6-2013

The Geology of the South Antelope Pass Area of the Southern Peloncillo Mountains, Hidalgo County, New Mexico

John A. Yellich
Western Michigan University

THE GEOLOGY OF THE SOUTH ANTELOPE PASS AREA OF THE SOUTHERN PELONCILLO MOUNTAINS, HILDALGO COUNTY, NEW MEXICO

by

John A. Yellich

A thesis submitted to the Graduate College
in partial fulfillment of the requirements
for the degree of Master of Science
Department of Geosciences
Western Michigan University
June 2013

Master's Committee:

Mohamed Sultan, Ph.D., Chair
Richard V. McGehee, Ph.D.
W. David Kuenzi, Ph.D.
John Grace, Ph.D.

THE GEOLOGY OF THE SOUTH ANTELOPE PASS AREA
OF THE SOUTHERN PELONCILLO MOUNTAINS,
HILDALGO COUNTY, NEW MEXICO

John A. Yellich, M.S.

Western Michigan University, 2013

Volcanic activity during the middle and late Tertiary has been recorded in the mountain ranges of the southwestern United States and northern Mexico and the two provinces of prominent volcanic activity, the Sierra Madre Occidental and the Mogollon Plateau, dominantly rhyolitic in composition, are connected by the Peloncillo Range. The predominant rock chemistry of the south Antelope Pass area is “rhyolitic”; however, lava rock types dominate over welded tuff rock types of the two provinces. There is a limited pre-Tertiary rock record of limestones and sandstones in the northeastern part of the study area. The rest of the study area is Tertiary and Quaternary volcanic rocks and alluvium. The first episode of deformation in the area is associated with the deposition of Unit-T5 lava where the rock unit flow direction was modified, but the source of the lava could not be located. The second episode of deformation is associated with Basin and Range mountain building in mid to late Tertiary, which outlined the present day north-south trending Peloncillo Range and where contemporaneous local faults occurred through the interior of the range, while there was erosion of vast quantities of material filling the adjoining basins. Late Tertiary to Recent time had limited basalt flows in both the San Simone and Animas valleys. No evidence of economic mineralization was identified.

ACKNOWLEDGMENTS

Dr. Richard V. McGehee who advised and critically reviewed the manuscript as well as my work in the field and in the laboratory.

Dr. W. David Kuenzi whose review of the manuscript provided thought provoking criticism.

Dr. John Grace for his thoughtful technical review of the manuscript.

Dennis Gebben who worked in the adjacent area and whose ideas were shared openly in order to solve respective field problems in this study.

A personal thank you to Sandi Yellich for understanding this long ordeal and to Liza, my daughter, who was exposed to a different life in the field during the summer of 1970, and to Sara, my daughter, who assisted in the final phase of this thesis process.

The Department of Geosciences at Western Michigan University for the use of the laboratory facilities.

A special thank you to my fellow students and recently my friends with whom I shared many hours of constructive encouragement. Also, a personal thank you to Mr. and Mrs. Fielder (Nettie) Hill who allowed us to camp and use the facilities of their ranch and for providing a welcome atmosphere for my family.

I am indebted to the New Mexico Bureau of Mines at Socorro for their financial assistance for the summer of 1970.

John A. Yellich

TABLE OF CONTENTS

CHAPTER

Table of Contents—Continued

LIST OF TABLES

LIST OF FIGURES

List of Figures—Continued

List of Figures—Continued

CHAPTER 1

INTRODUCTION

Purpose

This master's thesis summarizes the results of a study in the central portion of the southern Peloncillo Mountains of southwest New Mexico in the summer of 1970. The area of study is located in the Pratt quadrangle and a small portion of the Portal quadrangle in southwest New Mexico and southeast Arizona, respectively. Mapping in the Pratt quadrangle was divided between Dennis Gebben, Richard McGehee, and the writer. The purpose of my study was to map the Peloncillo range, to explore for potential areas of mineralization with the range, and to collect and analyze for a better understanding of the geologic history of the study area. This was done in partial fulfillment of my master's thesis.

Rock samples were collected in the field, from which selected samples were analyzed petrographically. They were used to aid in the description and interpretation of the different rock unites and the help interpret the geologic history of the study area.

Location and Physiographic Setting

The Peloncillo Mountains are located in Hidalgo County of southwestern New Mexico and Cochise County of southeastern Arizona (Figure 1). The major part of the range mapped at this time is located in the Pratt, New Mexico quadrangle (circa 1919).

The quadrangle is bounded by latitudes 32º00′ and 32º45′ and longitudes 108º45′ and 190º00′. The eastern part of the Portal, Arizona–New Mexico quadrangle is included in this thesis, because of the lateral extent of the mountain range to the west in the South Antelope Pass area. The Portal quadrangle joins the Pratt quadrangle on the west. The study area is within T. 28 S., R, 20 & 21W. There are approximately 42 square miles within the map area.

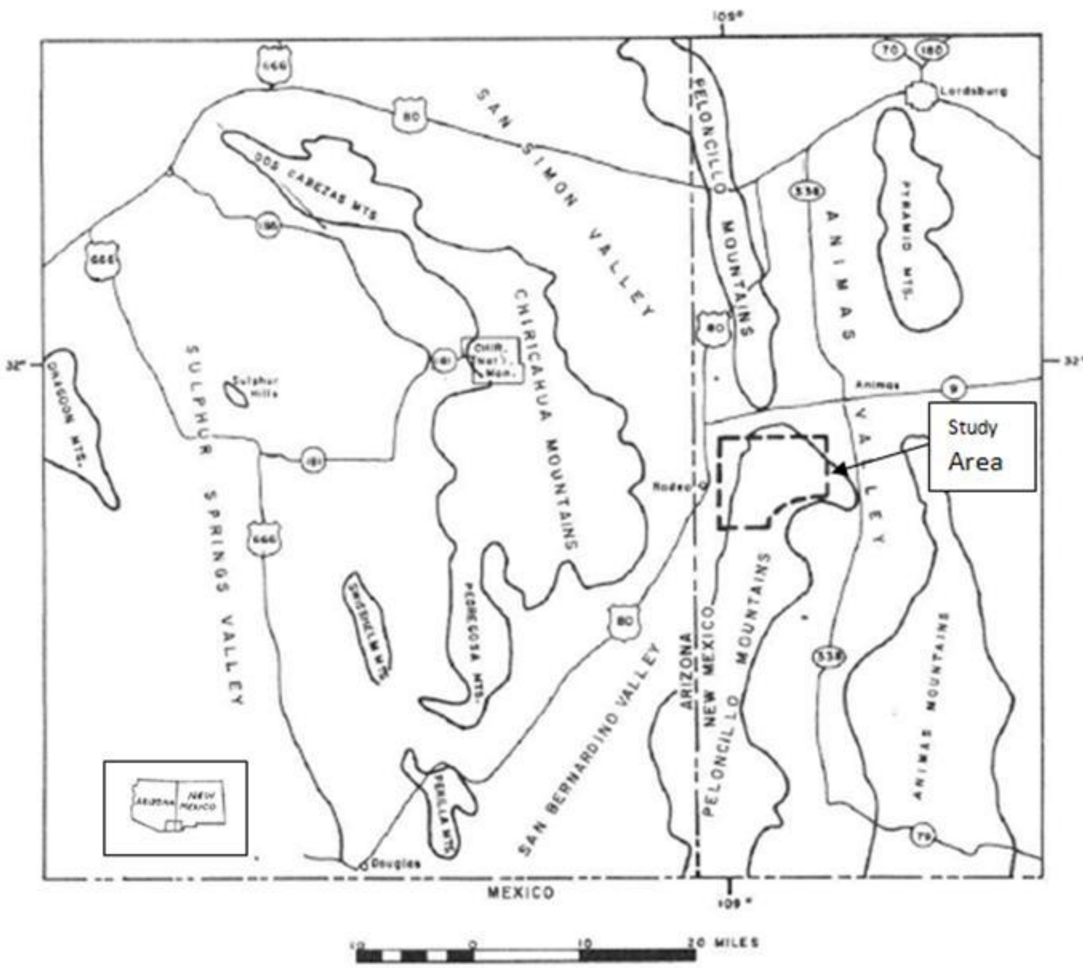


Figure 1. Location map of southeastern Arizona and southwestern New Mexico. Dashed line outlines the South Antelope Pass area.

None of the state or U.S. highways provided direct access to the map area. The El Paso Natural Gas Company's utility and repair pipeline road made the west side of the area more accessible. Most of the roads in the area are unmarked, with some of them in need of repair but they can be traveled by truck or jeep.

The Peloncillo Range is a north-trending fault block that has been dissected by east-west trending canyons which expose many hundreds of feet of rock. The maximum amount of relief in the study area is approximately 1400 feet. The relative relief in the interior part of the South Antelope Pass area decreases to the south. There is about 75 percent rock exposure in the study area.

Geologic Setting

The Peloncillo Mountains are located in the south-central part of the Basin and Range Province. The Peloncillo Mountains connect the gigantic volcanic provinces of the Sierra Madre Occidental and Mogollon Plateau (Figure 2). The volcanic deposits of these areas are characterized by thick sequences of silicic ash-flows of Miocene-Oligocene age (King, 1939, p. 1679; Smith, 1960, p. 816; Wisser, 1966, p. 71; Elston and others, 1968, p. 262). The ranges are uplifted fault blocks bounded by north trending, steeply dipping faults that have displaced the ranges and adjacent valleys (King, 1939, p. 1717).

The Peloncillo Range has been structurally divided by doming that occurred at Granite Gap (Figure 1) in Late Cretaceous (Gillerman, 1958, p. 78) and in the vicinity of Highway 9 (Figure 1) during Late Oligocene time. The area of Highway 9 could have been a topographic high during later volcanic deposition in the Peloncillo Mountains.

Mid-late tertiary faulting and uplift along border and interior faults with subsequent erosion has exposed the volcanic sequence within the range, as well as local outcrops of Paleozoic and Mesozoic strata in the area of Highway 9.

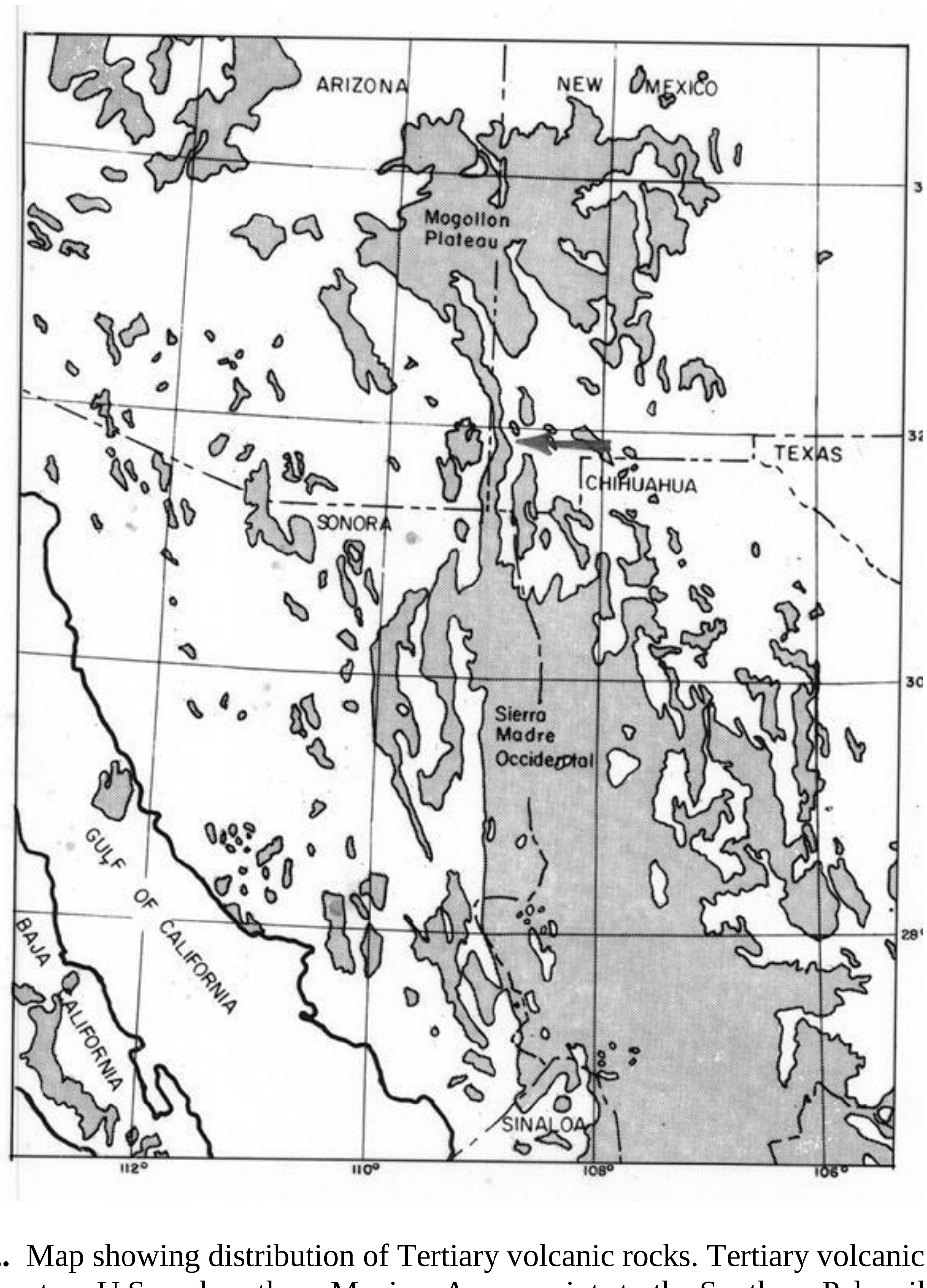


Figure 2. Map showing distribution of Tertiary volcanic rocks. Tertiary volcanic rocks in southwestern U.S. and northern Mexico. Arrow points to the Southern Peloncillo Range. From Geologic Map of North America, 1965.

Scope of Work

Field work extended form June 12, 1970 to August 22, 1970. Mapping was done using aerial photographs as base maps (Scale 1/20, 437 or 3.1″ = 1 miles) provided by the New Mexico Bureau of Mines and Mineral Resources. The data could not be transferred accurately to a topographic base because of the inaccuracy in contour lines of the Pratt quadrangle, a 1919, 15 minute Quadrangle. Thus, a drainage map (see Appendix C on the development of the drainage map) was constructed and the geologic data transferred with the aid of a stereoscope. Tectonic dips were measured to the nearest 5º. Color nomenclature follows the rock color chart (Goddard and others, 1951) distributed by the Geological Society of America.

Rock lithologies were differentiated in the field by bulk phenocryst content and genetic textures and structures. Many units were mapped as separate lithologies because of textural differences but were grouped together after petrographic analysis proved them to be compositionally the same unit. Petrographic study has indicated that the processes of the devitrification and re-crystallization can visually and chemically change a single rock type considerably over a short lateral or vertical distance. This makes field interpretations very difficult. Understanding the volcanic sequence of the South Antelope Pass area of the southern Peloncillo Mountains requires background in the literature associated with the welded tuffs and lava flows in the Great Basin (Armstrong and others, 1968; Christiansen and others, 1965; Cook, 1965; Cummings, 1964; Ekren and others, 1968; Gilluly, 1965; Lipman and Christiansen, 1964; Lipman and others, 1966; Mackin, 1960; Mckee and others, 1960; Ross and Smith, 1961; Smith, 1960a; Smith and Bailey, 1966), the Mogollon Plateau (Elston and others, 1968; Kuellmer 1954), the volcanic ranges to the west and surrounding the study area (see Figure 3) (Damon and associates, 1967, Enlows, 1955; Fernandez and Enlows, 1966; Gilluly, 1956; Marjaniemi, 1968, 1969; Raydon, 1952), as well as volcanic fields in other areas of the United States (Boyd, 1961; Smith and others, 1961; McTaggart, 1960, 1962).

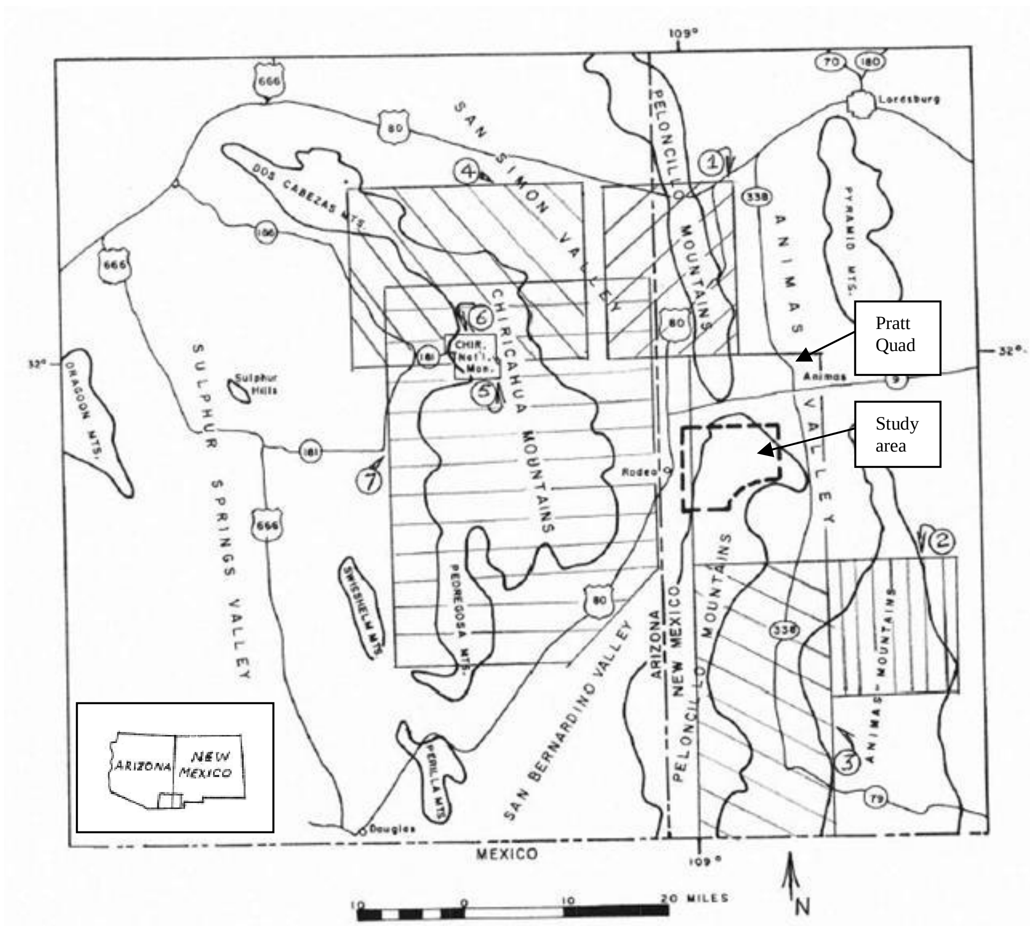


Figure 3. Location of published reports and maps. Location of published reports and maps adjacent to the study area and the 15 minute Pratt Quadrangle. Key to adjacent areas of study: 1 – Gillerman, E., 1958; 2 – Zeller, R.A., and Alper, A.M., 1965; 3 – Wrucke, C.T., and Bromfield, C.S., 1961; 4 – Sabins, F.F., 1957; 5 – Enlows, G.E., 1955; 6 – Fernandez, L.A., and Enlows, G.E., 1966; 7 – Marjaniemi, D.K., 1969.

Petrographic analysis of the rock samples was done on a flat stage microscope. Plagioclase Anorthite (An) content was determined by the Michel-Levy statistical method. Textural terminology is from Williams, Turner, and Gilbert (1954). Volcanic terminology (Table 1) was obtained from Ross and Smith (1961), Rittman (1952), Fisher (1966), and Smith (1960a and 1960b). Optical properties of the minerals were obtained from Heinrich (1965).

Table 1

Terms and Nomenclature as Defined and Used in this Thesis

Term	**Definition**
Ash flow:	The basic united of the deposit is analogous to, or the same as, the deposit resulting from the passage of one nuëe ardente. The unit contains 50 percent of more by weight of ash and fine ash. This is generally synonymous with the term ignimbrite.
Divitrification:	The process of alteration that takes place in acidic ash and lava flows where the glassy groundmass is altered to microcrystalline quartz and feldspars that form (megascopic structure), i.e. spherulites or a (non-descript) texture.
Epiclastic:	Sediments formed at the surface of the earth by the erosion, deposition and consolidation of fragments of pre-existing rocks.
Eutaxitic:	The structure imparted by the flattening of ejecta fragments that lie beside one another in a seemingly ordered distribution.
Fracture:	Used in thin section descriptions of phenocrysts to indicate the cracking of crystals but no separation.
Fiamme:	Used to describe black glassy inclusions that have a cross-section shaped like tongues of flame.
Lahar:	Is a type of mudflow or debris flow composed of a slurry of volcanic pyroclastic material, rocky debris, and water.

Table 1—Continued

Term	Definition
Lithic:	Refers to sediments and rocks in which rock fragments are more important proportionally than phenocrysts.
Lithophysae:	The large, hollow, bubble-like or rose-like (radial) and concentric structures, that occur in certain rhyolites, obsidians, and related rocks. Concentric structure commonly composed of radiating ascicular crystals of cristobalite and or tridymite.
Shattered:	Used in thin section descriptions to indicate broken and separated phenocrysts.
Spherulites:	Radial and polygonal aggregates of acicular and fibrous microcrystalline minerals composed of cristobalite and orthoclase formed during devitrification. They form about a “nucleus” in silicic lava flows and in obsidians.
Vitrophyre:	Volcanic glass with abundant phenocrysts.
Welded tuff:	A rock or rock body with vitric particles with some degree of cohesion that were viscous at the time of emplacement. In this text the term is used synonymous with welded ash-flow tuff.

Previous Work

In 1958 the New Mexico Bureau of Mines published Elliot Gillerman’s work in the central Peloncillo Mountains (Figure 3, area 1). Gillerman was primarily concerned with the Paleozoic and Mesozoic sequence, and the Tertiary volcanic sequence in the northern and southern portion of his area was studied in a reconnaissance fashion. He grouped all the volcanic rocks in the southern part of the area into the Weatherby Canyon

Ignimbrite. Most of the other work in the Peloncillo Mountains has been reconnaissance, and no detailed studies are in print at this time.

The Pratt quadrangle is included in an unpublished reconnaissance study done by R. A. Zeller (Dane and Bachman, 1961) of the New Mexico Bureau of Mines. Wrucke and Bromfield (1961) have compiled a reconnaissance map (Figure 3, area 3) of the area directly south of the Pratt quadrangle. R. A. Zeller has done a great deal of reconnaissance and detailed work in southwest New Mexico. In the published paper (1965, Figure 3, area 2) which Zeller co-authored with A. M. Alper, he correlated the thick quartz latite Gillespie Tuff, from the Animas Range, in the Walnut Wells quadrangle (Figure 3, area 2), to the Peloncillo Mountains to the west. Further unpublished work by Zeller has been summarized by Dane and Bachman (1961) on their preliminary reconnaissance map of southwest New Mexico. This work outlined the relative abundance of rhyolitic tuffs but did not recognize the thick lava sequence in the Pratt quadrangle.

Most of the detailed work on volcanic rocks in the vicinity of the Pratt quadrangle has been done in the Chiricahua Mountains to the west (Figure 1). The Chiricahua Range has been mapped quite extensively with most of the detailed work incorporated into a few papers. Enlows (1955) mapped (Figure 3, area 5) in detail the Rhyolite Canyon Formation (Table 2, area 5), of tentative Miocene age, in the Chiricahua National Monument. Floyd Sabins (1957) incorporated some of the work of Enlows and other earlier workers (Figure 3, area 4) in the Chiricahua and Dos Cabezas mountains. Enlows and Fernandez (1966) published a more detailed petrographic study of the Faraway

Table 2

Composite Section of Rhyolite Canyon Formation

Thickness (ft)	Member rock type	Field description
220	9. rhyodacite flow	Black to medium gray; vesicular
50	8. rhyolite welded tuff	Soft: light gray, grading into brittle, brown rock downward
10	7. rhyolite tuff	Fairly coherent, light gray
880	6. rhyolite welded tuff	Rather coherent light gray tuff, grading down into poorly welded light gray tuff, which in turn grades into a coherent, brittle, light brownish gray rock
3	5. rhyolite welded tuff	Glassy, light brownish gray
270	4. rhyolite welded tuff	Soft light gray top with strongly welded grayish red seams, grading down into coherent brittle pinkish gray rock
190	3. rhyolite welded tuff	Firmly welded, dusky red, with many prominent inclusions
270	2. rhyolite welded tuff	Soft light gray top grading into a brittle grayish red rock
30	1. rhyolite welded tuff	Brittle, dark gray with very firmly welded
Faraway Ranch Formation, rhyolite sillar		

Note. Rhyolite Canyon Formation in the Chircahua National Monument. After Enlows, 1955.

Range Formation from the Chiricahua range which is included in the detail of Table 3. Most of the previously outlined work as well as a few unpublished master's theses were summarized in the 1969 unpublished Ph.D. dissertation of D. K. Marjaniemi (Figure 3, area 7). Marjaniemi described the Turkey Creek Caldera and proposes that it is the source for some of the volcanics in southeastern Arizona and southwestern New Mexico. He has also done some reconnaissance work in the Peloncillo Mountains and has complied K-Ar dates for the Rhyolite Canyon Formation, which he proposes is also present in the Peloncillo Range.

Table 3

Summary of Faraway Ranch Formation

Thickness (ft)	Member	Field description
55	9. rhyolite sillar (gray)	Very light-gray, porous tuff containing small fragments of red andesite and light-brown pumice
25	8. rhyolite sillar (orange)	Moderate reddish-orange, porous, poorly consolidated tuff containing mainly angular pebbles and some boulders of red to black andesite and light-brown pumice
-----angular uncomformity-----		
500	7. rhyodacite flow	Pinkish-gray to pale reddish-brown, hard, marked by prominent flow structure. Grades upward from a dense, glassy, dark-gray base to a grayish-pink scoriaceous top
-----angular uncomformity-----		
200	6. volcanic fanglomerate	Fifty feet of grayish-pink, volcanic sandstones and breccias overlain by 150 feet of coarse volcanic breccia containing boulders of rhyolite, basalt, and pumice

Table 3—Continued

Thickness (ft)	Member	Field description
-----erosional uncomformity-----		
330	5. basalt breccia	Medium-gray to dusky-red basalt clasts up to 60 cm. in diameter embedded in a grayish-orange matrix
110	4. basalt flow and flow breccia	Dark-gray, porphyritic basalt
-----contact covered-----		
65	3. rhyolite welded tuff	Grayish-pink, porphyritic, welded tuff. Flattened pumice fragments develop a horizontal eutaxitic structure
-----contact covered-----		
40	2. vitric tuff	Pinkish-gray, massive, fine-grained tuff containing a few moderate-red to dusky-red lithic inclusions
-----contact covered-----		
50	1. lithic greywacke	Grayish-pink, coarse-grained sandstone
-----erosional unconformity-----		
150	Andesite	Grayish-blue porphyritic andesite with sandstone inclusions

Note. Summary of Faraway Ranch Formation and underlying andesite. After Fernandez and Enlows, 1966.

CHAPTER 2

STRATIGRAPHY

Introduction

Tertiary rocks cover about 88 percent of the study area with local Paleozoic and Mesozoic deposits located in the northern part of the area and Quaternary deposits veneering the sediments and partially filling the adjacent valleys (Plate I, Appendix A). Three Paleozoic and Mesozoic map units of unknown thickness and eighteen informal Tertiary and Quaternary units of both volcanic and sedimentary origin are distinguished in Plate II, Stratigraphy of the South Antelope Pass Area (Appendix B). In the South Antelope Pass area, the majority of the units are local in extent; most are lens shaped and are limited to the study area. Stratigraphic position for the units is according to the superposition with seven units. These units were placed in a relative stratigraphic position as a result of the lack of direct evidence in the study area. The estimated thickness of the Tertiary sequence is between 4800 and 5600 feet. Distinction between Tertiary rocks of questionable sedimentary or volcanic origin was based on structures and contacts found in the field. Thin section determination of possible volcanic sedimentary rocks was hampered by devitrification of rock fragments. The volcanic rock classification is based on thin section modal analysis and textures described in the field.

The stratigraphic sequence within the study area has been structurally disturbed by high angle faults that are difficult to distinguish within the altered rock units. The lack of fossils within the Tertiary sedimentary units hinders correlation of the sedimentary units within the study area. Absolute ages for some of the volcanic units within the Peloncillo Mountains have been obtained by Marjaniemi (1969, p. 151) and is only mentioned in reference in this thesis because no location of the sample was recorded.

Prior to this study, there has been no published detailed work done in the southern Peloncillo Mountains. The previous workers (Gillerman, 1958; Wrucke and Bromfield, 1961; Dane and Bachman, 1965) simply grouped the Tertiary deposits into a lower and upper sequence based predominantly on a mineralogic field classification.

Paleozoic Rocks

The Paleozoic outcrop in the study area amounts to about 10,000 square feet in the N ½ NE ¼ , section 5, T. 28 S., r. 20 W that has limited extent to the north from the study area. The outcrop is a massive limestone of Pennsylvanian to Permian age, as determined by the abundant fusilinids. A similar limestone was identified by Gillerman (1958, p. 32) as the Pennsylvanian to Permian Horquilla Formation, which is a coarse grained light to dark gray and pinkish gray fusilinid limestone found to the north of the study area. More extensive outcrops do occur to the north but they are not continuous. Because of the extent of the outcrop, the unit will be classified as an undifferentiated Pennsylvanian to Permian limestone. The outcrop is about 350 feet above the present alluvium but the relative amount of relief found today cannot be used to estimate the amount of relief that developed during late Mesozoic erosion and deposition (Gillerman, 1958, p. 90; Sabins, 1951, p. 1323).

Mesozoic Rocks

The assumed Mesozoic outcrops found in the study area are interpreted to be part of the Bisbee Group described by Gillerman (1958, p. 49). There are two lithologies that occur in local outcrops in NW ¼, NW ¼, section 5, T. 28 S.; R. 20 W. and NW ¼ section 4 and NE ¼ Section 5, T. 28 S., R. 20 W. (Plate I, Appendix A) which are interpreted to be the Still Ridge Formation and the Johnny Bull Sandstone, respectively.

Limestone conglomerate that crops out in N ½, section 4 and 5, T. 28 S., R. 20 W. has a limited extension to the north of the map area, and is correlated with the Still Ridge Formation (Gillerman, 1958, p. 50) or the Cowboy Spring Formation (Zeller and Alper, 1965, p. 21) based on textural similarities. The limestone conglomerate is exposed on the south facing lower slope of the Pennsylvanian to Permian limestone outcrop in section 5. The conglomerate has locally resistant layers that form ridges that protrude through the alluvium in this small area. This part of the unit is a poorly sorted conglomerate composed of sub-rounded cobbles and pebbles of Paleozoic limestones and some chert and possibly Cretaceous volcanic fragments cemented in a hematite-stained sparite. The limestone fragments are very similar to the underlying limestone with some dark gray to black limestone pebbles present. This unit is interpreted to have been deposited on the late Mesozoic erosion surface of considerable relief.

The sandstone unit is a small outcrop that is exposed through the alluvium in NW ¼, NW ¼ of section 5, T. 28 S., R. 20 W. This is an argillaceous sandstone with local beds of thick well-indurated quartzite-breccia that is more resistant to weathering. The exposure is limited in the South Antelope Pass area but the unit has been traced to the north and is more extensive in the North Antelope Pass area and is similar to the Johnny Bull sandstone described by Gillerman (1958, p. 52).

Tertiary Rocks in Known and Unknown Stratigraphic Position

Unit-T1 – Quartz Latite Welded Tuff

Tertiary Unit-T1 is a moderate orange pink (5YR8/4) to grayish pink (5R8/2) crystal rich quartz latite welded tuff (Table 4), located in the central portion of section 5, and the NW ¼ section 4, T. 28 S., R. 20 W. and extending to the north into the North Antelope Pass area. The unit rests uncomfortably on the Cretaceous limestone conglomerate and is limited to two exposures in the South Antelope Pass area. The upper contact is inferred to be conformable with Unit-T2, but discontinuities in the exposures, as a result of recent alluvial cover, have placed some doubt on this contact. The estimated range of thickness is between 0 and 44 feet in the South Antelope Pass area.

Unit-T1 weathers in thin plates sub-parallel to the flattened pumice in the unit. The unit has approximately 10 percent euhedral to subhedral, shattered quartz and about 15 percent feldspars that have been highly sericitized (Figures 4 and 5). (The two photomicrographs are from two separate outcrops. They were initially mapped as separate units until thin section study indicated they were the same unit.) Some highly altered rock fragments are present, as well as traces of biotite altered to magnetite and primary magnetite altered to hematite. Devitrified flattened pumice lapilli developed microspherulites as well as secondary quartz.

Table 4

Petrographic Description – Unit-T1

Quartz Latite Welded Tuff				
Percent Phenocrysts: 29%	**Average** 18 - 34 %		**Range**	0.3 to 4.4 mm
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Feldspars	18	.6-3mm 1.2 mm avg	euhedral to subhedral	Highly altered to sericite and kaolin; unable to distringuish type; some albite and carlsbad twinning; some grouping of crystals.
Quartz	10	.5-.4 mm 2.0 mm avg	subhedral to euhedral	Resorbed; fractured; some shattered
Biotite	1	.4-1.9 mm 1.0 mm avg	euhedral to subhedral	Reddish brown; highly altered to magnetite
Magnetite	Trace	.3 mm avg	euhedral	Associated with biotite; finely disseminated throughout; alteraton to hematite
Accessory Minerals				
Sphene and zircon	Trace			Traces of micro crystals
Secondary Minerals				
Sericite and kaolin				Alteration of feldspars
Quartz				filling of fractures and vugs
Hematite				staining of rock
Matrix	Glassy or cryptocrystaline; recrystallized and deveitrified with some shards still present; some axiolitic structure is present in the falttened pumice; lithic fragments are present; microspherulites are locally developed.			

Tertiary unit-T1 is the lowest volcanic unit in the stratigraphic column. The unit was traced by Dennis Gebben (1970) into the North Antelope Pass area.

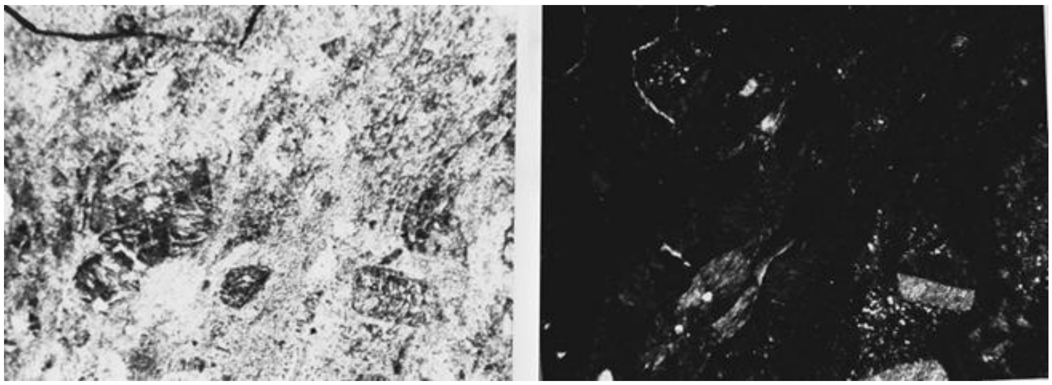


Figure 4. Unit-T1 T.S. Y-104. Twinned and sericitized feldspars in altered groundmass of the quartz latite welded tuff. NW1/4 Section 4, T. 28 S., R. 20 W. A – Plain Light. B – Crossed Nichols. 3.5X.

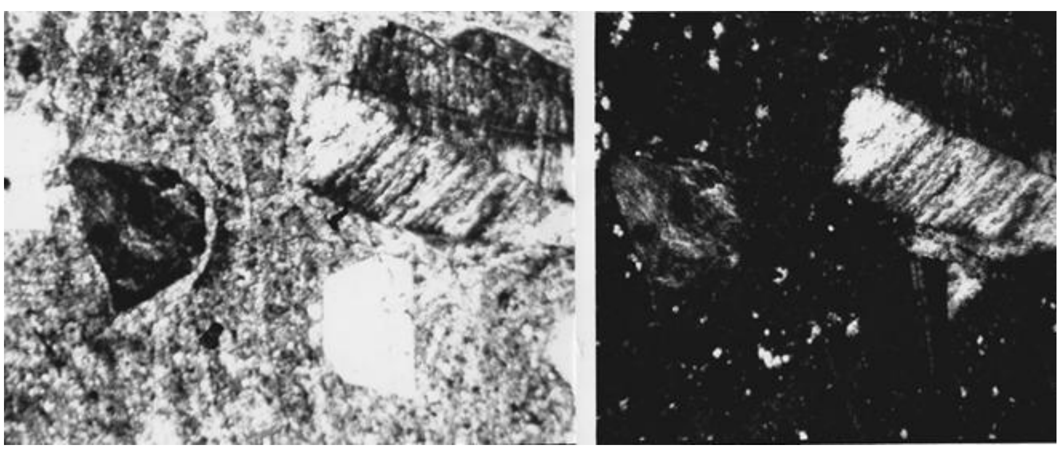


Figure 5. Unit-T1 T.S. Y-91B. Twinned and altered feldspars in altered groundmass of quartz latite welded tuff. NE 1/4 , SW ¼, Section 5, T. 28 S.; R. 20 W. A – Plain Light. B – Crossed Nichols. 3.5X.

Unit-T2 – Litharenite

In the northern sections of the South Antelope Pass area a volcanic litharenite of local extent crops out. The litharenite is located in the central portions of sections 4, 5, and 6, t. 28 S., R. 20 W. The unit is yellowish gray (5Y7/2) to grayish yellow (5Y8/4), cobbly to very fine quartz and calcite cemented immature biotite-rich, conglomeratic litharenite. The rock fragments are sub-angular to sub-rounded; most of them are reddish brown and range in diameter from 2 to 12 mm and are similar to those in Unit-T1 (Figure 6). Rounded pumice fragments are locally abundant. Unit-T2 is at least 200 feet thick but the total thickness is unknown because a full section of the unit is not exposed in any one outcrop. The lower contact is not exposed; therefore, the writer could not determine if the unit was conformable with Unit-T1; however, the upper contact is conformable with welded tuff Unit-T3. Unit-T2 dips 20º–30º to the south and southwest with normal bedding and some small scale cross bedding developed.

Unit-T2 is interbedded with yellow clay deposits about 12 to 18 inches thick which are interpreted as devitrified ash. The ash could not be traced in order to determine whether the glass shards were airfall or water deposited. Some parts of the unit are all indurated while others are friable. The biotite content is high throughout the unit and was used to aid correlation between outcrops.

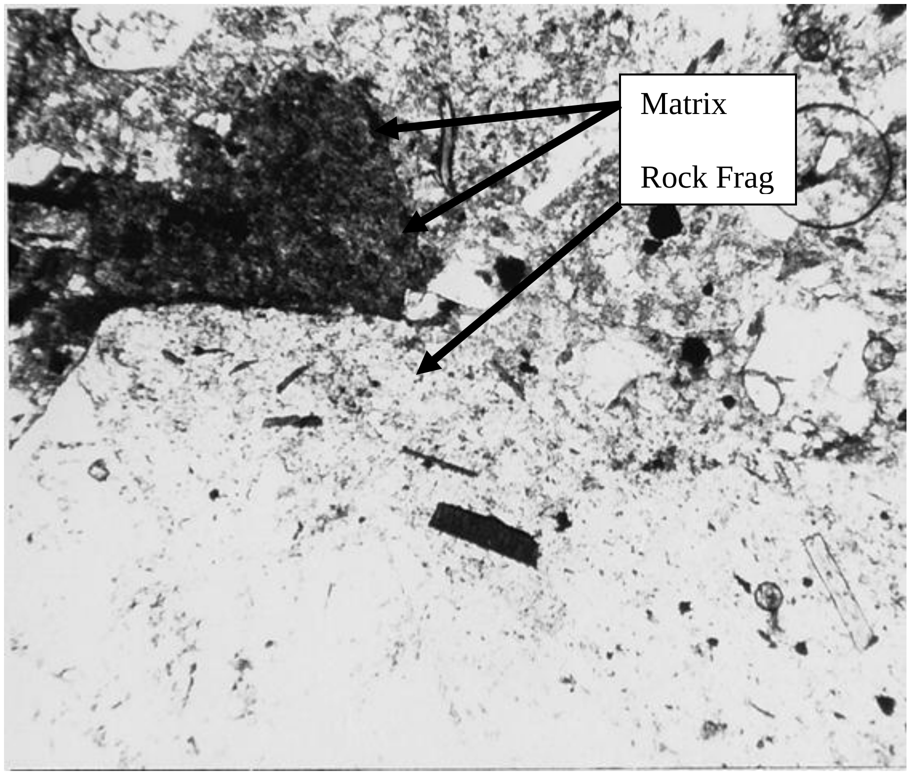


Figure 6. Unit-T2 T.S. Y-91A. Andesite rock fragment that is similar to Unit-T1 matrix in volcanic litharenite. A – Plain Light. 3.5X.

Interbedded within the litharenite is a local volcanic breccia of latite-andesite composition. The rock fragments are very similar to the matrix (Figure 7). The writer was unable to determine whether the breccia is an autobreccia flow or a local lahar. Biotite is very abundant in the sedimentary unit and in this breccia. The total thickness ranges between 20 and 40 feet, but the unit pinches out to the east. Normal faults have offset Unit-T2 with displacements between 15 and 60 feet in sections 5 and 6, T. 28 S., r. 20 W.

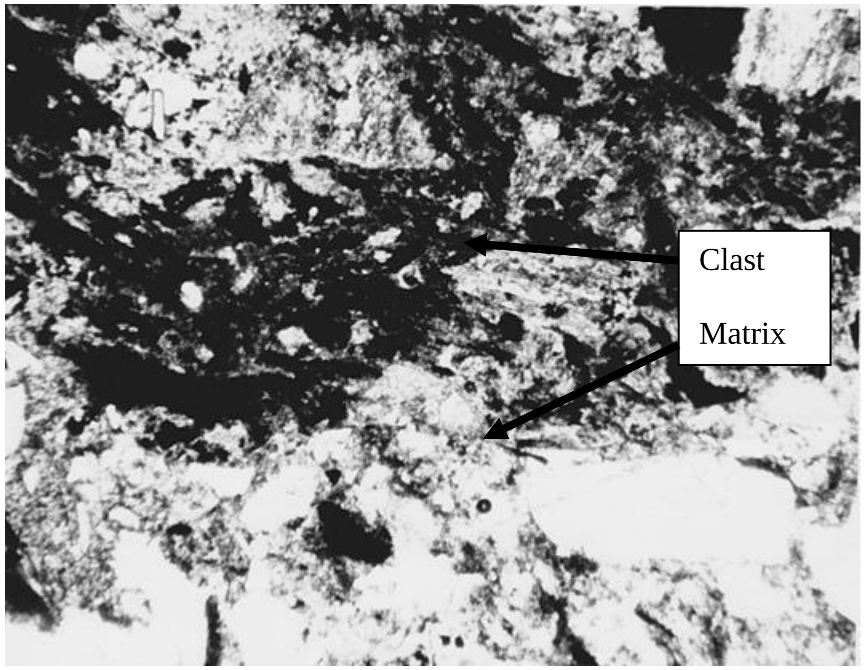


Figure 7. Unit-T2 T.S. Y-28. Local latite breccia within Unit-T2 illustrating the close similarity between the clasts and matrix. A – Plain Light. 3.5X.

Unit-T3 – Trachyte Welded Tuff

Tertiary unit-T3 is a dusky red (5R3/4) to greenish gray (5GY6/1) eutaxitic trachyte welded tuff (Table 5) that crops out in the northern part of the South Antelope Pass are in sections 4, 5, 6 and 8, of T. 28 S., 4. 20 W. The lower contact of Unit-T3 is conformable with the volcanic litharenite, Unit-T2. A baked zone of approximately 12 inches if found at the contact between Units-T2 and T3. The upper contact with Unit-T4, a lithic tuff, is unconformable. The upper contact of Unit-T3 is irregular and the total thickness of the unit varies. The estimated thickness of Unit-T3 is 75 feet.

Tertiary unit-T3, a eutaxitic trachyte tuff, shows a complete ash flow cooling sequence. The lower contact is unwelded with a laterally traceable perlitic greenish-gray glass approximately two feet thick. The unwelded portion has been chilled quickly by

Table 5

Petrographic Description – Unit-T3

Trachyte Welded Tuff					
Percent Phenocrysts:	10%	Average	7 - 16 %	Range	0.3 to 5 mm
Phenocrysts	**Avg. Vol. %**	**Size**		**Shape**	**Character**
Plagioclase	3	.4-5 mm 3 mm avg		euhedral	Albite and carlsbad twins; kolinized and fractured
Sanidine	3	.3-4 mm 3.5 mm avg		euhedral	Carlsbad twinning; fractured; alteration
Quartz	Tr	2 mm		subhedral	Resorbed; fractured.
Biotite	3	.8 mm avg		euhedral to subhedral	Altered reddish brown and green; magnetite rims and inclusions
Accessory Minerals					
Zircon	Tr			euhedral	
Secondary Minerals					
Hematite		Tr - 1			Alteration of magnetite; ubiquitous staining.
Quartz		10			Filling of flattened pumice and vugs
Matrix		Microcrystalline quartz and feldspar; complete recrystallization of the glassy components			

the cooler underlying rock while the glass formed because of the retention of the heat and the weight of the overlying tuff (Smith, 1960b, p. 801). The central portion of the unit is dusky-pale red and is densely welded showing eutaxitic texture (Figure 8); however, the upper portion is platy with an uneven, unwelded surface. Some of the preserved upper surface has partially flattened pumice with secondary quartz filling the voids. The upper surface is un-welded as a result of the lack of overlying ash and the rapid loss of gas and heat, as compared to the lower glassy zone. Devitrification is evident with microspherulites restricted to relic pumice within the unit. The unit was characterized in the filed by slabby weathering and high biotite, low quartz phenocryst content.

Figure 8. Unit-T3 Eutaxitic structure in hand specimen. Eutaxitic structure in hand specimen of the trachyte tuff within the central portion of Unit-T3 (inches).

In the eastern portion of the study area Unit-T3 has been offset by two east-west trending and two north-south trending normal faults in sections 5, 8 and 9, T. 28 S. R. 20W. Relative age of the faults is post-Unit-T5. Offset is on the order of tens of feet. Some repetition of Unit-T3 occurs in the SE ¼ of section 5. Structural dip was measured on the eutaxitic texture in Unit-T3 and is 26º and 30º to the south and southwest. The strike and dip of Unit-T3 is conformable with underlying Unit-T2.

Unit-T4 – Vitric Lithic Tuff

In the northern part of the study area Tertiary Unit-T4, a vitric-lithic tuff, crops out in sections 1 of T. 28 S., R. 21 W. and sections 6, 7, 8 and 9 of T. 28 S., R. 20 W. The unit is pale olive (10Y6/2)-grayish orange pink (5YR7/2) with massive bedded structures which may well represent successive pulses of brecciated, tuffaceous ash being deposited in the area. The bedded structures have abundant pumice, phenocrysts, and lithic fragments incorporated within a devitrified matrix. This matrix is probably devitrified glass shards and pumice with the phenocrysts of euhedral quart and feldspar amounting to approximately 15 percent of the rock. Local lenses of grayish olive green glass are nearly completely devitrified to yellow clay. Pink spherulites with milky opal disseminated throughout are also found associated with the glass. Weathering of the devitrified glass results in fine blockly yellow clay rubble. Small pods of glass still remain in these devitrified layers. This glass is interpreted to be local lava flows that were deposited in topographic depressions that had some moisture present and pinch out laterally. The reddish brown lithic fragments range from 2 to 20 mm and are completely re-crystallized. Fluvial reworking of portion of the lava, pumice, and lithic layers resulted in local channel conglomerates and cross-bedding within the unit in the NW ¼ section 6, T. 28 S., R. 20 W. and NE ½, section 1, T. 28 S., R. 21 W.

The lower contact between Units-T3 and T4 is unconformable with local relief developed (Figure 9). The upper contact of Unit-T4 with Unit-T5 is also unconformable with relatively little relief. Structural dips of Unit-T4 are parallel with Units-T2 and T3. Doming to the northeast of the South Antelope Pass area is reflected in the change of strike of Units-T2, T3, and T4. Unit-T4 ranges in thickness from 25 to approximately 200 feet. A petrographic summary is not included with this unit because of devitrification and silicification of the entire unit.

Figure 9. Contact of Units-T2, T3, T4, T5 in the study area. Looking southwest at the contacts between Units -T3 and T4, Units-T4 and T5, Units-T2 and T3, and Units-T2 and MF-3. Large bedded structures within Unit-4. Lower vitrophyre contact of Unit-T5 in contact with T4. Mud Flow (MF) – 3 in the foreground covering Unit-T2 with Unit-T2 exposed through the mud flow and rhyolite tuff Unit-Trt capping the lower units in Section 6, T. 28 S., R. 20 W.

Unit-T5 – Rhyodacite Rhyolite Lavas, Tuffs and Breccias

Tertiary unit-T5 is composed predominantly of rhyolite to rhyodacite lava flows (Table 6) with subordinate pyroclastic flows and breccia, and is the most extensive unit in the South Antelope Pass area. The unit shows lateral and vertical variations in color and texture, as well as local lithologic changes in the rock type. Textural variations of this unit crop out in nearly all the section of the study area. The unit extends from the Quaternary contact in San Simon Valley (Plate I, Appendix A) on the east, to the eastern margin of the study area in Animas Valley. Outcrops of the same unit extend eastward nearly to Tank Mountain, in sections 14 and 25 and T. 28 S., R. 20 W. (R. V. McGehee, personal communication, 1970) in the Animas Valley. Unit-T5 is light gray (N7)-pale red (10R6/2) with shades of blue, brown, and purple developed within the unit. Blotchy pink and gray is the dominant color of the unit.

The lower contact of Unit-T5 is unconformable with Units-T4 and T3 in sections 6, 7, 8, and 9, T. 28 S., R. 20 W. (Figure 10) and sections 1 and 2 of T. 28 S., R. 21 W. The lower contact, where observable, is indentified by a dark green to black, perlitic, vitrophyre of varying thickness. The vitrophyre ranges from approximately 2 to 50 feet thick. The lower limit of glass thickness was difficult to estimate because of the extent of devitrification of the glass. In some areas it was hard to differentiate devitrified glass and lava. Vitrophyres are noted throughout the unit and are interpreted to be the chilled base of upper vitrophyre (Christiansen and Lipman, 1966, p. 683) of the numerous lava flows within the unit.

Table 6

Petrographic Description – Unit-T5

Rhyodacite to Rhyolite Lava

Phenocrysts	Avg. Vol. %	Size	Shape	Character
Percent Phenocrysts: 16%		**Average** 3 - 24 %	**Range**	0.3 to 4 mm
Quartz	4	.7 - 2.3 mm 1.8 mm avg	subhedral to euhedral	Shattered; fractured; resorbed; some apatite inclusions.
Sanidine	4	.7 - 3. 0 mm 1.4 avg	euhedral to subhedral	Fractured; some kaolinazation; carlsbad twinning; some zoned; reaction rims present in alteraion samples.
Plagioclase An (30) Plagioclase Anorthite (An)	3	.4 - 4 mm 1.6 mm avg	euhedral to subhedral	Corroded; albite and carlsbad twinning; fractured; zoning; grouping of crystals; some alteraton to kaolin; some highly altered; some apatite inclusions.
Biotite	1	.6 mm avg	euhedral to subhedral	Highly altered and rimmed by magnetite; sphene and zircon associated with alteration; reddish brown color.
Magnetite	Trace	.3 mm avg	subhedral to euhedral	Secondary rims around biotite; also altered to hematite; finely disseminated throughout matrix.
Accessory Minerals				
Zircon, sphene, apatite	Trace			Occurs in matrix; as inclusions in phenocrysts; and as phenocrysts
Alteration Minerals				
Hematite				Locally abundant in alteration area, coloring rock with varing degrees of red.
Kaolin				Alteration of feldspars and matrix.
Tridymite				Crystals within lithophysae.
Matrix		Cryptocrystoline usually recrystallized and highly devitrified with sperulites developed; local outcrops having some lithic fragments; flow structure evident with bands of spherulites.		

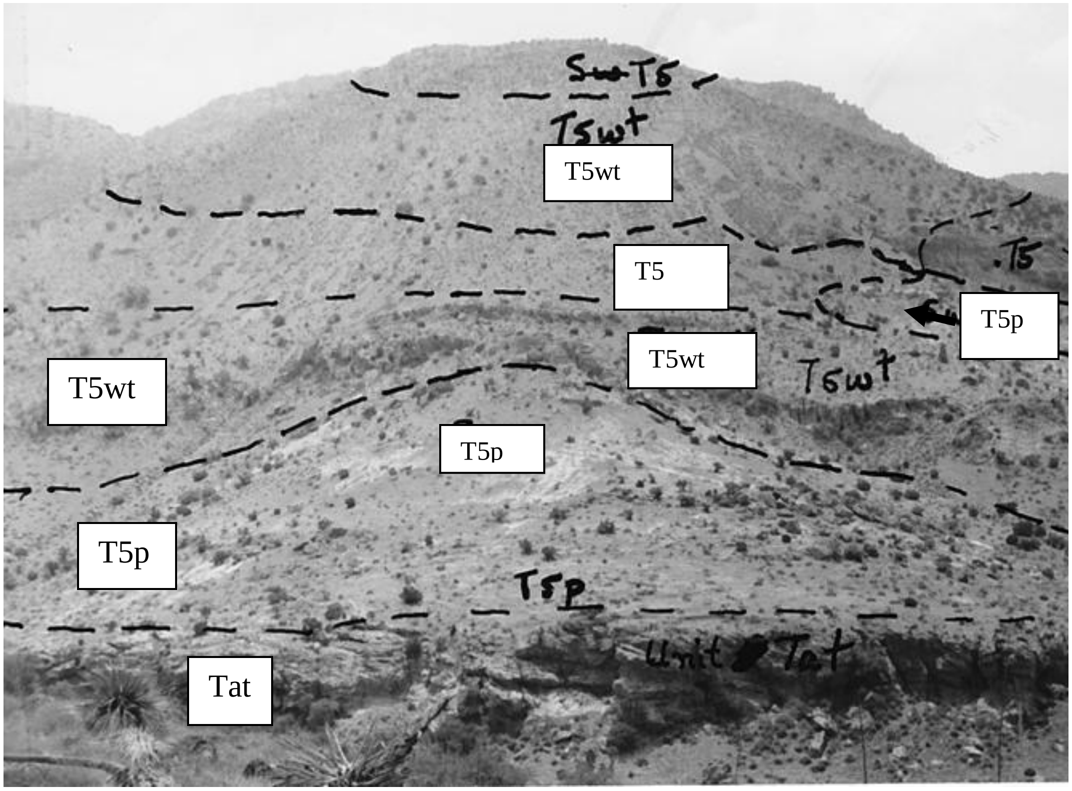


Figure 10. Unit-T5 and members. Pumice flows of member T5p in center foreground deposited on Unit-Tat. South border of section 6, T. 28 S., R. 20 W. Looking south at member T5wt interbedded with and capped by Unit-T5 rhyodacite lava.

The upper contact of Unit-T5 with the overlying Unit-T6 is an erosional surface with approximately 700 feet of relief. The estimated thickness of Unit-T5 is between 700 and 1600 feet. The uneven surface, buried basal contact with lack of measurable stratigraphic structures is the reason for the variation in estimated thickness.

Unit-T5 was identified in the field by primary, as well as secondary structures. Estimating the small percentages of quartz, partially altered biotite, sanidine, and plagioclase phenocrysts could not always be done accurately in the field. The character of the quartz is partially resorbed, euhedral to subhedral, clear crystals and the biotite is highly altered reddish brown with hematite stains surrounding the euhedral flakes.

Sanidine is unaltered or partially altered and was distinguished from plagioclase by the lack of albite twinning and from quartz by cleavage and Carlsbad twins.

Unit-T5 has abundant flow structure with amplitudes up to 80 feet or more. Examples are found in the NE ½ section 8, T. 28 S., R. 20 W. Most of the amplitudes of the flow structure are ½ to 6 feet, but the small structures may be part of a larger structure that is not exposed (Figures 11 and 12). Associated with the lamination in the flow structure are lithophysae and spherulites (Figures 13 and 14). The spherulites, a product of devitrification, are microcrystalline quartz and orthoclase radiating from a center outward to approximately 15mm (Figures 15 and 16).

Lithophysae are also abundant in Unit-T5. They have been locally filled by secondary quartz and feldspar, and therefore are difficult to see in hand specimen. Thin section identification was hampered because of recrystallization, but some tridymite was identified, however most of the lithophysae filling is now secondary quartz.

T5br – Breccia

Local zones of flow breccia were found within Unit-T5 with some portions containing fine, angular fragments that ranged from 2 to 10mm. Outcrops of breccia mapped separately are labeled T5br on the geologic map (Plate I, Appendix A).

Figure 11. Unit-T5 Flow structure. Large scale flow structure in rhyodacite flow. Tree in left foreground is approximately 6 feet. SE ¼ section 22, T. 28 S., R. 21 W.

Figure 12. Unit-T5 Small scale flow structure. Small scale flow structure in rhyodacite flow depicted in photo taken on the surface (Arrow to Brunton) above the outcrop in Figure 11.

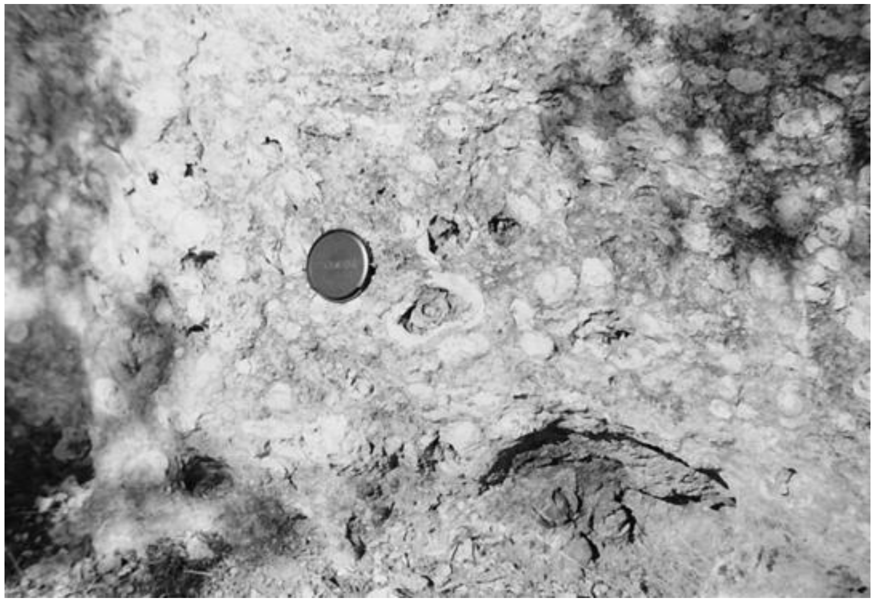


Figure 13. Unit-T5 Lithophysae. Abundance of Lithophysae associated with the flow structure in rhyodacite lava. South of map area in SE ¼ section 28, T. 28 S., R. 29 W.

Figure 14. Unit-T5 Spherulites on outcrop. Spherulites aligned (double arrows) with flow structure. NW ¼ section 7, T. 28 S., R. 20 W. Hammer in middle foreground for scale, small arrow.

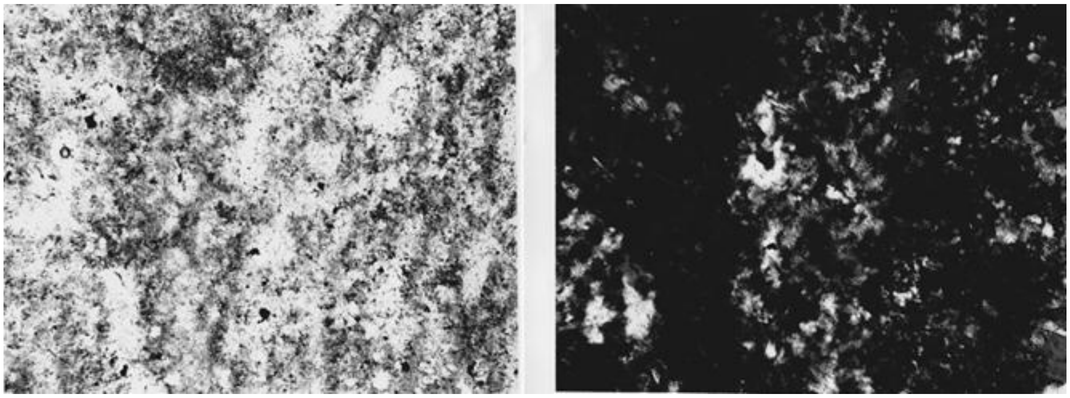


Figure 15. Unit-T5 T.S. Y-98 Microspherulites. Microspherulites within the re-crystallized groundmass of the rhyodacite lava flow. The laminea are only 1-3mm apart in this section. A – Plain Light. B – Crossed Nichols. 6.3X.

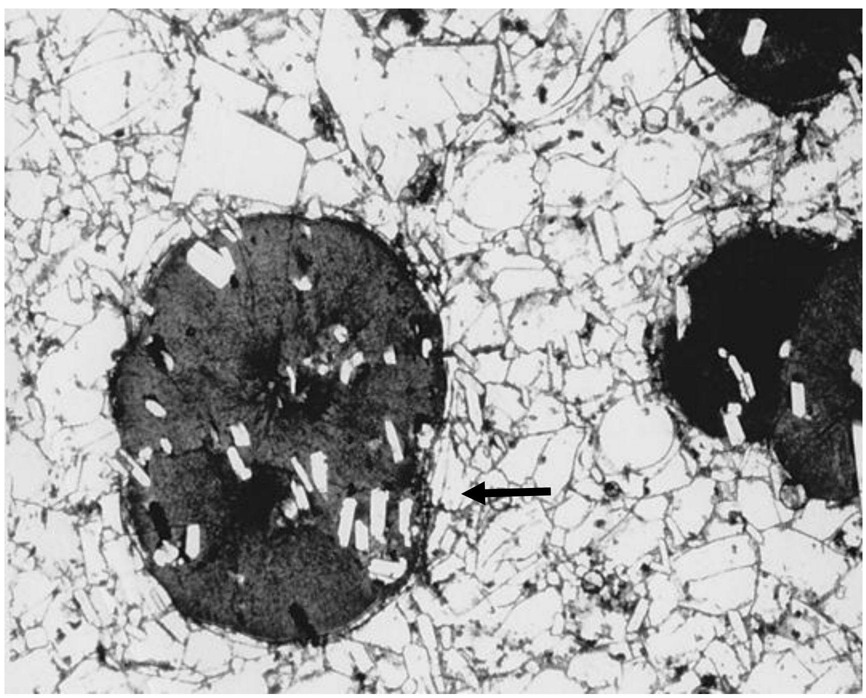


Figure 16. Unit-T5 T.S. Y-39 A rhyolite vitrophyre. Rhyolite vitrophyre with large spherulites developed within the glass, secondary quartz. SE ¼ NE ¼ NE ¼, section 7, T. 28 S., R. 20 W. A – Plain light. 1X.

An outcrop in E ½, section 22, T. 28 S., R. 21 W. has angular to sub-angular clasts to 50 mm (Figure 17). The clasts and matrix are nearly identical except for the hematite-stained matrix. Phenocryst content of the matrix is light and consists of quartz and sanidine, similar to Unit-T5 lava. Another outcrop of breccia in the northwest portion of the study area in sections 9 and 10, T. 28 S., R 20 W. is similar, but thin section study indicates that the rock has been completely recrystallized. Rock fragments that could be distinguished are angular to subangular, 2 to 4 mm in length, and identical to those in the massive portion of the unit. Hematite staining is locally very abundant but phenocryst content was difficult to estimate because the feldspars are completely altered. The red-stained breccia is mapped as part of Unit-T5 (Christiansen and Lipman, 1966, p. 675).

Figure 17. Unit-T5 Flow breccia. Flow breccia with interpreted auto flow breccia in place E 1/2, section 22, T. 28 S., R. 21 W.

T5-p – Pyroclastics

Moderate red pale yellow pyroclastic, pumice rich, deposits are observed, locally, in the SW ¼ section , and the N ½, section 7 and 8, T. 28 S., R. 20 W. These pumice and lithic units are interpreted to be members of Unit-T5 and will be denoted on the map as T5p. The same lithology is found in NW ¼ 1, in 2, NE ¼ 12 T. 28 S., R. 21 W., and in the W 1/2 section 15, T. 28 S., R. 20 W. These rocks have abundant pumice layers of pyroclastic origin and locally derived epiclastic layers. The pyroclastic layers are hematite-stained pumice flows with very low phenocryst content. Some partial flattening of pumice was observed in N ½, section 2, T. 28 S., R. 21 W. Lithic layers are composed of reddish purple, angular to subangular unrelated volcanic rock fragments. The pumice units are not continuous, therefore correlation was difficult. Most of these pumice rich units have layers and lenses of devitrified glass incorporated with the unit. Where observable the lower and upper contact of the pumice flows with the surrounding rock types was irregular.

T5vb – Vent Breccia

An outcrop of breccia 250 by 350 feet is located in the SE ¼ NW ¼ section 2, T. 28 S., R. 21 W. The unit is designated T5brv on the geologic map (Plate I, Appendix A). Angular light gray to dark green clasts up to 6 feet are incorporated in a completely glass matrix. Samples from the adjacent rock show recrystallization within Unit-T5 and not in the breccia. The breccia seems to be relatively fresh (Figures 18 and 19) and may occupy

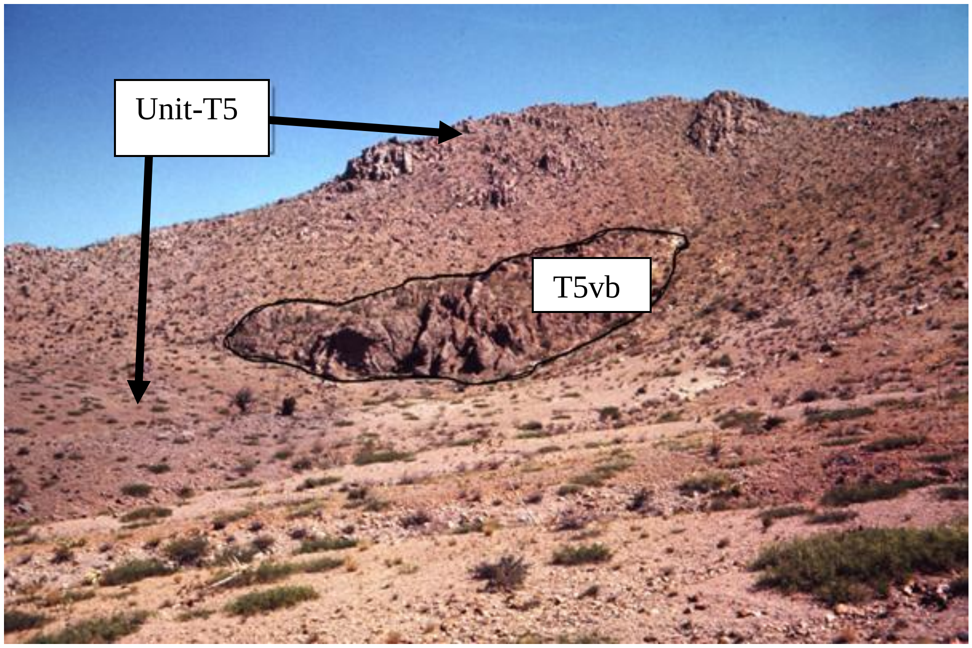


Figure 18. Unit-T5 Vent breccia. Large angular breccia, local possible vent breccia (T5vb) outcrop on the north side of the study area. This may be a hydrothermal vent. SE ¼ NW ¼, section 2, T. 28 S., R. 21 W.

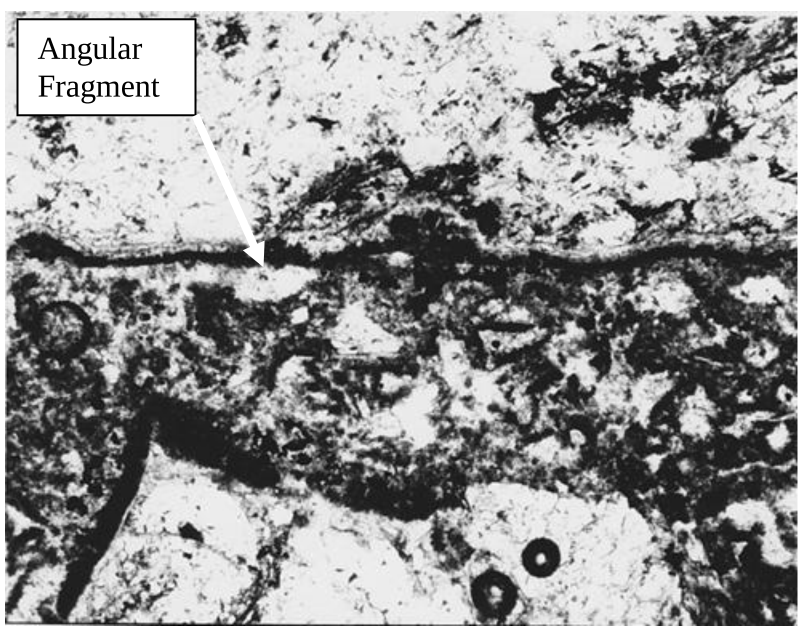


Figure 19. Unit-T5 T.S. Y-100A. Photomicrograph of the angular breccia. The angular quartz is not associated with the surrounding rock units. Plain light. 6.3X.

a former hydrothermal vent that altered the surrounding rock and was later filled by caving and erosion of material from above.

T5wt – Welded Tuff

Local eutaxitic welded tuff outcrops that occur in sections 7, 8 9, NW ¼ section 21 and NW ¼ section 22, T. 28 S., R. 20 W.; NW ¼ and C and SW ¼ section 2, T. 28 S., R. 21 W. are interpreted to be interbedded within Unit-T5 and they are designated as T5wt on the geologic map. Phenocryst content does not indicate a genetic relationship to the lava flows but the incorporation of Unit-T5 clasts and the conformable lower and upper contact in some outcrops indicate contemporaneous deposition with Unit-T5 lava flows. These welded tuffs are reddish brown to reddish purple with shades of light brown. Resorbed quartz up to 3 mm amounts to 9 percent of the rock. Alkali and plagioclase feldspars occur in equal amounts and total 8 percent. Some alteration of the 2 to 4 mm euhedral sanidine phenocrysts is evident. Lithic fragments 2 to 15 mm in size are subangular to angular. Flattened pumice with produces the eutaxitic structure is 6 to 30 mm long and 2 to 6 mm thick. The writer was unable to determine if these rock types were from the same source as Unit-T5. Their wide spread occurrence and their contacts with T5p and the lava have led to the interpretation that the welded tuffs are interbedded within Unit-T5.

An unusual sequence of Unit T5 welded tuff is found in SE ¼ SE ¼ section 2, T. 28 S., R. 21 W. (Figure 20). This sequence of welded tuff with interbedded perlitic glass is capped by Unit T5 lava. Within the lower portions of the sequence there are 14 consecutive, think cooling units (Smith, 1960b, p. 157). They were identified as cooling units by the amount of compaction of the pumice and the relative degree of welding within each cooling unit. The sequence lies unconformable, at this outcrop, on T5p with an irregular surface. The upper zones of each of the cooling units is frothy with many vesicles that are fused to glass shards. Glass found in the lower portion of the sequence, below the welded tuff perlitic and black to devitrified and reddish brown.

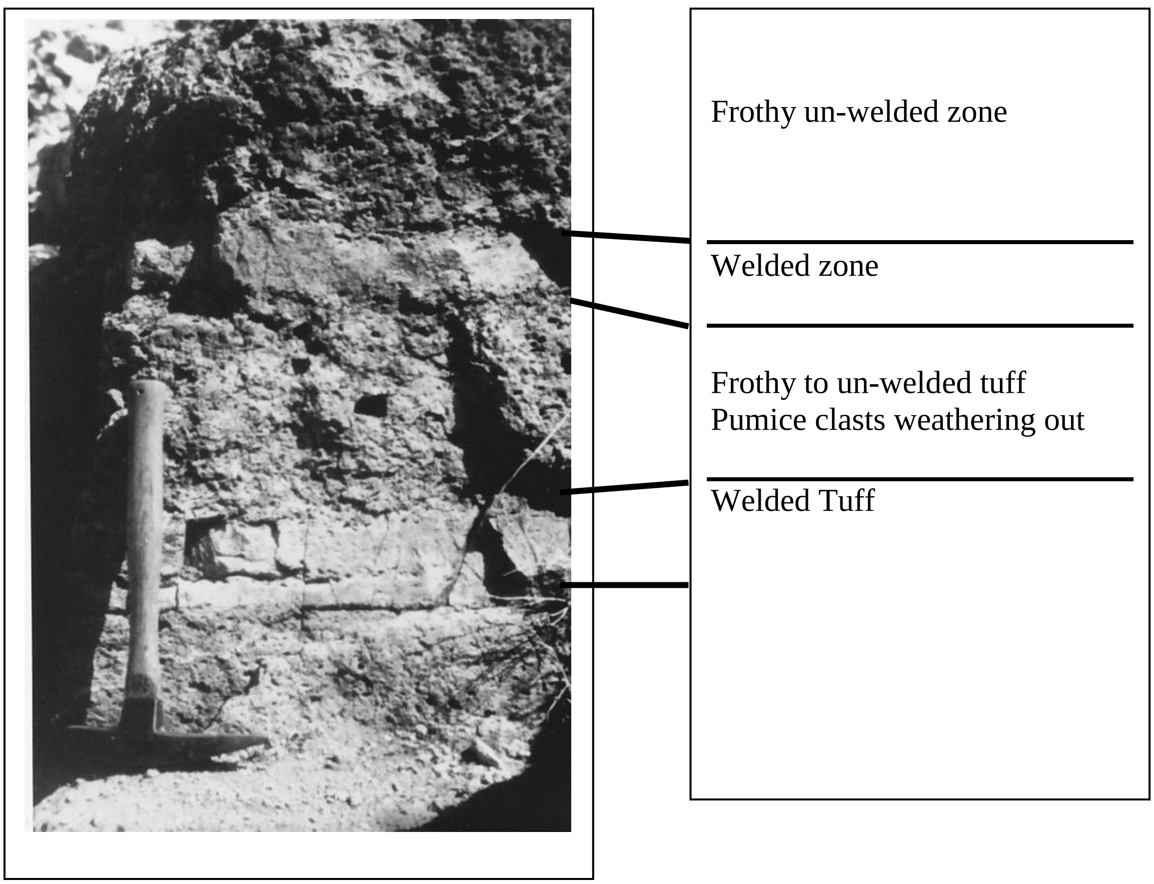


Figure 20. Unit-T5wt Cooling units. Two of the thinner cooling units within the welded tuff sequence. SE ¼ SE ¼ , section 2, T. 28 S., R. 21 W.

The upper zone is composed of globular masses of devitrified brown, bluish, to black perlitic glass. The character of the cooling units and glass places this sequence within T5wt as a member in the Unit-T5. The total thickness of this outcrop is approximately 115 feet of glass and cooling units.

T5a – "Altered" Rhyodacite to Rhyolite Lava

The northeast portion of the South Antelope Pass area in sections 15, 16 and the E ½ section 17, SE ¼ section 8, S ½ section 9, T. 28 S., R. 20 W. is highly altered. Thin section analysis indicates nearly complete alternation of the feldspars and abundant hematite staining of Unit-T5 in this area (Figure 21). Most of the area is bright red with flow structure and relic Lithophysae locally preserved. The alteration could be traced in the field and is delineated on the geologic map (Plate I, Appendix A) as T5a. The alteration was found to be hematite after magnetite in Unit-T5 and member T5br. This is in the same area as Unit-Tlp (latite porphyry) and the Animas Basalt outcrops. Perhaps the alteration was produced by minor intrusion that possibly were associated with the basalt, although Lowell and Guilbert (1970, p. 373) have outlined various sequences of alteration and mineralization associated with ore-bearing Tertiary intrusives in major mining districts in the western United States. There are no similarities between any of these ore-bearing mineral assemblages and the minerals found in the South Antelope Pass area, although local "mineralization" has been found outside the study area (R. V. McGehee, personal communication, 1970).

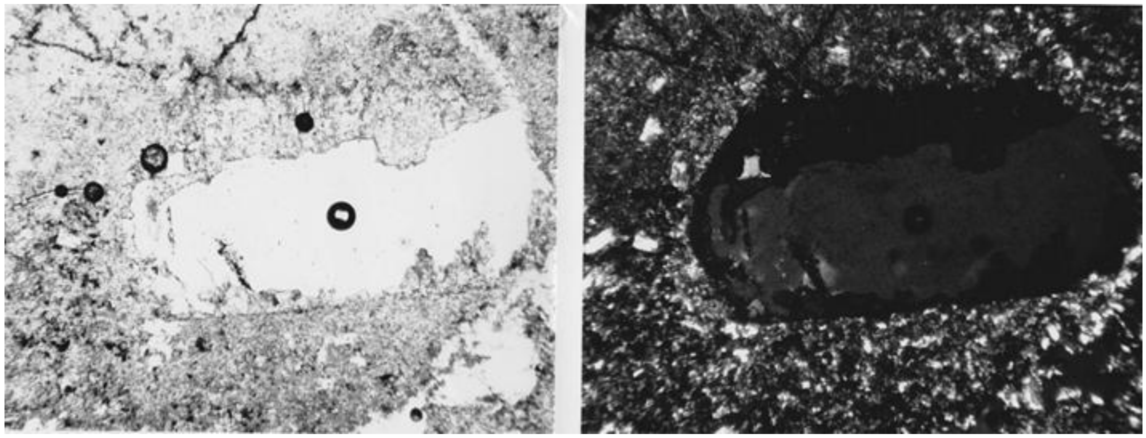


Figure 21. Unit-T5a T.S. Y-111. Photomicrograph of Unit-T5 rhyodacite alteration. Altered sanidine crystal. A – Plain Light. B – Crossed Nichols. 3.5X.

Tertiary Unit-T5 (Table 6) is an interbedded sequence of lava pyroclastics and welded tuffs with rhyodacite to rhyolite lava deposited in multiple flows. The writer interprets Unit-T5 as multiple lava flows for the following reasons:

1. The vitrophyres at or near the basal contact (Christiansen and Lipman, 1966, p. 675). Thin section analysis does not indicate the glass is composed of densely welded glass shards.
2. Brecciated portions (Unit-T5) within a very similar groundmass (Christiansen and Lipman, 1966, p. 675).
3. The widespread occurrence of large scale flow structures that could not be formed in an ash flow.
4. Lithophysae and spherulites are not direct evidence for lava flows, but they were found throughout the unit and were associated with the flow structures (Boyd, 1961, p. 404).

5. Flow structures of this type have been found in rhyolitic lava flows by Christiansen and Lipman (1966, p. 684), Boyd (1961, p. 404), and Elston and others (1968, p. 262), but features 1, 2 and 4 are also found in welded tuffs of great thicknesses in the Great Basin (Smith, 1960, p. 153).

Flow structures were not concentrated in any particular location; as a result, they could not be used to indicate the relative direction of movement of lava. Because of the lack of regional geochemical data the writer cannot predict a source for the flow. A geochemical study of trace elements is in progress for the Unit-T5 and related rock types from adjacent ranges by George V. Williams (master's thesis, WMU). His data is not available for use in this thesis.

Unit-T6 – Lithic Lapilli Tuff

Tertiary Unit-T6 is a very pale orange (10YR8/2), yellowish gray (5Y7/2) to pale red (5R6/2) variable sequence of lithic-lapilli tuffs with interbedded litharenites and air-fall tuffs. The unit is exposed in the central and southern portion of the study area and extends from the San Simon Valley on the wet to the Animas Valley on the east. Earlier Tertiary canyons that developed on Unit-T5 were later filled by Unit-T6 with massive bedding structures developed and high initial dips near the basal contact. Volcanic deposition continued to the south, as documented later in this thesis, and culminated in the mid–late Tertiary during Basin and Range block faulting (Marjaniemi, 1969, p. 28–30). Subsequent erosion of Unit-T6 and possible overlying rocks restricted outcrops of Unit-T6, in the study area, to erosional remnants, while leaving a continuous outcrop of the unit to the south. The erosional remnants of Unit-T6 generally form spired structures

(Figure 22) as a result of selective cementation and subsequent weathering along fractures. Unit-T6 weathers relatively easily; therefore, the thickest sections are preserved where it is capped by resistant Unit-T7. A sequence of Unit-T6 in contact with Unit-T5 and Unit-T7 is found in section 27, T. 28 S., R. 21 W. where the thickness is estimated at 300 feet. The upper contact, where exposed in the study area, does exhibit local relief. The unit is unconformably in contact with Unit-T7, a quartz latite welded tuff, and locally, Unit-T8 a rhyolite tuff.

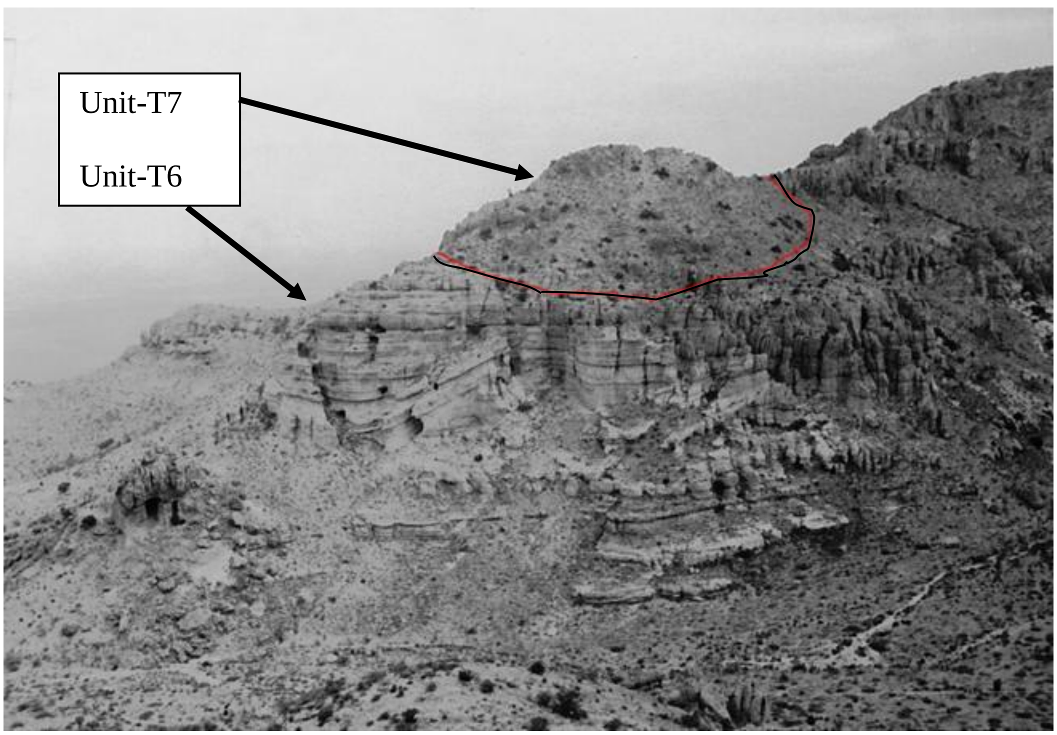


Figure 22. Unit-T6 Bedded and spired structures. Bedding and spired weathering structures. The unusual crossbedding is possibly due to slumping in the unconsolidated ash or crossbedded channel deposits. Capped by Unit-T7. Looking north-northwest. Section 14, T. 28 S., R. 21 W.

Structural and stratigraphic interpretation within Unit-T6 were hindered as a result of abundant textural changes near the contact with underlying T-5 (Figure 23) and the unconformable surface at the upper contact of Unit-T6. These factors and the discontinuities in the remnants of Unit-T6 limited the recognition of possible faults that could have led the writer to overestimate the thickness of Unit-T6 or Unit-T5.

The lithology near the lower contact of Unit-T6 (Figure 23) varies from one outcrop to another. Locally, basal T6 is composed of unsorted Unit-T5 lithic fragments up to 6 feet across, consolidated in a groundmass (Figure 24) of yellow clay similar to the devitrified glass within the unit. In most of the outcrops the basal rocks are devitrified ash with approximately 2 percent phenocrysts. The extent of devitrification of the glassy matrix made recognition of any interpretive textures in the bedded units difficult. Local sedimentary structures, such as cross and normal bedding that were found within the unit, were developed by water action while the small scale graded bedding is attributed to air fall deposits. Deposition of lithic fragments (Figure 25) on an ash surface with subsequent erosion has produced ridges. Some of the bedding texture is the result of reworking of the primary depositions. While some of the structure may be the result of slumping of water-saturated ash, rock fragments and mud, these features are contemporaneous with further deposition. Unit-T6 is identified in the field by massive bedding (Figure 26).

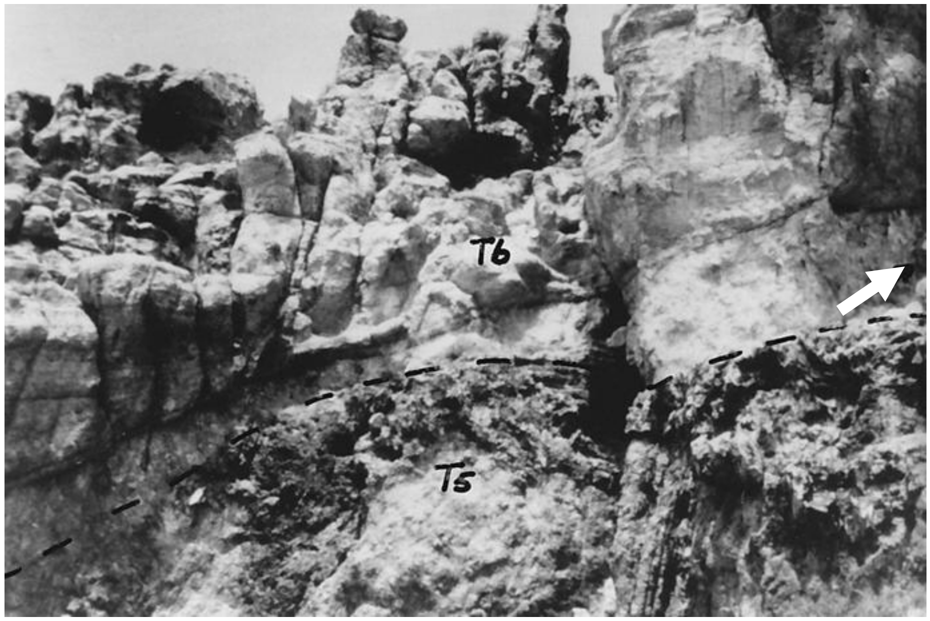


Figure 23. Unit-T6 Unconformable contact between Units-T5 and T6. Man standing (arrow) near contact Unit T5 and T6 contact on the right side. SW ¼ SW ¼ section 14, T. 28 S., R. 21 W.

Figure 24. Unit-T6 Basal contact. Basal contact of Unit-T6 with abundant lithic fragments of Unit-T5 within a devitrified glass and pumice matrix, yellow clay. SE ¼ NE ¼ section 14, T. 28 S., R. 21 W. Hammer (arrow) in center of photograph.

Figure 25. Unit-T6 Lithic fragment. Lithic fragment in rhyolite lithic tuff, similar to Unit-T5. Pot marked surface is weathered out pumice fragments.

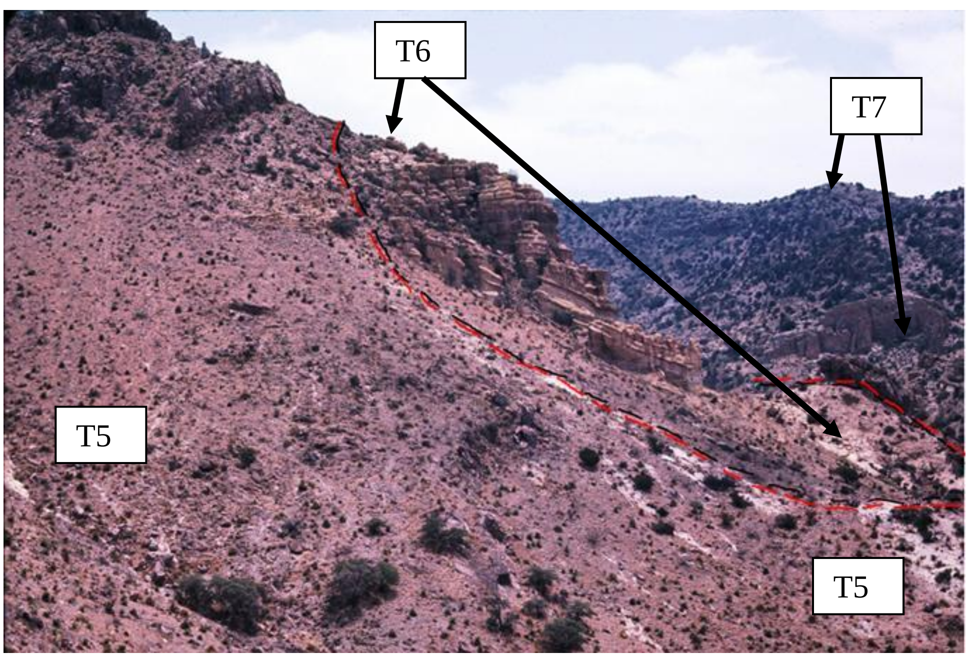


Figure 26. Unit-T6 Contacts of Units-T5, T6 and T7. Unconformable insipiant dip of Unit-T6 on the T5 contact. Unit-T7 unconformable with Units-T6 and T5. Looking southeast in SW ¼ SE ¼ section 14, T. 28 S., R. 21 W.

Mineralogically the Unit-T6 is quite similar throughout the outcrop. Field descriptions of the small percentages of phenocrysts were substantiated by thin section analysis (Table 7) subhedral to anhedral, resorbed, highly fracture quartz crystals are incorporated in a highly devitrified matrix of glass shards and pumice lapilli. Some relic shard and pumice structures are found in thin section (Figure 27). Sanidine and plagioclase are euhedral to subhedral laths having Carlsbad and albite twinning with slight alteration to kaolin, while the traces of biotite are altered to magnetite. The pumice lapilli and glass shards make up the greatest percentage of the rock by volume.

Unit-T7 – Welded Tuff

Tertiary Unit-T7 is phenocryst rich tuff of rhyolite to quartz latite composition that forms an east-west trending exposure in the southern portion of the study area with the largest and thickest exposures on the west that thins to the east. The unit is pale red (5R6/2) to grayish purple (5P4/2) with shades of brown and gray and exhibits white crystal rich streaks that are discontinuous within the unit. Thin exposures are found to the north in sections 14 and 15, T. 28 S., R. 21 W. and to the east in section 20 and 21, T. 28 S., R. 20 W. The northern exposures of the unit are discontinuous and therefore were mapped with some degree of difficulty while the south and eastern exposures could be traced continuously.

Unit-T7 lies unconformably on Units-T5 and T6 in most of the study area and on porphyritic latite (Trpl) in the southwestern corner (Plate I, Appendix A). The upper contact of the unit is seen only where locally capped by Unit-T8, a rhyolite tuff. Because

Table 7

Petrographic Description – Unit-T6

Quartz Latite Welded Tuff

Percent Phenocrysts: 28%	Average 24 - 32 %	Range 0.5 to 6 mm	

Phenocrysts	Avg. Vol. %	Size	Shape	Character
Quartz	5	.5 - 3.0 mm 1.9 mm avg	subhedral to euhedral	Fractured; resorbed.
Sanidine	9	2 - 6 mm 4.0 mm avg	euhedral to subhedral	Carlsbad twins; fractured; some sericite alteration; inclusions.
Plagioclase	2	.6 - 1.4 mm 1.0 mm avg	subhedral to euhedral	Shattered; altered to clay; albite and carlsbad twins; apatite inclusions
Biotite	Trace - 1	2.0 mm avg	euhedral	Lath shaped plates; alteration rim of magnetite; reddish brown.
Magnetite	Trace - 1	.5 mm avg	subhedral to euhedral	Secondary rims around biotite; also altered to hematite; finely disseminated throughout matrix.
Pyroxene	Trace		euhedral	Phenocrysts was partially shatted; rim of hematite alteration.
Accessory Minerals				
Apatite and Zircon	Trace			Some megascopic crystals; some associated with the matrix.
Zircon, sphene	Trace			Euhedral megascopic crystals; relatively abundant
Secondary Minerals				
Quartz				Secondary filling of pumice and fractures in the unit.
Matrix	Glassy to cryptocrystoline (some thin sections show devitrification of glass to spherulites); local bending of relic glass shards around crystals; hematite staining may be intense but varies with the rock; some flattened pumice has been devitrified.			

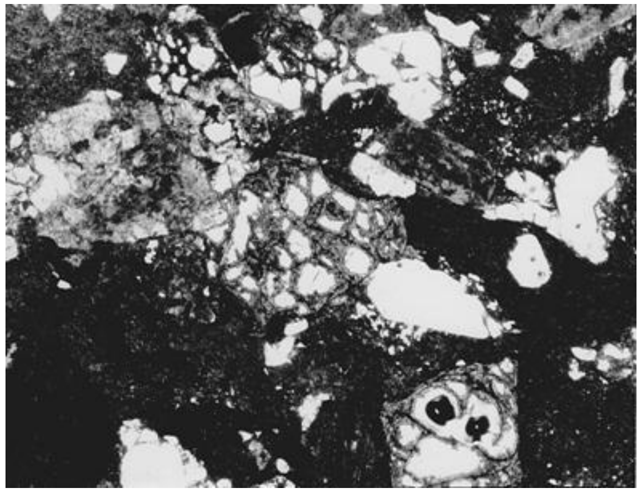


Figure 27. Unit-T6 T.S. Y-135. Photomicrograph of relic crystal with microcrystals of quartz forming a network within the fragment. A – Plain Light. 1X.

Unit-T8 does not everywhere occur on Unit-T7, the writer has interpreted that either of two scenarios, an erosional surface of unknown relief had developed after the deposition of Unit-T7 or Unit-T8 was removed by post Unit-T8 erosion partially exposing Unit-T7.

The central exposures of Unit-T7 are discontinuous, the exposures in SE ¼, section 14; S½, section 15; E½, section 22; and NW¼, section 23, T. 28 S., R. 21 W. are not as massive as the other portions of the unit, and as a result the unit weathers readily to rubbly outcrops. Unit-T7 lies unconformably on Unit-Trpl at the southwestern border of the study area where highly altered clasts of the igneous body are incorporated in the welded tuff.

Unit-T7 is characterized by the following features: it is dark in color, massive, has abundant phenocrysts of quartz and feldspar, and local outcrops in sections 26, 27, and 28 of T. 28 S., R. 21 W. have excellent columnar jointing developed (Figure 28). The distinctive mineralogy of Unit-T7 consists of subhedral to euhedral, fractured quartz crystals up to 3 mm long (Table 8). The feldspars were distinguished in the field by albite twinned plagioclase and the relative transparency of the sanidine. The phenocrysts were up to 6 mm in length and had euhedral to subhedral outlines. Some altered biotite is present, but was not distributed uniformly in the unit. White streaks of crystals were found scattered throughout the rock and were identified petrographically as quartz filling flattened and stretched pumice. Although glass shards were not evident in the hand specimen, they were found in thin section (Figure 29). Micro-spherulites were locally developed as a result of devitrification. The lower portion of Unit T7 is not the same throughout its exposure. Local vitrophyres are exposed in the SE¼, NE¼, section 33, and SW¼, section 15, T. 28 S., T. 21 W. The color of the unit in section 33 is pale brown, and the feldspars are completely altered.

Figure 28. Unit-T7 Columnar jointing. Columnar jointing in the thick sequence of Unit-T7. Section 33, T. 28 S., R. 21 W. Looking northeast.

Table 8

Petrographic Description – Unit-T7

Quartz Latite Welded Tuff

Percent Phenocrysts: 28% **Average** 24 - 32 % **Range** 0.5 to 6 mm

Phenocrysts	Avg. Vol. %	Size	Shape	Character
Quartz	5	.5 - 3.0 mm 1.9 mm avg	subhedral to euhedral	Fractured; resorbed.
Sanidine	9	2 - 6 mm 4.0 mm avg	euhedral to subhedral	Carlsbad twins; fractured; some sericite alteration; inclusions.
Plagioclase	2	.6 - 1.4 mm 1.0 mm avg	subhedral to euhedral	Shattered; altered to clay; albite and carlsbad twins; apatite inclusions
Biotite	Trace - 1	2.0 mm avg	euhedral	Lath shaped plates; alteration rim of magnetite; reddish brown.
Magnetite	Trace - 1	.5 mm avg	subhedral to euhedral	Secondary rims around biotite; also altered to hematite; finely disseminated throughout matrix.
Pyroxene	Trace		euhedral	Phenocrysts was partially shatted; rim of hematite alteration.
Accessory Minerals				
Apatite and Zircon	Trace			Some megascopic crystals; some associated with the matrix.
Zircon, sphene	Trace			Euhedral megascopic crystals; relatively abundant
Secondary Minerals				
Quartz				Secondary filling of pumice and fractures in the unit.
Matrix	Glassy to cryptocrystoline (some thin sections show devitrification of glass to spherulites); local bending of relic glass shards around crystals; hematite staining may be intense but varies with the rock; some flattened pumice has been devitrified.			

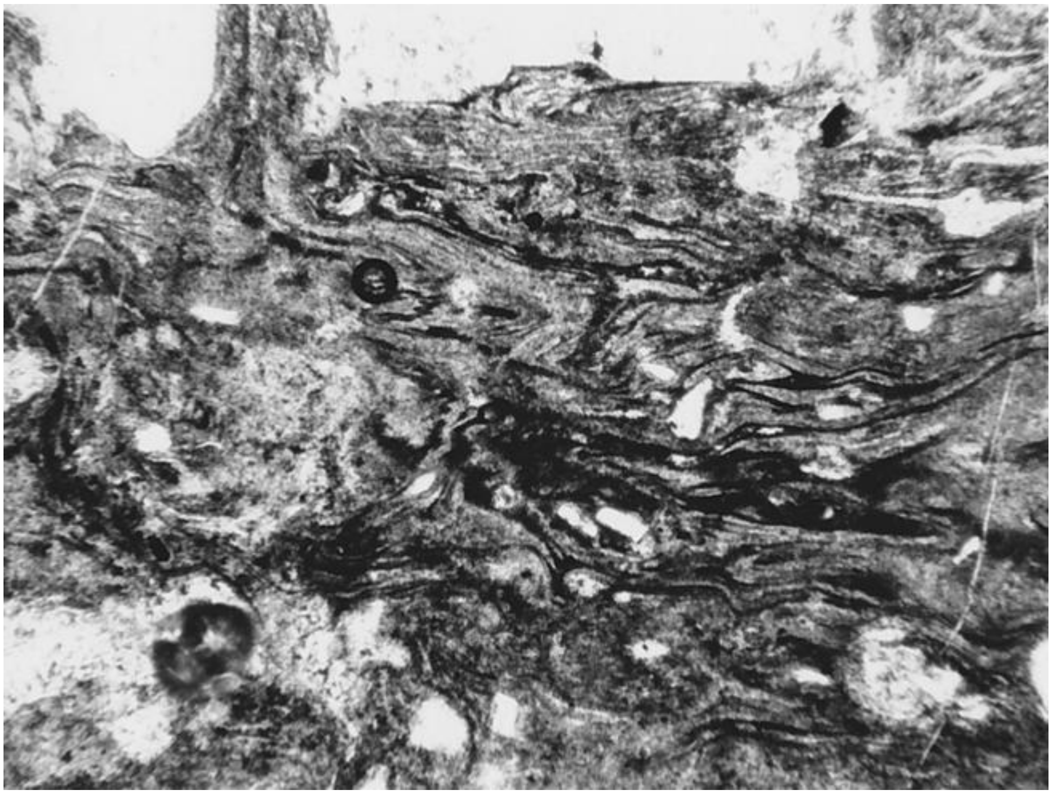


Figure 29. Unit-T7 T.S. Y-201. Photomicrograph of welded glass shards in Unit-T7. A – Plain Light. 3.5X.

There is also a tuffaceous basal portion of T7 in section 33 that does not have the same dark color as the major portion of the unit. The small exposure has black fiamme (Figure 30) within the pink, hematite-stained groundmass.

Unit-T7 is a quartz latite to rhyolite welded tuff that has a distinctively higher phenocryst content than any other unit in the area. The thickness is estimated at approximately 450 feet. The unit is predominantly massive and its resistance to weathering has locally formed a cap rock for the underlying Unit-T6.

Figure 30. Unit-T7 Black fiamme. Black fiamme in pink tuffaceous matrix near base of Unit-T7. NE ¼, Section 33, T. 28 S., R. 21 W.

Unit-T8 – Rhyolite Tuff

Tertiary Unit-T8 is a rhyolite tuff that has been mapped as a separate unit because of the marked change in phenocryst content of 12% (Table 9) versus the underlying Unit-T7 at 28%. Unit-T8 is exposed in E½, section 23, W½, section 24, T. 28 S., R. 21 W. Its total areal extent is limited to a few hundred square feet in each exposure/outcrop. The unit is pale, yellowish brown (10 YR6/2) to grayish red purple (5RP4/2) and has approximately 12 percent phenocryst.

Table 9

Petrographic Description – Unit-T8

Rhyolite Tuff

Percent Phenocrysts:	12%	Average	8-16%	Range	0.3 to 1.9 mm

Phenocrysts	Avg. Vol. %	Size	Shape	Character
Quartz	4	.5 - 2.5 mm 1.5 mm avg	subhedral to anhedral	Fracture;: resorbed
Sanidine	5	.7 - 2.4 mm 1.9 mm avg	subhedral to andheral	Some carlsbad twinning; fractured
Plagioclase	1	1.2 mm avg	subhedral to anhedral	Fractured; untwinned
Biotite	Trace	.8 mm avg	euhedral	Red brown; altered to magnetite
Magnetite	1	.3 mm	subhedral	Altering to hematite; primary throughtout the rock
Accessory Minerals				
Zircon	Very rare			

Secondary Minerals	
Cristobalite	Small laths identfied optically
Quartz	Filling cracks in mozaic pattern

Matrix	Nearly complete recrystallization; some relic shards do remain; glassy to cryptocrystalline; banding around phenocrysts.

The phenocrysts are small and average 1.5 mm with shattered, euhedral to subhedral, resorbed, quartz crystals amounting to 4 percent. The chatoyant sanidine is euhedral to subhedral with Carlsbad twins and totals 7 percent. The traces of biotite are partly altered to magnetite with traces of primary magnetite throughout the sample. The glass shards in the groundmass are not highly altered and were readily discernible in thin section (Figure 31).

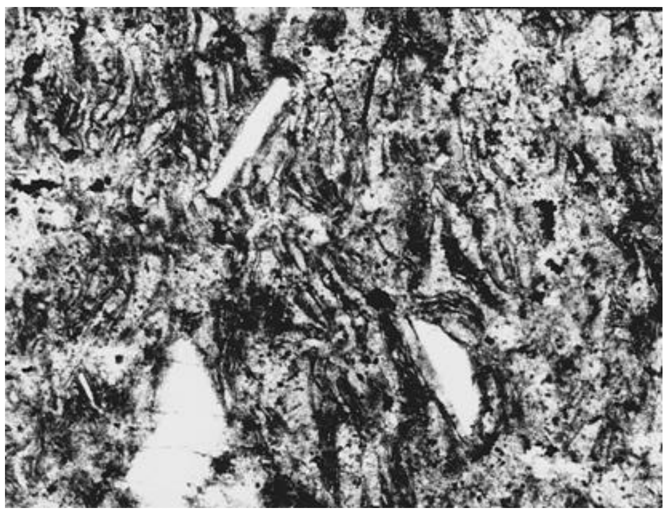


Figure 31. Unit-T8 T.S. Y-158. Photomicrograph of welded glass shards. A – Plain Light. 6.3X.

The lower contact of Unit-T8 lies on Unit-T6 and T7 in separate exposures and was difficult to interpret because of the small and discontinuous outcrops. It is interpreted that Unit-T8 is unconformable with Unit-T7. The upper portion of Unit T8 has been eroded; therefore, the original thickness of the unit is unknown but the remaining portion is estimated at 25 feet.

D. K. Marjaniemi (1969, p. 143) had sampled Unit-8 in the SE¼, section 23, T. 28 S., R. 21 W. and stated that it is similar to the lower portion of the Rhyolite Canyon Formation of the Chiracahua Mountains. The writer is not in the position to confirm or refute Marjaniemi's assumption because of not having seen the Rhyolite Canyon Formation rocks in the Chiracahua Mountains.

Unit Tat – Andesite Tuff

Units Tat; Tlp; Trt; Tmf-1, 2, and 3; Trpl; and Trfb are placed in relative stratigraphic position (see Plate II, Appendix B). Tertiary Unit-Tat is a eutaxitic, andesitic welded tuff and is not abundant in the northern part of the area; therefore, the exposures were studied to determine their relative importance with respect to the volcanic history of the area. The composition of Unit-Tat (Table 10) could not be correlated with or is present in other location in the South Antelope Pass Area. The unit is a pale red (5R6/2) to grayish pink (5R8/2) plagioclase rich, quartz-poor andesite tuff having up to 15 percent plagioclase crystals that are euhedral and 1 to 6 mm in length. Biotite composes about 3 percent of the rock and is highly altered to magnetite. Fractured and slightly altered sanidine is subhedral and amounts to 4 percent of the rock. Secondary minerals are abundant, with quartz crystals filling vugs within the unit and hematite staining the rock.

The lower contact of the Unit-Tat is not clearly exposed but the upper contact is covered by a sequence of Unit-T5 pumice flows, see Figure 10. The unit is exposed in an east-west orientation near the section boundary of section 6 and section 7, T. 28 S., R. 20 W. The thickness is estimated at 75 feet. The unit is cut by an east-west trending

Table 10

Petrographic Description – Unit-Tat

Andesite Welded Tuff				
Percent Phenocrysts: 20%	**Average** 16 - 25 %		**Range** 0.3 to 6 mm	
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Plagioclase An (55)	15	1 - 6 mm 4 mm avg	euhedral to subhedral	Some alteration to clay; albite and crlsbad twins; groups of crystals; zoning; fractured
Sanidine	6	<.6- 3 mm 1.8 avg	euhedral to subhedral	Carlsbad twins; fractured; zoned; some alteraton to clay
Biotite	2-Jan	.6 - 2 mm 1.4 mm avg	euhedral to subhedral	Reddish brown to green; alteration to magnetite
Magnetite	Trace	.3 mm avg	euhedral	Finely disseminated; alteration of biotite to hematite
Accessory Minerals				
Secondary Minerals				
Quartz				filling of fractures and vugs
Hematite				staining of the rock
Matrix	Cryptocrystoline to aphanitic - due to recrystalization; some relic banding is still present; Vitric Rock Fragments (VRF) having abundant plagioclase laths.			

normal fault in SE¼, SE ¼, section 6, T. 28 S., R. 20 W. There is no direct evidence for placing Unit-Tat in a fixed stratigraphic position; however, all andesite flows identified by other reports in the area (Figure 3) has the andesite rock types, lowest in the stratigraphic column, which is interpreted in this study area.

Unit-Tlp – Latite Porphyry

A highly altered pale red (5R6/2) to grayish red (10R4/2) exposure in the northeastern portion of the South Antelope Pass area (Figure 32) is interpreted to be a latite porphyry flow. The exposure is located in N½, SW¼, section 10, T. 28 S., R. 20 W. The lower contact is not exposed while the upper surface is in contact with the breccia flow, Unit T5br. The absence of an exposed lower contact is the basis for placing this unit in a relative stratigraphic position (see Plate II, Appendix B).

Alteration of this rock unit made thin section interpretation difficult, but some crystal structure remains and is used to attempt to classify the unit (Table 11). The sanidine is corroded and up to 3 mm in length with some Carlsbad twinning developed, while the plagioclase is also corroded but is about 5 mm in length with abundant albite twinning. There is no primary quartz evident in thin section or hand specimen but traces of biotite highly altered to magnetite are present. The exposure weathers to small rubble within the feldspar weathering to grayish white clay and leaving small euhedral vugs.

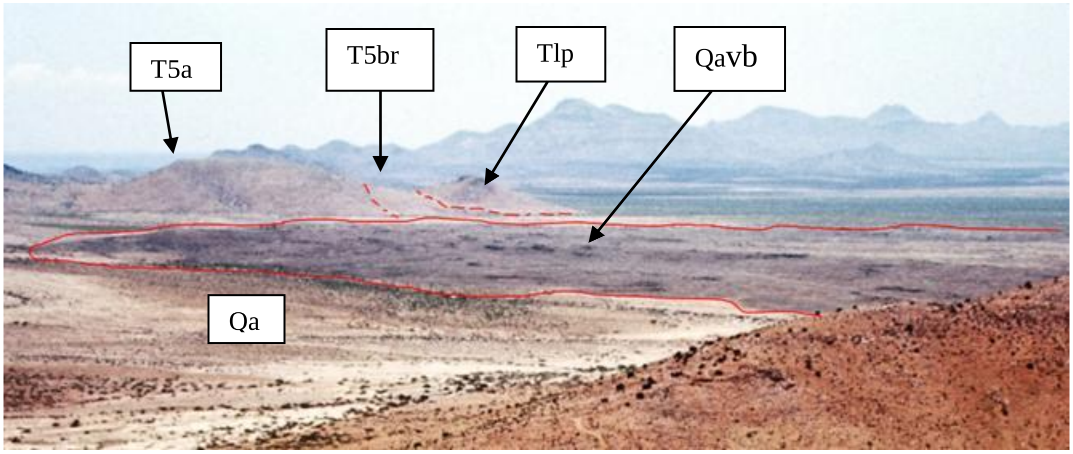


Figure 32. Unit-Tlp and Unit Qavb, northeast study area. Exposure of the latite porphyry, Tlp, with the T5 breccia, T5br, in contact at the base with altered unit T5, noted as T5a. N½, SW¼, section 10 T. 20 S., R. 20 W. Looking northwest from Tank Mountain in Animas Valley. Animas Valley Basalt (Qavb) in foreground.

Unit-Trt – Ryolite Tuff

Tertiary Unit-Trt is a dusky red (5R3/4) to grayish pink (5R8/2) welded tuff with abundant rock fragments. The unit is exposed at the northern border of the study area in the S½ of sections 35 and 36, T. 27 S., R 21W and NW ¼, Section 6, T. 28 S., T. 20 W. Exposure is limited to the lower portions of the north facing slopes and most of the unit is covered with Quaternary alluvium. The lower contact is angularly unconformable with Units-T5, T4, T3 and T2, in a west to east direction. The upper contact is unconformable with Unit-Tmf-3 (Figure 9). Total thickness is unknown because of the local nature of the outcrops, but is estimated to be between 5 and 30 feet.

Table 11

Petrographic Description – Unit-Tlp

Latite Porphyry				
Percent Phenocrysts:	12%	Average 11 - 14%	Range 0.25 to 5 mm	
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Plagioclase	6	1-5 mm 3.2 mm avg	euhedral to subhedral	Corroded; some untwineed; albite and carlsbad twins; alteration to clay; cloudy.
Sanidine	4	.4 - 3 mm 1.8 mm avg	euhedral to subhedral	Abundant alteration; at times difficult to distinguish grains; from carlsbad twins; cloudy.
Biotite	<1	<.6 - 2.1 mm 1.2 mm avg	euhedral	Red to green; altering to magnetite.
Magnetite	Trace	<.25 mm avg	euhedral	Assoicated with biotite; finely disseminated throughout the rock
Accessory Minerals				
Secondary Minerals				
Quartz		Fillung of vugs and fractures		
Hematite		Local staining of the rock		
Matrix		Complete recrystalization with a mozaic network of crystals up to 0.18 mm. To fine grained to determin optical properities; abundant clay alteration and hematite staining locally.		

Petrologically, Unit-Trt is classified as rhyolite tuff (Table 12). Subhedral to anhedral, resorbed, quartz crystals up to 5 mm make up approximately 5 percent of the rock. Approximately 7 percent sanidine up to 4 mm in length is euhedral with Carlsbad twinning. The euhedral plagioclase having albite twinning represents only 2 percent, by volume, of the rock. Traces of the altered biotite and highly altered magnetite to hematite are disseminated throughout the reddish portion of the unit. Angular to subangular lithic fragments up to 10 cm (Figure 33) make up about 15 percent of the rock. The matrix is welded glass shards with some flattened lapilli pumice making up the rest of the rock.

Unit-Trt is correlated between exposures by the characteristic red and green lithic fragments. The red fragments are angular to subangular cinders, which upon weathering leave a hematite stained vug. The green fragments are of an unknown lithology and origin. There are dark green, subangular to angular with cryptocrystalline texture. Some subangular Paleozoic limestone fragments are found throughout the unit. The limestone fragments weather readily and leave subangular vugs on the weathered surface which may have resulted in secondary calcite deposition in the fractures. Unit-Trt weathers slabby and offers little resistance to erosion.

Unit-Trt is interpreted to be a welded tuff of limited exposure and from an unknown source. A similar rock type is not exposed, to the north, in Dennis Gebben's area; therefore, the writer has placed the unit in an approximate stratigraphic position. The lack of data and limited outcrop place the relative position of the unit in doubt.

Table 12

Petrographic Description – Unit-Trt

lithic Rhyolite Tuff

Percent Phenocrysts: 15%	**Average**	12 - 18 %	**Range**	0.5 to 4 mm
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Sanidine	7	.5 - 4 mm 2.1 mm avg	euhedral to subhedral	Resorbed; carlsbad twins; fractured.
Quartz	5	,6 - 5 mm 2.9 mm avg	subhedral to euhedral	Resorbed; shattered
Plagioclase	2	.5 - 1.8 mm 1.1 mm avg	euhedral	Albite twins; fractured.
Biotite	1	.9 mm avg	euhdral	Dark red brown; alteration to magnetie that has altered to hematite.
Accessory Minerals				
Opal		lining the interior of vugs		
Calcite		Locally abundant concentrations possibly after weathered limestone.		
Hematite		Weathering of cinder frgments and alteration of magnetite.		
Secondary Minerals				
Matrix		Glassy to cryptocrystaline; some devitrification; some glass shards still evident; abundat flattened pumice with devitrified interior; some spherulites locally developed; red cinder rock fragments; limestone fragments; green rock fragments.		

Figure 33. Unit-Trt Limestone clasts. Limestone clasts and associated red and green lithic fragments in the light colored welded tuff. Lens cap in lower right hand corner. SE½, section 35, T. 27 S., R. 21 W.

Units Tmf-1, Tmf-2, Tmf-3 – Lahar

Tertiary Units-Tmf-1, Tmf-2, and Tmf-3 are local pale red (5R6/2) to grayish pink (5R8/2) unsorted lahars that crop out in multiple locations in the northern portion of the South Antelope Pass area. The unit is exposed in a discontinuous pattern in NE¼, section 6, and N½, section 5, T. 28 S., R. 20 W. Unit-Tmf-3 lies unconformably on Units-T1, T2, and T9, and the Mesozoic sandstone, and Still Ridge Conglomerate. The unit has recognizable clasts from Units-T1, T2, and T9 incorporated within a muddy crystal rich matrix. The upper contact is erosional and covered by Quaternary alluvium in NE¼, section 6, T. 28 S., R. 20 W. Unit Tmf-3 is estimated to be between 0 and 30 feet thick.

The lithic clasts are angular to subangular, range from <1 to 18 inches (Figure 34), and are incorporated in a calcite-cemented, hematite-stained matrix with abundant crystals. The matrix is undifferentiated clay, altered glass shards and hematite-stained. The crystals are shattered quartz and feldspars that amount to 18 percent of the rock by volume. There are many small angular lithic fragments that contain abundant plagioclase laths <.5 mm but they could not be correlated to a crystal composition rock unit in the South Antelope Pass area. The limited size, unsorted nature, of the unit and the amount of crystals and rock fragments within the unit limits distinct summary.

Figure 34. Unit-Tmf – 3 Lahar. Lahar with abundant angular to subangular poorly sorted clasts within the hematite-stained mud and glass matrix. SW ¼, NE ¼, section 6, T. 28 S., R. 20 W.

Unit-Tmf-3 is interpreted to be a lahar that was deposited in a mid-Tertiary canyon. This is thought to be a locally derived deposit because of the abundance of its surrounding proximal rock fragments.

Unit-Tmf-1, a local pale, dusky red lahar occurs in the center of section 6, T. 28 S., R. 20 W and also in section 8, T. 28 S., R. 20 W. This unit contains fragments of Units-T5 and T5wt within a rusty colored carbonate cemented matrix consisting of glass, phenocrysts and mud. The small exposures and position of this unit in both section 6 and section 8 in the field, supply meager evidence for placing this unit within the relative geologic column. This unit may be contemporaneous with Units-Tmf-2 and Tmf-3 depositions but there is no direct evidence.

A local unsorted deposit, Unit-Tmf-2, was found at the base of a canyon in SE¼, section 14, T. 28 S., R. 21 W. The unsorted nature of the rock and the size of clasts, Unit-T5 and Unit-T6, material give every indication of a lahar (Figure 35). The Unit-T5 clasts are angular and subangular and up to 8 feet in diameter, incorporated in a muddy, partially cemented matrix of broken and brecciated material similar to Unit T6. The lahar was locally derived from the surrounding hills in a muddy avalanche and deposited at the base of a late Tertiary canyon. Exposure today is limited to this local outcrop in the canyon.

Units-Tmf – 1, 2, and 3 are localized lahar deposits all exhibiting the lithic fragments of the volcanic units proximal to this outcrop, no attempt is made to interpret them as being a unit that can be correlated across the study area These units represent a climatic and localized site conditions suitable to erosion and deposition of rock and fine grain material deposited by water in a muddy matrix that has weathered from the immediate area above the canyon floor, that has survived more recent erosion.

Figure 35. Unit-Tmf – 2 Lahar Clasts. Local lahar with Unit-T5 clasts up to 8 feet in diameter. See hammer, arrow. SE ¼, SE ¼, Section 14, T. 28 S., R. 21 W.

Unit-Trpl – Rodeo Porphyritic Latite

A porphyritic latite intrusion, Trpl, is located in the southwest corner of the study area in sections 33, 34 and 35, T. 28 S., R. 21 W. The porphyritic latite is light gray (N7) and is topographically higher than the surrounding units (Figure 36). The latite extends south and east of the study area and ranges in color from olive gray (5Y6/1) to pale yellowish brown (10YR6/2) and is locally exposed in low lying areas to the east.

Figure 36. Unit-Trpl contact with Unit-T7. Photo looking north at the porphyritic latite (Trpl) unconformable with Unit-T7, below. SE1/4, section 34, T. 28 S., R. 21 W.

The contact of Unit-Trpl with the quartz latite welded tuff (Unit-T7) is unconformable. This contact, in section 34, is a relatively, straight line which the writer interprets to be the T7 quartz latite ash flow contact. Local zones of the contact of the quartz latite (T7) have highly altered rock fragments that are interpreted to be Unit-Trpl rock fragments.

Unit-Trpl is a holocrystaline, porphyritic latite with idiomorphic phenocrysts in a hypidiomorphic groundmass (Table 13). Some of the feldspars are kaolinized and sercitized (Figure 37). Zoned plagioclase is also present. There are reaction rims around most of the feldspars with the cores of some of the zoned crystals showing corrosion. This is interpreted to be a hypabyssal intrusion that was later exposed at the surface and

Table 13

Petrographic Description – Unit-Trpl

Porphyrritic Latite

Percent Phenocryst 58%	**Average** 22-64 %	**Range** 0.1 to 10 mm		
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Sanidine	34	<.4 - 10 mm 6 mm avg	euhedral to subhedral	Coronas; carlsbad twins; alteration to kaolin; zoned.
Plagioclase (An 40)	19	<.3 - 8 mm 6 mm avg	euhedral to subhedral	Locally sericitiezed; coronas; zoned; albite and carlsbad twins; some untwinned;
Pyroxene (Augite)	Trace	.8 - 2.5 mm	euhedral	Corroded; most plucked out.
Biotite	Trace	.5 - 1 mm .6 mm avg	euhedral to subhedral	Altered reddish brown; zircona and magnetite inclusions.
Magnetite	2-Jan	.1 - .8 mm	subhedral	Finely disseminated throughout the rock.
Accessory Minerals				
Apatite	Trace		euhedral	Associated with the feldspars
Zircon	Trace		Euhedral to subhedral	Associated with biotite or within the groundmass.
Secondary Minerals				
Matrix	Aphanitic with a hypdiomorphic texture; some clay alteraton; most of the grounmass is hard to identify.			

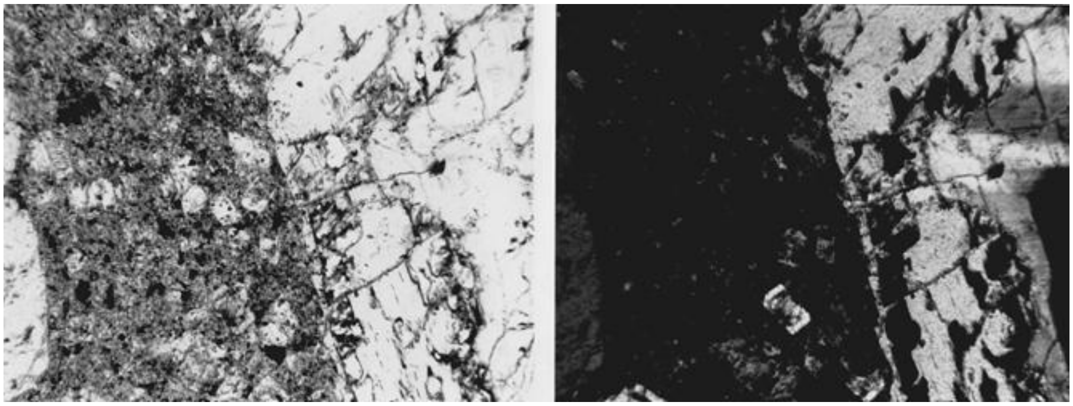


Figure 37. Unit-Trpl T.S. Y-231-B. Photomicrograph of porphyritic latite showing hypidiomorphic texture of the groundmass with altered feldspars. SE¼, SE¼, section 33, T. 28 S., R. 21 W. A-Plain light B-Crossed. Nichols. 3.5X.

subsequently, partially, covered by mid-Tertiary pyroclastic deposits of quartz latite ash flow in sections 33 and 34.

Unit-Trfb – Rhyolitic Flow Breccia

Unit-Trfb is a locally exposed rhyolitic flow breccia that is low in phenocryst content and crops out in the southwestern portion of the study area. The unit overlies Units-T7 and Trpl in sections 33, 34, and 35, T. 28 S., R. 21 W. and extends to the east of the map area of this thesis.

Unit-Trfb has a striking pale red (10R6/2) scoriaceous texture with abundant angular lithic clasts incorporated within a glassy welded matrix. Local bedding can be seen and is interpreted as flow bedding with no internal structures developed. The unit extends to the fault contact on the west side of the Peloncillo Mountains. Unit-Trfb is unconformable with Units-T7 and Trpl along the basal contact with no evidence of further deposition in the area.

Animas Valley Basalt

Animas Valley Basalt, San Simon Basalt, and alluvium represent the Quaternary to Recent rocks in the study area. Animas Valley Basalt (Qavb) crops out on the east side of the study area and extends for approximately 12 miles north on the west side of the north sloping Animas Valley with the southern extent of the basalt located in sections 13, 14, and 15, T. 28 S., R. 20 W. The outcrop area in section 15 is the topographic high for the basalt flow and is interpreted to be the vent source area for the basalt; however, there is no evidence of a fissure or vent in the area (see Figure 32). A collapse feature is present near this topographic high but this offers no clues to the nature of the source. Hot lava may have merely continued to flow beneath a chilled and crusted surface resulting in localized caves, which later collapsed.

The Animas Valley flow is a dark gray (N3) vesicular olivine basalt (Table 14) with columnar jointing and scoria developed in some areas (Figure 38). Euhedral plagioclase (An 65-70) and olivine phenocrysts occur in a groundmass of plagioclase (An 50-55), pyroxene (probably augite), and olivine (Figure 39). Many of the olivine crystals are fractured and altered to iddingsite. The flow is interpreted to be multiple small outpourings with thickening and thinning both laterally and vertically. There is approximately 50 feet of relief near the proposed source in section 15 with recent valley fill beginning to bury the flow along the flanks. A water well drilled in section 27, T. 27 S., R. 20 W by the Elbrock family (personal communication, 1970) indicates a flow thickness of 65 feet with unconsolidated gravel below the basalt. Topographic relief on the basalt at the well site is about 10 feet.

Table 14

Petrographic Description – Animas Valley Basalt

Olivine Basalt				
Percent Phenocrysts:	15%	**Average**	**Range**	0.1 to 6.0 mm
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Plagioclase phenocrysts An 65-70 groundmass An 50-55	60	.2 - 6 mm	euhedral	Resorbed phenocrysts; albite, pericline and carlsbad twins; some zoned crystals; some alteration to seicite.
Olivine	5	0.1 - .8 mm .4 mm avg	euhedral to subhedral	Fractured and altered to iddingsite
Pyroxene	32	.1 - 1.1 mm .5 mm avg	subhedral to euhedral	Pale green; cleavage evident; some hematite staining; small aggregates of pyroxene crystals.
Accessory Minerals				
Apatite	Trace	.1 mm	euhedral	Associated with the plagioclase
Magnetite	3-Feb	.09 - .2 mm	subhedral	Finely disseminated throughout the rock.
Secondary Minerals				
Iddingsite	Trace			Alteration of Olivine
Hematite	Trace			alteration of magnetite and pyroxene.
Matrix				

Figure 38. Animas Valley Basalt (Qavb). Columnar jointing developed along a flow front. Vesicular upper layer is found but the scoria is not well developed at this locality. NE¼, SE¼, section 35, T. 27 N., R. 20 W.

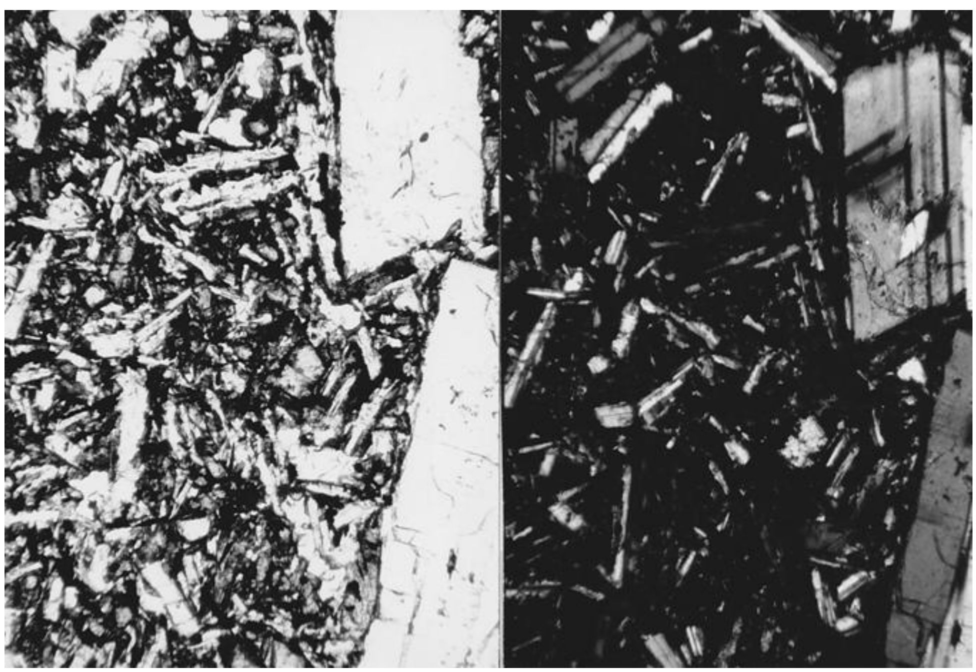


Figure 39. Animas Valley Basalt (Qavb) T.S. Y-215. Large plagioclase phenocrysts (An 65) within the fine grained groundmass of plagioclase (An 55) and augite. 3.5X
A – Plain Light; B – Crossed Nichols.

Examination of the Animas Valley basalt from air photos and from high peaks in the Peloncillo Mountains shows that the flow seems to follow a braided stream bed. The basalt separates and closes in narrow lobes that parallel the west side of the Animas Valley. There are local areas in the flow where the valley floor is exposed through "windows" in the lava where the basalt was not deposited. The relative freshness of the rock and the relation of the lava to the valley fill indicate a very late Pleistocene to Recent age.

San Simon Basalt (Q-Tssb)

The San Simon Valley has a small outcrop of pale red (5R6/2) to medium dark gray (N4) olivine basalt (Table 15) in section 32, T. 28 S., R. 21 W. The basalt outcrop rises about 30 feet from the valley floor with only a few areas of resistant rock now protruding above the scoriaceous rubble (Figure 40). There is some pahoehoe structure seen in float but most of the outcrop is now limited to rubble. Quaternary alluvium is higher on the east side of the outcrop with the drainage diverted around the basalt.

The rock is a holocrystaline, aphanitic, porphyritic olivine basalt having idiomorphic crystals of olivine within a hypidiomorphic groundmass of plagioclase and pyroxene (Figure 41). The San Simon (Q-Tssb), which is approximately 40 to 50 acres, and Animas (Qavb), which is approximately 5 square miles in the study area, differ in the size of exposures, percentage of phenocrysts, and the composition of the plagioclases. The San Simon basalt has about 64 percent uniform size plagioclase (An 45) phenocrysts and about 17 percent anhedral pyroxene in the groundmass, whereas, the Animas basalt is coarser grained and has a relatively higher pyroxene to olivine ratio with large

Table 15

Petrographic Description – San Simon Basalt

Olivine Basalt				
Percent Phenocrysts:	18%	Average	Range	
Phenocrysts	**Avg. Vol. %**	**Size**	**Shape**	**Character**
Olivine	16	1.2 - 2.1 mm 1.6 mm	euhedral	Clear; fractured; taces o iddingsite.
Plagioclase	<1	1.6 mm	euhedral	Reaction with liquid; carlsbad twins; full of inclusions;
Magnetite	3-Feb	0.01 mm	euhedral	Finely disseminated throughout the rock.
Accessory Minerals				
Apatite				Traces in matrix
Ground mass				
Plagioclase An (45)	~64	.2 mm avg	euhedral	Very fine grain
Pyroxene	~ 17	<0.01 mm		
Matrix				

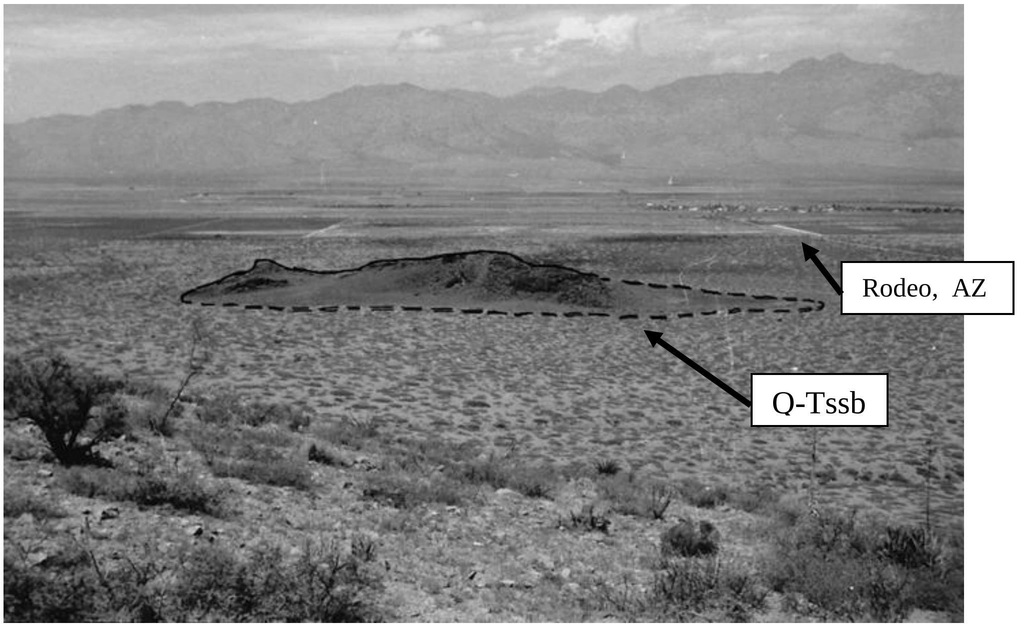


Figure 40. San Simon Basalt (Q-Tssb). The long outcrop of the San Simon basalt. Looking west from the foothills of the Peloncillo Mountains. Rodeo, New Mexico and the Chiracahua Mountains are in the background.

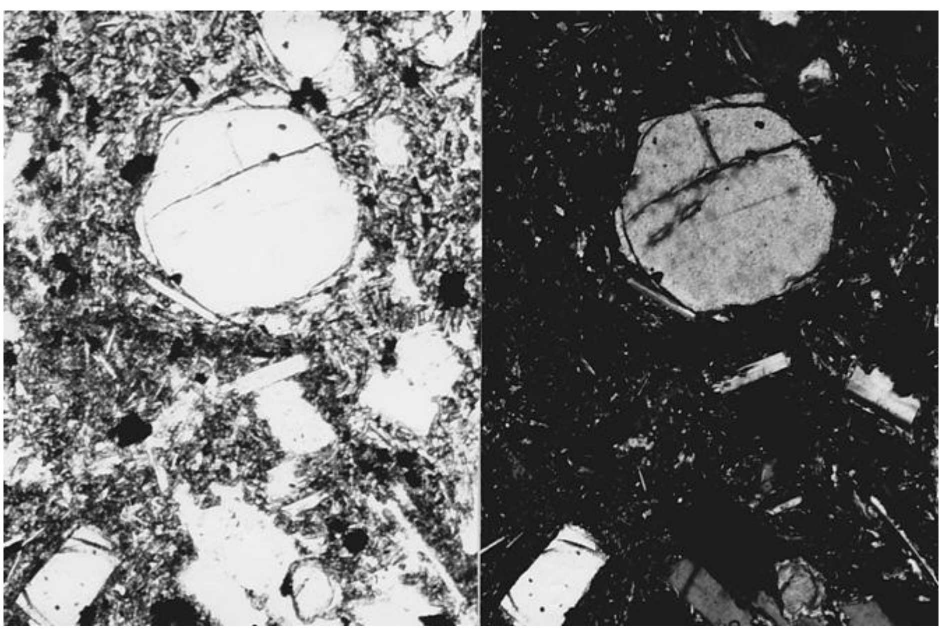


Figure 41. San Simon Basalt (Q-Tssb) T.S. Y-179. Photomicrograph of the euhedral olivine in the finer groundmass of pyroxene and plagioclase. 110X. A-Plain light. B-Crossed Nichols.

porphyritic plagioclase crystals in a pyroxene, plagioclase groundmass. The An content of the two basalts (San Simon An 45, Animas An 55) is similar but a relationship between the two basalts cannot be made on this factor alone.

There is an indication of a relative abundance of basalt deposited in the San Simon and Animas Valleys during the late Tertiary, Pleistocene to Recent Time. The writer proposes that the source or the relative age of the Perilla basalt, the San Simon basalt, and the Animas basalt may not be related. The Perilla basalt field of Pleistocene age is located approximately 18 miles to the southwest of the San Simon exposure and because of the distance and not having visited or sampled the Perilla basalt, no correlation can be made between the Perilla basalt and the Animas Valley and San Simon basalts located in the Peloncillo Range.

Quaternary Alluvium

Quaternary Alluvium (Qa) comprises the majority of the valley floor adjacent to the elevated rock units. The material is a gravely, sandy, silty material having local stream concentration of magnetite and other heavy minerals. Sand, gravel and boulder material is locally derived from the adjacent upland areas and is projected to be up to 7500 feet thick in the San Simon valley and the Animas valley. Micaceous minerals can be seen in the fine grain material. The alluvium is very porous and does not retain moisture after measurable rainfall.

CHAPTER 3

STRUCTURE

Introduction

The Peloncillo Mountain range is in the southeast portion of the Basin and Range Province. The mountain ranges of this province are outlined by northwest trending border faults of Miocene and Pliocene age (Marjaniemi, 1969, p. 28).

In the South Antelope Pass area at least two episodes of Tertiary faulting are recorded. The scarcity of pre-Tertiary outcrops prevents interpretation of any pre-Tertiary deformation that may have occurred. Geomorphic forms that are present today are important in the interpretation of the first episode of uplift in the area of Highway 9. High angle faults are found throughout the mountain range but the majority of the faults in the northern portion of the study are pre-Basin and Range forming faults. The second period of uplift outlined the present day ranges with north trending faults. Contemporaneous north-south and east-west trending normal faults occur in the interior portions of the mountain range, but cannot be traced through the entire width or length of the study area. Recent faulting is recorded in the Quaternary deposits of Animas Valley. No thrust faults have been recognized.

Depositional structures occur throughout the study area. Columnar jointing is found in Unit-T7 ignimbrite. Flow structure is locally prominent in Unit-T5, but only a few scattered measurements were taken on the orientation of spherulites and lithophysae which were interpreted to be parallel to the relic flow structure (Christensen and Lipman, 1966, p. 676). The flow structure is not continuous throughout the lava Unit-T5 but occurs sporadically throughout the area of study. Eutaxitic texture imparted by flattened pumice is used in some of the ash flow units to determine the amount of dip for each unit.

First Episode of Deformation

The writer wishes to point out the difficulty in trying to trace a fault contact through Unit-T5, the rock unit having the greatest extent of coverage in this study area. The texture of this unit varies and the writer could not be sure if linear features were a fault or a lineation in the flow of recrystallization structures along a contact. There are possibly many more faults in the area but they could not be differentiated.

The structural attitude of the units in the area of Highway 9 reflects the arching that took place during early Oligocene to mid-Tertiary time. The units in sections 5, 8, and 9, T. 28 S., R. 20 W. strike east-west with the strike changing to the northwest in section 6, T. 28 S., R. 20 W and section 1, T. 28 S., R. 21 W. This would indicate the maximum uplift is located to the northeast, in the area of the Paleozoic outcrops. A northwest trending lineament or fault which is nearly a straight line feature is evident in section 1, T. 28 S., R. 21 W. However, this could also be a lava flow in contact with a fault. A distinct fault plane could not be found in the area and the discontinuities in texture and lithology on either side of the lineament would seem to indicate a flow contact on one side.

Arching of the Highway 9 area in mid-Tertiary time stripped a major portion of the resistant welded tuffs and lava flows from the area. Local conglomerates, lahars

(Tmf-3), and welded tuffs (Unit-T9) were deposited in sections 5 and 6, T. 28 S., R. 20 W. during and after this period of erosion. An unknown thickness of rock was eroded from the uplifted area bringing the pre-Tertiary rocks closer to the surface than in the adjacent areas. The many northeast and northwest trending high angle normal faults with displacements ranging from 10 to 100 feet resulted in the deep erosion of the area. Neither the stratigraphic separation nor the fault planes of these faults could be traced through the overlying rock units.

Second Episode of Deformation

Normal faults trending north-northeast and northwest occur on the west side of the range in sections 1 and 2, and SW¼, section 14 and NE¼, section 15, T. 28 S., R. 21 W. and are interpreted to have been displaced after Unit T6 was deposited. Similar normal faults of small separation occur to the east in W½, section 9, and E½, section 8, T. 28 S., R. 20 W. and are interpreted as post-Unit-T5 deposition. Separation on the interior faults ranges from 10 to 300 feet. There is local offset in SE¼, section 16, T. 28 S., R. 20 W. but this fault could only be mapped in the area of the stratigraphic separation in member T5p of Unit-T5. The fault strikes northwest but its dip could not be determined. This fault is also post-Unit-T5 with a vertical displacement of about 75 feet.

In the northern portion of the area an east-west lineament can be seen on the aerial photographs and the Pratt quadrangle. Field mapping indicates an east-west striking normal fault of unknown separation in the eastern portion of the study area in S½, section 5, and SE¼ , SE¼, section 6, T. 28 S., R. 20 W. The fault is covered by Quaternary alluvium to the west. The east-west stream bed in section 6, T. 28 S., R. 20 W. and the adjacent stream bed with intervening saddle in sections 1 and 12, T. 28 S., R. 21 W. form linear features. Further investigation indicated minor lithologic changes in Unit-T5 in the N½, section 12 and S 1/2, section 1, T. 28 S., R. 21 W. Therefore, a probably fault is indicated, and the notation Big Bend Lineament is placed on the map (Plate I, Appendix A). The area of S 1/2, section 5, T. 28 S., R. 20 W is cut by two east-west faults impacting the geologic outcrop. Many blocks in section 5, T. 28 S., R. 20 W. are found jammed and crushed in the area. There may be more than two faults in the area and it will be termed a fault zone because of the complexity of the area.

The southwestern portion of the study area has one fault in the interior of the area. This is a normal fault that strikes east-west and although most of the fault is approximated in sections 27 and 26, T. 28 S., R. 21 W, and a small section of the vertical plane can be seen in the NW¼, section 25, T. 28 S., R. 21 W. This is a hinge fault with the maximum amount of displacement on the west side. The fault could not be traced to the east into the interior of the area. This fault truncates Unit-T7 with no evidence of younger rocks being truncated. Geomorphic features in the area south of this fault indicate a younger stage of erosion than the area to the north. Canyons are very steep south of the fault and do not cut deeply into the west side of the Peloncillo Mountain Range. The fault line scarp of the north trending border fault is very sharp in this area with triangular facets well developed. Conversely, the area to the north has a broad pediment developed with local outliers consisting of rounded hills of Unit-T5. To the north, the canyons are eroded deep into the interior with drainage gradients much less than the area south of the fault in section 25, 26, and 27, T. 28 S., R. 21 W.

The placement of the border faults is not approximated for the east and west borders of the study area except for the southwestern portion of the study area where the fault is mapped along the western border of the Peloncillo Mountains. The two outcrops that lie to the west of the fault in the W½, section 28, T. 28 S., R. 21 W. are interpreted to be slide blocks that broke off from the main part of the uplift after movement began on the north-south border fault. Because of the extent of pediment development, to the north, on both the west and east sides of the study area the position of the border faults are unknown and thus are not shown on the geologic map.

A Recent fault scarp of approximately 5 feet can be found on the west side of the Animas Valley to the north of the study area. The scarp could be traced for about 2 miles in the valley alluvium. This fault and others mapped by Gillerman (1958, p. 82) to the north indicates the relative instability of the area in Recent time.

Igneous Structures

There are planar structures developed within the pyroclastic deposits. They form by the flattening of viscous fragments as a result of the high temperature and the weight of the overlying material during deposition. The term eutaxitic is given to these structures but more important is the inference that they represent a horizontal surface during deposition (Smith, 1960). These eutaxitic structures were used to determine dips within the welded tuffs.

Flow structure in the lava flow of the Unit-T5 is very similar to that described by Christensen and Lipman (1966, p. 675) in the Great Basin. The amplitudes of the flow structure of pumice and other fragments within the flow observed in the study area are up to 80 feet or possibly more and usually have devitrification structures such as spherulites associated with them. The attitudes that were taken on the devitrified flow structures were not used in this thesis because of the local varying distribution of the measurements taken in the study area. The flow structures, where preserved, are very discontinuous.

The igneous body, Unit-Trpl, that is exposed in the study area does not show any indication of intrusion into the overlying rock units. The depositional contacts of the overlying deposits indicate a younger age for the overlying Unit-Trpl.

The lava flow contacts that developed with each successive flow made structural interpretations nearly impossible. In the northern portion of the study area there are two examples of the problem. The first is a relatively straight linear feature in section 1, T. 28 S., R. 21 W. Because a fault plane could not be found, it is inferred to be a flow contact although it could be a fault plane with an altered flow along the contact. The second feature is located in the NW¼, section 7, T. 28 S., R. 20 W. and is interpreted as a flow contact. There are four different subunits that are cut by Unit-T5. The single flow Unit-T5 is a pale gray to grayish yellow and locally is easily eroded. The tentative interpretation is that the lava flow butted up against a cliff or a fault of small displacement formed by the underlying units.

There were no characteristic caldera structures in this study area. However, this area may have been close to the source that Marjaniemi (1969, p. 133) proposed for the ash and lava flow sequence that occurs approximately ten miles to the west beneath the Rhyolite Canyon Formation in the Cave Creek area in the Chiracahua Mountains.

Economic Minerals

There is no mineralization of economic importance found in the South Antelope Pass area. Some prospect pits were found in the fault zone in the northeast portion of the study area but the mineralization was calcite filling of fractures. The hematitic alteration of sub unit T5a did not appear to be associated with mineralization of economic importance in the study area. Local residents have stated that some placer gold has been found in the Quaternary gravels in the area of Highway 9, but no source of the gold was found in the highlands of the study area.

CHAPTER 4

GEOLOGIC HISTORY

Interpretation of the major events in the South Antelope Pass area is built on a foundation of facts but is supplemented by the writer's ideas, thoughts and hypotheses. The Tertiary-Quaternary sequence is not delineated in all respects. Some map units cannot be placed in an exact stratigraphic position. The absolute age of the volcanic sequence for a large portion of the South Antelope Pass area is unknown. Adequate regional correlation was not completed; therefore, the writer has used the absolute age date obtained by Marjaniemi (1969, p. 152) for Unit-T8 in the Miocene and placed all the lower units in a relative position with respect to this unit. The units within the stratigraphic column on Plates I and II (Appendices A and B) have been described in detail previously and will not be discussed at this time. The purpose of this history is to place the major events in relative chronologic sequence.

The Mesozoic history in the South Antelope Pass area is fragmental and is tentatively interpreted to be as follows. Pennsylvanian to Permian limestone were deposited and subsequently was exposed and eroded during the Cretaceous period to produce a limestone cobble conglomerate, which was deposited on a Mesozoic erosion surface. The conglomerate is similar to the Still Ridge Formation described by Gillerman (1958, p. 90) in the central Peloncillo Mountains and the Cowboy Spring Formation described by Zeller and Alper (1965, p. 71) in the Animas Range. The source area for the conglomerate developed in this area during the period of post-Paleozoic uplift and erosion. The Johnny Bull Formation was deposited contemporaneously on the limestone conglomerate to an unknown thickness.

The depositional history of the initial volcanic sequence in the northern portion of the study area is fragmentary because of the erosion that occurred and the current limited extent of volcanic rock units. The lower Tertiary Units -T1,T2, T3, T4, and T5 sediments and welded tuffs were deposited in a structurally conformable sequence in the area of Sections 5 and 6, T. 28 S., R. 20 W. Some of the contacts are inferred to be unconformable but this may be due to discontinued distribution of individual volcanic units and not to erosion. The intrusion of Unit-Trpl is interpreted as in place pre-Units-T5 and T7, respectively. No further evidence was found to place this unit in an absolute position.

During accumulation of Unit-T5, the igneous activity was such that nueë ardentes and lava flows were being deposited contemporaneously. The lava flows represent the major sequence of Unit-T5. The structural attitude of the lower sequence of units in the northern position of the study area indicates uplift and local faulting in sections 5, 6, 7, and 8. T. 28 S., R. 20 W. The faulting contemporaneous with Unit-T5 suggests deposition of the flows were being diverted to the west of the local uplift, as evidenced by the northwest trending “Big Bend” lineament in section 1 and possibly with contact in section 7. Unit-T5 comprises the greatest area and volume for a rock type in the South Antelope Pass area. The displacement within Unit-T5 was possibly responsible for the lack of lava to the north where welded tuffs are the dominant rock type (Gebben, personal communication, 1970). Unit-T5 in sections 7, 8, and 18, T. 28 S., R. 20 W. forms the topographic high in both the North and South Antelope Pass areas. Perhaps this area was the eruptive source that was a topographic high after the lava and nueë ardente deposition. Subsequent erosion of Unit-T5 and the area of Highway 9 developed canyons and broad pediments.

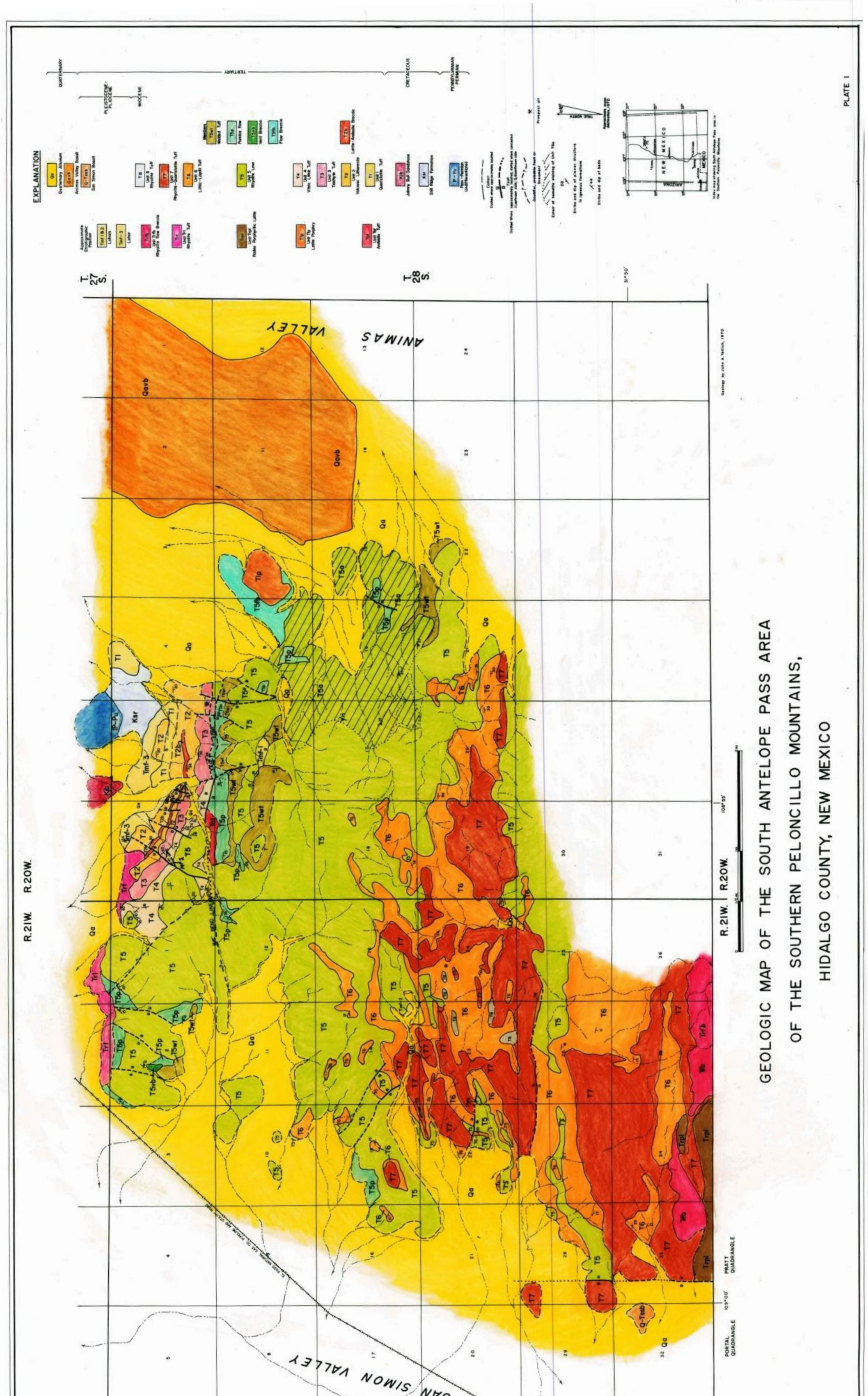
Deposition of Unit-T9 is placed in a relative stratigraphic position and occurred after Paleozoic limestone was exposed in the area of Highway 9. Unit-T6 was deposited on the Unit-T5 erosion surface. There was some erosion of Unit-T6 prior to the eruption of the nueë ardentes that deposited Unit-T7. The deposition of Unit-T8, a localized rhyolite tuff, in second T23 and T24, was immediately following Unit 6 deposition (Marjaniemi, 1969, p. 132), but this is questionable because of the two difference lower contacts of unit T8 in the southern portion of the area.

There was some evidence of deposition on Unit-T7 other than Unit-T8. A local outcrop of flow breccia caps Unit-T7 and flanks Unit-Trpl in the southwestern corner of the study area SW¼, section 23, T. 28 S., R 21 W. This breccia may be either pre- or post-Unit-T8 deposition. There is no further evidence of volcanic deposits within the study area. Subsequent to this deposition Basin and Range faulting occurred and outlined the Peloncillo Mountain range (Marjaniemi, 1969, p. 29; Elston and others, 1968, p. 272). Local differential uplift produced the faults in the southwestern portion of the area (Wisser, 1966, p. 77). Subsequent erosion of the mountains filled the adjacent valleys to more than 7500 feet (Sabins, 1957, p. 1340) and further developed the pediments to the north. Local lahars Tmf-1, 2, and 3 were probably deposited at this time.

The Pleistocene climate was wet and humid with lakes developing in the Animas and San Simon Valleys to the north of the study area (Gillerman, 1958, p. 92). These lakes drained to the north with a more arid climate developing in the Recent time period. In the very Late Pliocene or Early Pleistocene to Recent a small basalt plug formed in the San Simon Valley with the present outcrop limited to a local exposure that is being covered by alluvium. The Late Pleistocene to Recent eruption of basalt in the Animas Valley was from a possible vent in the northeastern portion of the study area. The basalt erupted in numerous flows that followed the ancient Animas Creek in a braided pattern that becomes more evident to the north. Recent debris from the mountains is covering the flanks of the basalt and continuing to fill the valley with Quaternary alluvium.

Appendix A

Plate I: Geologic Map of the South Antelope Pass Area of the Southern Peloncillo Mountains


GEOLOGIC MAP OF THE SOUTH ANTELOPE PASS AREA
OF THE SOUTHERN PELONCILLO MOUNTAINS,
HIDALGO COUNTY, NEW MEXICO
EXPLANATION
ANIMAS VALLEY
SAN SIMON VALLEY
R.21W.
R.20W.
T. 27 S.
T. 28 S.
PLATE I

Appendix B

Plate II: Stratigraphic Summary of the South Antelope Pass Area

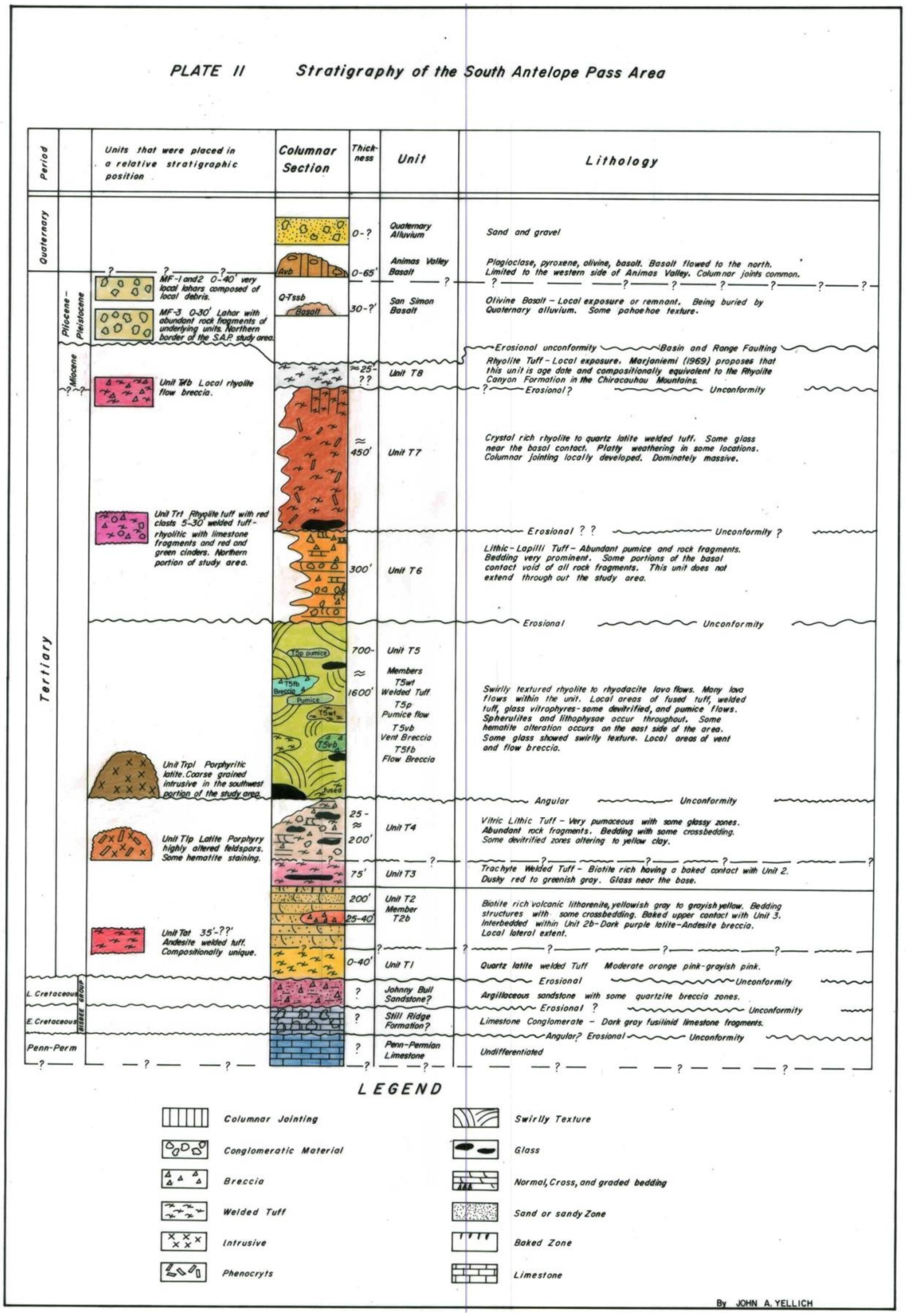


PLATE II Stratigraphy of the South Antelope Pass Area
Period
Units that were placed in a relative stratigraphic position
Columnar Section
Thickness
Unit
Lithology
Quaternary
Pliocene – Pleistocene
Miocene
Tertiary
L. Cretaceous
E. Cretaceous
Bisbee Group
Penn-Perm
0-?
Quaternary Alluvium
Sand and gravel
0-65'
Avb
Animas Valley Basalt
Plagioclase, pyroxene, olivine, basalt. Basalt flowed to the north. Limited to the western side of Animas Valley. Columnar joints common.
MF-1 and 2 0-40' very local lahars composed of local debris.
MF-3 0-30' Lahar with abundant rock fragments of underlying units. Northern border of the S.A.P. study area.
Q-Tssb
Basalt
30-?'
San Simon Basalt
Olivine Basalt – Local exposure or remnant. Being buried by Quaternary alluvium. Some pahoehoe texture.
Erosional unconformity
Basin and Range Faulting
≈25-??
Unit T8
Rhyolite Tuff – Local exposure. Marjaniemi (1969) proposes that this unit is age date and compositionally equivalent to the Rhyolite Canyon Formation in the Chiracauhau Mountains.
Erosional? Unconformity
Unit Trfb Local rhyolite flow breccia.
≈450'
Unit T7
Crystal rich rhyolite to quartz latite welded tuff. Some glass near the basal contact. Platy weathering in some locations. Columnar jointing locally developed. Dominately massive.
Unit Trt Rhyolite tuff with red clasts 5-30 welded tuff – rhyolitic with limestone fragments and red and green cinders. Northern portion of study area.
Erosional ?? Unconformity ?
300'
Unit T6
Lithic – Lapilli Tuff – Abundant pumice and rock fragments. Bedding very prominent. Some portions of the basal contact void of all rock fragments. This unit does not extend through out the study area.
Erosional Unconformity
T5p pumice
T5fb Breccia
Pumice
T5wt
T5vb
Fused
700- ≈ 1600'
Unit T5
Members
T5wt Welded Tuff
T5p Pumice flow
T5vb Vent Breccia
T5fb Flow Breccia
Swirlly textured rhyolite to rhyodacite lava flows. Many lava flows within the unit. Local areas of fused tuff, welded tuff, glass vitrophyres – some devitrified, and pumice flows. Spherulites and lithophysae occur throughout. Some hematite alteration occurs on the east side of the area. Some glass showed swirlly texture. Local areas of vent and flow breccia.
Unit Trpl Porphyritic latite. Coarse grained intrusive in the southwest portion of the study area.
Angular Unconformity
25- ≈ 200'
Unit T4
Vitric Lithic Tuff – Very pumaceous with some glassy zones. Abundant rock fragments. Bedding with some crossbedding. Some devitrified zones altering to yellow clay.
Unit Tlp Latite Porphyry highly altered feldspars. Some hematite staining.
75'
Unit T3
Trachyte Welded Tuff – Biotite rich having a baked contact with Unit 2. Dusky red to greenish gray. Glass near the base.
200'
25-40'
Unit T2
Member T2b
Biotite rich volcanic litharenite, yellowish gray to grayish yellow. Bedding structures with some crossbedding. Baked upper contact with Unit 3. Interbedded within Unit 2b – Dark purple latite-Andesite breccia. Local lateral extent.
Unit Tat 35'-??' Andesite welded tuff. Compositionally unique.
0-40'
Unit T1
Quartz latite welded Tuff Moderate orange pink-grayish pink.
Erosional Unconformity
Johnny Bull Sandstone?
Argillaceous sandstone with some quartzite breccia zones.
Erosional ? Unconformity
Still Ridge Formation?
Limestone Conglomerate – Dark gray fusilinid limestone fragments.
Angular? Erosional Unconformity
Penn-Permian Limestone
Undifferentiated
LEGEND
Columnar Jointing
Conglomeratic Material
Breccia
Welded Tuff
Intrusive
Phenocryts
Swirlly Texture
Glass
Normal, Cross, and graded bedding
Sand or sandy Zone
Baked Zone
Limestone
By JOHN A. YELLICH

Appendix C

Map Preparation

Map Preparation

The geologic map was not compiled using contours on the Pratt quadrangle as a base map. The accuracy of the Pratt Quadrangle is poor; as a result, a different type of base map was made from the aerial photographs. Section corners were plotted in the field on the photographs, where they could be found. Section fences were used to correct for some of the distortion that is present in aerial photographs. The geology was mapped directly on the photos without being transferred to a base map while in the field. Upon completion of the field season the photos were brought back to the Geology Department of Western Michigan University. The following is a description of how the map was produced and the degree of accuracy the writer feels was obtained.

The writer had the South Antelope Pass area aka Pratt quadrangle enlarged photographically to a scale of approximately 3.3:1 mile. This scale was approximately 0.2 of an inch more that the scale of the aerial photographs (3.1:1 mile). The section lines were traced from this photographic enlargement and the drainage from the aerial photographs, superimposed on the section line map. The transfer was aided by the use of a stereoscope. The section lines and drainage were used for control in plotting the geology on the new drainage map. The writer feels that there was better control with this map than with the topographic base.

This map is intended to be a preliminary map from which a final map of the entire quadrangle will be produced. All areal designation in the test are made in accordance with the Township and Range system.

The writer feels that there was 50–60 percent accuracy in using the Pratt quadrangle (1919). The new drainage map gives the author better control for plotting the contacts of the lithologies found in the South Antelope Pass area.

Appendix D

Rock Specimen and Thin Section Development and Petrographic Interpretation

Rock Specimen and Thin Section Development and Petrographic Interpretation

The thesis work generated more than 160 rock samples of various sizes which were transported back to Western Michigan University. The rock specimens were further evaluated in hand specimens and from these samples, 110 rock specimens were cut and thin sections (T.S.) were prepared by the writer in the rock laboratory at Western Michigan University. From these, 80 were petrographically reviewed, and 50 were described in detail and used for developing the understanding of the geologic units and in assisting in preparing this thesis. Tables 4–15 list the results of the thin section description.

BIBLIOGRAPHY

Armstrong, R. L., Ekren, E. B., McKee, E. H., and Noble, D. C., 1969. Space – time relations of Cenozoic silicic volcanism in the Great Basin of the western United States. *American Journal Science*, v. 267, p. 478-490.

Boyd, F. R., 1961. Welded tuffs and flows in the rhyolitic plateau of Yellowstone Park, Wyo. *Geol. Soc. America Bull.*, v. 72, p. 387-426.

Christiansen, R. L., and Lipman, R. W., 1966. Emplacement and thermal history of a rhyolite lava flow near Fortymile Canyon, southern Nevada. *Geol. Soc. America Bull*., v. 77, p. 671-684.

Cook, E .F., 1965. Stratigraphy of Tertiary volcanic rocks in eastern Nevada. *Nevada Bur. Mines Rept*. 11, 61p.

Cummings, David, 1964. Eddies as indicators of local flow direction in rhyolite. *E.S. Geol. Survey Prof. Paper*, 475-D, p. D70-D72.

Damon, P. E., and associates, 1967. Correlation and chronology of ore deposits and volcanic rocks. *U.S. Atomic Energy Comm. Prog. Rept*. C00-689-76, p. 63-69.

Dane, C. H., and Bachman, G. O., 1961. Preliminary geologic map of the southwestern part of New Mexico. *U.S. Geol. Survey Misc. Geol. Invest.*, Map 1-344.

Ekren, E. B., Rogers, C. L., Anderson, R. E., and Orkild, P. P., 1968. Age of Basin and Range normal faults in Nevada Test Site and Nellis Air Force Range, Nevada, in Nevada Test Site. *Geol. Soc. America Spec. Paper* 80, 69p.

Elston, W. E., Coney, P. J., and Rhodes, R. C., 1968. A progress report on the Mogollon Plateau volcanic province, southwestern New Mexico. *Colorado School of Mines Quarterly*, v. 63, no. 3, p. 261-287.

Enlows, G. E., 1955. Welded tuffs of Chiricahua National Monument, Arizona. *Bull. Geol. Soc. America*, v. 66, p. 1215-1246.

Fernandez, L. A., Jr., and Enlows, H. E., 1966. Petrography of the Faraway Ranch Formation, Chiricahua National Monument, Arizona. *Bull. Geol. Soc. America,* v. 77, p. 1017-1030.

Fisher, R.V., 1966. Rocks composed of volcanic fragments and their classification. *Earth-Sci. Rev.*, no. 1, p. 287-298.

Gillerman, E., 1958. Geology of the central Peloncillo Mountains, Hidalgo County, New Mexico, and Cochise Country, Arizona. *Bull. New Mexico Bureau Mines and Mineral Resources,* v. 57, 152p.

Gilluly, J., 1956. General geology of central Cochise County, Arizona. *U.S. Geol. Survey Prof. Paper* 281, 169 p.

________, 1965. Volcanism, Tectonism, and plutonism in the western United States. *Geol. Soc. America Spec. Paper* 80, 69p.

Goddard, E. N., and others, 1951. Rock-color chart. *Boulder, Colo. Geol. Soc America.*

Heinrich, E. W., 1965. *Microscopic identification of minerals.* McGraw-Hill, 414p.

King, R. E., 1939. Geological reconnaissance in northern Sierra Madre Occidental of Mexico. *Geol. Sec. America Bull.,* v. 50, p. 1625-1722.

Lipman, P. W., Christiansen, R. L., and O'Connor, J. T., 1966. A Compositionally zoned ash flow sheet in southern Nevada. *U.S. Geol. Survey Prof. Paper* 524-F, 47p.

Lowell, J. D., and Gilbert, J. M., 1970. Lateral and vertical alteration-mineralization zoning in porphyry ore deposits. *Economic Geol.*, v. 65, p. 373-408.

Mackin, J. H., 1960. Structural significance of Tertiary volcanic rocks in southwestern Utah. *American Journal Science,* v. 258, no. 2, p. 81-131.

Marjaniemi, D. K., 1968. Tertiary volcanism in the northern Chiricahua Mountains, Cochise County, Arizona. *Southern Arizona Guidebook* 111, Ariz. Geol. Soc., Tucson, Arizona, p. 209-214.

_________, 1969. *Geologic history of an ash-flow sequence and its source area in the Basin and Range province of southeastern Arizona.* Unpublished Ph.D. dissertation, Univ. of Arizona, 176p.

Mckee, E. H., Noble, D. C., and Silberman, M. L., 1970. Middle Miocene hiatus in volcanic activity in the Great Basin area of the western United States. *Earth and Planetary Sci. Letters*, 8, p. 93-96

McTaggart, K. C., 1960. The mobility of Nuëes Ardentes. *American Journal Science,* v. 258, p. 369-382.

________, 1969. Nuëes Ardentes and fluidization – A reply. *American Journal Science.,* v. 260, p. 470-476.

Raydon, G. T., 1952. *Geology of the northeastern Chiricahua Mountains, Arizona.* Unpublished master's thesis, Univ. Calif., Berkeley.

Rittman, A., 1952. Nomenclature of volcanic rocks. *Bull. Volcanologique,* Ser. 2, v. 12, p. 75-102.

Ross, C. S., and Smith, R. L., 1961. Ash-flow tuffs—their origin, geologic relations, and identification. *U.S. Geol. Survey Prof. Paper* 366, 81p.

Sabins, F. F., Jr., 1957. Geology of the Cochise Head and western part of the Vanar Quadrangles, Arizona. *Geol. Soc. America Bull.*, v. 68, p. 1315-1342.

Smith, R. L, 1960a. Ash flows. *Geol. Soc. America Bull.*, v. 71, p. 795-842.

__________, 1960b. Zones and zonal variations in welded ash flows. *U.S. Geol. Survey Prof. Paper* 354-F, p. 149-159.

Smith, R. L., and Bailey, R.A., 1966. The Bandelier Tuff: a study of ash-flow eruption cycles from zoned magma chambers: *Bull. Volcanologique,* v. 29, p. 83-104.

Smith, R. L., Bailey, R. A., and Ross, C. S., 1961. Structural evolution of the Valles Caldera, New Mexico, and its bearing on the emplacement of ring dikes. *U.S. Geol. Survey Prof. Paper,* 424-D, p. 145-149.

Williams, Howel, Turner, F. J., and Gilbert, C. M., 1954. *Petrography–an introduction to the study of rocks in thin sections.* San Francisco, W.H. Freeman and Co., 406p.

Wisser, E., 1966. The epithermal precious-metal province of northwest Mexico. *Nevada Bur, Mines Rept.* 13, Part C, p. 63-92.

Wrucke, C. T., and Bromfield, C. S. 1961. Reconnaissance geologic map of part of the southern Peloncillo Mountains, Hidalgo County. *U.S. Geol. Survey Map,* MF-160.

Zeller, R. A., and Alper, A. M., 1965. Geology of the Walnut wells Quadrangle, Hidalgo County, New Mexico. *Bull. New Mexico Bureau Mines and Mineral Resources*, v. 84, 105p.