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Geology of the Apache No. 2 Mining District Hidalgo County, New Mexico

Stephen L. Peterson

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GEOLOGY OF
THE APACHE
NO. 2
MINING
DISTRICT
HIDALGO
COUNTY,
NEW MEXICO

PETERSON

THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO 87106

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Master of Science

Geology of the Apache No. 2 Mining District
Hidalgo County, New Mexico

Title

Stephen L. Peterson

Candidate

Geology

Department

Bernard Spolsky

Dean

April 22, 1976

Date

Committee

Wolfgang E. Elston *Chairman*

Gary P. Landis

Lee A. Woodward

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B. S., Idaho State University, 1969

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Abstract

The Apache Hills, 10 km south of Hachita, New Mexico are a WNW-trending series of low hills, approximately 12 km long.

The rocks range in age from Paleozoic to Holocene. Limestone and sandstone of the Lower Cretaceous U-Bar and Mojado Formations are overlain by a thrust plate of Paleozoic limestone. The Oligocene Chapo Formation (new name) overlies the thrust plate unconformably. The Formation is over 1,700 m thick and ranges in composition from rhyolite to basalt. The sedimentary and volcanic rocks have been intruded by several igneous rock types, the most prominent of which is a stock of quartz monzonite porphyry, elongated WNW. The stock was emplaced at shallow depth and has been dated at 27 m.y.

The first post-Mojado structural event was the formation of thrust faults with attendant drag folds. Orientation of drag folds and fracture patterns in the footwall rocks suggest northeastward yielding. WNW-trending open folds were subsequently formed. Volcanism began 30 m.y. ago with the extrusion of quartz latite flows and culminated 3 m.y. later with intrusion of a quartz monzonite porphyry stock. Cauldron formation is suggested by the large volume of silicic flows, resurgent nature of the subvolcanic stock, the alignment of rhyolite dikes and plugs along possible cauldron margins, and possible moat deposits. Movement on high-angle faults post-date volcanic rocks.

Two types of ore deposits are present. Contact metasomatic copper mineralization occurs adjacent to monzonite porphyry

Abstract

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The first post-Mojado structural event was the formation of thrust faults with attendant drag folds. Orientation of drag folds and fracture patterns in the thrust plate suggest northeastward yielding. NNW-trending open folds were subsequently formed. Volcanism began 35 m.y. ago with the extrusion of quartz latite flows and culminated 2 m.y. later with intrusion of a quartz monzonite porphyry stock. Cauldron formation is suggested by the large volume of ash-flow tuff. [illegible] nature of the subvolcanic stock, the alignment of [illegible] and [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible]

intrusive rocks at the Chapo, Summertime, and Apache mines. Mineralization is characterized by pods and disseminations of chalcopyrite and secondary copper minerals in a calc-silicate gangue. Quartz-sulfide veins containing Pb, Zn, and Cu minerals are zoned peripheral to the center axis of the Apache stock. Their distribution appears to be related to possible cauldron structures. Pervasive silicification and quartz veining in the Mojado Formation coincides with a magnetic anomaly in secs. 12 and 13, T. 29 S., R. 14 W. South of the Apache mine, in sec. 13, T. 28 S., R. 14 W. and in adjacent areas, volcanic rocks of the Chapo Formation are propylitically altered and contain up to several percent pyrite.

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INTRODUCTION

Location and setting

The Apache Hills of Hidalgo County, New Mexico are located in the Mexican Highlands section of the Basin and Range Province. They are a WNW-trending series of hills approximately 11 km (6 mi) long and extend from 9 km (5 mi) south of Hachita, New Mexico to the Mexican border (Fig. 3). The Apache Hills are separated from the Sierra Rica by 5-8 km (3-5 mi) of low outcrops and thin pediment gravel. Relief between Apache Peak (the highest topographic feature at just over 1,900 m (5,700 ft) and the low-lying outcrops of the pediment surface is around 300 m (1,000 ft). In most areas relief is considerably less. All drainage is intermittent. Access to the main part of the Apache Hills is from State Highway 81 south of Hachita or from State Highway 9 about 6 km (4 mi) east of Hachita. Jeep trails serve as access for most of the area.

Previous Work

Around 1905, Waldemar Lindgren (in Lindgren, Graton, and Gordon, 1910) visited the Apache Hills and described some aspects of the ore deposits of the Apache mine. The first detailed work in the vicinity was published by Lasky (1947) who mapped the Little Hatchet Mountains. Lasky's stratigraphic nomenclature was extended to the Apache Hills and Sierra Rica by Strongin (1958). Later, stratigraphic units described by Zeller (1965) in the Big Hatchet Mountains and Sierra Rica were found to correlate with strata in the Apache Hills and superseded Lasky's nomenclature. Van der Spuy (1970) mapped the Sierra Rica and interpreted geochemical and geophysical data.

INTRODUCTION

Location and Setting

The Apache Hills of Hidalgo County, New Mexico are located in the Mexican Highlands section of the Basin and Range Province. They are a NNW-trending series of hills approximately 11 km (8 mi) long and extend from 8 km (5 mi) south of Hachita, New Mexico to the Mexican border (Fig. 1). The Apache Hills are separated from the Sierra Rica by 5-8 km (3-5 mi) of low outcrops and thin pediment gravel. Relief between Apache Peak (the highest topographic feature at just over 1,800 m (5,900 ft)) and the low lying outcrops of the pediment surface is around 300 m (1,000 ft). In most areas relief is considerably less. All drainage is intermittent. Access to the main part of the Apache Hills is from State Highway 81 south of Hachita or from State Highway 9 about 6 km (4 mi) east of Hachita. Jeep trails serve as access for most of the area.

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Several mining companies have conducted base-metal exploration programs in the area. A considerable amount of drill-hole, geochemical, and geophysical data has been gathered.

Methods

The area of investigation covers approximately 130 sq km (42 sq mi) and lies within the Hachita 15-minute quadrangle and the Victorio Ranch 7-1/2 minute quadrangle. The topographic base for this report was prepared from these at a scale of 1:20,000 with 50-foot contours. Location of roads was brought up to date. The southwest quarter of the geologic map was mapped at a scale of 1:10,000 on aerial photographs furnished by the Minerals Division of Superior Oil Company. The remainder of the area was mapped on 1:20,000 aerial photographs furnished by the New Mexico State Bureau of Mines and Mineral Resources. Field work was done during the summer and fall of 1974. Whole-rock analyses were done by John Husler of the University of New Mexico and trace-metal analyses were done by the author using atomic absorption spectroscopy.

Acknowledgments

Numerous individuals have generously contributed their ideas, comments, and support in one way or another to this report. The Minerals Division of Superior Oil Company supplied aerial photographs and drill-hole data. Mr. William C. Bastian, claimant of the Apache mine, was most co-operative in sharing drill-hole data and in explaining the history of the Apache mine. During the latter part of the 1974 field season, employment was furnished by

Several mining companies [illegible]
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the summer and fall of [illegible]
John Hasler of the [illegible]
analyses were done by the [illegible]

Numerous individuals have [illegible]
comments, and support to the [illegible]
Minerals Division of [illegible]
grams and drill-hole data [illegible]
this quarter mile, [illegible]
and for maintaining [illegible]
several years of [illegible]

Leonard Resources and full access was given to their drill-hole, geochemical, and geophysical data. Many useful conversations were had with Mr. Ben Donegan, regional manager of Leonard Resources. Dr. Paul E. Damon, Laboratory of Isotope Geochemistry, University of Arizona, determined radiometric dates for three rock samples. The Minerals Exploration Branch of Continental Oil Company shared the cost of dating with the University of Arizona and permitted use of the data. Above all, appreciation is expressed to Dr. Wolfgang E. Elston who suggested the project and who contributed constructive criticism and valuable aid.

Special thanks are due my wife for her patience, understanding, and encouragement throughout the entire project.

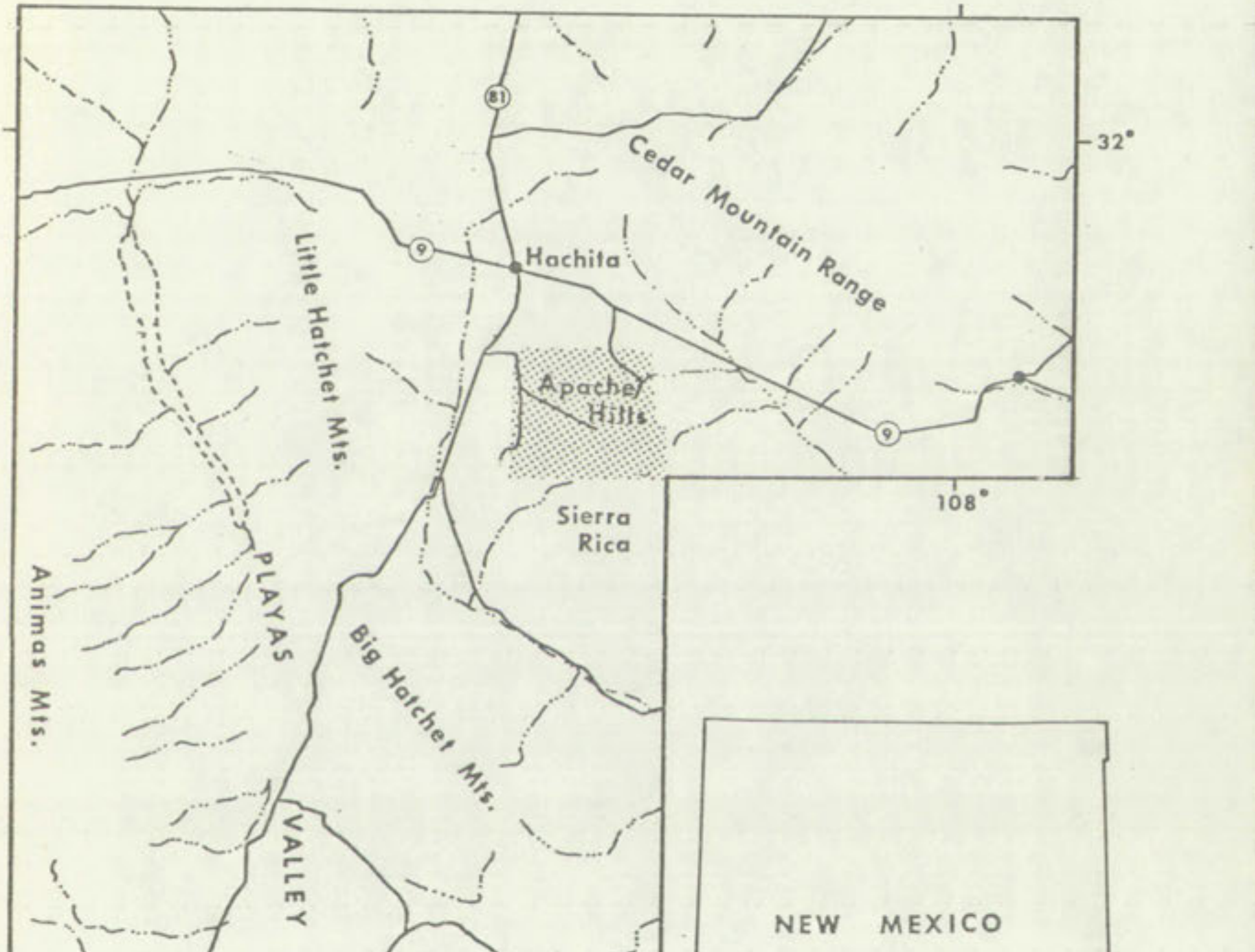

Figure 3. Location map of the study-area. Adapted from the U.S. Geological Survey, Base Map of New Mexico, 1:500,000

ROCK UNITS

General statement

Rock units range in age from Paleozoic to Holocene. Paleozoic limestone is exposed in klippen formed by erosion of one or more thrust sheets that once covered the area. Lower Cretaceous U-Bar and Mojado Formations are the oldest autochtonous rocks in the area. Neither the bottom of the U-Bar nor the top of the Mojado Formations are exposed, but the U-Bar - Mojado contact is exposed in a few localities in the east-central part of the area. Table 2 is a measured section across the contact.

A thick sequence of volcanic rocks, here named the Chapo Formation, unconformably overlies the thrust sheet of Paleozoic limestone. Its thickness may be as much as 1,700 m (5,000 ft) but ranges considerably over relatively short distances. The Chapo Formation, although younger than thrust faulting, has been folded and faulted. The formation is composed of four members. In ascending order they are: the Lower Quartz Latite Member, the Andesite Member, the Upper Quartz Latite Member, and the Basalt and Andesite Member. The Basal Quartz Latite Member has been dated by P. E. Damon of the University of Arizona (personal communication, August 1975) at 30.64 ± 1.15 m.y. (K-Ar date of K-feldspar).

Several igneous rock types intrude the Chapo Formation and older rocks. Most notable is the Apache stock of quartz monzonite composition. It is small (3.2 sq km) and was emplaced at shallow depth. The stock is elongate N. 70 W. and is intruded

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A heterogeneous unit of flow-banded rhyolite, vesicular latite, and rhyolite tuff is designated the Rhyolite of Wamels Pond. Its members are thin and very difficult to trace. The rhyolite of Wamels Pond unconformably overlies the U-Bar Formation and members of the Chapo Formation.

Paleozoic Limestone (undivided)

Paleozoic limestone outcrops constitute one or more sheets thrust over Lower Cretaceous rocks. Outcrops are restricted to small windows in alluvium or klippen. The largest areal exposure of a single klippe is less than 0.6 sq km (0.25 sq mi); but at one time the thrust sheet(s) probably covered most of the Apache Hills area. South of the Apache fault numerous outcrops of Paleozoic limestone are exposed along the N. 70 W. - trending axis of an open, upright, and gently dipping anticline. On the north and south limbs the thrust is concealed by overlying Tertiary volcanic rocks. Outcrops here are not as prominent topographically as the nearby klippe of Doyle's peak (Van der Spuy, 1970). North of the Apache fault, klippen occur on the east end of the Apache Hills. Most of the klippen in this area stand out in positive relief due to the resistant nature of abundant chert fragments which they contain (Fig. 5).

along the [illegible]

the lower [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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Formation and [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

north and south [illegible]

[illegible]

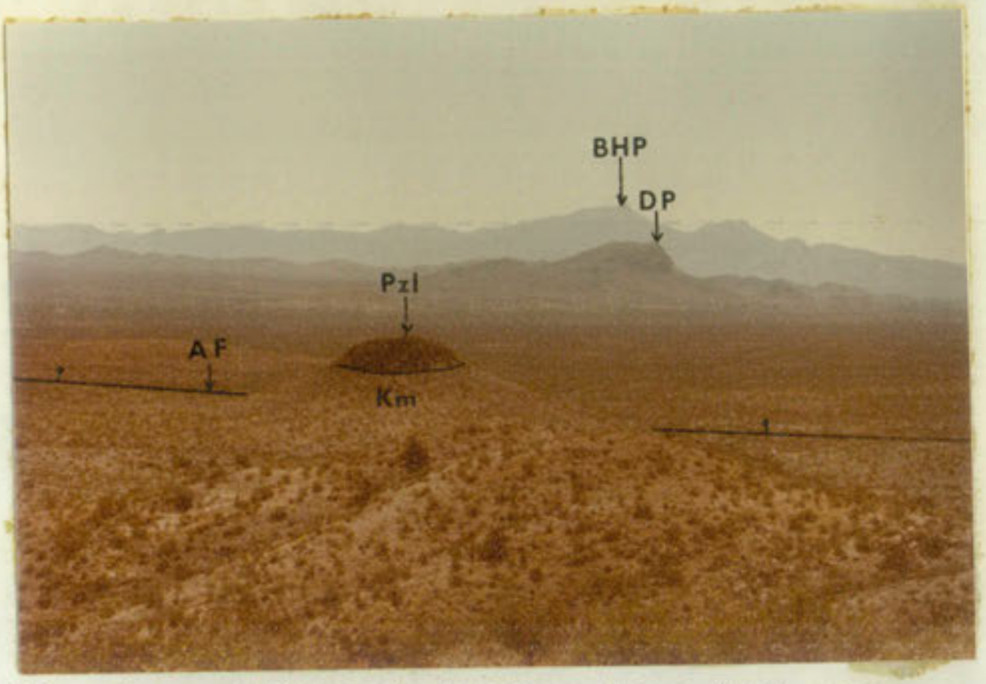

Figure 4. View of a small Paleozoic limestone klippe (Pzl) overlying Mojado Formation (Km). Doyle's Peak (DP) is in the background. Big Hatchet Peak (BHP) is in the far background. The Apache Fault (AF) is also shown. View is to the southwest.

Figure 5. Structurally broken Paleozoic limestone exposed in a klippe. Chert fragments stand out in positive relief. Note calcite-filled tension gashes in some breccia fragments.

In hand specimen, the Paleozoic limestone is massive, dark-gray, bioclastic with abundant chert and white calcite veinlets in small en echelon tension gashes (Fig. 5). Internal shearing and deformation is intense. Angular chert fragments range from less than 2 cm (1 in) in diameter to greater than 30 cm (12 in). Most of the chert is light brown and weathers rusty brown, although black and tan chert is also present. Hematite commonly cements chert and limestone rubble. Stratification in the klippen is obscure but can be detected in some places. Due to erosion prior to deposition of volcanic rocks, the remnant of the thrust plate is not over 30 m (100 ft) thick and many klippen are less than 3 m (10 ft) thick.

The Paleozoic limestone is structurally broken and recrystallized to the extent that the primary lithologic character, bedding, and fossils have been lost or obscured. "Crinoid hash", syringopora, and horn corals are found in the limestone. Some distorted and recrystallized brachiopods and unidentified sponges(?) were also found. None of the fossils were specifically identified. The absence of good index fossils, notably fusulinids, makes correlation of the limestone difficult. Parts of the El Paso, Montoya, Escabrosa, Paradise, Horquilla, and Earp Formations (Ordovician to Permian) are exposed in thrust sheets just south of the map area (Van der Spuy, 1970). Due to uncertainties of identification, rocks of the klippen were mapped as Paleozoic limestone, undivided (Pzl). It is possible that a detailed examination of fossils could lead to identification of individual formations. The

In hand specimen [illegible] gray, [illegible] in small en [illegible] and deformation [illegible] less than 1 cm [illegible] Much of the sheet [illegible] although bl[illegible] and [illegible] cements chert and [illegible] Klippen is chaotic but [illegible] somewhat prior to deposition [illegible] the thrust plate is [illegible] klippen are less than [illegible]

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Strongin (1958) mapped some of the Paleozoic limestone as Skunk Ranch fanglomerate of Tertiary age. The rock unit is usually so shattered that its base has a conglomeratic appearance; however, there are many criteria which distinguish it from fanglomerate. Some of these are; 1) the Paleozoic limestone of the thrust sheet overlie drag-folded Lower Cretaceous rocks, 2) the klippen contain calcite filled tension gashes, indicating internal deformation, 3) fossil content is entirely of Paleozoic organisms and fossils or lithologies from younger rocks are not found.

Lower Cretaceous Rocks

U-Bar Formation

The U-Bar Formation was named by Zeller (1965) for exposures of the dominant limestone part of the Lower Cretaceous section. The formation is exposed on the west end of the Apache Hills and in extensive exposures from east of the Chapo mine to the Mexican border. The base of the formation is not exposed within the map area but it is believed to be underlain by the normal stratigraphic sequence for the region (Table 1).

The U-Bar Formation consists of black, fossiliferous, crystalline limestone with interbeds of shale and sandstone. The limestone weathers light gray. Where it is massive it tends to be a cliff former. Zeller (1965) divided the U-Bar Formation into five members on the basis of paleontologic and lithologic characteristics.

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Table 1

Summary of pre-Tertiary sedimentary rock formations
in Hidalgo County, New Mexico (after Zeller 1965)

Age			*Rock units*			*Measured thicknesses (feet)*	*Lithology and remarks*
EARLY CRETACEOUS	Albian	Washita		Mojado Formation	Upper member	5195	Sandstone and shale. Thin to medium beds of strongly cross-laminated brown and gray sandstone are interbedded with thin units of shale. Lens-shaped sandstone masses probably represent channel fillings. Most of formation is of terrestrial origin. Calcareous fossiliferous marine beds are present in upper member and increase in number upward.
					Lower member		
		Fredericksburg		U-Bar Formation	Suprareef ls. mem.	3500	Limestone. Most of formation consists of medium and thin beds of bioclastic limestone alternating with thin gray shale beds. Lenses and thin beds of sandstone are found in lower part. Massive limestone near top of formation is a reef which ranges in thickness from 500 to 20 feet within the area.
					Reef ls. member		
		Trinity			Ls.-sh. member		
					Oyster ls. member		
	Aptian				Brown ls. member		
	— ? —	— ? —		Hell-to-Finish Formation		1274	"Red beds." Composed mostly of interbedded red arkose and sandstone, red and gray shale, and red siltstone. Basal bed is conglomerate composed of chert pebbles derived from Concha Limestone.
				Erosional unconformity			
PERMIAN	Leonard		Naco Group	Concha Limestone		1376	Limestone. Medium-bedded limestone characterized by abundance of purple chert nodules and silicified productid brachiopods. Upper beds often dolomitized. Pre-Cretaceous erosion removed varying amounts of upper beds.
	Leonard or Wolfcamp			Scherrer Formation		5-20	Quartz sandstone and limestone. Sandstone occurs as strata and lenses in limestone.
				Epitaph Dolomite		1480-1519	Dolomite. Medium-bedded light to dark gray dolomite with small knots of quartz. Lower part has a few lumpy limestone and dolomitic limestone beds. A red-weathered interval in lower part has red siltstone and, in one area, massive gypsum.
				Colina Limestone		355-505	Limestone. Thin-bedded limestone which is black on fresh fracture and which weathers light gray. Upper contact lies at different levels depending upon depth in section of Epitaph dolomitization.
				Earp Formation		997	Siltstone and claystone. Composed mainly of interbedded terrestrial brown-weatherod cross-laminated siltstone and light gray claystone. Upper part contains marine limestone beds which increase in abundance upward.
				Local disconformity			
	Wolfcamp			Horquilla Limestone		3245-3530	Limestone. Lower third is medium-bedded bioclastic limestone which includes oolitic and crinoidal beds and some zones rich in gray chert nodules. Upper two-thirds is complicated by basin, reef, and shelf facies. The crest of the Big Hatchet Mountains in general follows the reefs; the basin lies southwest of the range; the shelf lies along the east side of the range. The reefs consist of massive bioclastic limestone with dolomitized areas. Basin deposits consist of dark shale and black thin-bedded limestone. The shelf beds consist of light-colored medium-bedded bioclastic limestone.
PENNSYLVANIAN	Virgil						
	Missouri						
	Des Moines						
	Derry						
	Morrow?						
— ? —	— ? —			*Erosional unconformity*			
MISSISSIPPIAN	Chester			Paradise Formation		318	Limestone. Thin-bedded yellowish-brown-weathered bioclastic and oolitic limestone rich in well-preserved fossils. Quartz sandstone beds and lenses near top have plant fossils. Pre-Horquilla erosion removed varying amounts of upper beds.
	Meramec			Escabrosa Limestone	Upper member	1261	Limestone. Lower member composed of thin-bedded limestone and a few shale beds. Middle member consists of rhythmic succession of thin limestone strata and nodular chert strata. Upper member composed largely of crinoidal limestone. Upper two members together usually form single cliff hundreds of feet high.
	Osage				Middle member		
	Kinderhook				Lower member		
— ? —	— ? —						
DEVONIAN				Percha Shale		280	Clay shale. Basal beds include a few strata of calcareous argillaceous siltstone and black shale. Upper beds include thin strata of nodular limestone. Bulk of formation is gray shale.
				Unconformity			
ORDOVICIAN	Cincinnatian			Montoya Dolomite	Cutter Member	385	Dolomite. Basal member consists of 10 to 20 feet of dolomitic quartz sandstone interbedded with dolomite. Aleman Member composed of rhythmic succession of dark gray dolomite strata and strata of black chert nodules.
					Aleman Member		
	Champlainian				Upham Member		
					Cable Canyon Mem.		
				Disconformity			
	Canadian			El Paso Formation	Bat Cave Member	916-1070	Limestone and dolomite. Sierrite Member composed of dolomite and dolomitic limestone; some strata rich in chert nodules and brown reticulated chert laminae. Bat Cave Member consists of bluish-gray-weathered bioclastic limestone. Uppermost beds dolomitized.
					Sierrite Member		
— ? —	— ? —						
LATE CAMBRIAN	Trempealeauian?			Bliss Formation		192-327	Arenaceous rocks. Basal beds composed of arkose and boulder conglomerate. Middle beds consist of white orthoquartzite. Upper beds composed of dolomite with varying quantities of quartz sand. Thickness and lithology of units variable.
	Franconian						
	Dresbachian?						
				Erosional unconformity			
PRECAMBRIAN							Coarsely crystalline porphyritic granite and quartzite.

They are in ascending order: 1) the brown limestone member characterized by brown, clayey, silty limestone and thin sandy interbeds, 2) the oyster limestone member which consists of gray massive limestone in the upper part and thinly stratified limestone in the lower part, 3) the limestone-shale member, 4) the reef limestone member characterized by biohermal, massive, blue-gray limestone, and 5) the suprareef limestone member which is composed of dark, blue-gray limestone in evenly stratified 2 to 4 m (6 to 12 ft) beds. The contact between U-Bar Formation and the overlying Mojado Formation is gradational and conformable. Fresh rocks of the U-Bar Formation in the Apache Hills closely resemble those described by Zeller and Van der Spuy but contact metamorphic effects have locally produced marble, hornfels, and calc-silicate rock. Mapping of formation members was not attempted in this study because of correlation uncertainties caused by alteration.

Van der Spuy (1970) measured 1,100 m (3,500 ft) of U-Bar Formation in the Sierra Rica and found it to be similar in thickness and lithology to the type section measured by Zeller in the Big Hatchet Mountains. A 100 m (300 ft) section measured from the upper part of the U-Bar Formation to the contact with the Mojado Formation in sec. 2, T. 29 S., R. 14 W., (Table 2) correlates well with the section measured by Van der Spuy in the Sierra Rica approximately 9 km (6 mi) away.

Rocks of the U-Bar Formation can be easily distinguished from Paleozoic limestone by their abundant fossils. The most that are in ascending order: 1) the brown-weathering member characterized by brown, clayey, silty limestone and thin sandy interbeds, 2) the gray-weathering limestone member which consists of gray, massive limestone in the upper part and thinly stratified limestone in the lower part, 3) the limestone shale member, 4) the reef limestone member characterized by thick-bedded, massive, blue-gray limestone, and 5) the [illegible] limestone member which is composed of dark, blue-gray limestone in evenly stratified 2 to 4 m (6 to 12 ft) beds. The contact between U-Bar Formation and the overlying Mojado Formation is gradational and conformable. Fresh rocks of the U-Bar Formation in the Apache Hills closely resemble those described by Zeller and Van der Spuy but contact metamorphic effects have locally produced marble, hornfels, and calc-silicate rocks. Mapping of formation members was not attempted in this study because of correlation uncertainties caused by alteration.

Van der Spuy (1970) measured 1,300 m (4,300 ft) of U-Bar Formation in the Sierra Rica and found it to be similar in thickness and lithology to the type section described by Zeller in the Big Hatchet Mountains. A [illegible] section measured from the upper part of the U-Bar Formation to the contact with the Mojado Formation [illegible] R. 14 W. (Plate 1) [illegible]

[illegible]

Table 2. Measured section across the U-Bar - Mojado Formation contact. The measured section is located in the north-central part of sec. 2, T. 29 S., R. 14 W. The section was measured with a Jacob's staff.

LITHOLOGY	THICKNESS	CUMULATIVE
PALEOZOIC LIMESTONE		
Limestone, cobbles and boulders of a Paleozoic limestone, abundant chert. Contains crinoid hash and rugose corals.	14 feet	309 feet
Covered, float of Paleozoic limestone.	16	295
▲▲ Thrust fault ▲▲		
MOJADO FORMATION		
Sandstone, medium to coarse grained, crossbedded, silicified wood, abundant fractures with hematite stains, numerous quartz veins reheal fractures.	25	279
Sandstone, medium to fine grained. Weathers into brown rectangular chips, 1-5 cm in diameter.	16	254
Limestone, silty, gray, fossiliferous.	2	238
Breccia, in sandstone parallel to bedding, recemented with limonite.	1	236
Sandstone, medium grained, massive, pink to rose colored.	5	235
U-BAR FORMATION		
Limestone, flaggy bedding, appears strongly fractured, abundant pelecypod shell fragments.	30	230
Limestone, massive, medium-gray, pelecypod and *Orbitulina* hash. Some white calcite veins.	15	200
Sandstone, medium grained, light-gray to pink, crossbedded.	8	185
Sandstone, medium grained, light-gray with platy bedding.	20	177
Limestone, blue-gray, fossiliferous, silty, flaggy bedding.	12	157
Sandstone, medium grained, calcareous, minor crossbedding weathers brown.	4	145
Covered, float is blue-gray, fossiliferous limestone.	16	141
Limestone, massive, ledge former, pelecypod coquina, limonite stains on fractures.	5	125
Limestone, gray-brown, very fossiliferous, pelecypod coquina.	20	120
Sandstone, fine to medium grained, calcareous, light-gray, platy to shaley bedding.	15	100
Lamprophyre dike, aligned hornblende laths in an aphanitic green matrix.	2	85
Sandstone, fine grained, medium-gray, calcareous, weathers to brown 2-6 cm rectangular chips.	33	83
Limestone, flaggy to massive with numerous small fragmented pelecypod shells.	22	50
Covered, float same as below but with minor brown silty limestone.	25	28
Limestone, massive, dark-gray on fresh fractures, weathers gray to light-blue.	3	3

common fossils are oysters, Orbitulina, and rudistids. A characteristic light-gray, weathered surface and absence of chert are also indicative of U-Bar Formation. The U-Bar Formation commonly contains long stringers of milky-white calcite parallel with bedding in places where a thrust sheet of Paleozoic limestone lies directly above it (Fig. 6).

Mojado Formation

The most prominent exposure of the Mojado Formation in the Apache Hills is in a north-trending ridge in secs. 12 and 13, T. 29 S., R. 15 W. At this locality approximately 600 m (1,800 ft) of Mojado Formation crop out but neither the base nor the top of the formation are exposed. A thrust fault truncates the upper part of the Mojado Formation at Doyle's Peak and cuts stratigraphically lower northward, eliminating the entire Mojado section at the Daisy mine. Here allochthonous Paleozoic sediments directly overlie the U-Bar Formation.

The Mojado Formation consists of reddish-brown, massive and crossbedded sandstone and interbedded siltstone and shale. The sandstone is composed of subrounded, medium to well-sorted quartz grains with intergranular ferruginous clay. In the two thin sections examined, only quartz grains were observed; however, Van der Spuy (1970) has found allogenic chert grains, sparse biotite flakes, and feldspar grains. Cross-bedding is common and cut-and-fill scouring and channeling was observed in one locality. Fragments of fossil wood and ripple marks common fossils are oysters, Orbitolina, and rudistids. A characteristic light gray, weathered surface and absence of chert are also indicative of U-Bar Formation. The U-Bar Formation commonly contains long stringers of milky-white calcite parallel with bedding in places where a thrust sheet of Paleozoic limestone lies directly above it (Fig. 8).

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Figure 6. Echelon tension fractures filled with calcite veins in U-Bar Formation limestone underlying a klippe of Paleozoic limestone.

were found in sec. 2, T. 28 S., R. 14 W. and sec. 13, T. 29 S., R. 14 W. Zeller (1965) and Van der Spuy (1970) noted sandy, brown-weathered limestone in the upper part of the Mojado Formation. Total thickness of the formation measured by Zeller (1965) in the Big Hatchet Mountains is 1,700 m (5,300 ft). Van der Spuy (1970) measured a similar thickness in the Sierra Rica.

The Mojado Formation is highly silicified in a north-trending ridge in the southwest quadrant of the map. Here the rocks have been metamorphosed to hornfels and quartzite and fault planes are occupied by vuggy quartz that cements quartzite rubble. Numerous milky-white quartz veins cut the rock throughout the quartzite ridge. Exposures of Mojado Formation in the eastern half of the map area are relatively unaltered.

Tertiary Layered Rocks

Chapo Formation

General Features

The Chapo Formation is here named for prominent exposures of bedded volcanic rocks between the Big Chapo Tank and the Chapo mine in secs. 5 and 8, T. 29 S., R. 14 W. and sec. 33, T. 28 S., R. 14 W. It is a thick volcanic unit that comprises approximately 50 percent of all outcrops within the map-area.

The largest exposure of the Chapo Formation is in the area of low relief between the Apache Hills and Sierra Rica. Chapo

Formation also crops out extensively on the north flanks of the Apache Hills. The top of the formation is not exposed and the base is commonly concealed by alluvium. The formation strikes N. 70-90° W. and dips to the north, except where locally interrupted by folding or faulting. A section measured from a locality near the base of the formation in sec. 8, T. 29 S., R. 14 W. to the Apache fault near the Chapo mine is approximately 1,600 m (5,000 ft) thick.

The Chapo Formation is composed of four lithologically distinct units: the Basal Quartz Latite Member, the Andesite Member, the Upper Quartz Latite Member, and the Basalt and Andesite Member. Between the Lower Quartz Latite Member and Andesite Member and the Upper Quartz Latite and Basalt and Andesite Members there are 2 to 4 m (6 to 12 ft) zones of thinly-bedded sediment. The sediment is composed of angular to sub-rounded grains of feldspar, quartz, and lithic fragments of andesite composition.

Lasky (1947) tentatively correlated the andesites of the Chapo Formation in the Apache Hills with the Hidalgo volcanics in the Little Hatchet Mountains which he considered to be Lower Cretaceous. Subsequently, Zeller (1970) found fossil evidence that the Hidalgo volcanics were early Tertiary, "with only a slight possibility that it is late Cretaceous". In addition, Zeller mapped Lower Cretaceous sediments thrust over Hidalgo volcanic rocks, but in the Apache Hills the Chapo Formation unconformably overlies thrust-faulted rocks and is therefore

Formation also crops [illegible] Apache Butte. The [illegible] base is generally conce[illegible] N. 70-80° W. and dips [illegible] interrupted by faulting [illegible] a locality near the [illegible] E. 24 N. to the south [illegible] 1,600 m (5,300 ft) [illegible]

The Chapo Formation [illegible] distinct units [illegible] Member, the Upper Quartz [illegible] Andesite Member. [illegible] Andesite Member and [illegible] Andesite Member [illegible] thinly bedded and [illegible] to sub-rounded grains of [illegible] of andesite composition [illegible]

Lasky (1947) [illegible] Chapo Formation in the [illegible] in the Little Hatchet [illegible] Cretaceous. Subsequently [illegible] that the Hidalgo [illegible] slight possibility that [illegible] Zeller mapped [illegible] volcanic beds [illegible] unconformably [illegible] younger than thrust faulting. This would suggest that the Hidalgo volcanics are not correlative with the Oligocene dated Chapo Formation.

A K-Ar age determination on K-feldspar in the Basal Quartz Latite Member of the Chapo Formation (Damon, personal communication, August 1975) has yielded a date of 30.64 ± 1.15 m.y. The Basal Quartz Latite and Andesite Members of the Chapo Formation are intruded by quartz monzonite of the Apache stock which has been dated by Damon (personal communication, August 1975) at 27.16 ± 0.62 m.y. Sodic plagioclase was used to obtain the K-Ar age determination in the quartz monzonite stock. The upper two members of the Chapo Formation (the Upper Quartz Latite Member and the Basalt and Andesite Member) are not intruded by the Apache stock, however their conformable relationship with the underlying members suggests a continuous episode of volcanism.

Strongin (1958) gave the name, Last Chance Volcanics to the andesite and basalt in the Apache Hills. The name has been dropped in this report in favor of Chapo Formation. The name "Last Chance Volcanics" was preempted by Ferguson (1927) for a unit in the Mogollon mining district, New Mexico. In addition, Strongin did not include in his Last Chance Volcanics two quartz latite flows which are interbedded with basalt and andesite. He considered them to be sills rather than extrusive flows.

younger than [illegible] [illegible]. [illegible] [illegible] [illegible]
Hidalgo volcanics are [illegible] [illegible] [illegible] [illegible]
during [illegible] [illegible].

A K-Ar age determination [illegible] [illegible] [illegible] [illegible]
Quartz Latite Member of the Canoe Formation [illegible] [illegible]
communication, August 1977) [illegible] [illegible] [illegible]
[illegible] m.y. The [illegible] Quartz Latite and [illegible] Member of the
Canoe Formation are [illegible] [illegible] [illegible] [illegible]
stock which has been dated by [illegible] [illegible] communication,
August 1977) at [illegible] [illegible] [illegible] [illegible]
to obtain the best age determination on the quartz monzonite
stock. The upper two members of the Canoe Formation (the
Upper Quartz Latite Member and the [illegible] and [illegible]
are not intruded by the quartz monzonite stock [illegible]
relationship with the underlying [illegible] [illegible]
episode of volcanism.

Thompson (1968) gave the name [illegible] [illegible] to the
andesite and basalt in the [illegible] [illegible] [illegible]
dropped in this report in favor of Canoe Formation. The name
"[illegible] [illegible] Volcanics" was proposed by [illegible] [illegible] for a
unit in the Hidalgo mining district, [illegible] [illegible]. In addition,
Thompson did not include in the [illegible] [illegible] Volcanics the
quartz latite flows [illegible] [illegible] [illegible] [illegible] and
rhyolite. It [illegible] [illegible] [illegible]
Flows.

Lower Quartz Latite Member

The Lower Quartz Latite Member of the Chapo Formation is exposed in a broad east-west band that extends through the Big Chapo Tank. Its base is exposed in only a few outcrops of low relief. On the north side of the Apache fault, in sec. 27, T. 28 S., R. 14 W., the Lower Quartz Latite Member is intruded by the quartz monzonite stock. Similarity in lithology between the quartz latite flow and the quartz monzonite stock make mapping of the contact difficult.

The Lower Quartz Latite Member is composed of a pale purple matrix with conspicuous white feldspar phenocrysts. Near its upper contact with the Andesite Member the matrix is pale blue. The member is composed of extrusive flows which show almost no physical discontinuity or compositional change between flows. The unit weathers to low, rounded outcrops commonly covered by cobble to pebble-sized float.

Phenocrysts make up 50 to 60 percent of the rock. The phenocrysts are fragmented and are composed of plagioclase, orthoclase, strongly resorbed bipyramidal quartz, and opaque oxides. Biotite is replaced by chlorite and less commonly by sericite. The groundmass is cryptofelsitic. Pink and cream colored xenoliths of angular to subrounded felsic material 1-3 mm long are common. Weak flow structure is sometimes visible in thin sections, but generally is obscure in hand specimens. Glass shards and pumice fragments were not found.

Lower Quartz [illegible]

The lower qu[illegible]
exposed in a small [illegible]
Big Cedar Tank. [illegible]
Joe Wilbur. Of [illegible]
27, T. 14 S., R. [illegible]
intruded by [illegible]
lithology between [illegible]
stock [illegible] mapping [illegible]

The lower [illegible]
matrix with [illegible]
upper contact with the [illegible]
The member is [illegible]
physical [illegible]
The unit weathers [illegible]
cobble to pebble [illegible]

Phenocrysts [illegible]
phenocrysts are [illegible]
orthoclase, strongly [illegible]
oxides. [illegible]
by sericite. The [illegible]
cream colored [illegible]
material 1-2 [illegible]
Sometimes visible [illegible]
In hand specimen [illegible]
not found.

Results of chemical analysis and a calculated norm are in Table 3, no. 4. The following mode was counted from a specimen near the base of the section: quartz 12 percent, orthoclase 27 percent, plagioclase 11 percent, biotite (including chlorite after biotite) 5 percent, and cryptofelsitic groundmass 45 percent. The mode of this thin section has a high ratio of orthoclase to plagioclase phenocrysts. This appears to be characteristic of the base of the unit. A second thin section from near the center of the section contains nearly equal amounts of orthoclase to plagioclase phenocrysts. The norm in Table 3, no. 4, is of a third specimen and is probably representative of most of the member. The chemical analysis compares closely with Nockold's (1958) average quartz latite and the calculated norm contains approximately equal amounts of orthoclase and plagioclase.

A section was measured in sec. 8, T. 29 S., R. 14 W. The unit dips 35 to 40° N. and is approximately 400 m (1,300 ft) thick. Over most of the outcrop width its appearance is uniform but approximately 300 m (1,000 ft) above the base of the section there is a 5 m (16 ft) zone of strongly-oriented autolithic inclusions in a crystal-poor matrix which can be traced along strike for over 100 m (300 ft). No such zone was observed north of the Apache fault, but it could have been missed among outcrops of low relief. Approximately 26 m (80 ft) below the upper contact the color of the matrix changes from purple to pale blue and the rock contains less

Results of chemical analysis and a calculated mode are in Table 2, no. 4. The following mode was computed from a specimen near the base of the section: quartz 10 percent, orthoclase 27 percent, plagioclase 11 percent, biotite (including chlorite after biotite) 4 percent, and cryptocrystalline groundmass 48 percent. The mode of this thin section has a high ratio of orthoclase to plagioclase phenocrysts. This appears to be characteristic of the base of the unit. A second thin section from near the center of the section contains nearly equal amounts of orthoclase to plagioclase phenocrysts. The mode in Table 5, no. 4, is of a third specimen and is probably representative of most of the member. The chemical analysis compares closely with Nockolds's (1954) average quartz latite and the calculated mode contains approximately equal amounts of orthoclase and plagioclase.

A section was measured in sec. 8, T. 27 S., R. 11 W. The unit dips 35 to 40° N. and is approximately 400 m (1,300 ft) thick. Over most of the outcrop width its appearance is uniform but approximately 600 m (2,000 ft) above the base of the section there is a 5 m (16 ft) zone of strongly-oriented autolithic inclusions in a crystal-poor matrix which can be traced along strike for over 150 m (500 ft). No such zone was observed north of the Squaw fault, but it would have been missed among [illegible] approximately 10 m (30 ft) [illegible] changes [illegible]

Table 3. Chemical analyses and norms of selected igneous rocks from the Apache No. 2 Mining District, Hidalgo County, New Mexico.

CHEMICAL ANALYSES (OXIDE PERCENTAGES)

	1	2	3	4	5	6	7	8
SiO_2	61.18	61.52	65.26	65.50	74.63	54.00	62.08	53.91
Al_2O_3	14.20	14.55	14.30	14.35	12.01	14.10	15.00	15.28
FeO	8.14	5.67	7.29	5.70	3.44	9.05	8.96	3.87
Fe_2O_3	2.41	2.60	1.60	2.12	1.12	5.94	0.07	3.62
MgO	1.08	1.34	0.74	0.76	0.35	1.97	0.75	0.94
CaO	2.21	3.50	1.48	1.88	0.23	5.29	3.02	6.29
Na_2O	4.50	2.92	4.11	3.11	1.93	4.00	4.90	2.43
K_2O	4.26	3.23	4.35	4.22	5.08	2.50	4.07	7.70
TiO_2	0.58	0.66	0.34	0.43	0.16	1.49	0.26	0.40
MnO	0.08	0.117	0.07	0.09	0.04	0.14	0.11	0.10
SrO	0.03	0.02	0.03	0.02	0.01	0.07	0.07	0.10
P_2O_5	0.20	0.20	0.15	0.15	0.04	0.37	0.13	0.24
H_2O^+	0.01	1.14	0.11	0.37	0.45	0.02	0.07	0.68
H_2O^-	0.10	0.24	0.12	0.28	0.14	0.22	0.10	0.49
CO_2	0.98	2.47	0.50	1.32	0.15	1.30	0.70	3.63
Total	99.96	100.18	100.45	100.30	99.78	100.46	100.29	99.68

CIPW NORMS (WT % OF NORMATIVE MINERALS)

	1	2	3	4	5	6	7	8
Q	8.28	20.63	15.60	23.19	41.09	5.99	5.01	--
Or	25.47	19.82	25.79	25.37	30.32	14.95	24.21	48.01
Ab	35.53	25.66	34.89	26.77	16.49	34.24	41.74	19.64
An	6.04	16.67	6.38	8.49	0.89	13.29	6.96	8.49
Di	3.23	--	--	--	--	9.15	6.37	12.55
Hy	13.34	11.15	13.52	10.24	6.13	9.93	14.80	--
Wo	--	--	--	--	--	--	--	3.27
Mt	3.54	3.91	2.33	3.13	1.64	8.71	0.10	5.54
Il	1.11	1.30	0.65	0.83	0.31	2.86	0.50	0.80
Ap	0.47	0.48	0.35	0.35	0.09	0.87	0.30	0.59
Sp	--	--	--	--	--	--	--	--
Ru	--	--	--	--	--	--	--	--

1. Chapo Formation andesite (Tca), north of Apache Peak (sec. 20, T 28 S, R 14 W).
2. Chapo Formation andesite (Tca), south of the Apache Fault (sec. 5, T 29S, R 14 W)
3. Quartz Monzonite porphyry (Tqm) from the west flank of Apache Peak (sec. 31, T 28 S, R 14 W)
4. Chapo Formation, lower quartz latite member (Tcql) near middle of stratigraphic section (sec. 8, T 29 S, R 14 W)
5. Chapo Formation, upper quartz latite member (Tcqu), ash flow tuff at base of section (sec. 5, T 29 S, R 14 W)
6. Chapo Formation, basalt and andesite member (Tcba) south of the Apache Fault near middle of stratigraphic section (sec. 33, T 28 S, R 14 W)
7. Monzonite porphyry (Tm) west of the Apache Mine (sec. 30, T 28 S, R 14 W)
8. Monzonite porphry (Tm) in endoskarn zone with sulfide mineralization at Chapo Mine area (sec., T 28 S, R 14 W)

quartz. A thin bed (1-3 m, 3-9 ft) of volcaniclastic sediment is present at the contact with the overlying Andesite Member. It is composed of subangular grains of quartz and feldspar, and of fragments of quartz latite and trachyte. The sediment was deposited during a hiatus between volcanic events.

The Lower Quartz Latite Member of the Chapo Formation is younger than thrust faults in the area. Drilling with an auger bit in sec. 9, T. 29 S., R. 14 W., has confirmed that the Lower Quartz Latite Member overlies a klippe of Paleozoic limestone. One hole was drilled through the Paleozoic limestone and intersected Mojado Formation sandstone. Another hole, collared in the Lower Quartz Latite Member, near a klippe, intersected Paleozoic limestone at shallow depth.

Strongin (1958) mapped the Lower Quartz Latite Member as a sill but an extrusive origin is suggested by internal layering, lack of metamorphic effects in underlying Paleozoic limestone, and the volcaniclastic sediment at the upper contact.

Andesite Member

The Andesite Member of the Chapo Formation crops out in an east-west band south of the Apache fault and is prominently exposed north of the Apache stock. It also occurs as a small roof pendant in quartz monzonite on the southwest flank of Apache Peak. Near the contact with the Apache stock it is strongly epidotized (Fig. 7).

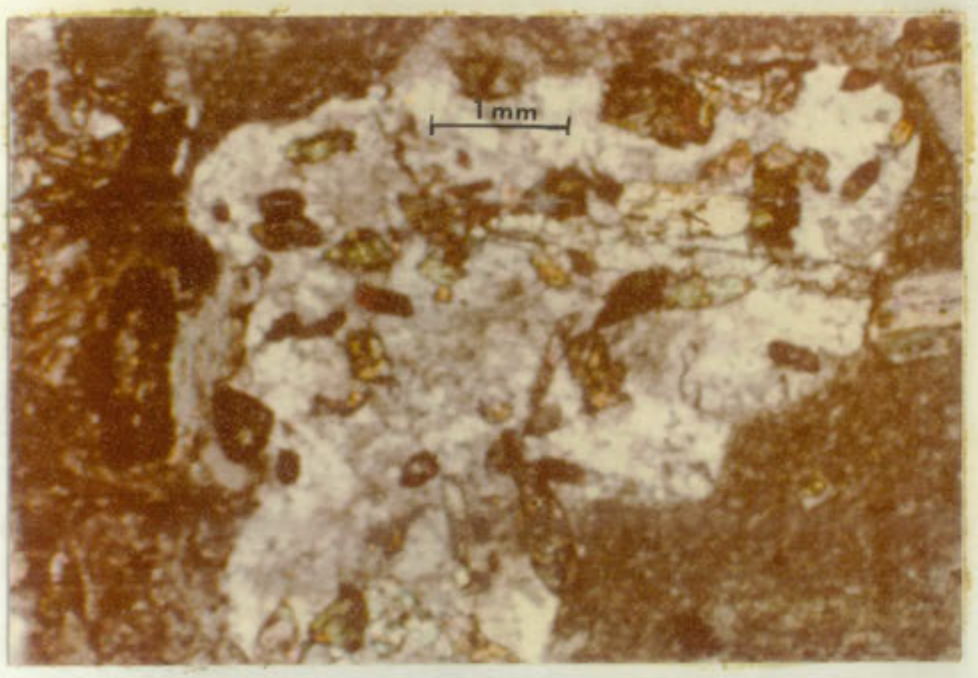


Figure 7. Photomicrograph of propylitized andesite. Andesite Member of the Chapo Formation near its contact with the Apache stock. Epidote replaces a large plagioclase phenocryst. The matrix is composed of epidote and felty chlorite.

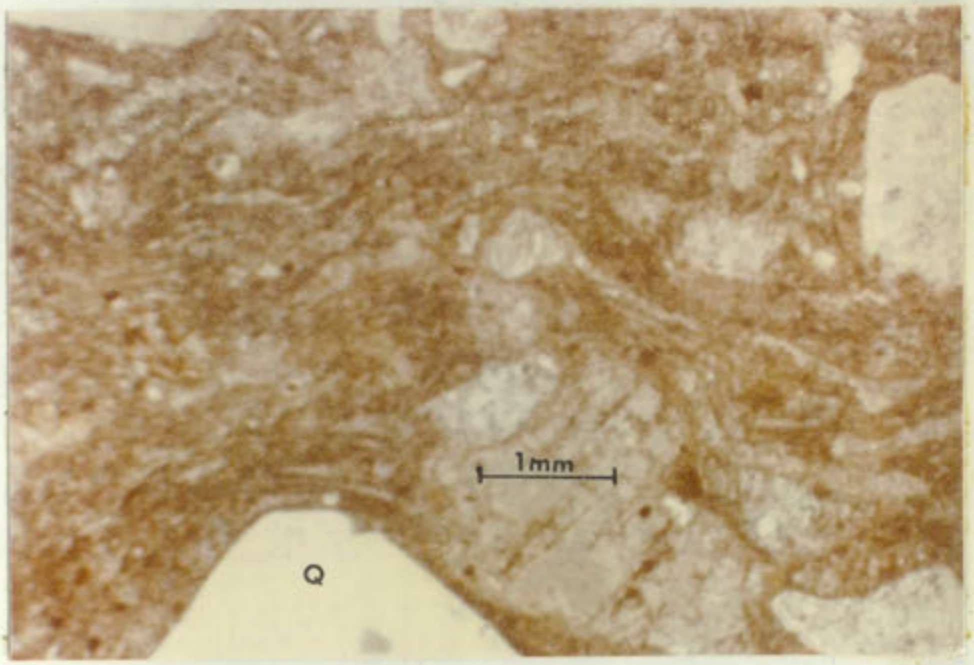


Figure 8. Photomicrograph of ash-flow tuff in the Upper Quartz Latite Member of the Chapo Formation. The orientation of shards around a quartz crystal (Q) may represent flow or compaction.

The Andesite Member has a dark-purple aphanitic matrix and 15 to 25 percent euhedral plagioclase phenocrysts, commonly as long as 1 cm. Its appearance is distinctive due to the dark-purple aphanitic matrix and conspicuous white feldspar phenocrysts. The texture is uniform throughout the unit. The matrix is brown to green in areas of hydrothermal alteration or near igneous contacts. Flow structure and lamination are obscure in hand specimen. Microscopically, the andesite has a matrix composed of plagioclase microliths and magnetite with hematite rims. The composition of the small plagioclase microliths is An_{30-45} but for larger phenocrysts (3-5 mm) it is An_{60-75}. Hornblende and augite constitute 5 to 7 percent of the rock. Ferromagnesian minerals are largely altered to iron oxides and chlorite and epidote coats fractures and joints in the rock.

Although the norm and chemistry show that the rock is a latite, it was mapped as an andesite because the mode contained no visible K-feldspar or quartz.

North of the Apache fault, Strongin (1958) mapped the Andesite Member of the Chapo Formation as "the monzonite facies of the Apache Hills composite stock". South of the Apache fault he mapped the unit as part of the Last Chance Volcanics. Several criteria suggest that Strongin's "monzonite" is extrusive and that it is the same unit that crops out south of the Apache Fault: 1) The Andesite Member everywhere lies concordantly between the Upper and Lower

Quartz Latite Members of the Chapo Formation. Only in the western part of the Apache Hills, the Apache stock locally cuts out the Lower Quartz Latite Member. 2) There is no alteration in rocks adjacent the andesite. 3) Whole-rock chemistry shown in Table 3, no. 2 for andesite south of the Apache fault (Strongins's Last Chance Volcanics) is similar to that of andesite (Strongin's monzonite) sampled north of the Apache fault (Table 3, no. 1), and 4) rocks in both areas are petrographically similar.

Thickness of the Andesite Member is difficult to determine because of uncertainties in measuring dips. Northwest of the Big Chapo tank a 220 m (700 ft) section was measured. Separate flow units were not identified and the hand-specimen appearance is remarkably uniform throughout. Andesite outcrops are more extensive in the southeast quadrant of the map, probably as a result of lower dips rather than a thickening of the unit. The andesite appears to thin appreciably in the northeast quadrant of the map.

Upper Quartz Latite Member

The Upper Quartz Latite Member of the Chapo Formation crops out in an east-west band approximately 0.6 km (0.3 mi) wide, between the Andesite Member and the overlying Basalt and Andesite Member. The outcrop band is present on the north and south sides of the Apache fault.

Quartz Latite Members of the Chuco Formation. (Qu). In the western part of the Apache Hills, the Apache stock locally cuts out the Lower Quartz Latite Member. 2) There is no alteration in rocks adjacent the andesite. 3) Whole rock chemistry shown in Table 5, no. 4 for andesite south of the Apache fault (Strangway's Last Chance Volcanics) is similar to that of andesite (Strangway's monzonite) sampled north of the Apache fault (Table 5, no. 3), and 4) rocks in both areas are petrographically similar.

Thickness of the Andesite Member is difficult to determine because of uncertainties in measuring dips. Northeast of the Big Chuco tank a 220 m (700 ft) section was measured. Separate flow units were not identified and the hand-specimen appearance is remarkably uniform throughout. Andesite outcrops are more extensive in the southeast quadrant of the map, probably as a result of lower dips rather than a thickening of the unit. The andesite appears to thin appreciably in the northwest quadrant of the map.

Upper Quartz Latite Member

The Upper Quartz Latite Member of the Chuco Formation crops out in an east-west band approximately 0.8 km (0.5 mi) wide, between the Andesite Member and the overlying Basalt and Andesite Member. The outcrop band is present on the north and south sides of the Apache fault.

The Upper Quartz Latite Member resembles the Lower Quartz Latite Member in lithology, hand-specimen appearance, and outcrop characteristics. Major differences are stratigraphic position, the presence of a basal ash-flow tuff, and a larger percentage of quartz phenocrysts in the upper member.

At the base of the unit is an air-fall tuff. It is thinly bedded, light green to buff, and forms inconspicuous outcrops due to its friable nature. It has a uniform vitreous texture devoid of phenocrysts. No fluvial structures were observed. Thickness of the tuff does not exceed 3 m (10 ft) and it is absent north of the Apache Fault. An ash-flow tuff with conspicuous shards and pumice fragments is exposed above the air-fall tuff. The tuff contains up to 25 percent resorbed, bipyramidal quartz phenocrysts (Fig. 8). A whole rock analysis and CIPW norm are in Table 3, no. 5. The upper contact of the ash-flow tuff is not exposed but quartz latite flows are present 30 m (100 ft) above the base and continue to the upper contact. They contain 40 to 60 percent phenocrysts and have weak microscopic flow structures but no pumice fragments, shards, or other criteria indicative of ash-flow tuffs. At the upper contact with the Basalt and Andesite Member there is a 2 to 5 m (6 to 16 ft) bed of volcaniclastic sediment with graded beds 1 to 2 cm (1/2 to 1 in) thick. Clasts generally do not exceed 5 mm and sorting is poor. The sediment is composed of lithic fragments of andesite and angular to subrounded grains of quartz and plagioclase set in a matrix of

ferruginous clay. The volcaniclastic sediment is present wherever the contact between the Upper Quartz Latite Member and Basalt and Andesite Member is exposed.

Thickness of the Upper Quartz Latite Member in a measured section north of the Big Chapo Tank was 300 m (950 ft). Thickness does not vary noticeably within the map area.

Basalt and Andesite Member

The Basalt and Andesite Member of the Chapo Formation is exposed in a wide east-west band south of the Chapo mine. The upper part of the unit is truncated by the Apache Fault. On the north side of the Apache Hills the unit is exposed along the Grant County-Hidalgo County line. There its upper part is concealed by younger volcanic rocks and pediment gravel.

The Basalt and Andesite Member is easily identified on aerial photographs by its dark color. In hand-specimen its appearance is variable but generally it has a black to dark-purple, aphanitic matrix with 1 to 3 mm plagioclase phenocrysts.

Although the top of the member was not exposed, approximately 700 m (2,200 ft) of section was measured. The thickness could vary considerably from that measured as a result of unrecognized variations in dip or by repetition or omission of strata by faulting. The basal 300 m (1,000 ft) of the measured section is composed of andesite characterized by a dark-purple to dark-green cryptofelsitic matrix and 2 to 10 percent small plagioclase phenocrysts. The phenocrysts range from An_{48} to An_{60} and some of them show weak compositional zoning with more sodic rims.

ferruginous chert. The volcaniclastic sediment is present wherever the contact between the Upper Quartz Latite Member and Basalt and Andesite Member is exposed.

Thickness of the Upper Quartz Latite Member in a measured section north of the Big Chapo Tank was 280 m (920 ft). Thickness does not vary noticeably within the map area.

Basalt and Andesite Member

The Basalt and Andesite Member of the Chapo Formation is exposed in a wide east-west band south of the Chapo mine. The upper part of the unit is truncated by the Apache Fault. On the north side of the Apache Hills the unit is exposed along the Grant County-Hidalgo County line. There its upper part is concealed by younger volcanic rocks and pediment gravel.

The Basalt and Andesite Member is easily identified on aerial photographs by its dark color. In hand specimen its appearance is variable but generally it has a black to dark-purple, aphanitic matrix with 1 to 3 mm plagioclase phenocrysts.

Although the top of the member was not exposed, approximately 701 m (2,300 ft) of section was measured. The thickness could vary considerably from that measured as a result of unrecognized variations in dip or by repetition or deletion of strata by faulting. The basal 30 m (100 ft) of the measured section is composed of [illegible]

grained [illegible]

Plagioclase phenocrysts constitute 10 percent of the rock near the base of the unit and decrease to approximately 2 percent 300 m (1,000 ft) above the base. Hornblende and augite phenocrysts are rare. Overlying the lower 300 m (1,000 ft) of section is a volcaniclastic sediment composed of sand sized (0.25 mm to 2 mm) angular to sub-rounded grains of andesite. The sediment is approximately 10 m (30 ft) thick where exposed in sec. 33, T. 28 S., R. 14 W. It rarely crops out because of its friable nature.

The upper 300 m (1,000 ft) of the Basalt and Andesite Member is composed of basalt flows and andesite flows similar to those in the basal part of the member. A whole-rock analysis of andesite near the center of the measured section is represented in Table 1, no. 6. In thin section the rock contains a holocrystalline matrix of plagioclase microlites, iron oxides and chlorite. Iron oxides and chlorite replace hornblende. Small phenocrysts (1-3 mm) of andesine constitute 10 percent of the rock. Vesicular andesite is common near the center of the measured section. Orientation of vesicles located in the north half of sec. 4, T. 29 S., R. 14 W. suggest a flow direction from west to east (Fig. 9). Here the oblate part of the vesicle is on the east end and the sharply tapered end points west.

Basalt flows are present in the upper part of the Basalt and Andesite Member. Due to poor outcrops, the earliest appearance of basalt and the contact relationships with andesite flows was not determined. It appears that basalt is restricted to the upper 200 m (600 ft) of the measured section and it is assumed that

Plagioclase phenocrysts constitute 10 percent of the rock near the base of the unit and decrease to approximately 2 percent 300 m (1,000 ft) above the base. Hornblende and augite phenocrysts are rare. Overlying the lower 300 m (1,000 ft) of section is a volcaniclastic sediment composed of sand sized (visible to 2 mm) angular to sub-rounded grains of andesite. The sediment is approximately 10 m (30 ft) thick where exposed in sec. 30, T. 27 S. R. 19 W. It rarely crops out because of its friable nature.

The upper 300 m (1,000 ft) of the Basalt and Andesite Member is composed of basalt flows and andesite flows similar to those in the basal part of the member. A whole-rock analysis of andesite near the center of the measured section is represented in Table 1, no. 8. In thin section the rock contains a holocrystalline matrix of plagioclase microlites, iron oxides and chlorite. Iron oxides and chlorite replace hornblende. Small phenocrysts (1-3 mm) of andesine constitute 10 percent of the rock. Vesicular andesite is common near the center of the measured section. Orientation of vesicles located in the north half of sec. 4, T. 28 S., R. 19 W. suggest a flow direction from west to east (Fig. 9). Here the oblate part of the vesicle is on the west end and the sharply tapered end points east.

Basalt flows are present in the upper part of the Basalt and Andesite Member. Due to poor exposure, the earliest appearance of basalt and the contact relationships with andesite flows are not determined. It appears that basalt is present in the upper

300 m [illegible]

the basalt flow(s) are conformable with andesite flows. The basalt is dark-brown to black and is composed of plagioclase microlites, devitrified glass, and grainy opaque material. Plagioclase microlites are labradorite composition (An$_{60-70}$) and have been largely altered to sericite. The rock contains 5 to 8 percent iddingsite and crysotile after olivine.

Flow-banded Rhyolite

Flow-banded rhyolite crops out south of the Apache Fault near the Apache mine and in a small exposure northwest of the Christmas mine.

The rock is buff to tan and is composed of flow breccia and thinly laminated flows of rhyolite composition. It contains approximately 20 percent plagioclase and bipyramidal quartz phenocrysts. The basal part of the unit exposed south of the Apache Fault is composed of ash-flow tuff. It cannot be traced laterally due to truncation by the Apache Fault to the north, and due to cover by pediment gravel east and south.

The relative age of the flow-banded rhyolite is not certain. It unconformably overlies the Andesite Member of the Chapo Formation west of the Christmas mine and contains clasts of andesite and quartz latite similar to the underlying Chapo Formation. South of the Apache Fault, the base of the flow-banded rhyolite is concealed by pediment gravels. The flow-banded rhyolite is not overlain or intruded by younger Tertiary rocks. Its age relationship with rocks younger than the Chapo Formation is not known.

the basalt [illegible] basalt is [illegible] microlites, [illegible] Plagioclase [illegible] have been [illegible] 8 percent [illegible]

[illegible]

The [illegible] the Apache [illegible] zone.

The [illegible] thirty [illegible] approximately [illegible] phenocrysts [illegible] Apache fault [illegible] laterally [illegible] and then to [illegible]

The relative [illegible] is [illegible] most of the [illegible] quartz latite [illegible] the Apache fault [illegible] by [illegible] intruded [illegible]

Porphyritic Rhyolite

Porphyritic rhyolite crops out as dikes, plugs, and local flows throughout the map-area. Several dikes and two plugs of porphyritic rhyolite lie along the axis of a broad anticline in the southern part of the map. Their localization suggests emplacement along a zone of structural weakness, possibly a cauldron margin. Another group of small plugs, dikes, and local flows is present in the northcentral part of the map-area.

The rock is characterized by a white to buff aphantic matrix with up to 25 percent phenocrysts of plagioclase and bipyramidal quartz. Fragmentation of phenocrysts and weak flow structure are observed in thin section in in-rusive and extrusive phases of the rock. Porphyritic rhyolite is mapped separately from intrusive "rhyolite porphyry" even though in hand-specimen their appearance is similar. The rhyolite porphyry usually contains small epidote clots and sparse xenoliths of quartz monzonite or sedimentary rocks. The porphyritic rhyolite is devoid of xenoliths and is generally unaltered except for minor pyritization in some outcrops. The two rhyolites may represent intrusion from the same magma at nearly the same time. The distinction is that the rhyolite prophyry forms a thick, continuous dike along the southern margin of the Apache stock and is associated with mineralization while the porphyritic rhyolite crops out as flows as well as dikes and plugs and appears not to be associated with mineralization. Outcrops of the porphyritic rhyolite occur only near the postulated cauldron margins while rhyolite porphyry crops out only near the center of the proposed cauldron.

Porphyritic Rhyolite

Porphyritic rhyolite crops out as dikes, plugs, and local flows throughout the map area. Several dikes and two plugs of porphyritic rhyolite lie along the axis of a broad anticline in the southern part of the map. Their localization suggests emplacement along a zone of structural weakness, possibly a caldera margin. Another group of small plugs, dikes, and local flows is present in the northcentral part of the map area.

The rock is characterized by a white to buff aphanitic matrix with up to 25 percent phenocrysts of plagioclase and bipyramidal quartz. Fragmentation of phenocrysts and some flow structure are observed in thin section in intrusive and extrusive phases of the rock. Porphyritic rhyolite is mapped separately from intrusive "rhyolite porphyry" even though in hand-specimen their appearance is similar. The rhyolite porphyry usually contains small epidote clots and sparse xenoliths of quartz monzonite or sedimentary rocks. The porphyritic rhyolite is devoid of xenoliths and is generally unaltered except for minor pyritization in some outcrops. The two rhyolites may represent intrusion from the same magma at nearly the same time. The distinction is that the rhyolite porphyry forms a thick, continuous dike along the southern margin of the Apache stock and is associated with mineralization, while the porphyritic rhyolite crops out as flows as well as dikes and plugs and occurs not [illegible]

[illegible]

Volcaniclastic conglomerate

A single outcrop area of volcaniclastic conglomerate is exposed in the northcentral part of the map-area along the Grant-Hidalgo County line. It forms a small conical hill approximately 80 m (250 ft) high. The top of the rock unit is not exposed but it appears to be at least 70 m (200 ft) thick.

In hand-specimens the rock is dark red. It is a poorly sorted conglomerate with clasts up to 15 cm (6 in) in diameter (Fig. 10). The matrix is composed of sand-sized lithic fragments, quartz, feldspar, and ferruginous clay. Clasts are angular to subrounded and are composed of rhyolite, andesite, and trachyte. Rhyolite clasts predominate.

The volcaniclastic conglomerate unconformably overlies the Basalt and Andesite Member of the Chapo Formation. The predominance of rhyolite clasts suggests that the conglomerate was deposited contemporaneous with or after porphyritic rhyolite. The conglomerate may be overlain by the rhyolite of Wamels Pond. The relative age cannot be determined by outcrop position. The volcaniclastic sediment is discontinuous along its strike, probably because of erosion. The single hill in which it crops out appears to be resistant to weathering due to silicification.

Rhyolite of Wamels Pond

The Rhyolite of Wamels Pond crops out in a discontinuous band from Wamels Pond to the Mexican border. The rock consists of white to buff rhyolite tuff, flow-banded rhyolite, and latite.

Figure 9. Elongated vesicles in the Basalt and Andesite Member of the Chapo Formation. The orientation of elongation suggests flow from west to east.

Figure 10. The volcaniclastic conglomerate exposed near Wamels Pond.

[illegible]

It unconformably overlies parts of the Mojado, U-Bar, and Chapo Formations. The attitude of the beds appears to be horizontal. Due to deep weathering and low relief of outcrops, no specimen was found fresh enough for thin section examination.

It is uncertain whether the Rhyolite of Wamels Pond is the same unit or a time equivalent unit to the "flow-banded rhyolite" exposed in the west part of the Apache Hills. Both units unconformably overlie the Chapo Formation and are composed of silicic volcanic rocks, however, the Rhyolite of Wamels Pond contains a latite flow while the "flow-banded rhyolite" is entirely composed of rhyolite. In addition, the outcrops are separated by 7 to 9 km (5 to 6 mi) which also makes correlation doubtful.

Tertiary intrusive rocks

Trachyte

A trachyte sill intrudes the fault plane of several exposures of thrust faults in the Apache Hills. It is exposed between the Mojado Formation and the overlying allochtonous Paleozoic limestone in the area south of the Big Chapo tank and in a few outcrops north of the Apache fault. If the sill is continuous it represents an areal extent of greater than 48 sq km (14 sq mi). Thickness is difficult to determine due to low relief of outcrops, but in an exposure east of the Little Chapo tank it appears to be less than 5 m (15 ft). In other outcrop locations the thickness cannot be determined.

It [illegible]
Formation. The [illegible]
but in this [illegible]
was found [illegible]

It is uncertain [illegible]
same unit or a time [illegible]
exposed in the west part [illegible]
unconformably overlie [illegible]
volcanic rocks, however, [illegible]
latite flow [illegible]
of dunite. In addition, [illegible]
(8 to [illegible] m) which [illegible]

[illegible]

A maximum will [illegible]
of thrust faults in the Alpine [illegible]
Mojado Formation and the [illegible]
in the area south of [illegible]
of the Apache fault. [illegible]
areal extent of [illegible]
difficult to [illegible]
importance of the [illegible]
[illegible]
be [illegible]

The trachyte is reddish-brown to black and weathers into small (2-4 cm) rectangular slabs. Microscopically it is composed of quartz and sanidine phenocrysts in a pilotaxitic groundmass of feldspar microliths and opaque material. The rock is intensely weathered. It contains hematite rims around magnetite and calcite has replaced some plagioclase.

The trachyte was emplaced after thrust faulting. Mojado Formation and the overlying plate of Paleozoic limestone are structurally broken, but the trachyte is not. The trachyte does not intrude rocks younger than the lower Cretaceous Mojado Formation and it is not intruded by younger rocks, therefore its age relative to post-Lower Cretaceous rocks is unknown.

Quartz Monzonite Porphyry

Quartz monzonite porphyry forms a stock in the central part and topographically highest part of the Apache Hills. It is elongated N. 70 W. and is approximately 5 km (3 mi) long and 1.6 km (1 mi) wide at its widest point. The stock is exposed over 3 sq km (1.3 sq mi). The stock is largely concordant with the strike of adjacent volcanic rocks but appears to cut across layering in a few localities. Small outcrops of quartz monzonite porphyry occur adjacent the Apache fault southeast of the Apache mine and a dike of equigranular, phaneritic quartz monzonite intrudes andesite west of the Christmas mine. The Andesite Member of the Chapo Formation is intensely epidotized near the porphyritic quartz monzonite. Small rhyolite dikes are common along the andesite-quartz monzonite porphyry contact.

The dacite is porphyroaphanitic and weathers into small (1-4 cm) rectangular slabs. Microscopically it is composed of quartz and andesine phenocrysts in a pilotaxitic groundmass of feldspar microlites and opaque material. The rock is intensely weathered. It contains hematite rims around magnetite and calcite has replaced some plagioclase.

The dacite was emplaced after thrust faulting. Bisbee Formation and the overlying plate of Paleozoic limestone are structurally broken, but the dacite is not. The dacite does not intrude rocks younger than the Lower Cretaceous Bisbee Formation and it is not intruded by younger rocks, therefore its age relative to post-Lower Cretaceous rocks is unknown.

Quartz Monzonite Porphyry

Quartz monzonite porphyry forms a stock in the central part and topographically highest part of the Apache Hills. It is elongated N. 30 W. and is approximately 5 km (3 mi) long and 1.6 km (1 mi) wide at its widest point. The stock is exposed over 8 sq km (3.2 sq mi). The stock is largely concordant with the strike of adjacent sedimentary rocks but appears to cut across bedding in a few localities. Small outcrops of quartz monzonite porphyry occur adjacent the Apache fault southeast of the Apache mine and a suite of equigranular, phaneritic, quartz monzonite [illegible]

The quartz monzonite porphyry is pink to gray and in some areas has a pale purple matrix. Outcrops weather to rounded boulders and cobble-sized rocks with a pale orange hue. Its crystal content ranges from 60 to 90 percent with an average of 75 percent. Phenocrysts are quartz, orthoclase, oligoclase-andesine (An_{20}-An_{40}), biotite, and, less commonly, hornblende. Quartz phenocrysts are partially resorbed and are 1-4 mm in diameter (Fig. 11). The plagioclase occurs as fragmented and euhedral crystals averaging 1.5-3 mm in diameter. Partial replacement of plagioclase by epidote and chlorite is common. Biotite and hornblende are largely altered to chlorite and magnetite. Weak orientation of elongate phenocrysts can sometimes be seen in thin sections but is seldom observed in hand specimen. Xenoliths of andesite and fine grained quartz monzonite are common near the border of the stock (Fig. 12), as are epidote clots which have probably been formed by alteration of inclusions of sedimentary rock.

In general appearance the quartz monzonite porphyry is similar to the Lower Quartz Latite Member of the Chapo Formation which it intrudes. This makes mapping of the contact between the two rocks difficult. Some criteria used to distinguish the two are as follows: 1) The Lower Quartz Latite Member commonly contains elongate, subtly oriented, dark, fine-grained inclusions while the quartz monzonite porphyry seldom contains perceptible orientation of clasts. It does contain ovate or round epidote

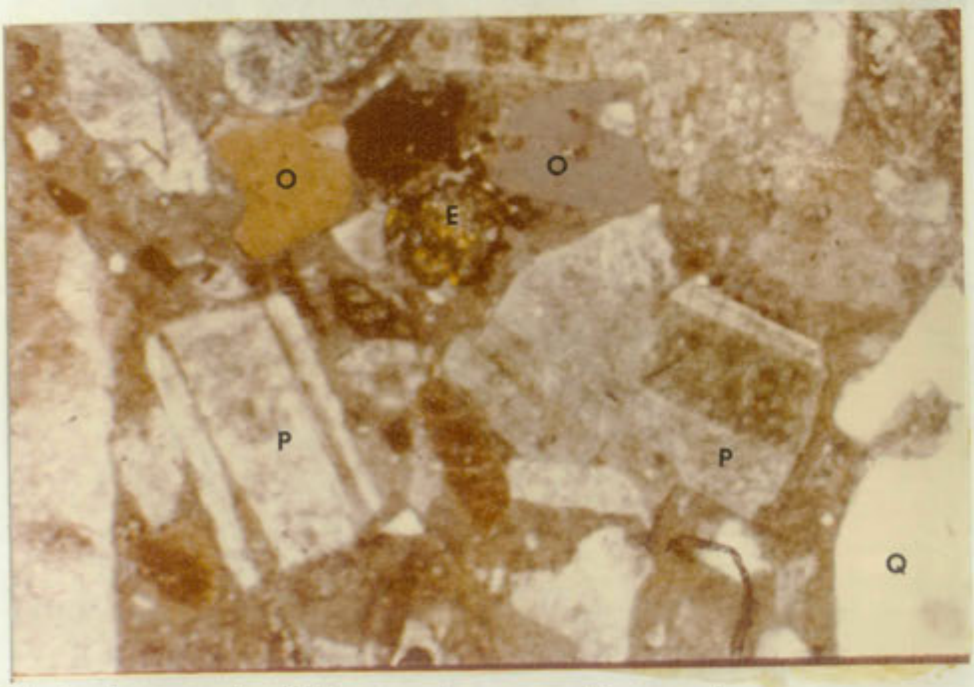


Figure 11. Photomicrograph of the quartz monzonite porphyry of the Apache stock. Note the embayment of quartz and fragmentation of some plagioclase crystals. Quartz (Q), orthoclase (O), plagioclase (P), epidote (E).

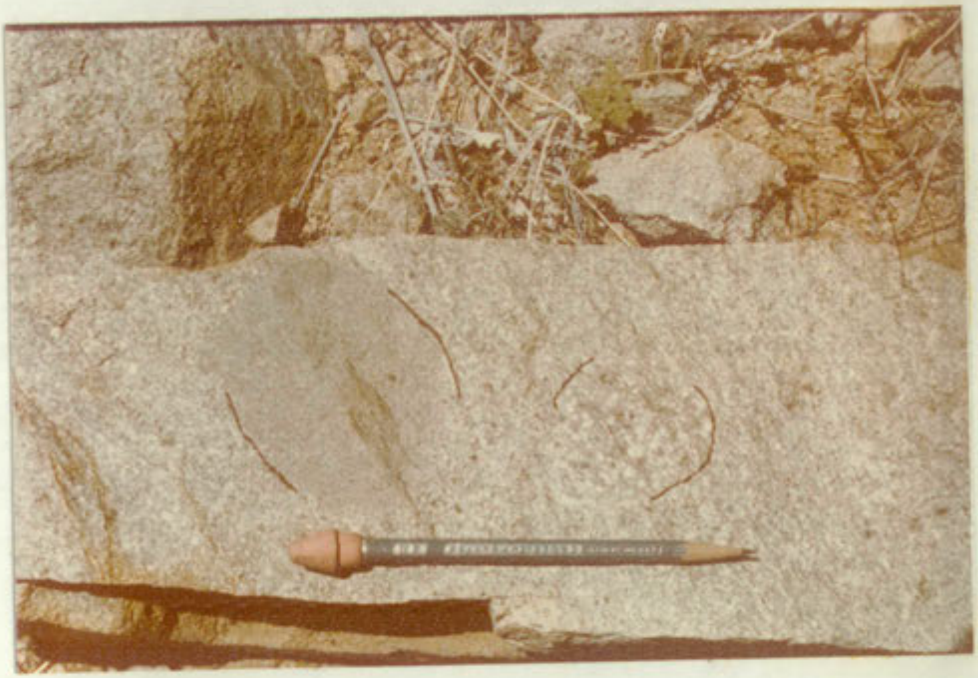


Figure 12. Rounded xenoliths of andesite and fine-grained diorite in the quartz monzonite porphyry of the Apache stock.

clots up to 4 cm. 2) The quartz monzonite porphyry is locally jointed or sheeted so that it has the appearance of bedding, but layering is more pronounced in the Basal Quartz Latite Member. 3) The Lower Quartz Latite Member is less homogeneous in its fabric and composition. 4) The percent of phenocrysts in the Lower Quartz Latite Member is similar along strike of the flows but varies when examined up or down section. The texture of the stock varies but not in any apparent systematic manner. 5) The matrix of the quartz monzonite porphyry stock is usually pink to gray and rarely a pale purple. The Basal Quartz Latite Member usually contains a matrix of a darker pink or purple than the stock.

The quartz monzonite porphyry is believed to be intrusive on the basis of contact metamorphic effects which are produced by it in the overlying andesite, by the presence of partially assimilated xenoliths, and by a cross cutting relationship with the Chapo Formation. The absence of flow laminae, pumice fragments, shards and other obvious extrusive criteria supports the conclusion of an intrusive origin.

The stock is believed to have been emplaced at shallow depth. This is suggested by an aphanitic matrix, fragmentation of phenocrysts, the presence of bipyramidal quartz, and flow structure. The thickness of the volcanic pile that the quartz monzonite porphyry intruded was probably not in excess of 1,700 m (5,000 ft). Emplacement of the stock post-dates the extrusion of the Lower Quartz Latite Member of the Chapo Formation by 3 m.y. and the

Upper Quartz Latite Member, presumably, by less time. This relatively small difference in the age of the rocks and the similarity in composition (Table 3, no. 3 and 4) suggests consanguinity. After extrusion of the Upper Quartz Latite Member of the Chapo Formation the magma apparently resurged and emplaced the stock at its present level in the volcanic pile.

Monzonite Porphyry

Monzonite porphyry crops out near the Apache and Chapo mines. It intrudes limestone of the U-Bar Formation at the Apache mine and Mojado and U-Bar Formations in the Chapo mine area. The outcrop area of the monzonite porphyry is not large but is very irregular in its boundaries. Drill-hole data indicate that the monzonite porphyry continues at depth as dikes and possible sills. A stock-like mass has not been intersected by drill holes. Copper sulfide mineralization commonly occurs in skarn near contacts of monzonite porphyry and limestone of the U-Bar Formation.

Monzonite porphyry is a buff to tan colored rock. It contains chalky-white plagioclase phenocrysts and pale green chlorite in a matrix of microcrystalline quartz and feldspar with some opaque material. The matrix constitutes approximately 50 percent of the rock volume. Alteration is well advanced in all outcrops. Chlorite and epidote replace ghost phenocrysts of hornblende. Quartz, calcite, and clay minerals commonly replace feldspar phenocrysts. A generalized

mode based on the examination of 5 thin sections is as follows; 50 percent microcrystalline matrix, 20 percent plagioclase phenocrysts, 10-15 percent K-feldspar phenocrysts (orthoclase and microcline), and 2-6 percent quartz. Chemical analyses for two monzonite porphyry specimens are given in Table 3. The analysis in column 8 represents a rock collected within 2 m (6 ft) of a calc-silicate skarn zone. The analysis in column 7 is of a propylitically altered specimen collected 20 m (60 ft) from the nearest contact.

Strongin (1958) mapped the monzonite porphyry as quartz diorite porphyry. The chemical data and a CIPW norm for the rock in Table 3, no. 7 place it in the monzonite field.

The monzonite porphyry intrudes Lower Cretaceous sediments and is intruded by rhyolite porphyry. It has been dated at 27.12 ± 0.59 m.y. (Damon, personal communication, August 1975). This date is identical within experimental error with the date obtained for the quartz monzonite porphyry of the Apache stock (27.16 ± 0.62 m.y.). Crosscutting relationships are not observed between the two rocks since they crop out in different areas.

Diorite

Diorite is exposed in sec. 32, T. 28 S., R. 14 W. and in sec. 6, T. 29 S., R. 14 W. Outcrops are confined to small exposures which intrude the Chapo Formation. More extensive diorite bedrock may be concealed by shallow alluvium. Recent diamond core drilling in the southeast corner of sec. 1, T. 29

S., R. 14 W., penetrated 55 m (180 ft) of diorite (Appendix, drill hole AH-9) under shallow alluvium.

Diorite is dark green with a salt-and-pepper appearance. It is holocrystalline and is composed of plagioclase laths from 1 to 3 mm and of hornblende and augite largely altered to chlorite and opaque material. Interstitial quartz is present as is a trace of magnetite. Locally the diorite contains pyrite and calcite veinlets (Appendix, drill holes AH-8 and 9). In sec. 32, T. 28 S., R. 14 W. the diorite contains up to 5 percent pyrite and has been bleached and agrillized. Assays from drill holes in diorite and near the diorite contact do not contain anomolous base metal values.

The diorite is younger than the Chapo Formation which it intrudes. A minimum age could not be determined because of the absence of observable crosscutting relationships with other rocks.

Latite

Latite dikes crop out in the southwestern and northcentral part of the map-area. A dike 1.5 km (0.9 mi) long and 200 m (600 ft) wide is exposed in sec. 18, T. 29 S., R. 14 W. The rock is similar in hand-specimen to a dike rock which is exposed in a long sinuous dike in the central part of the Sierra Rica (Van der Spuy, 1970). In the northcentral part of the map-area small, seemingly discontinuous latite dikes intrude the Chapo Formation and are intruded by porphyritic rhyolite.

T., R. 18 W., are exposed in a 1500 ft [illegible] dioritic (Appendix, drill holes [illegible] using [illegible].

Diorite is dark green with a salt-and-pepper appearance. It is holocrystalline and is composed of plagioclase laths from 1 to 3 mm long, of hornblende and augite largely altered to chlorite and epidote (?). Interstitial quartz is present as is a trace of magnetite. Locally the diorite contains pyrite and calcite veinlets (Appendix, drill holes [illegible] and 9). In sec. 36, T. 9 S., R. 18 W. the diorite contains up to 5 percent pyrite and has been bleached and argillized. Assays from drill holes in diorite and near the diorite contact do not contain anomalous base metal values.

The diorite is younger than the Chapo Formation which it intrudes. A minimum age could not be determined because of the absence of observable crosscutting relationships with other rocks.

Latite

Latite dikes crop out in the southeastern and north-central part of the map area. A dike 1.5 km (0.9 mi) long and 150 m (500 ft) wide is exposed in secs. 16, 17, T. 8 S., R. 18 W. The rock is similar in [illegible] to a dike [illegible] is exposed in a long [illegible] in the central part of the Sierra Blanca (Lee and others, 1964). In the north-central part of the map area small, seemingly discontinuous dikes cut Chapo Formation and are [illegible] by prospect pits [illegible].

The rock is buff to tan, leucocratic, and porphyritic, and it contains up to 30 percent phenocrysts. Phenocrysts are largely small plagioclase crystals (0.5-3 mm) with some quartz and chlorite after biotite. Plagioclase is andesine (An_{40}) composition. The matrix is cryptocrystalline and contains 1-2 percent opaque material.

Latite is younger than the Basalt and Andesite Member of the Chapo Formation which it intrudes and older than felsite and porphyritic rhyolite dikes, which intrude it.

Rhyolite Porphyry

Rhyolite porphyry crops out in a N. 70 W. band along the southern margin of the quartz monzonite stock. The outcrop band is 7 km (4 mi) long and 200 to 400 m (600 to 1200 ft) wide. The rhyolite intrudes quartz monzonite porphyry, monzonite porphyry, and Lower Cretaceous sediments. At the east end of the stock rhyolite porphyry outcrops spread out and continue east where they intrude U-Bar Formation and Paleozoic limestone.

In hand-specimen the rhyolite is white to buff with bipyramidal quartz phenocrysts, sparse plagioclase phenocrysts, and small epidote clots. Limestone and skarn xenoliths up to 12 m (35 ft) long occur in outcrops between the Apache and Chapo mines. The xenoliths usually have a rind of coarse marble and iron oxide around a dense, recrystallized limestone core. Away from the rhyolite porphyry-quartz monzonite porphyry contact, the rhyolite contains 15 to 25 percent phenocrysts but as the contact is approached the phenocryst

The rock is gray to tan, locally mafic, and porphyritic with [illegible] containing 30-40 percent phenocrysts. Phenocrysts are largely small plagioclase crystals (0.5-3 mm) with some quartz and chlorite after biotite. Plagioclase is andesine (An_{40}) composition. The matrix is cryptocrystalline and contains 1-2 percent opaque material.

Latite is younger than the basalt and andesite breccias of the Chapo Formation which it intrudes and older than latite and porphyritic rhyolite dikes, which intrude it.

Rhyolite Porphyry

Rhyolite porphyry crops out in a N. 70 W. band along the southern margin of the quartz monzonite stock. The outcrop band is 2 km (1 mi) long and 200 to 400 m (650 to 1250 ft) wide. The rhyolite intrudes quartz monzonite porphyry, monzonite porphyry, and Lower Cretaceous sediments. At the east end of the stock rhyolite porphyry outcrops spread out and continue east where they intrude U-Bar Formation and Paleozoic limestone.

In hand specimen the rhyolite is white to buff with bipyramidal quartz phenocrysts, sparse plagioclase phenocrysts, and small xenolithic clots. Limestone and [illegible] xenoliths up to 15 m (50 ft) long occur in outcrops between the [illegible] and Chapo mines. The xenoliths usually have a rim of coarse marble and iron oxide stain, a sugary, recrystallized limestone core. Away from the rhyolite porphyry-quartz monzonite porphyry contact, the rhyolite contains 15 to 20 percent phenocrysts [illegible] content decreases and the frequency of inclusions increases. Within 10 to 13 m (30-40 ft) of the contact a breccia of rhyolite and quartz monzonite porphyry clasts is present. The breccia is present along the contact between the Apache mine and Apache Peak but is less conspicuous elsewhere. On the south side of Apache Peak a 3 m (10 ft) diameter block of quartz monzonite porphyry was found engulfed in rhyolite over 30 m (100 ft) from the contact. Xenoliths of epidotized sediment from several millimeters to several centimeters are common (Fig. 13).

The intrusive nature of the rhyolite porphyry is shown by an apophysis of the rhyolite which cuts U-Bar Formation, the xenolith-rich contact with quartz monzonite porphyry, and presence of skarnified limestone blocks. Strongin (1958) mapped the contact between the rhyolite and quartz monzonite stock as a fault. The contact is nearly linear but, the breccia zone at the contact appears to be a result of forceful intrusion rather than of brecciation resulting from fault movement. There is no gouge at the contact and the breccia clasts are surrounded by a matrix of rhyolite. This does not preclude the possibility that the rhyolite was emplaced along a fault or zone of weakness, but evidence for post-intrusion fault movement at the rhyolite-quartz monzonite contact is lacking.

Felsite

Felsite forms small dikes and a circular, plug-like mass within the map-area. It crops out in discontinuous dikes, usually elongated west-northwest. One swarm of dikes is exposed west of content decreases and [illegible]

Within 10 to 12 m (3[illegible]

and quartz monzonite [illegible]

present along the cont[illegible]

Peak but is less abundant [illegible]

Apache Peak ~ 3 m (10 [illegible]

porphyry was found [illegible]

the contact. Xenolith[illegible]

millimeters to several [illegible]

The intrusive nature [illegible]

an apophysis of the rhyolite [illegible]

xenolith-rich contact [illegible]

presence of silicified [illegible]

the contact between the rhyolite and quartz monzonite [illegible]

a fault. The contact is nearly [illegible]

the contact appears to be [illegible]

than of brecciation [illegible]

gouge at the contact [illegible]

matrix of rhyolite. This [illegible]

that the rhyolite was emplaced [illegible]

weakness, but evidence [illegible]

the rhyolite quartz monzonite [illegible]

[illegible]

Felsite dikes [illegible]

within the map area. [illegible]

Figure 13. Epidote clots and xenoliths of quartz monzonite porphyry in rhyolite porphyry near the contact with the Apache stock.

Wamels Pond and another group is exposed near Big Chapo Tank. The felsite dikes are localized near the inferred cauldron margins.

The rock is holohyaline with a porcelain-like texture and white to pale yellow color. The rock contains up to 15 percent opaque material, including small euhedral pyrite crystals. Outcrops of felsite commonly weather yellow to orange due to oxidation of the pyrite they contain.

It is assumed that the felsite is a phase of the porphyritic rhyolite without phenocrysts. In several outcrops felsite dikes grade into porphyritic rhyolite. Felsite is mapped as a separate unit because of its distinctive lithology and because no porphyritic rhyolite is present in many of its outcrops.

Lamprophyre

Two small outcrops of lamprophyre are present in the map-area. A small dike is exposed near the Apache fault on the south boundary of sec. 2, T. 29 S., R. 14 W. and a small sill intrudes U-Bar Formation in the center of sec. 34, T. 28 S., R. 14 W. The rock is dark-green, with hornblende phenocrysts up to 4 mm in a fine grained matrix of hornblende and plagioclase microliths. The matrix contains 10 to 20 percent of opaque material. Chlorite and calcite are common alteration products of hornblende.

Search Fork [illegible]
The details [illegible]
samples.

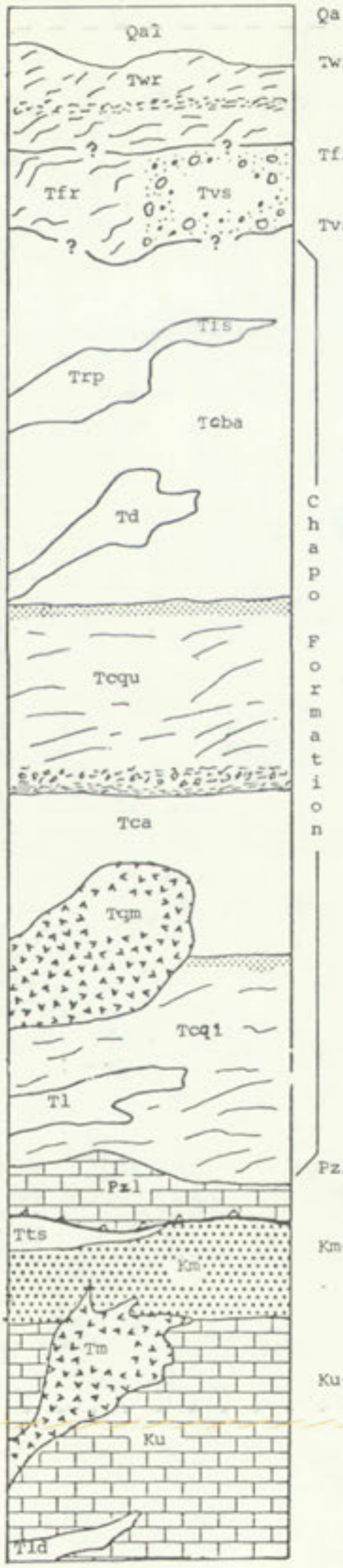
The [illegible]
white to [illegible]
opaque [illegible]
Outcrops of [illegible]
solution of [illegible]

It is [illegible]
rhyolite [illegible]
grade into [illegible]
unit becomes [illegible]
porphyritic [illegible]

[illegible]

The [illegible]
A small [illegible]
of sec. 2, [illegible]
Formation [illegible]
is dark-green, [illegible]
rounded [illegible]
matrix [illegible]
and outcrops [illegible]

Figure 14. Stratigraphic relationships of rocks in the Apache No. 2 mining district, Hidalgo County, New Mexico.



INTRUSIVE ROCKS

Trp- rhyolite porphyry: crops out as dikes and plugs. Forms skarn mineralization at the Apache mine. Younger than the 27m.y. stock(Tqm) which it intrudes.

Tfs- felsite: crops out as dikes. Some outcrops grade into rhyolite porphyry.

Td- diorite: crops out as dikes in the southwest part of the map area. Younger than Tcba which it intrudes. Minimum age unknown.

Tqm- quartz monzonite stock: forms the central part of the Apache Hills. K-Ar date of 27m.y.

Tl- latite: crops out as local dikes on the north and south flanks of the Apache Hills. It is younger than Tcql and older than Trp.

Tfs- trachyte sill: locally intrudes the base of thrust faults. Minimum age unknown.

Tm- monzonite porphyry: forms copper skarn mineralization at the Chapo, Summertime, and Apache mines. K-Ar date of 27m.y.

Tld- lamprophyre: forms a dike and sill in the east part of the map area. Minimum age unknown.

LAYERED ROCKS

Qal- alluvium and pediment gravel

Twr- Rhyolite of Wamel Pond: top not exposed, weathered outcrops of rhyolite tuff, flow-banded rhyolite, and latite.

Tfr- flow-banded rhyolite: only exposed near Apache and Christmas mines. top not exposed.

Tvs- volcaniclastic conglomerate: excess of 70m, top not exposed. Discontinuous along strike. Possible time equivalent to Tfr.

Tcba- basalt and andesite member: excess of 700m thick, top not exposed.

Tcqu- upper quartz latite member: measured thickness, 230m.

Tca- andesite member: measured thickness, 230m.

Tcql- lower quartz latite member: measured thickness, 400m. K-Ar date of 30m.y.

Pzl- Paleozoic limestone: allochtonous, 0-40m exposed. Erosional unconformity at top.

Km- Mojado Formation: 600m exposed in the south part of the map area, cut out by thrust faults to the north.

Ku- U-Bar Formation: base not exposed, approximately 300m of section exposed in the map area.

STRUCTURE

General features

Rocks in the Apache Hills area have been involved in at least two major periods of deformation. The first stage involved Cretaceous and older rocks and consisted of the formation of thrust faults of large displacement with attendant drag folds. Broad, open folds were formed after the emplacement of thrust faults. The thrust sheet(s) of Paleozoic limestone were then eroded to remnants, generally less than 30 m (100 ft) thick.

The second deformational stage began with volcanism and intrusion approximately 30 m.y. ago. Over 1,600 m (5,000 ft) of volcanic rocks were extruded and a quartz monzonite porphyry stock was intruded near the center of the volcanic complex. High-angle faulting undoubtedly occurred with volcanism and resurgence of the central stock. A second movement on high-angle faults postdates volcanic rocks and is probably related to post-Oligocene Basin and Range faulting.

Late Cretaceous to Early Tertiary Deformation

Thrust faults

In the Apache Hills numerous small klippen of Paleozoic limestone overlie a thick sequence of Lower Cretaceous sediments. The klippen are exposed along a broad anticlinal axis in the southern part of the map-area and are preserved on the flanks and axes of broad, open synclines in the east-central part of the map-area.

Rocks in the [illegible]

two major periods of [illegible]

Cretaceous and [illegible]

thrust faults of large [illegible]

broad, open folds [illegible]

faults. The [illegible]

eroded to [illegible]

The second [illegible]

intrusion approximately [illegible]

volcanic rocks [illegible]

stock was intruded [illegible]

angle faulting [illegible]

of the central [illegible]

postdates volcanic [illegible]

Basin and Range faulting.

Late Tertiary [illegible]

In the [illegible]

limestone [illegible]

the Klippen [illegible]

that are part [illegible]

[illegible]

the [illegible]

Allochtonous Paleozoic rocks lie on progressively older autochtonous rocks from south to north. Approximately 600-900 m (2,000 to 3,000 ft) of Lower Cretaceous section is cut out in 6 km (4 mi) of horizontal distance. On Doyle's Peak (1 km south of the map-area), Pennsylvanian Horquilla Formation overlies Upper Mojado Formation (Van der Spuy, 1970; Zeller, 1958). Stratigraphic separation there could be as much as 6,000 m (19,000 ft). Approximately 5 km (3 mi) northeast of Doyle's Peak, in sec. 2, T. 29 S., R. 14 W., Paleozoic limestone is thrust over a thin sliver of basal Mojado Formation. One and a half km (1 mi) north of this location, at the Daisy Mine, Mojado Formation is entirely cut out and allochtonous Paleozoic rocks overlie U-Bar Formation.

The orientation of drag fold axes and fractures in the upper and lower plates suggest that movement of the thrust plate(s) was to the northeast or southwest. Drag folds at the base of a klippe are exposed in sec. 2, T. 29 S., R. 14 W. Where folds are best exposed their axial trace usually trends N. 30 W. No overturned beds were observed. Drag folding is present at least 10 m (30 ft) below the thrust plane but is not everywhere present. Where the thrust plate directly overlies U-Bar Formation limestone, numerous echelon fractures in the footwall are filled with milky-white calcite (Fig. 6). The strongest fracture pattern is northwest trending, with a subordinate system of northeast tension gashes. Zeller (1958) and Van der Spuy (1970) concluded that the thrust faults at

Approximately [illegible] underlying rocks [illegible] (2,000 to 3,000 ft) of [illegible] 6 km (4 mi) [illegible] (1 km south of the map area). Pennsylvanian [illegible] Formation [illegible] Belden Formation [illegible] 1970; [illegible] as much as 1,000 m (3,300 ft). Approximately 5 km (3 mi) northeast of [illegible] Peak, in sec. 2, T. 10 S., R. 80 W., Paleozoic limestone is thrust over a thin sliver of [illegible] Belden Formation, [illegible] km (1 mi) north of this location, [illegible] Formation [illegible] Formation.

The orientation of drag fold axes and fractures in the upper and lower plates suggests that movement of the thrust plate(s) was to the northeast or southwest. Drag folds at the base of a klippe are exposed in sec. 2, T. 10 S., R. 79 W. Where folds are best exposed their axial trends average [illegible] W. [illegible] Drag folding is present at least [illegible] not everywhere present. [illegible]

Doyle's Peak have yielded northeast. In the Little Hatchet Mountains, Zeller (1970) noted that "the configuration of the fault surfaces and incomplete evidence from drag folds indicate that thrusting was from the west or west-southwest". Corbitt and Woodward (1973) have demonstrated that the Cordilleran foldbelt trends west-northwest through southwestern New Mexico and that the majority of thrusts have yielded northeastward. Unless evidence is found to the contrary, it is suggested that yielding in the Apache Hills fits the regional pattern.

The original dip of the thrust plane has been modified by subsequent folding and faulting. Some thrusts now dip south and some dip north. Since stratigraphic separation is in excess of 4,000 m (12,000 ft) and the fault has a low dip, it is assumed that the thrust has yielded considerably more than 4 km (2.5 mi).

Thrust faults cut Lower Cretaceous sedimentary rocks and are therefore younger than Lower Cretaceous sediments. Volcanic rocks dated 30 m.y. unconformably overlie allochtonous sediments. A more precise bracketing of the age does not appear possible in the Apache Hills.

Folds

Several shallow, open folds are exposed in the east-central part of the Apache Hills. Their axes strike N. 70 to 90 W. The fold axes are non-plunging and their limbs commonly dip between 20 and 32 degrees. Klippen of Paleozoic limestone are preserved in the axes of synclines and on the limbs of some anticlines.

Broad, open folds are confined to rocks that are Lower Cretaceous and older. Several local, minor folds in the Tertiary Chapo Formation are controlled by intrusions and high-angle faults. The Basal Quartz Latite and Andesite Members of the Chapo Formation appear to thin considerably in the east-central part of the map-area, where folds are best exposed. The apparent thinning may be due to non-deposition in an area of positive relief created by folding prior to volcanism.

Folding appears to have occurred prior to volcanism and after thrust faulting. Zeller (1970) observed folding of a thrust sheet in the Little Hatchet Mountains that was probably synchronous with thrusting.

A broad anticlinal flexure is present in the southern part of the map-area. It was recognized by Van der Spuy (1970) and can be traced by exposures of numerous, small klippen and rhyolite and felsite plugs and dikes along its axis. The anticline may have been formed by rhyolite intrusion along a zone of structural weakness, possibly a cauldron margin.

Oligocene and Later Deformation

Volcano-tectonic structure

The distribution of rocks and structural style of volcanism in the Apache Hills bears some similarity to the structure described by Smith and Bailey (1968) for resurgent cauldron complexes. Over 1,600 m (5,000 ft) of silicic and andesitic rock of the Chapo Formation thins away from the central part of the Apache Hills, which suggests a local source and possible cauldron subsidence.

The Apache stock is similar in lithology and chemical composition to the Basal Quartz Latite Member of the Chapo Formation (Table 3) and was emplaced near the center of the inferred cauldron within 3 m.y. of the quartz latite flow. Possibly, the stock represents a resurgent intrusive phase of the same magma which had earlier erupted to form the quartz latites. Resurgent doming by the stock is evidenced by the high structural level of intrusion and by the outward dip of overlying strata. Two belts of rhyolite and felsite dikes, symmetrically disposed around the resurgent stock, and nearby volcaniclastic sediments may represent ring-fracture intrusion and moat deposits. Solfataric hot spring activity, typical of the terminal stage of volcanic activity is suggested by a large pyrite zone and by deposits of amorphous silica, southeast of the Apache Mine in sec. 32, T. 28 S., R. 14 W.

Several features in the Apache Hills are not typical of cauldron structures. Most notably is the absence of thick ash-flow tuffs. The silicic extrusives in the Chapo Formation are interpreted as quartz latite and rhyolite lava flows. Only one ash-flow tuff was definitely identified at the base of the Upper Quartz Latite Member of the Chapo Formation. A few thin ash-flow tuffs are present in rocks younger than the Chapo Formation associated with flow-banded rhyolite and the rhyolite of Wamels Pond. The Apache Hills contains no recognizable arcuate ring fractures. The principal fault pattern is one of linear faults which trend N. 70° W., parallel to the elongation

The [illegible] deposit[illegible] Formation [illegible] inferred [illegible] Possibly, [illegible] the same [illegible] lation. [illegible] high stream [illegible] overlying [illegible] symmetrical [illegible] volcaniclast[illegible] and most [illegible] of the lacustr[illegible] large portion [illegible] southeast of th[illegible]

Several [illegible] cauldron [illegible] ash-flow tuff[illegible] are interpre[illegible] Only one [illegible] of the [illegible] A few thin [illegible] Chepo Format[illegible] rhyolite [illegible] of linear [illegible]

Figure 15. Generalized geologic structure and alteration in the Apache No. 2 mining district

Tqm, quartz monzonite porphyry

Tm, monzonite porphyry

▥ Trp, rhyolite porphyry

☐ Tpr, felsite and porphyritic rhyolite

Scale 1:62,500

1 mi

▩ silicic alteration

☐ intense propylitic alteration

anticline

syncline

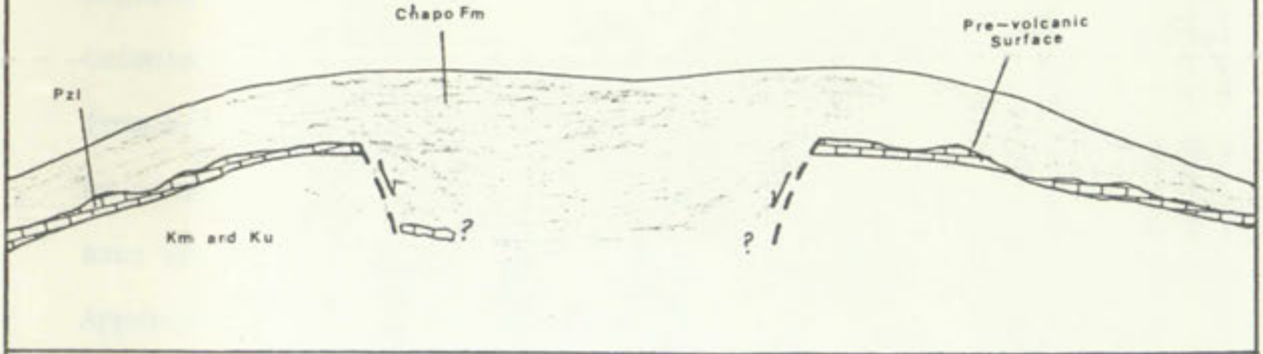
fault, dashed where inferred

★ mine or prospect

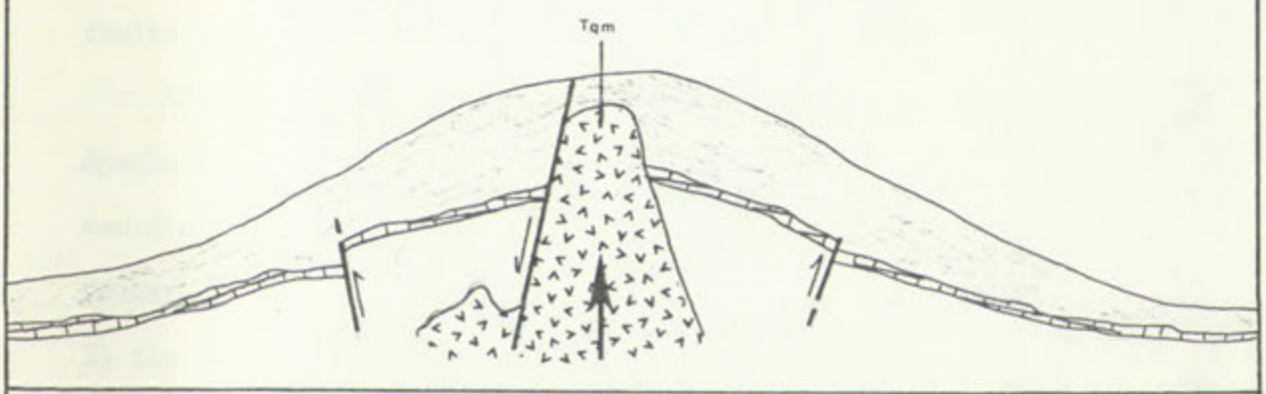
☐ stock tank

Figure 16. INTERPRETED VOLCANO-TECTONIC DEVELOPMENT OF THE APACHE HILLS

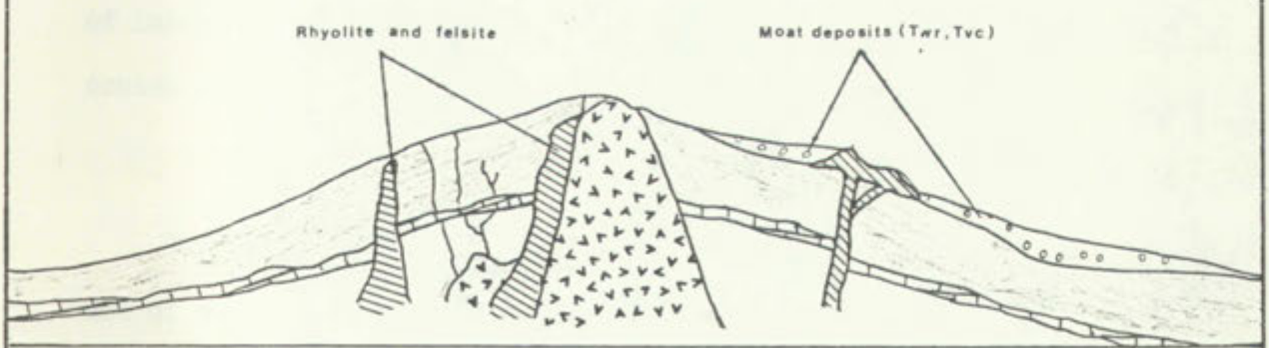
Stage 1. Eruption and collapse



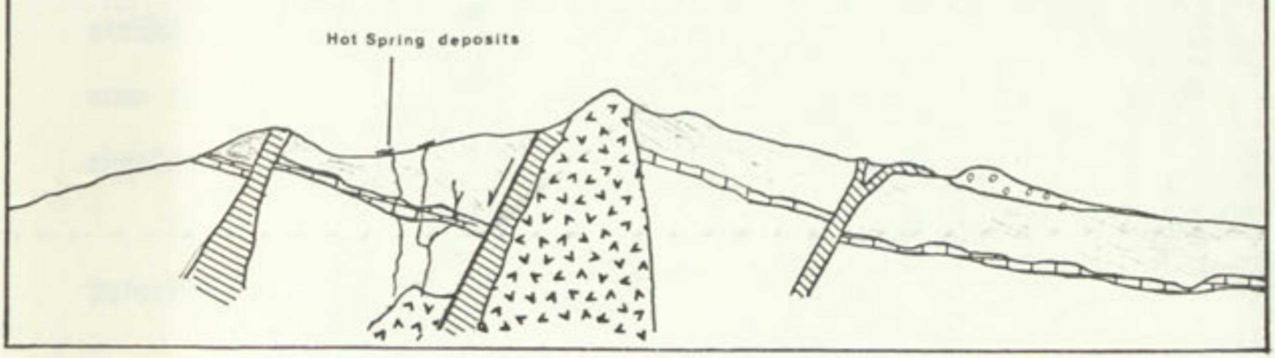
Stage 2. Resurgence



Stage 3. Ring fracture intrusion and moat filling



Stage 4. Basin and Range faulting, tilting, and erosion



★ see figure 1 for key to symbols

of the stock, and of transverse faults which trend within 20 degrees of north (Fig. 15). The fault pattern and the orientation of possible cauldron margins may have been inherited from a pre-volcanic structural grain or it could have been formed by an active stress field during the period of volcanism. The axes of folds developed prior to volcanism trend N. 70° W. Apparently, the pre-volcanic structural grain or anisotropic stress field during volcanism prevented the development of radial faults in the Apache Hills.

Although there are differences between volcanism in the Apache Hills and volcanism described in other well-known cauldron structures, it appears that the Apache Hills were the center for 1) a volcanic pile in excess of 1,700 m (5,000 ft), 2) the intrusion of numerous dikes, plugs, and sills of lithologies ranging from rhyolite to diorite, and 3) the site of intrusion of a later quartz monzonite porphyry stock in the center of the volcanic complex

High-angle faults

Two sets of high-angle faults dominate the Apache Hills. One set of normal faults strikes N. 70-90° W., parallel to the structural grain of pre-volcanic rocks. A second set of faults strike within 20 degrees of north. Rhyolite dikes intrude some faults, suggesting that the fault originated prior to rhyolite intrusion but was subsequently rejuvenated.

It is postulated that high-angle faults which formed the inferred cauldron walls were developed during major subsidence.

[illegible] of

[illegible] (Fig. [illegible]) [illegible] and the

[illegible]

[illegible]

[illegible] during the period of [illegible].

[illegible]

[illegible] structural grain [illegible]

[illegible] the [illegible]

[illegible] to the Spade Hills.

Although there should be some [illegible] between [illegible] of the Spade Hills and [illegible] described [illegible] other well-known [illegible] structures, it appears that the Spade Hills were the center for 1) a [illegible] of 1,700 [illegible] (Fig. [illegible]), 2) the intrusion of numerous dikes, plugs, and sills of lithologies ranging from rhyolite to diorite, and 3) the site of intrusion of a later quartz monzonite porphyry stock in the center of the volcanic complex.

High-angle Faults

Two sets of high-angle faults dissect the Spade Hills. One set of normal faults strikes N. [illegible] W., parallel to the structural grain of pre-volcanic rocks. A second set of faults strike within [illegible] degrees of north. [illegible] and [illegible], suggesting that the [illegible] volcanic [illegible] [illegible] for [illegible]

[illegible] the high-angle faults [illegible]

[illegible]

These faults have been subsequently concealed by flows of the upper members of the Chapo Formation and later intruded by rhyolite and felsite. The only indication of their existence is the alignment of rhyolite and felsite dikes and possible thinning of the Chapo Formation outside the faults.

The largest and most persistent high-angle fault was named the Apache Fault by Strongin (1958). It extends through the entire map-area, from beyond the Mexican border to the northwest corner of the area, where it is concealed by pediment gravel. Throw on the fault is greater than 1,700 m (5,000 ft) near the Chapo mine, where the Basalt and Andesite Member of the Chapo Formation is in fault contact with U-Bar Formation. Near the Mexican border, the stratigraphic separation decreases to approximately 600 m (1,800 ft). The Apache Fault appears to be the youngest structural feature in the Apache Hills. Several north-south faults are cut off by it and no faults are observed to offset it. Its fault plane contains an open, vuggy breccia with overgrowths of quartz crystals on breccia clasts (Fig. 17). The breccia zone is generally no wider than 2 m (6 ft).

Figure 17. Silica-cemented breccia in the Apache Fault. Note drussy quartz overgrowths on breccia fragments.

MINERAL DEPOSITS

General features

The Apache No. 2 mining district consists of several prospects but only the Apache mine has produced significant amounts of ore. Ore occurrences were first described by Lindgren (in Lindgren, Graton, and Gordon, 1910) and later by Lasky and Wooton (1933), and Strongin (1958). The district was reported by Lindgren (in Lindgren, Graton, and Gordon, 1910) to have been discovered by Robert Anderson in the late 1870's. The history of the district was described by Strongin (1958).

Howard (1967) estimated total production of the Apache mine at "about 50,000 tons of copper-silver ore, 500 tons of lead ore, and minor amounts of bismuth ore". The Apache mine is located on four unpatented claims and has 2,520 ft of lateral workings on several levels. All shafts and tunnels are now inaccessible.

Mineral deposits in the Apache No. 2 mining district consist of skarn-sulfide bodies related to the border zones of monzonite porphyry, and possibly to rhyolite porphyry, and of quartz-sulfide veins peripheral to the main part of the Apache Hills. It is concluded that mineralization in the district is of Oligocene age because quartz-sulfide veins cut rocks dated at 30 m.y. and skarn-sulfide mineralization is related to monzonite porphyry dated at 27 m.y.

Skarn deposits

Mineralization in contact metasomatic deposits occurs at the Apache, Summertime, and Chapo mines. The mines are located along the Apache fault in T. 28 S., R. 14 W. At the Chapo and Summertime mines, mineralization consists of disseminated clots and veinlets of chalcopyrite in andradite skarn. The skarn was formed in U-Bar Formation limestone and in calcareous beds of the Mojado Formation adjacent to monzonite porphyry.

In the Chapo mine area, several holes have been drilled through mineralized rock (Fig. 19). Drill hole data and surface mapping indicate that the monzonite porphyry forms irregular dikes and sills. A stock-like mass has not been intersected by drill holes. The monzonite porphyry generally contains 50 percent phenocrysts and is pervasively propylitized. Chlorite and epidote replace ghost phenocrysts of hornblende, and quartz, calcite, and clay minerals commonly replace feldspar phenocrysts. Near the contact with sediments the monzonite porphyry contains abundant epidote on fractures. Commonly, the contact is diffuse over 2 to 3 cm and the rock at the contact is composed of massive garnet, feldspar and some diopside. Two chemical analyses of monzonite porphyry are given in Table 3, nos. 7 and 8. The analysis in column 7 is of a propylitically altered specimen collected a considerable distance from a sedimentary contact. The analysis in column 8 represents a specimen collected within 2 m (6 ft) of a calc-silicate skarn zone. The analyses show metasomatic introduction of K_2O, CaO, and CO_2 and a loss of

SiO_2 in monzonite porphyry near the skarn contact. Such chemical gains and losses are typical in skarn zones and have been described in detail by Bowen (1940), Zharikov (1970), and others.

The exoskarn is generally composed of three zones: 1) massive, pale-green to brown garnet and diopside adjacent the contact, 2) an intermediate zone of garnet with calcite pods containing sulfides and with sulfides in veinlets, and 3) marble, hornfels, and recrystallized limestone in an outer zone. The three zones generally do not extend more than 12 m (40 ft) away from the monzonite porphyry contact at the Chapo and Summertime mines.

Copper mineralization consists of chalcopyrite localized in pods and veinlets of the intermediate zone. The mineralized pods observed in prospect pits and recognized in drill core range in size from a few centimeters to a few meters. Small mineralized pods are near spherical, but pods 1 m (3 ft) or larger usually have a pronounced elongation. Mineralized pods are composed of chalcopyrite with only traces of pyrite and of secondary malachite, copper oxides, and chrysocolla. Drilling near the Chapo and Summertime mines suggests that mineralization does not selectively follow stratigraphic horizons. Correlation between holes spaced 400 to 800 feet apart was not possible (Appendix).

A zinc or lead halo around the skarn has not been found in the Chapo and Summertime mine area. Monzonite porphyry generally contains less than 100 ppm copper, except where it has been

fractured and enriched by deposition of secondary copper minerals.

Mineralization at the Apache mine is less well exposed than at the Summertime and Chapo mines because of alluvial cover and the inaccessibility of mine workings. Structure and mineralogy are more complex than at the Chapo and Summertime mines. Strongin (1958) has reported ores of Cu, Pb, Zn, Au, Ag, Bi, and W. Mineralization is reported to be confined largely to replacement veins in calcareous sediments controlled by fractures related to the McKinley fault. Most of the ore production has been from coarsely crystalline calcite which contains small, disseminated blebs of copper minerals (Fig. 18). Lindgren (in Lindgren, Graton, and Gordon, 1910) has stated that "... the ore follows a certain stratum which has been changed by contact metamorphism to coarse calcite instead of to garnet". Gangue and stockpiled ore from the mine workings are chalcopyrite-bearing, massive, garnet skarn, with minor calcite, epidote, actinolite, and some propylitized monzonite porphyry.

A drill hole (HS-1, Appendix), located approximately 80 m (250 ft) northeast of the main Apache shaft and headframe, intersected baked and mildly altered sediments to a depth of 1,221 feet. Some monzonite porphyry was present in the upper 250 feet of the hole. The sediments adjacent the monzonite porphyry were largely unmineralized, but, sediments between 775 and 1,100 feet contained more than 500 ppm of lead

Pennsylvanian [illegible]
minerals [illegible]

[illegible]
than at the Esmeralda and Shoo-fly [illegible]
cover and [illegible]
and surroundings [illegible]
[illegible] 15, 16, [illegible]
continue [illegible]
controlled by fractures related to the [illegible]
of the ore [illegible] has been [illegible] calcite
which contains small disseminated blebs of copper minerals
(Fig. 18). Lindgren (in Lindgren, Graton, and Gordon, 1910)
has stated that "... the ore follows a certain stratum which
has been changed by contact metamorphism to coarse calcite
instead of to garnet". [illegible] ore from the
zone [illegible] garnet,
skarn, [illegible], epidote, tremolite, and [illegible]
propylitic [illegible] property.

A [illegible]
[illegible]
intersected [illegible]
1,221 feet. [illegible]
221 feet of the hole. [illegible]
property were largely [illegible]
705 and [illegible]

Figure 18. Coarsely crystalline calcite in an open pit at the Apache Mine. Note the pencil near the center of the picture for scale.

(Table 2, analyses 7-10). Copper values for the same interval were less than 40 ppm. The lead anomaly, approximately 70 m (200 ft) northeast of the garnet skarn ore, suggests mineral zoning.

Limonite gossans from the Apache mine area contain up to 6 percent lead and several ounces of silver per ton (Table 2, assay 12). The gossans are best exposed at the north end of the main workings. Cerussite was identified in hand-specimen and the silver mineral is probably cerargyrite.

Rhyolite porphyry crops out north of the Apache mine. In one location rhyolite is in contact with silicated, mineralized limestone but it is not clear whether the rhyolite formed the skarn or merely intruded a block of silicated limestone. In several locations east of the Apache mine rhyolite porphyry engulfs limestone blocks. Here the limestone usually has a thin rind of marble and a relatively unaltered core. Veins or fracture fillings of specular hematite are common in the blocks but base metal mineralization is absent. The rhyolite porphyry intrudes monzonite porphyry and may be post-mineral but its role is not clear.

Vein deposits

Sulfide mineralization in quartz veins occurs in several prospects around the Apache Hills. The Christmas, Luna, Queen's Taste, and Daisy mines are located on the north flank of the Apache Hills. The Last Chance and Mairland mines are located south of the Apache fault. The distribution of the prospects

Table 4. Assay data from mines and prospects in the Apache No. 2 mining District, Hidalgo County, New Mexico

Assay values in ppm (parts per million) unless otherwise expressed

SAMPLE LOCATION	Cu	Mo	Pb	Zn	Ag	DESCRIPTION OF SAMPLE
1. Summertime mine sec.33, T28S, R14W	1.1%	66	200	100	---	andradite skarn with chalcopyrite
2. Last Chance mine sec. 32, T28S, R14W	182	126	3.8%	300	---	quartz vein in quartz latite host rock
3. Luna mine sec. 22, T28S, R14W	2.0%	224	5.2%	2.8%	---	quartz vein in a rhyolite dike
4. Christmas mine sec. 20, T28S, R14W	0.5%	37	1.6%	0.1%	---	quartz vein in a rhyolite dike
5. Queen's Taste mine sec. 23, T28S, R14W	0.4%	3	1.2%	0.3%	---	quartz vein in andesite host rock
6. Daisy mine sec. 36, T28S, R14W	0.4%	22	850	625	2.1 oz.	limonite gossan sampled over a 50 ft. traverse
7. Apache mine	18	77	800	48	0.2 oz.	drill core at 778 feet dark mottled marble
8. Apache mine	18	77	480	52	0.2 oz.	drill core at 795 feet dark mottled marble
9. Apache mine	26	66	720	42	0.2 oz.	drill core at 926 feet dark gray marble
10. Apache mine	35	11	500	42	0.1 oz.	drill core at 1109 feet calcareous hornfels
11. Apache mine	14	800	90	15	0.1 oz.	drill core at 762 feet dark-gray marble
12. Apache mine	1.3%	96	6.0%	0.1%	5.1 oz.	limonite gossan sampled over a 100 foot traverse
13. Apache mine south prospect pit	0.6%	3	320	0.2%	---	6 foot channel sample
14. Apache mine	120	17	220	200	0.25 oz	100 foot sample traverse over main waste dump
15. Apache mine north prospect pit	---	---	0.7%	---	2.0 oz.	limonite gossan along rhyolite-marble contact.

Note: Assay samples 7-11 are from 4 to 6 inch samples of split core from drill hole HS-1 (Appendix).

suggests a zoning of quartz-sulfide veins peripheral to the central monzonite porphyry and quartz monzonite stock.

The quartz veins are uniform in size and mineralogy. The predominent sulfide mineral is galena; copper oxides and sphalerite are of secondary importance (Table 3, assays 1-6). The veins are narrow (10 to 30 cm) and wall-rock alteration is generally confined to a narrow zone of bleaching and argillization adjacent to the veins. No quartz vein is exposed at the Daisy mine, where mineralization occurs at the base of a thrust plate. Strongin (1958) discussed the prospects individually.

Distribution of the prospects appears to be related to possible cauldron structures. The Luna and Queen's Taste mines are located near the postulated cauldron margin. The Daisy, Last Chance, and Christmas mines are located on faults intruded by rhyolite porphyry. Several authors (Burbank and Luedke, 1968; Steven, Luedke, and Lipman, 1974) have discussed structural controls of mineralization by cauldron margins in the San Juan volcanic field. They suggest that mineralization is more pronounced near calderas which had complex histories of post-subsidence intrusive and extrusive igneous activity. The Apache Hills has undergone resurgence and has a complex intrusive history.

Areas of hydrothermal alteration

Two areas of extensive hydrothermal alteration are present in the Apache Hills aside from the skarn zone previously mentioned region [illegible]

[illegible]

The [illegible] which are [illegible]. The predominant [illegible] and sphalerite [illegible] (Table [illegible]). The [illegible] and wall-rock alteration is generally confined [illegible] of bleaching and argillic alteration adjacent to the veins. No quartz vein is exposed at the [illegible] mine, where [illegible] of the [illegible] of a [illegible]. Drewes (1971) [illegible] the prospects briefly.

Distribution of the prospects appears to be related to possible cauldron structures. The [illegible] mines are located near the postulated cauldron margin. The Daley, Last Chance, and Christmas mines are located in faults intruded by rhyolite porphyry. Several authors ([illegible], 1968; [illegible]) have discussed structural controls on mineralization in [illegible] fields. They suggest that mineralization is [illegible] in the complex histories of post-caldera intrusive and [illegible] igneous activity. The Apache [illegible] intrusive bodies.

AREAS OF HYDROTHERMAL ALTERATION

The areas of [illegible] alteration [illegible] are present in the [illegible]

(Fig. 15). The Mojado Formation is strongly silicified to quartzite in a prominent ridge in secs. 12 and 13, T. 29 S., R. 15 W. The second area covers approximately 5 sq km (2 sq mi) and is centered south of the Apache mine in sec. 32, T. 28 S., R. 14 W. Alteration is characterized by disseminated pyrite and several irregularly shaped outcrops of amorphous silica. A prominent ridge of Mojado Formation in secs. 12 and 13, T. 29 S., R. 15 W. is strongly silicified to quartzite. Alteration in the second area is characterized by disseminated pyrite and several irregularly shaped outcrops of amorphous silica. The area covers approximately 5 sq km (2 sq mi) and is centered south of the Apache mine in sec. 32, T. 28 S., R. 14 W.

The prominent ridge of silicified Mojado Formation is bounded on the east by a normal fault with a minimum stratigraphic throw of 400 m (1,200 ft) and is transected by several east-striking normal faults. Sandstone of the Mojado Formation has been silicified and shaly beds have been altered to hornfels. Quartz veinlets, generally less than 1 cm wide, are abundant. Fault planes in the quartzite ridge are vuggy and contain angular quartzite clasts with overgrowths of drusy quartz. Geochemical sampling has detected anomolous concentrations of molybdenum, generally associated with small quartz veins containing limonite. Geochemical background in the area is less than 10 ppm Mo but one rock chip sample from the quartzite ridge contained 570 ppm Mo and several other samples were anomolously high. Van der Spuy (1970)

(Fig. 15). The highest percentage of strongly silicified [illegible] quartzite in a prominent ridge in secs. 12 and 13, T. 19 S., R. 15 W. The second area covers approximately 5 sq km (2 sq mi) and is centered south of the Apache mine in sec. 32, T. 18 S., R. 14 W. Alteration is characterized by disseminated pyrite and several irregularly shaped outcrops of amorphous silica. A prominent ridge of Bolsa(?) Formation in secs. 12 and 13, T. 19 S., R. 15 W. is strongly silicified to quartzite. Alteration in the second area is characterized by disseminated pyrite and several irregularly shaped outcrops of amorphous silica. The area covers approximately 5 sq km (2 sq mi) and is centered south of the Apache mine in sec. 32, T. 18 S., R. 14 W.

The prominent ridge of silicified Bolsa(?) Formation is bounded on the east by a normal fault with a minimum stratigraphic throw of 600 m (2,000 ft) and is transected by several east-striking, normal faults. Sandstone of the Bolsa Formation has been silicified and shaly beds have been altered to hornfels. Quartz veinlets, generally less than 1 cm wide, are abundant. Fault planes in the quartzite ridge are rough and contain angular brecciated clasts with overgrowths of drusy quartz. Geochemical sampling has detected anomalous concentrations of molybdenum, generally associated with drusy quartz veins containing limonite. Geochemical background in the area is less than [illegible] ppm Mo and [illegible] rock chip sample from the quartzite ridge contained [illegible] and several other samples were [illegible].

showed an aerial magnetic high with a closure of 180 gammas centered on the southern part of the quartzite ridge. A ground magnetic traverse has confirmed the presence of the anomaly. Van der Spuy (1970) concluded that the anomaly is part of a northwesterly trending magnetic belt and is "the reflection of a buried granitic intrusive....". If the magnetic anomaly indeed reflects a buried intrusion, silicification of the quartzite and introduction of molybdenum into the system could be easily explained by ascending heated waters derived from it or convecting around it. Recent drilling (drill hole AH-14, Appendix) by Leonard Resources centered on the magnetic high and encountered anomolous zinc values in marble after passing through a fault zone at 648 feet. Zinc values averaged 630 ppm over a 20 foot interval between 930 and 950 feet. The drill hole was terminated at 953 feet when bridging of the hole prevented further penetration. The zinc anomaly suggests an outer halo of mineralization over an intrusive rock at depth.

The area of silica deposits and pyritization occurs in the Basalt and Andesite Member of the Chapo Formation. The Basalt and Andesite Member has been propylitically altered. The alteration resulted in the formation of chlorite and the introduction of up to several percent pyrite. Calcite is pervasive. Up to several percent calcite occurs in the matrix and in crosscutting veinlets in the volcanic rocks.

zones. [illegible] gross [illegible] namely, [illegible] is part [illegible] reflect [illegible] magnetic [illegible] silicification [illegible] into the [illegible] waters [illegible] drilling, [illegible] centered [illegible] values in table [illegible] feet. [illegible] between [illegible] 953 feet [illegible] The zinc [illegible] an intrusive [illegible]

The [illegible] the basal [illegible] Basalt [illegible] The [illegible] [illegible] pervasive [illegible] matrix [illegible]

Sericite and secondary quartz are alteration products in some drill holes. Oxidation of pyrite by perculating ground water has resulted in acid leaching causing supergene argillic alteration. Several outcrops of intensely kaolinized andesite and diorite at the surface, grade into progressively fresher rock at depth.

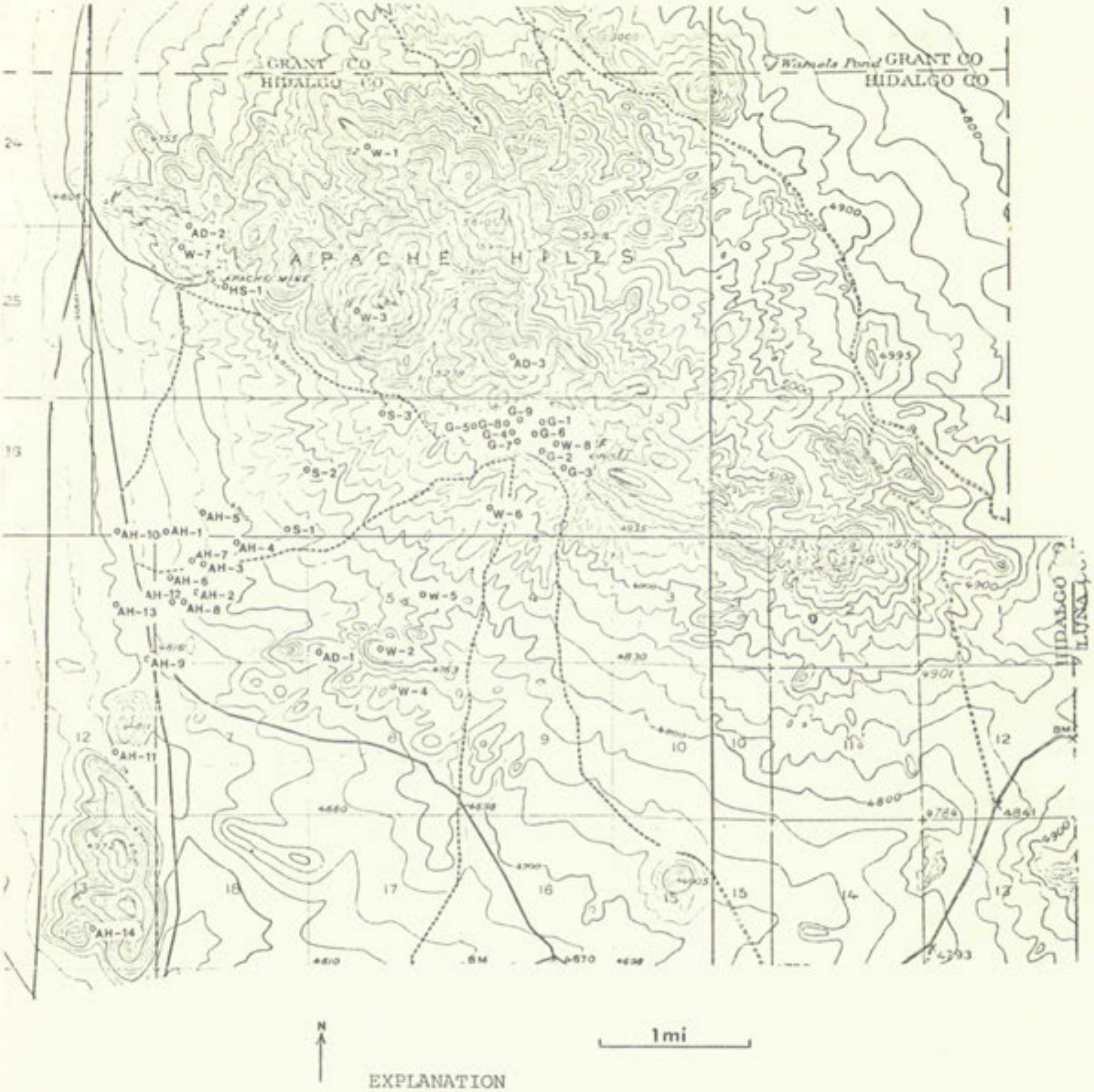
The area of pyritization contains very low values for copper and molybdenum. In 19 rock chip samples copper averaged less than 10 ppm and molybdenum averaged less than 4 ppm. Lead and zinc values are generally less than 150 ppm in leached surface rocks but anomalies have been encountered by drill holes (S-1, S-2, Appendix and Assays 8-10, Table 3).

Several diorite dikes and masses of brecciated, amorphous silica crop out in the area. Geologic relationships with host rocks are obscured by pediment gravels. The silica contains up to several percent sericite and is brecciated but has no banding or other type of internal structure. Although its origin is uncertain, the amorphous silica is thought to represent a thermal-spring deposit. Brecciation of the silica may have been formed by movement on the same faults which gave rise to it.

Smith and Bailey (1968) have noted that hot springs and solfataras are typical of the terminal stage of volcanic activity in cauldron structures. Sillitoe (1975) and Steven and Ratte (1960) have described irregular patches of fine-grained quartz rock, similar to that found in the Apache Hills, which have formed in the terminal stage of volcanic

activity. Propylitic alteration with the introduction of pyrite and the formation of amorphous silica in the Apache Hills is believed to have been produced by a hydrothermal system created by a crystallizing magma at depth. The alteration post-dates the Chapo Formation and probably represents the terminal stage of volcanism in the area.

Figure 19. Location map of drill holes and of samples for whole-rock chemical analyses of K-Ar dating.



EXPLANATION

LOCATION OF DRILL HOLES
- HS-1 Hidden Splendor
- AH-8 Leonard Resources
- G-1 Geochemical Surveys
- S-3 Mineral Division, Superior Oil Co.

LOCATION OF SAMPLES FOR AGE DATES
- AD-1 Basal Quartz Latite Member of the Chapo Formation
- AD-2 monzonite porphyry
- AD-3 quartz monzonite of the Apache stock

LOCATION OF SAMPLES FOR WHOLE ROCK CHEMICAL ANALYSIS
- W-1 Andesite Member, Chapo Fm.
- W-2 Andesite Member, Chapo Fm.
- W-3 quartz monzonite, Apache stock
- W-4 Lower Quartz Latite Member, Chapo Fm.
- W-5 Upper Quartz Latite Member, Chapo Fm.
- W-6 Basalt and Andesite Member, Chapo Fm.
- W-7 and 8 monzonite porphyry

ECONOMIC MINERAL POTENTIAL

The mineral deposits of the Apache No. 2 mining district occur in Oligocene rocks except for possible mineralization related to a magnetic anomaly in the Lower Cretaceous Mojado Formation in the southwestern part of the map-area. Here the age of mineralization is not known. In southwestern New Mexico and adjacent Arizona the major base metal mineral deposits were formed in Laramide time (55-70 m.y.). Oligocene mineralization, such as occurs in the Apache Hills, is not uncommon but is not noted for economic deposits in this area (Kottlowski, Weber, and Willard, 1969). Nevertheless, considerable hydrothermal alteration is present in the Apache No. 2 mining district and copper ore has been mined.

Several areas show some promise for further mineral exploration. Skarn-sulfide mineralization at the Chapo, Summertime, and Apache mines appears restricted to within approximately 12 m (40 ft) of the monzonite porphyry contact. Although the skarn occasionally contains good copper grade (see G-4, Appendix) it is local and very erratic in its distribution. Drilling to date has not intersected an ore horizon with any continuity. Future exploration for skarn mineralization should be directed toward finding an area that has had pre-ore ground preparation by faulting and fracturing to permit ingress of mineralizing fluids and where the host rock is favorable for formation of replacement ores.

Vein mineralization in the area is weak. Quartz veins bearing sulfides are generally narrow and not persistent. The potential for their development is slight. Their distribution suggests fissure filling in faults related to cauldron structures. More extensive vein deposits may occur in major cauldron margin faults that are presently concealed by rocks which post-date cauldron collapse. Lower Cretaceous limestones could form replacement deposits at depth in such an environment.

Mineralization is associated with a magnetic anomaly centered on the southern end of the quartzite ridge in secs. 12 and 13, T. 29 S., R. 14 W. The quartz veining and silicification of sandstone in the Mojado Formation may have occurred in the early stages of the crystallization of a magma at depth. The quartzite would then have formed an impermeable cap over the inferred intrusion. There are possibilities for mineralization in the inferred intrusion or in replacement ore in the U-Bar Formation limestone which underlies the Mojado Formation. A recent drill hole (AH-14, Appendix) centered on the magnetic anomaly encountered anomalous zinc values in marble before it was lost at 953 feet due to caving. Re-entry of the hole has not yet been attempted (as of April, 1976).

The area of pyritic alteration and amorphous silica deposits in sec. 32, T. 28 S., R. 14 W. appears to be the upper part of a hydrothermal system which may be mineralized at depth. The rock contains up to several percent pyrite but trace element

Such concentrations in the form of veins, [illegible] bodies [illegible] are generally narrow and of small [illegible]. The potential for their development is slight. Their distribution suggests fissure filling in faults related to [illegible] structures. [illegible] ore deposits may occur in [illegible] faults that are presently [illegible] [illegible]. Lower Carboniferous limestones could host replacement deposits at depth in such an environment.

Mineralization is associated with a magnetic anomaly located on the northern end of the quartzite ridge in secs. 12 and 13, T. 30 S., R. 14 W. The quartz veining and silicification of sandstone in the Nopah Formation may have occurred in the early stages of the crystallization of a magma at depth. The quartzite would then have formed an impermeable cap over the inferred intrusion. There are possibilities for mineralization in the inferred intrusion or in replacement ore in the other formation limestone which underlies the Nopah Formation. A recent drill hole (AU-14, Appendix) centered on the magnetic anomaly [illegible] in [illegible]. It was lost at 853 feet due to caving. The extent of the hole has not yet been determined (as of April, 1979).

The area of pyritic alteration and [illegible] in sec. 28, T. 30 S., R. 14 W. appears to be the [illegible] of a hydrothermal system which may be mineralized at depth. The [illegible] in several pyritic [illegible] amounts of copper and molybdenum are low. Propylitically altered andesite has been drilled to a depth of 955 feet (S-1, Appendix) and lead-zinc anomalies have been encountered. The possibilities for encountering ore appear to be greatest in the Lower Cretaceous sediments underlying the volcanic rocks or in quartz-sulfide veins controlled by cauldron structures.

CONCLUSIONS

Data gathered in this investigation show that the Apache Hills have been a center of volcanism that has extruded a large volume of rock. The lower 1,700 m (5,000 ft) of Oligocene volcanic rocks have been named Chapo Formation. The formation has been divided into the Basal Quartz Latite Member (400 m), an Andesite Member (230 m), an Upper Quartz Latite Member (230 m), and a Basalt and Andesite Member (greater than 700 m). The Basal Quartz Latite Member has been dated at 30 m.y.

A stock of quartz monzonite porphyry was emplaced in or near the center of the volcanic complex. It has been dated at 27 m.y. and probably represents resurgence of the same magma which extruded quartz latite flows 3 m.y. earlier. A cauldron complex is suggested by the large volume of silicic volcanic rocks, resurgent nature of the subvolcanic stock, alignment of rhyolite dikes and plugs along possible cauldron margins, and possible moat deposits.

Several small klippen composed of Paleozoic limestone overlie Lower Cretaceous sediments in the map-area. Orientation of drag folds and calcite filled fractures in the footwall rocks suggest northeast yielding of the thrust plate(s). Stratigraphic separation of the klippen is as much as 4,000 m (12,000 ft). No root zones were identified but total displacement on the faults probably measures several kilometers.

Skarn copper mineralization is related to monzonite porphyry dated at 27 m.y. Mineralized quartz veins are emplaced in Oligocene volcanic rocks. The most promising areas for mineral exploration are in favorable host rocks adjacent the monzonite porphyry exposed near the Chapo, Summertime, and Apache mines and for possible concealed mineralization under the silicified quartzite ridge in secs. 12 and 13, T. 29 S., R. 15 W.

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[illegible], V. A., 1968, Skarns (Parts I, II, and III), International Geol. Rev., v. 12, p. [illegible]

APPENDIX

SELECTED DRILL HOLE LOGS AND ASSAYS FROM THE APACHE NO. 2 MINING DISTRICT, HIDALGO COUNTY, NEW MEXICO

Selected drill hole logs and assays from four mining exploration companies follow. Location of the holes are shown in Figure 19. Many of the drill logs have been summarized from the originals and assays have been compiled into composites. Depths are given in feet and assay values are in parts per million (ppm) unless otherwise indicated. Where assay data are not presented, they were not available. Drill holes HS-1, AH-9, 10, 11, 12, and 13 were logged by the writer. Other drill holes were logged by company geologists. Appreciation is expressed to the companies involved for permission to release the data.

Company name: Hidden Splendor
Drill Hole designation: HS-1
Date drilled: unknown
Type of drill hole: diamond drill hole, NX core

0 - 20	Alluvium
20 - 45	Monzonite porphyry, 40% euhedral plagioclase crystals (2-6mm), olive-green, aphanitic matrix. Trace disseminated pyrite. Fault at 33.5 feet.
45 - 51	Shale, dark green, with milky white calcite veins. Fault at 51 feet, kaolinized fractures in siltstone.
51 - 61	Monzonite porphyry, disseminated goethite after pyrite.
61 - 129	Quartzite, pale pink and gray, fine grained, and epidote hornfels, light green, fractures re-healed with calcite veins. Trace disseminated pyrite.
129 - 135	Monzonite porphyry, trace pyrite, abundant epidote.
135 - 136	Fault, breccia cemented with calcite and quartz, no sulfides.
136 - 248	Monzonite porphyry, 50-80% plagioclase phenocrysts, abundant epidote and chlorite in the matrix. Several 6-12 inch zones of hematite staining after disseminated pyrite.

248 - 278	Shale, red and olive green, fractures re-healed with milky calcite.
278 - 323	Quartzite, medium grained, gray and green, hematite on fractures.
323 - 389	Quartzite alternating with hornfels, mottled pale red to greenish-gray, abundant epidote.
389 - 389.5	Quartz vein, contains vugs with black manganiferous calcite, no sulfides.
389.5- 552	Hornfels, mottled pale red and green, numerous calcite veins, clay in fractures, fractures and veins are near vertical.
552 - 554	Breccia, angular fault breccia re-cemented with psilomolane and calcite.
554 - 608	Siltstone, gray-green dense, and fine grained quartzite, abundant epidote, trace limonite and hematite after pyrite.
608 - 641	Quartzite, fine grained, ranges gray to green, 3-4% finely disseminated pyrite. Oxidation along fractures.
641 - 727	Siltstone, dark-gray to green with minor quartzite, fine grained, light gray, abundant chlorite, numerous near vertical 1-3mm calcite veins, 1-2% disseminated pyrite and limonite after pyrite.
727 - 823	Marble, medium-gray, finely crystalline, 1% disseminated pyrite, occasional mottled appearance. One small crystal of molybdenite identified at 762.5 feet.
823 - 837	Siltstone, light-gray to pale-green, abundant chlorite on fractures.
837 - 846	Marble, dark-gray, finely crystalline, 1% finely disseminated pyrite.
846 - 923	Siltstone, pale-green, numerous calcite veins, 1-3% pyrite disseminated and in clots, abundant chlorite.
923 - 977	Limestone, medium to dark-gray, massive, alternating with light green-siltstone with abundant chlorite, 1-2% pyrite in siltstone and 0.5% pyrite in limestone.
977 - 990	Monzonite porphyry, pale-gray, 40% plagioclase phenocrysts, 1% disseminated pyrite.
990 - 1040	Limestone, gray mottled, trace of pyrite on numerous hairline fractures.
1040 - 1061	Quartzite, white, fine grained, calcareous.
1061 - 1079	Limestone, gray, silty, massive bedding.
1079 - 1100	Marble, coarsely crystalline, with silty interbeds, 3% pyrite.
1100 - 1130	Quartzite, white, fine grained, and mottled light and dark gray siltstone, bleached white within one inch of fractures.
1130 - 1135	Rhyolite, white, contains approximately 20% quartz phenocrysts 1-4mm diameter.
1135 - 1137	Monzonite porphyry, dark-gray aphanitic matrix with approximately 25% plagioclase phenocrysts, 0.5-1% pyrite.

Remainder of the drill core is missing. Reported end of hole is 1,221 feet.

Company name: Minerals Division, Superior Oil Company
Drill hole designation: S-1
Date drilled: 1966
Type of drill hole: rotary

0 - 26	Alluvium
26 - 76	Andesite, pale-blue to purple, porphyritic, strongly fractured, 2-3% pyrite and limonite after pyrite disseminated and on fractures.
76 - 101	Fault breccia, broken and crushed fragments of porphyritic andesite, 3-5% pyrite, chlorite replaces hornblende, breccia partly re-cemented with calcite.
101 - 147	Andesite, blue-gray, some chlorite present, numerous fractures 60-70° from horizontal, 5% disseminated pyrite with local bands of up to 10% pyrite.
147 - 166	Fault breccia, brecciated andesite, silicification of matrix.
166 - 249	Andesite, light-green to gray, contains 1-4 cm calcareous, fine grained, clots which have the appearance of porphyroblasts, 5% pyrite, 57% plagioclase phenocrysts largely altered to sericite, calcite, and quartz, up to 5% quartz found as rims around altered plagioclase phenocrysts.
249 - 286	Andesite, as above, vuggy, vugs contain drussy quartz, 6-7% disseminated pyrite, trace of galena and sphalerite(?) in narrow 1/4 to 1/8th inch horizontal bands.
286 - 423	Andesite, light-green to gray, strong vertical fractures, 5-6% pyrite disseminated and in clots, fractures and matrix are silicified.
423 - 526	Andesite, light-green to gray, finely banded, matrix silicified, plagioclase phenocrysts sericitized, calcite cements fractures, 7-8% pyrite.
526 - 719	Andesite, as above, but less silicified, abundant calcite in veinlets and disseminated, 10% pyrite, frequent faults and shattered zones.
719 - 914	Andesite, porphyritic, strongly fractured, silicified, minor calcite veinlets, plagioclase phenocrysts replaced by sericite, calcite, and quartz. 7-8% pyrite, trace of galena and sphalerite at 865 feet.
914 - 955	Andesite, as above, but 4-5% pyrite.

End of Hole at 955 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
26 - 50	5	5	30	140
50 - 100	6	11	35	110
100 - 150	7	13	65	95
150 - 200	20	9	160	95
200 - 250	340	14	900	710
250 - 300	204	15	1100	1000
300 - 350	10	13	60	55
350 - 400	19	5	45	40
400 - 450	20	4	25	65
450 - 500	22	15	30	120
500 - 550	24	7	25	95
550 - 600	22	10	170	255
600 - 650	13	4	45	45
650 - 700	20	13	480	430
700 - 750	18	3	30	40
750 - 800	22	4	80	70
800 - 850	15	6	85	80
850 - 900	65	9	260	220
900 - 955	12	7	70	55

Company name: Minerals Division, Superior Oil Company
Drill hole designation: S-2
Date drilled: 1966
Type of drill hole: core, inclined 60°, N. 32° W.

0 - 15	Alluvium
15 - 138	Andesite, green to buff, porphyritic, plagioclase phenocrysts largely replaced by sericite and quartz. Strongly fractured and stained with limonite, manganese dendrites on some joint surfaces.
138 - 337	Andesite, green to buff, porphyritic, silicified, trace calcite on fractures and disseminated in the matrix, 7-8% pyrite, chlorite replaces hornblende, weak bleaching along fractures.
337 - 382	Andesite, green, fine grained, weak silicification, trace calcite, 1-2% pyrite.
382 - 395	Andesite, mottled pale-red and green, fine grained, potassically altered. Two thin sections from this zone have the following mode: 78% fine-grained, anhedral, K-feldspar, 15% chlorite, 5% pyrite, with traces of biotite, sericite, and quartz. Small quartz and calcite veinlets cut K-feldspar.

End of Hole 395 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
15 - 50	7	8	135	280
50 - 100	9	8	205	655
100 - 150	10	6	95	180
150 - 200	6	3	60	115
200 - 250	5	6	60	55
250 - 300	6	5	30	65
300 - 350	12	4	210	45
350 - 395	15	1	15	45

Company name: Minerals Division, Superior Oil Company
Drill hole designation: S-3
Date drilled: 1966
Type of drill hole: rotary

0 - 30	Alluvium
30 - 92	Andesite, light-gray to light-brown, pervasive limonite staining, weak silicification.
92 - 205	Andesite, gray to pale green, feldspar phenocrysts partly kaolinized and sericitized, trace chlorite, trace calcite, 12-14% fine grained, disseminated pyrite, strongly fractured between 152-160 feet, 180-188 feet, and 200-205 feet.
205 - 243	Andesite, gray-green, weak silicification, strong sericitization of plagioclase, abundant chlorite, 7-9% fine grained, disseminated pyrite, brecciated zone from 205 to 232 feet.

End of Hole 243 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
30 - 50	22	2	45	20
50 - 100	18	4	45	40
100 - 150	18	7	70	140
150 - 200	22	8	160	215
200 - 243	18	21	120	130

Geochemical Surveys drilled nine holes within 1,800 feet of the Chapo mine. It is believed that the presentation of the logs of three selected drill holes is sufficient to demonstrate the general geologic environment and controls of mineralization near the Chapo mine. Assay data have been compiled from bar graphs.

Company name: Geochemical Surveys
Drill hole designation: G-4
Date drilled: 1968
Type of drill hole: core

0 - 7	Alluvium
7 - 10	Quartzite, medium grained, greenish-gray, iron stained fractures.
10 - 13	Limestone, greenish-gray, silicified, some disseminated pyrite, trace of chalcopyrite.
13 - 32	Garnet, tan, chalcopyrite in veinlets of calcite and epidote, disseminated chalcopyrite and pyrite.
32 - 33	Limestone, dark gray, recrystallized, disseminated chalcopyrite.
33 - 35	Limestone, and calcite, fractured, iron stained.

35 - 48	Monzonite porphyry, light-gray, disseminated sulfides, veinlets of sulfides, some 2 inch diameter blebs of pyrite with epidote, fractures are iron stained.
48 - 67	Garnet, greenish-tan, disseminated chalcopyrite, blebs and veinlets of chalcopyrite, disseminated pyrite, masses of epidote in some zones.
67 - 82	Limestone, light-gray, and silicified siltstone, trace of epidote and chalcopyrite in veinlets.
82 - 106	Garnet, brown, with large amounts of chalcopyrite occurring as large (6 inch diameter) clots, veinlets and dissemination. Pyrite occurs with chalcopyrite in masses and veinlets, trace of epidote in veinlets, a few small blebs of molybdenite.
106 - 116	Siltstone, light-gray, silicified, veinlets of pyrite and epidote, some open fractures lined with quartz crystals.
116 - 126	Monzonite porphyry, light-gray, small amount of chalcopyrite disseminated and in veinlets, trace of epidote.
126 - 130	Quartzite or garnetized calcareous fine-grained sandstone, light-gray, trace of chalcopyrite in veinlets.
130 - 136	Limestone, light-gray, silicified, aphanitic and mottled, small quantity of finely crystalline sulfides, trace of epidote in veinlets.
136 - 146	Limestone, light-gray, silicified, blebs and veinlets of pyrite and chalcopyrite, some veinlets of epidote.
146 - 150	Garnet, light-brown, veinlets and small blebs of chalcopyrite and pyrite, trace of epidote.
150 - 159	Monzonite porphyry, light-gray, altered, silicified, disseminated pyrite and chalcopyrite.
159 - 176	Garnet, light-brown, chalcopyrite and pyrite in veinlets and blebs, red mineral with chalcopyrite may be cuprite .
176 - 206	Monzonite, light-gray, finely crystalling groundmass with hornblende phenocrysts, silicified, trace of pyrite in fractures.
206 - 210	Garnet, light-brown, chalcopyrite in blebs and veinlets, possible cuprite, trace of pyrite.
210 - 211	Marble, light-gray, aphanitic, partly silicified.
211 - 251	Marble, tan, aphanitic, some zones are mottled, no sulfides, black Mn dendrites on some fractures.
251 - 277	Marble, light-gray, medium and finely crystalline, mottled, trace of disseminated pyrite.
277 - 278	Garnet, light-tan, pyrite disseminated and in veinlets.
278 - 316	Marble, light-gray, mottled, trace of disseminated pyrite, hematite stains on fractures.

316 - 317	Fault
317 - 374	Limestone, black, very finely crystalline, fresh, strongly sheared and fractured, fractures filled with calcite, abundant <u>Orbitulina</u> at 340 feet, trace of disseminated pyrite.
374 - 389	Limestone, black and light-gray mottled, aphanitic, very slightly recrystallized, small elongate blebs of pyrite.
389 - 401	Limestone, black, very finely crystalline, fresh, strongly fractured, trace of pyrite in some zones.
401 - 418	Limestone, black to light-gray and white mottled, slightly recrystallized, trace of pyrite.
418 - 423	Limestone, silicified, light-gray, disseminated pyrite.
423 - 427	Limestone, black to light-gray, slightly recrystallized, trace of disseminated pyrite.
427 - 437	Limestone, black, fresh, strongly fractured, fractures filled with calcite,trace of disseminated pyrite.

End of Hole 437 feet.

Assays: (ppm)	Cu
7 - 50	0.12%
50 - 100	1.02%
100 - 150	0.39%
150 - 200	0.25%
200 - 250	0.32%
250 - 300	<100
300 - 350	<100
350 - 400	<100
400 - 437	<100

Company name: Geochemical Surveys
Drill hole designation: G-7
Date drilled: 1968
Type of drill hole: downhole air hammer

0 - 10	Garnet, tan, limonite stained, trace of epidote.
10 - 25	Garnet and monzonite, chalcopyrite with calcite disseminated in garnet, trace of epidote.
24 - 35	Limestone, silicified, light-gray, disseminated pyrite, trace of epidote.
35 - 65	Garnet, tan, disseminated chalcopyrite, large amount of epidote, disseminated pyrite.
65 - 180	Monzonite, silicified, medium-gray, disseminated pyrite, trace of epidote, trace of garnet throughout.
180 - 280	Marble, white and light-gray, medium crystalline, disseminated pyrite, no epidote.
280 - 281	Fault zone.
281 - 285	Limestone, dark-gray, finely crystalline.
285 - 310	Monzonite, medium-gray, silicified, trace of disseminated pyrite.
310 - 325	Marble, white, disseminated pyrite

End of hole 325 feet.

Assays: (ppm)	Cu
0 - 50	1710
50 - 100	520
100 - 150	160
150 - 200	110
200 - 250	33
250 - 325	34

Company name: Geochemical Surveys
Drill hole designation: G-9
Date drilled: 1968
Type of drill hole: downhole air hammer

0 - 10	Sandstone, tan, medium grained, arkosic, a few grains of brown garnet.
10 - 15	Garnet, brown, trace of disseminated pyrite, some medium grained sandstone.
15 - 30	Sandstone, tan, medium grained, trace of garnet with calcite, trace of disseminate pyrite.
30 - 35	Marble, white and medium gray, finely crystalline.
35 - 50	Monzonite, silicified, medium crystalline, trace of disseminated pyrite.
50 - 65	Marble, white finely crystalline, some disseminated pyrite, trace of chalcopyrite.
65 - 70	Silicified limestone and marble, white and light-gray.
70 - 75	Monzonite, silicified, contains hornblende.
75 - 90	Marble, white, finely crystalline, disseminated pyrite.
90 - 95	Monzonite, silicified, with disseminated pyrite.
95 - 100	Marble with some monzonite.
100 - 110	Marble, white and medium-gray, trace of disseminated pyrite.
110 - 120	Monzonite, and marble, trace of disseminated pyrite, trace of garnet.
120 - 250	Monzonite, silicified, light-gray, trace of disseminated pyrite.
250 - 280	Marble, white, finely crystalline, trace of disseminated pyrite.
280 - 305	Monzonite, light-gray, silicified, disseminated pyrite.
305 - 315	Marble, white, finely crystalline, trace of disseminated pyrite.
315 - 330	Monzonite, altered, light-gray, disseminated pyrite.

Assays: (ppm)	Cu
0 - 50	680
50 - 100	395
100 - 150	450
150 - 200	48
200 - 250	66
250 - 300	55
300 - 330	65

Company name: Leonard Resources
Drill hole designation: AH-1
Date drilled: 1972
Type of drill hole: rotary

0 - 14	Alluvium
14 - 20	Limestone, buff to gray, fine grained, dense.
20 - 30	Limestone, white to gray, fine grained, dense, trace of dessiminated limonite after pyrite.
30 - 60	Limestone, white to gray, fine grained, dense, 1% pyrite, disseminated and in veinlets.
60 - 66	Limestone, gray to black, fine grained, highly fractured with 5% limonitic calcite veinlets.

End of hole 66 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
60 - 66	20	15	210	185

Company name: Leonard Resources
Drill hole designation: AH-2
Date drilled: 1972
Type of drill hole: rotary

0 - 76	Andesite, moderate argillic alteration with a few calcite veinlets, 2-5% limonite, disseminated and in veinlets.

End of hole 76 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
70 - 76	25	1	60	120

Company name: Leonard Resources
Drill hole designation: AH-3
Date drilled: 1972
Type of drill hole: rotary

0 - 35	Alluvium
35 - 110	Andesite, strong argillic alteration, abundant chlorite, 5-10% calcite veinlets, 5% limonite.
110 - 162	Rhyolite porphyry, white, possibly bleached, 2-5% pyrite

End of hole 162 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
40 - 45	5	1	40	140
150 - 162	5	1	30	50

Company name: Leonard Resources
Drill hole designation: AH-7
Date drilled: 1973
Type of drill hole: rotary

0 - 24	Alluvium
24 - 95	Rhyolite, abundant disseminated limonite, argillized euhedral plagioclase phenocrysts, trace of small quartz veinlets.
95 - 125	Rhyolite, with trace of finely disseminated epidote, chlorite, disseminated limonite and specular hematite, 1-3%.

125 - 160	Rhyolite, largely oxidized, 2-4% pyrite and limonite after pyrite, abundant chlorite in the matrix.

End of hole 160 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
24 - 50	385	4	105	440
50 - 53	190	8	75	210
60 - 110	60	8	40	150
110 - 160	30	6	25	120

Company name: Leonard Resources
Drill hole designation: AH-8
Date drilled: 1973
Type of drill hole: 0-82 feet, rotary; 82-156 feet, diamond core

0 - 10	Alluvium.
10 - 35	Diorite, dark, equigranular, chlorite after biotite, trace of sericite, disseminated limonite after pyrite.
35 - 70	Quartzite, white, fine grained, calcareous, 2-4% limonite after pyrite.
70 - 82	Rhyolite, white, aphanitic, with some small bipyramidal quartz phenocrysts, trace of limonite and epidote.
82 - 91	Diorite, abundant epidote and chlorite, silicified plagioclase phenocrysts, abundant calcite veins, limonite after pyrite, 5-8%.
91 - 92	Hornfels, green fine grained, broken by numerous calcite veinlets.
92 - 119	Diorite, light-gray to green, medium to coarse grained, epidote, calcite veins, and limonite after pyrite 4-6%.
119 - 123	Hornfels, fine grained, medium-gray, with epidote, garnet, and calcite.
123 - 124	Calcite vein, no sulfides.
124 - 130	Hornfels and calc-silicate, light-gray, dense rock with garnet, epidote, calcite, and very small quartz veinlets, trace pyrite and magnetite.
130 - 132	Diorite, medium to coarse grained, epidote and limonite after pyrite 1-3%.
132 - 156	Calc-silicate and silicified sediment, garnet, epidote, quartz, and calcite are abundant, trace of magnetite, 152-156 feet strongly kaolinized, 1-2% limonite after pyrite.

End of hole 156 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
10 - 35	20	6	25	138
35 - 50	45	20	20	75
50 - 82	70	6	45	85
82 - 88	20	8	30	68
119 - 123	10	4	30	-
126 - 130	10	6	225	-
152 - 156	18	4	45	-

Company name: Leonard Resources
Drill hole designation: AH-9
Date drilled: 1974
Type of drill hole: core

0 - 12	Alluvium.
12 - 180	Diorite, medium to fine grained, chlorite after hornblende, unaltered plagioclase, abundant magnetite, numerous calcite veinlets 45° to vertical.

End of hole 180 feet.

Company name: Leonard Resources
Drill hole designation: AH-11
Date drilled: 1974
Type of drill hole: core

0 - 20	Alluvium.
20 - 296	Quartzite, red to gray alternating with siltstone, and silicified, dense, shale; abundant hematite on fractures.
296 - 310	Quartzite, brecciated zone, angular fragments rehealed with quartz, quartz druse in vuggy zones.

End of hole 310 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
20 - 70	11	5	20	80
70 - 120	12	7	10	50
120 - 170	16	14	5	75
170 - 200	25	13	10	140
200 - 250	32	8	-	-
250 - 300	21	7	-	-

Company name: Leonard Resources
Drill hole designation: AH-13
Date drilled: 1974
Type of drill hole: downhole air hammer

0 - 70	Siltstone and fine grained quartzite, strongly weathered with abundant limonite.
70 - 90	Siltstone, yellow-orange, limonite stained and calcareous quartzite with trace of marble and 2-3% pyrite finely disseminated.
90 - 120	Siltstone, dark-gray to buff, trace of pyrite.
120 - 150	Marble, blue-gray, and siltstone with finely disseminated pyrite.
150 - 200	Quartzite, calcareous, abundant limonite and blue-gray marble with 1-2% pyrite.

End of hole 200 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
0 - 50	62	4	10	105
50 - 100	20	6	35	115
100 - 150	20	6	15	60
150 - 200	12	6	25	60

Company name: Leonard Resources
Drill hole designation: AH-14
Date drilled: 1975
Type of drill hole: downhole air hammer

0 - 20	Alluvium
20 - 70	Quartzite and gray hornfels, trace of hematite.
70 - 100	Quartzite, tan, fine to medium grained, hematitic with trace of magnetite, pyrite, and muscovite.
100 - 160	Quartzite, partly oxidized, trace of magnetite.
160 - 440	Quartzite, partly oxidized, trace of magnetite and hornfels.
440 - 540	Quartzite and hornfels, trace of hematite, limonite, and pyrite. Small calcite veinlets.
540 - 600	Quartzite and hornfels, partly oxidized, 1% disseminated pyrite, trace of pyrite and chlorite in quartz veinlets.
600 - 650	Quartzite, slightly calcareous, partly oxidized.
650 - 700	Quartzite and hornfels, limonitic with some hematite, clots of talc-serpentine, trace of marble with disseminated pyrite (strong water zone at 648 feet, hole caving, hammertool replaced by tricone bit at 669 feet).
700 - 770	Quartzite, white to gray, calcareous, trace of pyrite, locally 2% pyrite, finely disseminated magnetite, trace actinolite, abundant phlogophite in marble.
770 - 810	Quartzite and hornfels, limonitic, calcareous, 1% pyrite.
810 - 860	Quartzite and marble, locally 2% pyrite, trace very finely disseminated sphalerite, trace pyrrhotite(?).
860 - 910	Marble and quartzite, 1-2% pyrite, trace of very finely disseminated sphalerite, abundant quartzite cavings. (trip made to change bit, hole bridged at 390 feet and below, hole could not be re-entered without casing or heavy mud).

End of hole 953 feet.

Assays: (ppm)	Cu	Mo	Pb	Zn
300 - 350	10	3	40	75
350 - 400	10	1	-	-
400 - 450	5	4	20	40
450 - 500	10	2	-	-
500 - 550	10	2	20	75
550 - 600	8	2	-	-
600 - 650	5	1	15	45
650 - 700	5	4	55	126
700 - 750	5	4	110	250
750 - 800	5	4	145	300
800 - 850	5	1	170	350
850 - 900	5	2	170	350
900 - 950	10	4	220	400
930 - 950	29	-	370	630