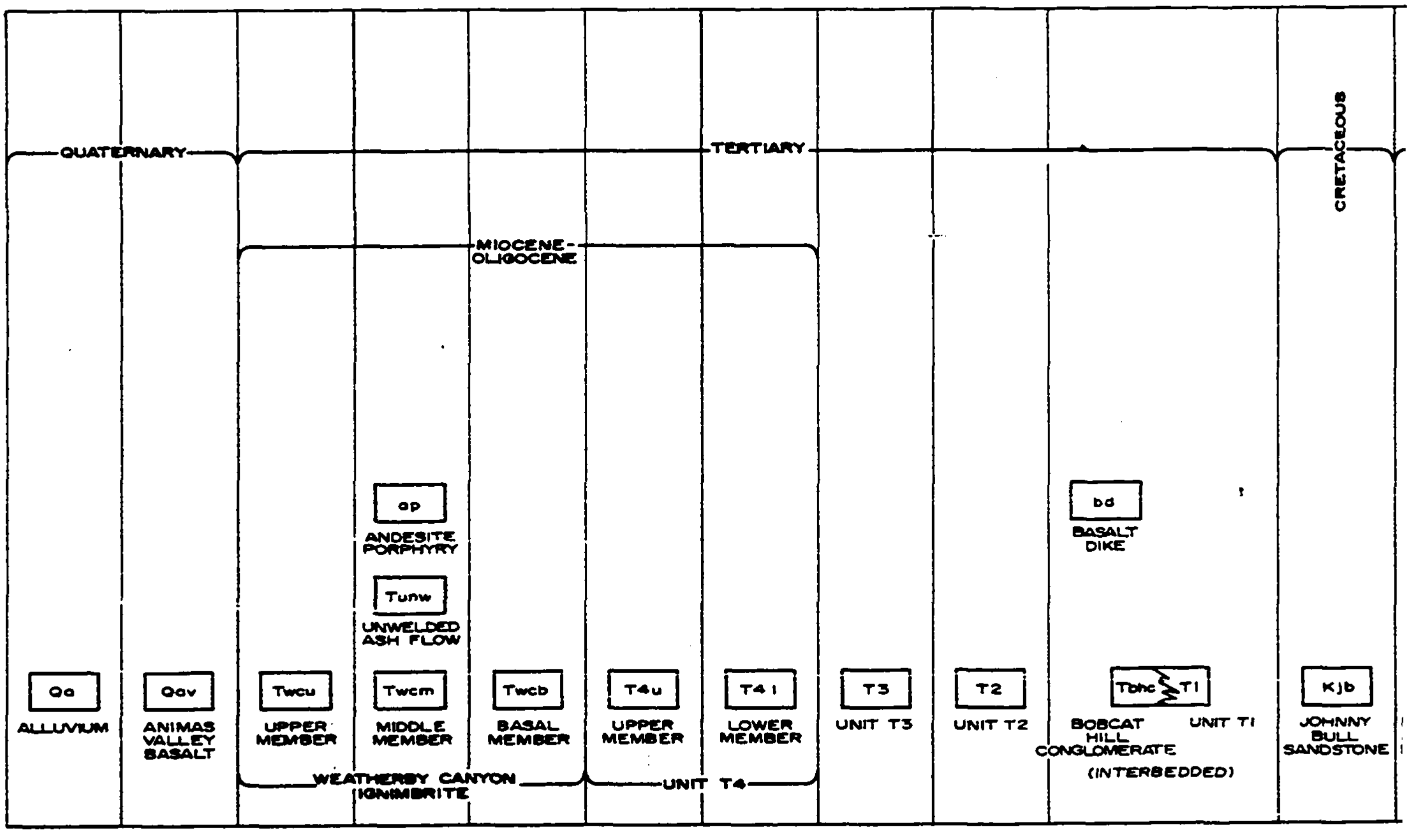
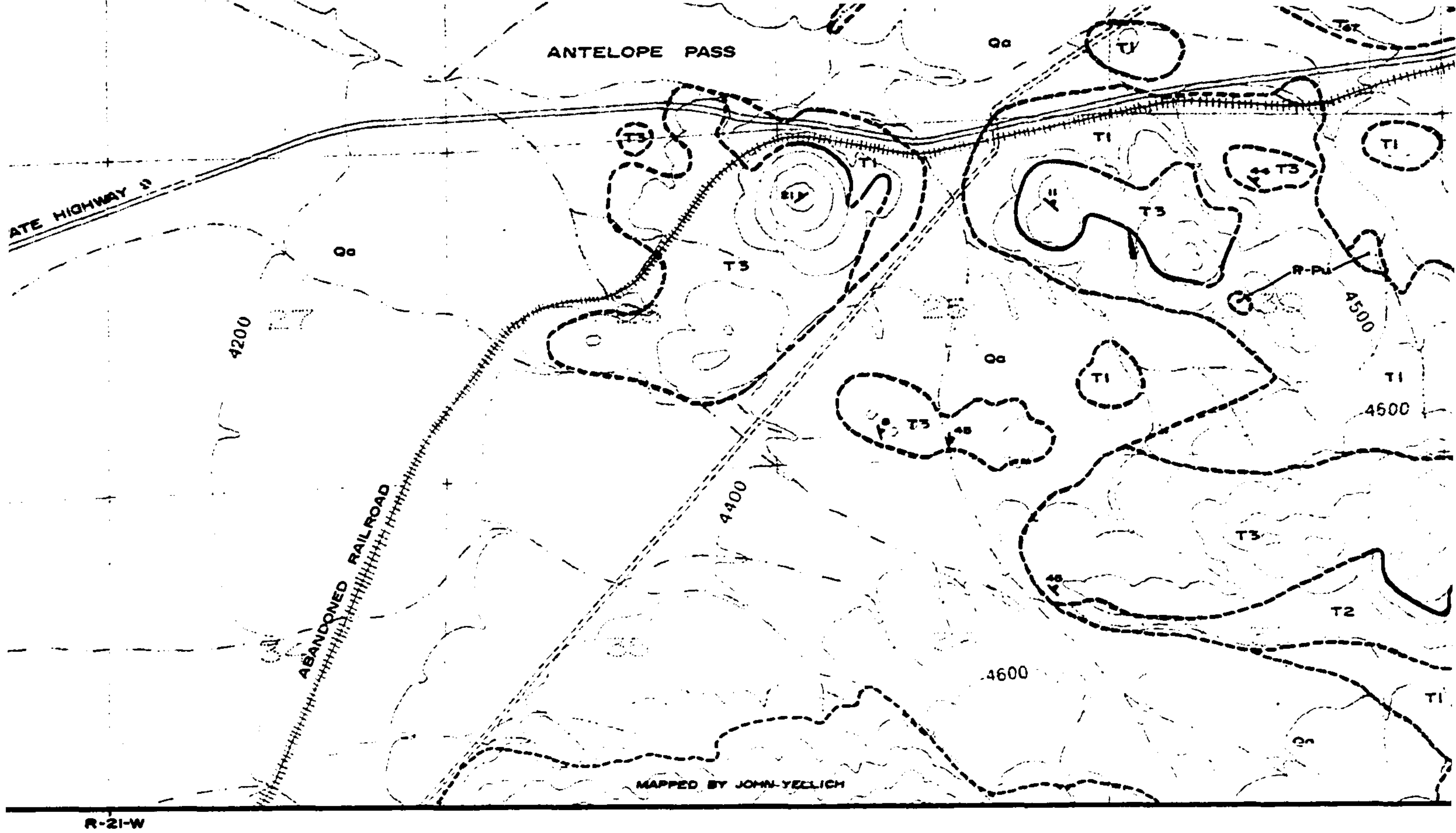
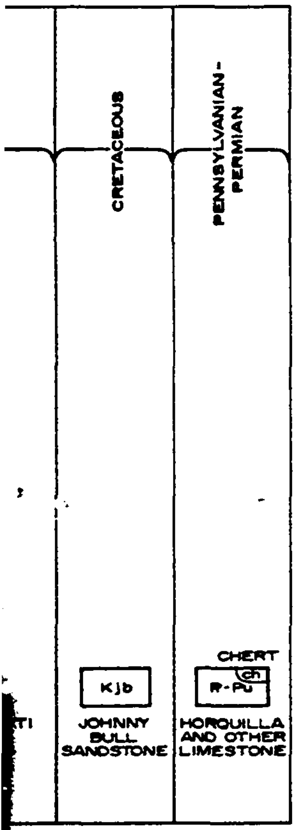


GEOLOGY BY: DENNIS J. GEBBEN, SUPERVISED BY: RICHARD V. McGEHEE
BASE MAP PREPARED FROM A PHOTOGRAPHIC ENLARGEMENT OF THE PRATT QUADRANGLE.

EXPLANATION







CONTACT
DASHED WHERE APPROXIMATELY LOCATED

FAULT
DASHED WHERE APPROXIMATELY LOCATED; DOTTED WHERE CONCEALED; U, UPTHROWN SIDE; D, DOWNTHROWN SIDE.

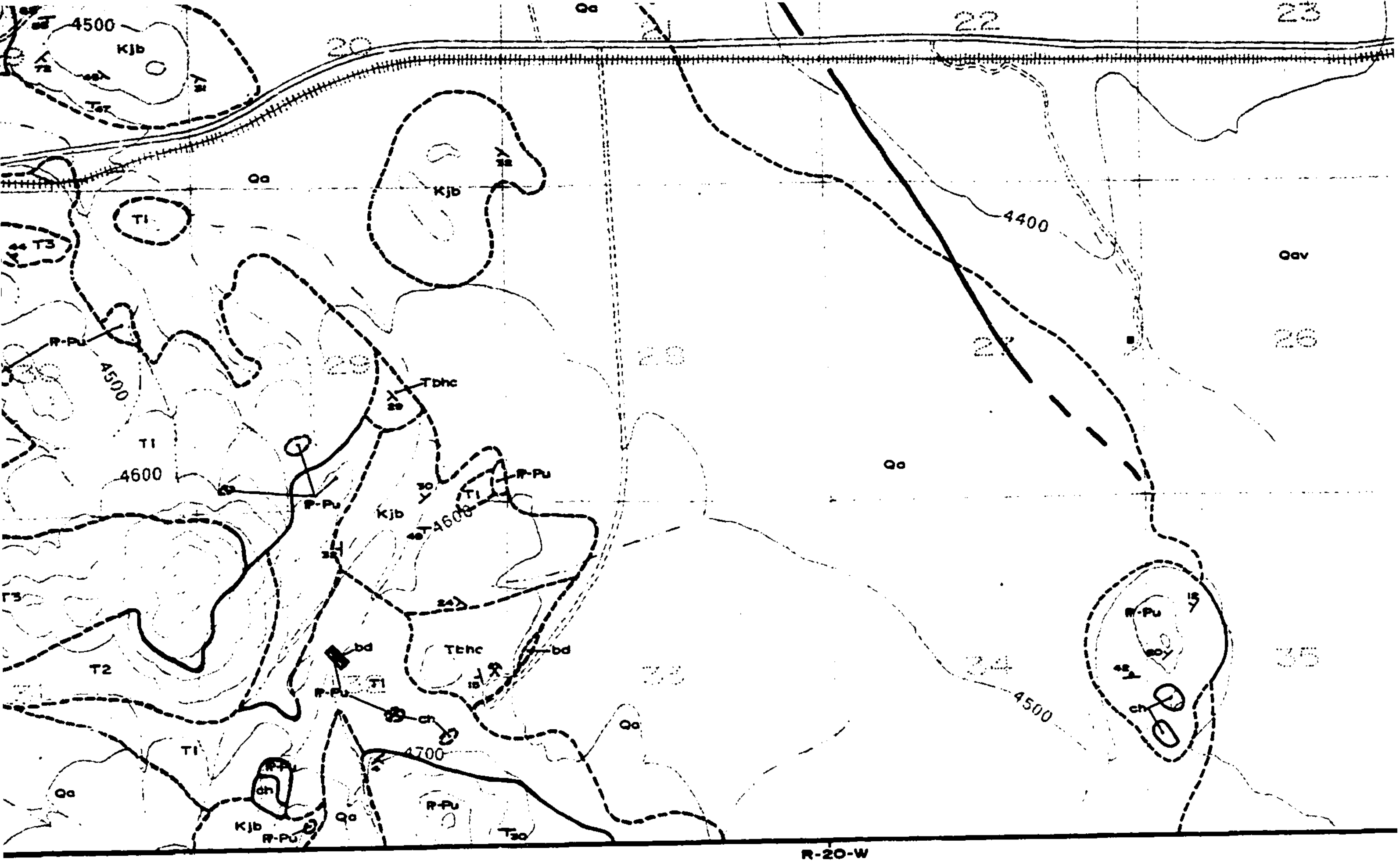
POSSIBLE FAULT

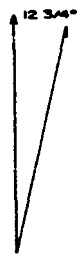
STRIKE & DIP OF PLANAR STRUCTURE IN IGNEOUS ROCKS.

STRIKE & DIP OF BEDS

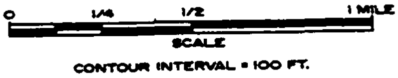
DWELLING

PROSPECT PIT OR MINE



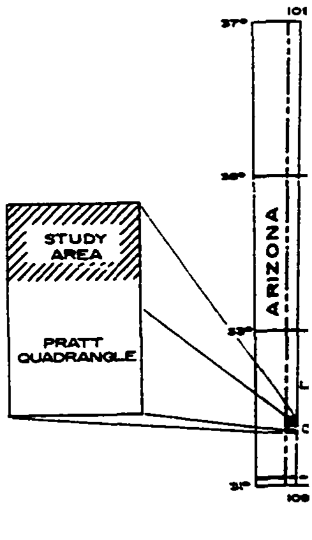


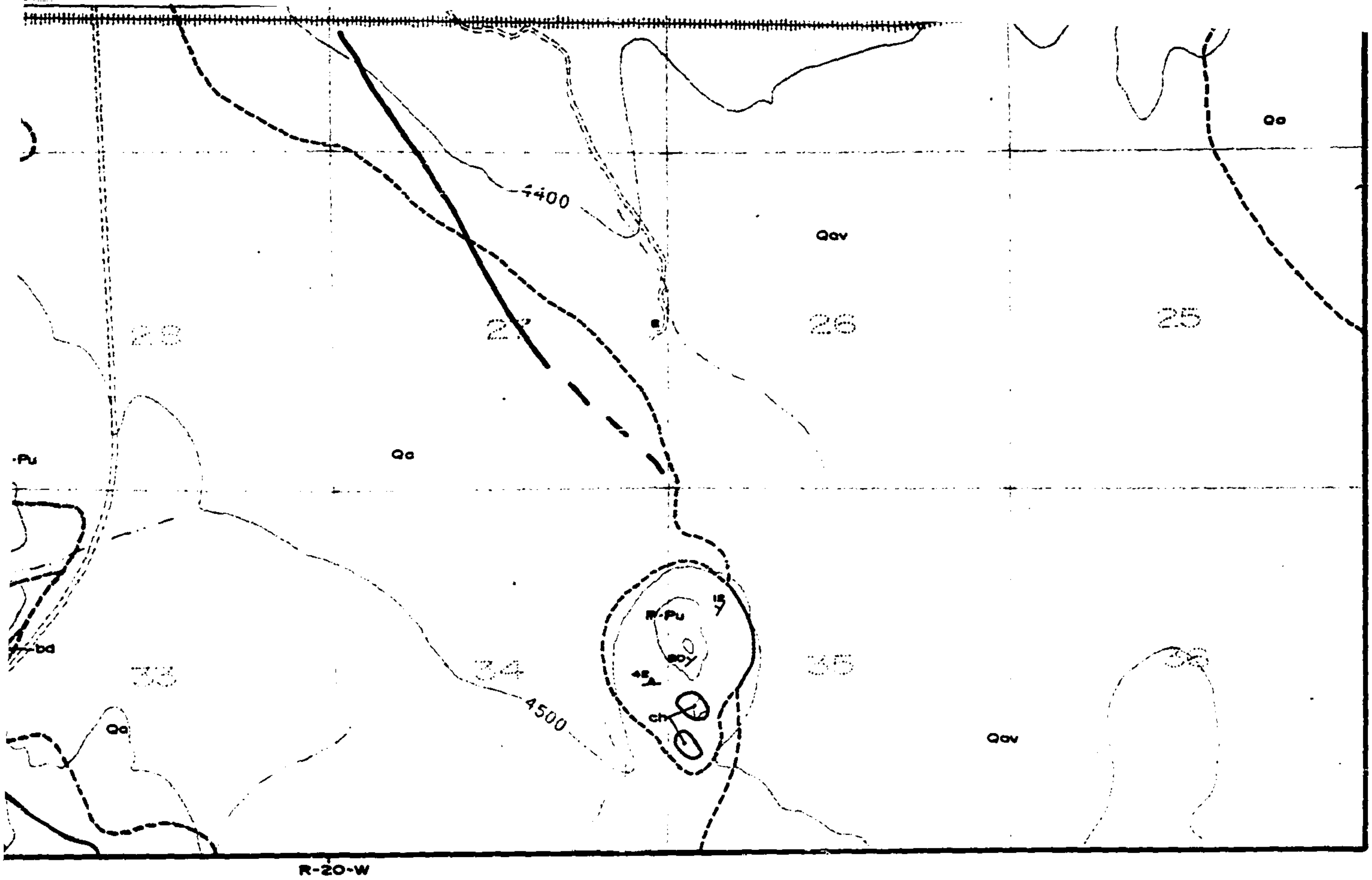
APPROXIMATE
MEAN DECLINATION, 1970

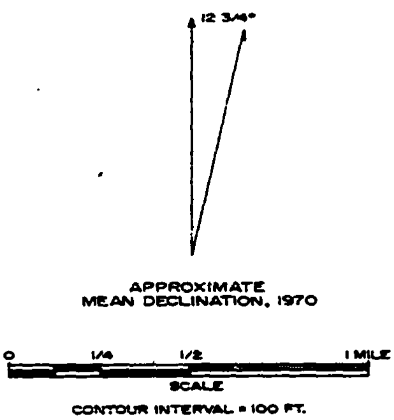


SCALE

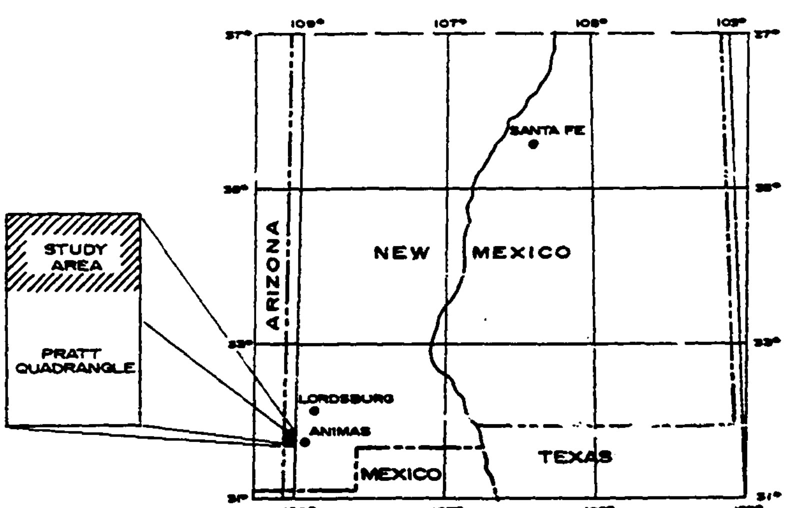
CONTOUR INTERVAL = 100 FT.




Qa
4400
Qav
28
27
26
25
Pu
Qa
Pu
15
60
45
ch
bd
33
34
35
36
4500
Qa
Qav
R-20-W


12 3/4°
APPROXIMATE
MEAN DECLINATION, 1970
0
1/4
1/2
1 MILE
SCALE
CONTOUR INTERVAL = 100 FT.

INDEX MAP


109°
107°
105°
103°
37°
35°
33°
31°
SANTA FE
STUDY AREA
PRATT QUADRANGLE
ARIZONA
NEW MEXICO
LORDSBURG
ANIMAS
MEXICO
TEXAS