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Geology of the Knight Peak Area, Grant County, New Mexico

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Abstract

Precambrian granite, intruded by dikes of Precambrian diabase, is present on the northeast and southwest sides of the Knight Peak area.

Outliers of Cambrian-Ordovician Bliss sandstone and Ordovician El Paso limestone, of approximately the same thickness as these same units elsewhere in the Silver City region, suggest that the uplift of the Big Burro Mountains did not begin in Precambrian time.

An arkose, possibly of the Lobo(?) formation of Cretaceous(?) age, is present locally above the Precambrian granite.

Tertiary volcanic rocks, consisting of a lower rhyolitic series of lavas, tuffs and agglomerate, early andesitic lava and tuff, and middle rhyolitic breccia, lava, and tuffs, accumulated to a thickness of over 5,000 feet. Andesite was intruded locally along minor faults. Two large perlite bodies are among the early rhyolitic rocks.

Erosion in nearby areas furnished detritus for the lower beds of Gila conglomerate. Faulting along the Taylor fault on the northeast side of the area began at this time. Continued downward movement along this fault produced a basin in which the upper beds of the Gila accumulated. Greater displacement in the northern half of the area produced hinge faulting along the Malone fault, which bounds the northern half of the area on the west.

Several phases of late volcanic activity in Quaternary time produced rhyolitic cones and intrusive bodies, dacite lava, and andesitic lava and tuff, which overlie the tilted rocks of the Knight Peak area with an angular unconformity. Later Quaternary events include the deposition of high-level gravels, pediment gravel, and alluvium. Dissection of the mountains and some crossfaulting continue to the present.

Introduction

ACKNOWLEDGMENTS

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PURPOSE

This project has as its purpose the investigation of the structure and st•atigraphy of the Knight Peak arca. Special emphasis has been placed upon deciphering the Tertiary volcanic history of the area.

METHODS OF INVESTIGATION

At the time the study was made, no topographic maps of most of the area were available. The United States Geological Survey is preparing topographic maps of the northern third of the Knight Peak area in its 1:24,000 series as part of the Steeple Rock quadrangle, and these should be available soon. A topographic map of the entire southwestern corner of New Mexico was published by the United States Geological Survey in its 1:250,000 series in 1958.

For this study of the geology of the Knight Peak area, geologic features were plotted on uncontrolled aerial photographs taken in 1946 and available through the Soil Conservation Service of the United States Department of Agriculture. This information was later projected onto the Grant County highway map (edition of 1941). Elevations of points for structure profiles were determined with two aneroid barometers (one stationary). Some traverses were measured with a tape and Brunton compass.

In the central and western portions of the area, exposures are sufficiently good that contacts can be traced easily. In the extreme northern and southern ends of the area and over much of its eastern half, soil and gravel cover make accurate plotting of contacts difficult.

The summers of 1955 and 1957 and part of the summer of 1956 were spent in the field. The laboratory studies were conducted at the University of Illinois during the winters of 1955 to 1958.

LOCATION AND ACCESSIBILITY

The area under investigation comprises approximately 260 square miles in southwestern New Mexico. It is elongate from northwest to southeast and lies about midway between Silver City and Lordsburg, just west of the Big Burro Mountains. Deming lies about 30 miles to the east of the area. See Figure 1.

New Mexico Highway 180 crosses the Knight Peak area from the northeast to the southwest. At White Signal (just off the map, to the northeast along Highway 180), New Mexico Highway 189 heads southward across the area toward the town of Separ (p1. 1). U. S. Highway 70-80 crosses east-west between Deming and Lordsburg, 10 miles south of the area. Numerous ranch roads crisscross the area.

PHYSIOGRAPHIC SETTING

The Knight Peak area is situated within the Mexican Highlands section of the Basin and Range province. West of the Rio Grande valley in New Mexico, this province is characterized by a series of subparallel northwest-trending tilted fault blocks. Along the Rio Grande valley itself, the fault blocks trend north-south. These tilted fault-block mountains are separated by nearly flat basins which have been filled with detritus from the surrounding hills (Fenneman, 1931, p. 379-393).

The southern boundary of the Colorado Plateau province lies about 70 miles to the north of the area. Twenty-five miles to the west is the Arizona-New Mexico State line, straddled by the Peloncillo Mountains. Seventy miles to the south lies the international boundary between Mexico and the United States. The Rio Grande is approximately 70 miles to the east.

The Big Burro Mountains rise to just over 8,000 feet 6 miles to the northeast. About 13 miles to the southwest lies the Lordsburg bolson. A

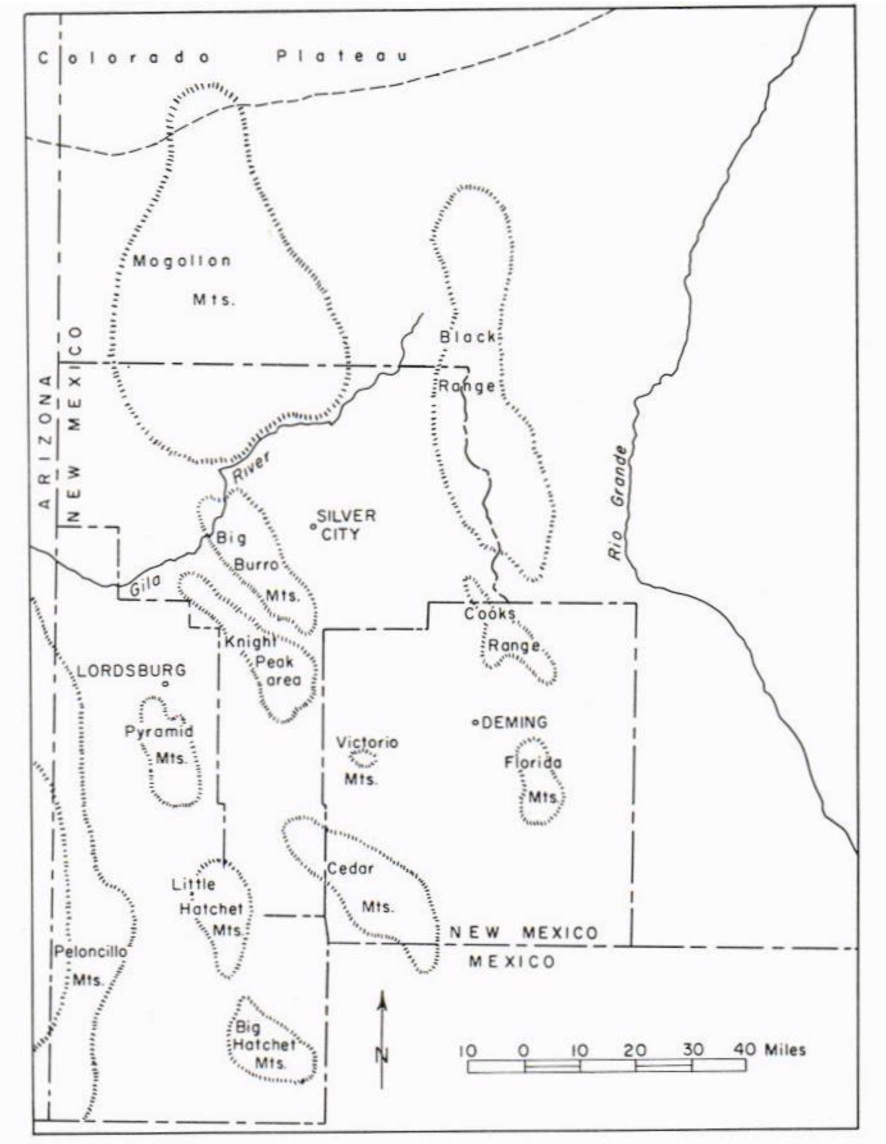

Figure 1

Physiographic index map of Southwestern New Mexico structural and topographic break between these two features is present in the Knight Peak area. Fifty miles to the east lie the Black Range and Cooks Range. Both are composed largely of Tertiary volcanic rocks similar to the rocks of the Knight Peak area. In Luna County, to the south and southwest of the Knight Peak area, the Cedar Mountains, Victorio Mountains, and Florida Mountains rise out of their gravel cover to expose portions of the Tertiary volcanic series and part of the Paleozoic section. See Figure 1.

Knight Peak and adjoining mountains are part of a tilted fault block of volcanic rocks and postvolcanic conglomerates. A granite surface which slopes to the south and southwest away from the Big Burro Mountains to form a pediment bounds the area along most of its northeast side. This granite is covered by bajada deposits west and southwest of the highland. The tilted volcanic rocks of the area plunge beneath the bajada to the south and southeast. The steep scarp of the Knight Peak range faces southwest, the dip slope being gentler and to the northeast.

CLIMATE AND VEGETATION

The climate of the Knight Peak area is semiarid. Variations in altitude cause considerable differences in temperature and rainfall from place to place. Table 1 provides selected monthly average temperatures for Silver City and Lordsburg. The Knight Peak area lies about midway between these two stations.

TABLE I. SELECTED MONTHLY AVERAGE TEMPERATURES FOR SILVER CITY AND LORDSBURG, NEW MEXICO (Source: Climatological Data, U.S. Weather Bureau)

MONTH	AVERAGE: MAX. TEMP. (°F)	AVERAGE MIN. TEMP. (°F)	AVERAGE DAILY RANGE (°F)	STATION
January	57.9	27.8	30.1	Lordsburg
	50.4	25.2	25.2	Silver City
April	77.9	43.5	34.4	Lordsburg
	68.4	38.0	30.4	Silver City
July	96.7	66.6	30.1	Lordsburg
	89.2	59.8	29.4	Silver City
October	81.0	47.8	33.2	Lordsburg
	72.5	42.0	30.5	Silver City

The mean annual precipitation for Grant County is 14 inches. The Knight Peak area lies in one of the drier parts of the county, where the average rainfall is about 10 inches. No accurate records, however, are available. The major portion of the rainfall comes in the form of rather violent afternoon and evening showers in July and August, the rainy season. At least one Gulf storm passes over the region from the southeast during the rainy months, and a steady soaking of several days' duration results.

Most of the conifers found in the area are juniper and piñon, although locally there are a few ponderosa pines. Live oak is abundant on the lower hills. Tamarisk, clumps of cottonwood, and black walnut are found along the streams. Yuccas, several varieties of cactus, and bear grass are common. The several varieties of grass thrive when rainfall is sufficient, and the area supports an important cattle industry.

RELIEF

Knight Peak and adjacent mountains form a mountain range typical of the Basin and Range province. The southern three-quarters of the range has an overall trend of N. 25° W. The northern quarter, north of Thompson Canyon, changes its strike to about N. 75° W. The range is composed of tilted Tertiary and Quaternary volcanic rocks and post-volcanic conglomerates. The gentle northeast dip slope looks relatively smooth from a distance, but closer investigation reveals a network of dip-slope streams which have cut canyons several hundred feet deep. The southwest-facing scarp in the northern half of the range is almost vertical in places. The topography in the southern half of the range is more subdued; here, steep cliffs are present only along major canyons.

Two peaks dominate the Knight Peak area: Knight Peak and Soldiers' Farewell Mountain. The sheer southwestern scarp of Knight Peak is visible from Lordsburg as a prominence on the skyline (fig. 2). Soldiers' Farewell Mountain is a craggy peak south of Highway 189 (p1. 1). Lesser peaks are numerous in the area. Between Mill Canyon, north of Knight Peak, and Thompson Canyon, five peaks line the Malone fault scarp. Just north of Thompson Canyon, along Malone fault, is Eagle's Eye Peak. The series of hills from Knight Peak to Eagle's Eye Peak is developed in the rhyolitic rocks. To the northeast, Chocolate Peak is sculptured from dipping beds of the overlying conglomerate. It differs from the other northern peaks in that its slopes are more gentle and its shape more nearly conical. The hills to the northwest are more rounded and less prominent. South and southeast of Soldiers' Farewell Mountain, four unnamed rhyolite hills appear.

The ruggedness of the Precambrian granite in the northeast part of the area is the result of stream erosion. Locally this granite has been planed to a pediment and is covered with a thin veneer of soil and gravel. To the southwest, the Precambrian granite underlies a pediment sloping gently southwestward. Local knolls made up largely of quartz veins break the evenness of the pediment surface.

The upper edge of the bajada deposits in the west and southwest part of the area is about 2 miles west of the scarp face of the highland. The main constituent of the gravel deposits is detritus from the Precambrian rocks. Lateral cutting in Thompson Canyon, in the NE¼ sec. 23, T. 20 S., R. 17 W., has exposed a section of the pediment gravels over 20 feet thick. This indicates that these deposits thicken rapidly toward

Figure 2

KNIGHT PEAK FROM THE AIR

the southwest. Similar deposits occur along the southern half of the highland in the vicinity of Soldiers' Farewell Mountain.

DRAINAGE

The streams of the Knight Peak area can be classified into three principal groups: a set of subsequent streams which flow westward and northwestward along the strike of the beds in the extreme northern part of the area, a series of obsequent streams which empty into Thompson Canyon in the northern quarter of the range, and a series of subsequent streams which follow the strike of the beds southeastward from the Continental Divide. Lesser consequent streams abound along the entire dip slope of the range.

The streams which deliver their water west of the Continental Divide empty into the Gila River drainage, which joins the Colorado River at Yuma, Arizona. Streams east of the Divide empty into the drainage of the Rio Grande. These rivers were probably well established before the structure of the Knight Peak highland reached its present proportions; this might explain why the Continental Divide crosses this highland transverse to the major structure.

The streams in Burro Springs Canyon and its principal tributary, Mulberry Canyon (not named in pl. 1), are the largest of the west-
and

northwest-flowing subsequent streams. The canyons in which these streams flow are deep and V-shaped along much of their upper course. As soon as they pass out of the Gila conglomerate onto the pediment gravels to the north and northwest, these canyons widen, and their walls become more gently sloping.

The major obsequent stream flows in Thompson Canyon, which has its source in the steep valleys off the western slope of the Big Burro Mountains to the east of the Knight Peak highland. Road Canyon and Pines Canyon are the major obsequent tributaries to Thompson Canyon. Gold Gulch is a northwest-flowing subsequent tributary to Thompson Canyon. Mill Canyon heads on the Malone fault scarp just north of Knight Peak and empties into Thompson Canyon. Knight Canyon has its source in a series of subsequent streams which flow northwestward from the Continental Divide. Just south of Knight Peak, the stream of Knight Canyon is an obsequent stream and crosses the Malone fault, carrying runoff waters westward into Thompson Canyon. Thompson Canyon has a rather wide valley, generally U-shaped to V-shaped, above its junction with Gold Gulch. At this point, the stream cuts across the most rugged portion of the range and has carved an imposing box canyon through the perlite and rhyolitic rocks. It emerges from the gorge to become a braided stream with a flat, ever-broadening valley.

The south- and southeast-flowing subsequent streams are characterized by relatively wide alluvium-filled channels. The canyons for the more important of these streams are Cow Creek and McDonald Draw, which flow across Precambrian rocks; Whiterock Draw, which merges with McDonald Draw at the Grant County—Luna County line; Silver City Draw, Whitetail Canyon, Walking-X Canyon, and C-Bar Canyon, which merge within the Knight Peak highland to form Burro Cienega. The sands of Burro Cienega are saturated from its junction with Silver City Draw southward almost to Highway 189. Many small springs emerge from the fractured perlite into which this saturated portion of Burro Cienega is cut. Where the stream flows back onto rhyolitic rocks, its sand bed is dry. Another major unnamed stream flows southward across Precambrian rocks west of the Tertiary volcanic rocks.

STRUCTURAL CONTROL ON DRAINAGE

The drainage network of the Knight Peak area is almost entirely dependent upon the structure of the area, especially the bedding and faulting. The subsequent stream network at both ends of the area is invariably developed along the strike of the beds. Radical departure from this general rule is noted only where crossfaults or zones of extreme fracture are present normal to the strike of the beds. Every major obsequent stream of the Thompson Canyon drainage network is developed along zones of crossfaults. The stream in Thompson Canyon itself is downcutting along a major crossfault. This is indicated by the offset of beds on opposite sides of the canyon.

Precambrian Rocks

GRANITE

Granite crops out on both sides of the Knight Peak highland, and a horst of granite is present south of Highway 180 along Silver City Draw. The age of the granite is believed to be Precambrian because of its position below the Bliss sandstone of Cambrian age.

The massive, coarse-grained granite is reddish buff to pale pinkish gray. The major minerals are feldspar, quartz, and biotite. The gray color of the rock is evident in fresh samples. Most outcrops, however, because of weathering, display the buff color.

Microscopically the granite is hypidiomorphic granular and granophyric. Granophyric intergrowths form elongate and irregular patches. Many of the interstices are lined with minute magnetite grains. Table 2 contains two estimated modes of the granite. Quartz occurs as intergranular anhedra and as part of the granophyric intergrowths. The quartz grains commonly contain numerous small inclusions, extending in many cases into grains of plagioclase. Small amounts of myrmekite are present.

Subhedral to anhedral plagioclase has a maximum extinction angle of 12° normal to (010). This corresponds to a composition of An_{28} (Chudoba, 1933). The plagioclase is more clouded than the quartz, and much of it is sericitized. A few plagioclase grains are bent, suggesting that the granite has undergone some internal deformation. A few small plagioclase crystals show minute grid twinning. Perthite is abundant in the granite. The potash feldspar in the perthite is untwinned and clear, and has the optical properties of orthoclase.

Euhedral to subhedral biotite occurs as thin shreds between grains of quartz and plagioclase. The biotite is pleochroic from dark green to brown. Magnetite is present as euhedral to anhedral grains; some is developed between larger mineral grains and penetrates minute crevices in grains. Fluorite occurs as occasional interstitial fillings, and, although

TABLE 2. ESTIMATED MODES OF THE PRECAMBRIAN GRANITE

East side of area		West side of area	
MINERAL	**PERCENT**	**MINERAL**	**PERCENT**
Perthite	48	Perthite	55
Quartz	22	Quartz	23
Plagioclase (An28)	21	Plagioclase (An28)	16
Biotite	9	Biotite	6
Magnetite	tr	Magnetite	tr
Sphenc	tr	Apatite	Er
Apatite	tr	fluorite	tr
Total	100	Total	100

none was observed in specimens taken from the east side of the graben, fluorite is known to occur here (Gillerman, 1952). Sphene and apatite occur locally as accessory minerals in the granite.

DIABASE

Diabase dikes with apparent random orientation are common in the Precambrian granite. Locally they contain inclusions of the enclosing granite. Megascopically the diabase is a dark-green to black, fine- to medium-grained rock with plagioclase laths up to 4 mm long.

Microscopically the diabase is holocrystalline and exhibits the typical diabasic texture. The major minerals are plagioclase (An_{28-32}), hornblende, and pyroxene. Some of the hornblende and pyroxene grains are intergrown with the plagioclase laths. Minor amounts of potash feldspar and anhedral magnetite (0.5 mm and less) are present. Occasional subhedral biotite flakes occur on hornblende grains, and a small amount of the hornblende is altered to chlorite. Nearly all the plagioclase is altered to sericite in the coarser grained portions of the dikes, whereas in the finer grained portions, only small amounts of the plagioclase have been altered to sericite. Magnetite is more abundant in the fine-grained phase; much of it is elongate parallel to the cleavage directions in the hornblende.

Paleozoic Rocks

CAMBRIAN-ORDOVICIAN ROCKS

The Bliss sandstone crops out near the eastern edge of the map area in secs. 14, 23, 24, 26, 35, T. 21 S., R. 14 W., near the Grant County—Luna County line. It occurs as a series of outliers resting unconformably on the Precambrian granite. The largest of the outliers (sec. 26) is approximately 0.4 mile in diameter.

Lithologically the Bliss here consists of hematitic, dolomitic, and glauconitic sandstone and siltstone, as well as some thin limestone, pebble conglomerate, and orthoquartzite (fig. 3).

The basal unit is a buff to pink pebble conglomerate which grades upward into a red hematitic sandstone yielding a trilobite fauna. About 50 feet up from the base, a greenish-buff glauconitic sandstone with dolomite stringers is present. This unit grades into a crossbedded pink orthoquartzite. A thin-bedded gray dolomitic sandstone with a few siliceous stringers overlies the orthoquartzite and grades upward into another hematitic sandstone bed. About 20 feet from the top of this hematitic bed, a layer of glauconitic sandstone 1 foot thick contains abundant linguloid fossils. The hematitic sandstone is overlain conformably by the El Paso limestone of Ordovician age. There is disagreement as to the exact position of the Bliss—El paso contact. In this report, it has been placed at the top of the uppermost hematitic sandstone bed.

Kuellmer (1954) presents an excellent summary of the dispute over the age of the Bliss sandstone. Richardson (1909), who originally named and described the Bliss sandstone, considered it to be Upper Cambrian in age on the basis of its linguloid brachiopod fauna. The Bliss has yielded a Lower Ordovician gastropod fauna in the Van Horn region in Texas (King, 1940, p. 152-156). Flower (1953) convincingly demonstrated the Cambrian—Ordovician age of the Bliss sandstone. In the outlier described here, the lowest hematitic bed occurs near the base of the section and yields trilobites *(Camaraspis* sp.) of Late Cambrian age (Christina Lochman-Balk, personal communication). This is the first reported occurrence of this genus in New Mexico.

The other outliers in the vicinity are smaller than the one described. Radioactivity is reported in one of them 0.3 mile to the southwest. A shaft has been sunk through the Bliss into the Precambrian granite. This suggests that the mineralization is associated with dikes in the granite, as is the *case* a few miles to the north around White Signal.

ORDOVICIAN SYSTEM

Two small incomplete sections of El Paso limestone are associated with the Bliss outliers described above. The smaller is a knoll of dipping limestone just east of the Bliss outliers in sec. 14, T. 21 S., R. 14 W., along

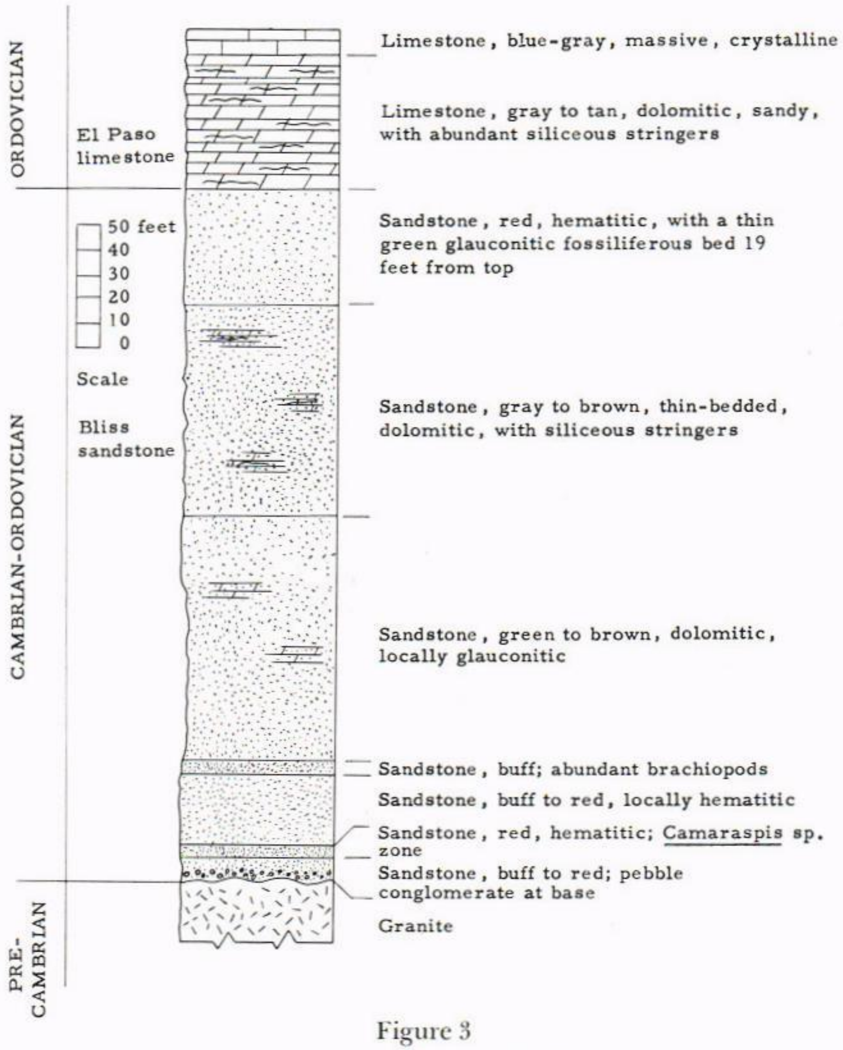

Figure 3

MEASURED SECTION OF THE BLISS AND EL PASO FORMATIONS

Cow Creek. It is partially buried, so that its base is not visible. The rock is the typical gray to buff fine-grained slabby limestone of the El Paso formation. This section is approximately 30 feet thick.

To the south, in sec. 26, T. 21 S., R. 14 W., along McDonald Draw, the larger El Paso section overlies conformably the Bliss sandstone outlier. The lowest 54 feet of the section consists of thin-bedded dolomitic sandstone with abundant chert stringers. This lower unit contains the typical El Paso fauna of gastropods and trilobite spines; it is overlain by 12 feet of blue-gray sandy massive crystalline limestone.

STRUCTURAL RELATIONS OF THE PALEOZOIC ROCKS

The outliers of Paleozoic rocks near the eastern margin of the area are erosional remnants of tilted Paleozoic strata. These beds strike N. 8° E. and dip S. 19° E. More complete sections of the Paleozoic rocks arc present in the Peloncillo Mountains to the west, in the Silver City region to the northeast, and 18 miles to the southeast in the Victorio Mountains. Thicknesses of the individual systems remain rather constant even at the outcrops of the various units nearest to the B.g Burro Mountains. Geologists working in this area usually date the Burro Mountains uplift as Precambrian. It should be pointed out that these mountains may be younger than Precambrian. The Paleozoic outliers off the south flank of the Big Burro Mountains in the Knight Peak range and the constant thickness of the younger Paleozoic rocks in the surrounding areas suggest a late Paleozoic or early to middle Mesozoic age for the Burro Mountains uplift.

Mesozoic Rocks

CRETACEOUS(?) SYSTEM

Lobo(?) FORMATION

Along the Malone fault at the base of Knight Peak, a section of tilted arkose lies unconformably on the Precambrian granite. The arkose deposit is lens shaped, with a convex lower contact. The lens extends for about a mile along the strike of the Malone fault. The thickness of this unit at Knight Peak is about 80 feet. It strikes N. 16° W. and dips N. 58° E. A similar but smaller remnant is present along the Malone fault north of Mill Canyon. Lenses of this unit are present south of Highway 180 along the Malone fault, and along the Prevost fault on the east side of Silver City Draw. From C-Bar Canyon southward, for a distance of nearly 5 miles, an almost continuous thin layer of the arkose is present between the Precambrian and Tertiary rocks.

Megascopically the arkose is medium- to coarse-grained, poorly sorted, well- to poorly bedded pink rock composed of rounded to sub-angular quartz, feldspar, and biotite, with abundant cobbles of weathered granite, schist, and milky vein quartz as much as 8 inches in diameter. The matrix is noncalcareous. The microscope reveals that the cement is quartz. No fossils have been found in the arkose.

Darton (1916) gave the name Lobo formation to an arkose which occurs in the Florida Mountains, 10 miles southeast of Deming. Because of its similarity to the Triassic red beds of northern New Mexico and its stratigraphic position, he tentatively dated this arkose as Triassic. A similar unit is present in Cooks Range northeast of Deming. The age of the Lobo is discussed by Elston (1957), who concludes that it is of Permian and Triassic age and should be included in the Abo formation.

In the type locality, the Lobo unconformably overlies Ordovician limestones and at one place rests unconformably on an uplifted fault block of Precambrian granite. It is overlain unconformably by Upper Cretaceous sandstone (Darton, 1916).

Wherever the arkose is present in the Knight Peak range it rests unconformably on the Precambrian granite. In the area south of C-Bar Canyon, it is overlain unconformably by the earliest of the Tertiary rhyolites. If the arkose were part of the Permian succession, remnants of other Permian rocks might be expected in the Knight Peak range. None occur, however; so a Permian age for the arkose is doubted. Because the earliest of the Tertiary volcanic rocks rests unconformably on a remarkably even erosion surface of arkose, the arkose is tentatively dated as Cretaceous.

Tertiary Rocks

A series of volcanic rocks and one intrusive rock make up the sequence of rock units younger than the Mesozoic(?) in the Knight Peak area. The volcanic rocks occur as tuffs, agglomerates, and flows. The general appearance of each unit varies from place to place, as does the thickness of the units. Because of the great range in lithologic character, groups of beds which exhibit mineralogical similarity and occur in the same general sequence throughout the range are grouped together under a single name.

The Tertiary section for the Knight Peak range, beginning with the oldest at the bottom, is as follows:

5. Intrusive andesite;
4. Middle rhyolitic rocks;
3. Vitric rhyolitic breccia;
2. Early andesitic flow and tuff;
1. Early rhyolitic tuffs, perlite, and agglomerate.

As Kuellmer (1954, p. 29) points out, the ages of these rocks can only be estimated by comparison with other regions in the vicinity. In general, they are less altered than volcanic rocks of possible Cretaceous age described by Paige (1916, p. 7) in the Silver City region.

EARLY RHYOLITIC ROCKS (Ter)

The lowermost volcanic rocks of the Knight Peak area consist of a group of rhyolites which lie unconformably on the Lobo(?) arkose or on the Precambrian granite. They are unconformably overlain by early andesitic rocks. The thickness of this lower rhyolitic series is extremely variable. An estimated maximum thickness of this unit is 2,000 feet. Although portions of the series are locally missing, rocks of the early rhyolitic series are present throughout the entire Knight Peak range. The rocks of this series are predominantly porphyritic tuffs and flows of rhyolitic composition. The common phenocrysts are quartz, feldspar, and biotite. Hornblende is very rare. Porphyritic welded tuffs and lithic tuffs are dominant varieties, and a widespread agglomerate is also important. Locally important is porphyritic perlite. A few water-laid tuffs complete the sequence.

WELDED RHYOLITIC LITHIC TUFF

The lowest of the early rhyolites is a massive white to brown (frequently pink or lavender) lithic tuff. Angular lithic fragments up to 3 inches in diameter occur. Sanidine and biotite phenocrysts up to 2 mm are present in the tuffaceous matrix. The unit reaches a maximum thickness of 300 feet.

Microscopically this unit reveals a welded tuff matrix. Euhedral to subhedral sanidine phenocrysts are embayed; many contain inclusions of glass. Orthoclase phenocrysts are euhedral to anhedral and frequently cloudy. Some perthite occurs, but this is unusual. Euhedral to anhedral twinned plagioclase phenocrysts are present. They are usually sericitized. Albite and Carlsbad twins are common. Quartz phenocrysts are usually anhedral and embayed. Some show undulatory extinction, but this is rare. Much of the quartz is present as plumose growths in the glassy matrix. Biotite is usually euhedral and in some instances shredded and bent. Magnetite is finely disseminated throughout the glassy matrix. The angular to rounded lithic fragments are nearly all rhyolitic. Occasional rounded andesite fragments are present, but they are small, and their source is unknown.

PERLITE

Perlite overlies the above unit at Thompson Canyon and along Burro Cienega on the McDonald ranch. The perlite is usually a shattered, contorted mass of thin- to thick-bedded gray glass. The lower and upper portions of the perlite are extremely brecciated and usually cemented in a dense red glassy matrix.

The deposit at Thompson Canyon will be referred to as the Brock perlite after Julius Caesar Brock, a pioneer rancher in Thompson Canyon, who cut a water tunnel through this perlite along the south side of Thompson Canyon. It is a lens-shaped deposit of red to greenish-gray perlite. The bottom 5 feet of Brock perlite consists of a perlite breccia set in a red glass matrix. Individual blocks of perlite are 10 inches in diameter. This lower breccia zone grades upward into a shattered gray to greenish-gray thin-bedded perlite. Eutaxitic banding is common throughout the unit. Several lithoidal rhyolite beds, commonly 1 to 2 feet thick, occur within the perlite. They are severely contorted and broken. These stony rhyolite layers are from 20 to 150 feet apart and seem to represent rhyolitic flows which cooled more slowly than the glassy portions.

Megascopically the perlite is gray to greenish gray, dense, and of vitreous luster. Perlitic cracks in the glass are usually visible and attain a maximum size of 8 mm. Biotite phenocrysts up to 2 mm are locally very abundant.

Microscopically the perlite exhibits excellent perlitic structures. Many of these cracks are zones of devitrification, especially where the perlite is intensely fractured. A few fractured phenocrysts of euhedral plagioclase and sanidine, up to 1.85 mm in length and free of perlitic cracks, are present. Minor amounts of euhedral biotite, up to 2 mm in diameter, and clusters of magnetite grains are present. The mean index of refraction for the perlite is 1.503. Color variations are due to abundant pale-green to brown margarites, longulites, and skeleton crystals.

The upper portion of the perlite is extremely brecciated. It is bonded in a matrix of dense red glass or rhyolitic vitric tuff. Fragments of this brecciated perlite occur in the overlying tuffs and agglomerates of the lower rhyolitic series.

The overall appearance of the Brock perlite body is that of a perlite dome about 0.8 mile wide and approximately 2,000 feet thick. Accurate measurements of the thickness are difficult because of the extreme shattering and faulting to which the deposit has been subjected. Apparent flow banding within the perlite body is difficult to trace for any great distance. The average dip suggests general conformity with the dips of the other volcanic rocks of the lower rhyolite series. Abundant milky quartz veins are injected along many of the joints in the perlite.

The McDonald ranch perlite deposit is considerably larger than the Brock deposit. It crops out along Burro Cienega from just south of the junction with Silver City Draw to a point east of Soldiers' Farewell Mountain, a total distance of 6 miles. It has the general appearance of a malformed lens. The northern boundary on the west side of Burro Cienega is a typical wedgeout margin. The body thickens rapidly to the south, and its overall shape is somewhat irregular.

Most of the McDonald ranch perlite is greenish gray and similar lithologically to the Brock perlite. It differs from the latter in that dense red glass lenses and disconnected colloform blobs are interbedded with the typical gray perlite. This red glass does not exhibit perlitic structures. Nearly all the red glass colloform bodies were once hollow but are now filled with chalcedony and opal. At its northern extremity west of Burro Cienega, the perlite contains numerous spherulites. The radiating ribs of these spherulites display a red plumose texture, which is due to the presence of radially arranged reddish-brown trichites and margarites (fig. 4).

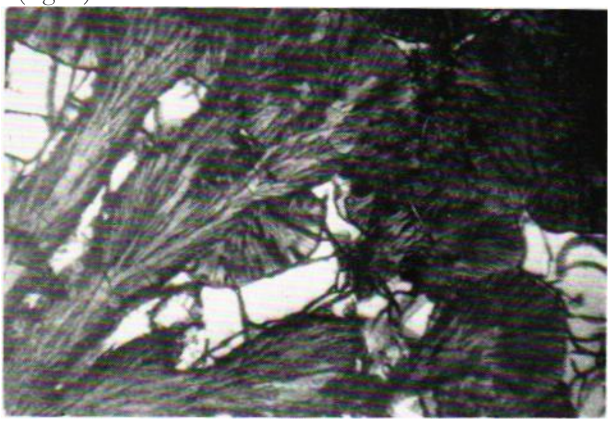

Figure 4

PHOTOMICROGRAPH OF SPHERULITES IN PERLITE

Plane polarized light. x 6.

Layers of lithoidal rhyolite are present at several levels in the perlite. They are generally thicker than those in the Brock perlite. The thickness of one of these layers, about 1.5 miles north of Highway 189 along the west side of Burro Cienega, is from 100 to 140 feet. In the northern half of the deposit, the thinnest zones of perlite are those which are most severely shattered. These zones might represent portions of a domelike bubble in which the greatest amount of collapse occurred. Figures 5 and 6 offer a series of diagrammatic sketches to illustrate the suggested history of these large perlite bodies. The sketches are highly diagrammatic.

Two smaller disconnected perlite lenses are present southeast of the McDonald ranch deposit. One is about 0.5 mile long and located about 3 miles south of Highway 189 along the east side of Burro Cienega. The second has about the same size and shape and lies a mile east of the other. It probably represents a portion of the first body which was upthrown and repeated by faulting.

Southeast of the junction of Gold Gulch and Thompson Canyon, a small lens-shaped perlite body is present. At its western edge, it is cut off by a fault. It is highly fractured and intruded by quartz veinlets. It is surrounded by volcanic rocks of the early rhyolitic series. Lithologically it is the same as the Brock perlite. This small body almost certainly represents an eastward extension of the Brock body which has been upthrown by faulting.

A small dike of perlite occurs on the east side of Silver City Draw about 0.5 mile above its junction with Burro Cienega. The dike is 3 feet wide and cuts across the structure of the rhyolitic rocks for a distance of about 10 feet. The rhyolite on both sides of the dike exhibits a dense glassy zone up to about 2 inches thick.

RHYOLITIC AGGLOMERATE

The prominent scarp of Knight Peak is formed in a buff to pink massive rhyolitic agglomerate slightly over 400 feet thick. It is of chalky texture where weathered and frequently forms grotesque monoliths. Angular fragments of a dense banded rhyolite up to 6 inches in diameter occur, and fragments of gray perlite are common. The matrix consists of a poorly sorted rhyolitic tuff. Biotite, quartz, and sanidine phenocrysts, some as much as 2 mm in diameter, are present in the tuffaceous matrix.

The agglomerate is thickest at Knight Peak. Over the whole range, however, this unit is the most prominent of the early rhyolitic sequence. Over the Brock perlite, the agglomerate is only about 70 feet thick. It thickens away from the perlite dome along the strike. This suggests that the perlite body existed as a topographic high at the time when the agglomerate was being deposited. The fact that fragments of perlite and banded stony rhyolite from the upper part of the perlite constitute most of the coarsest material in the agglomerate supports this view.

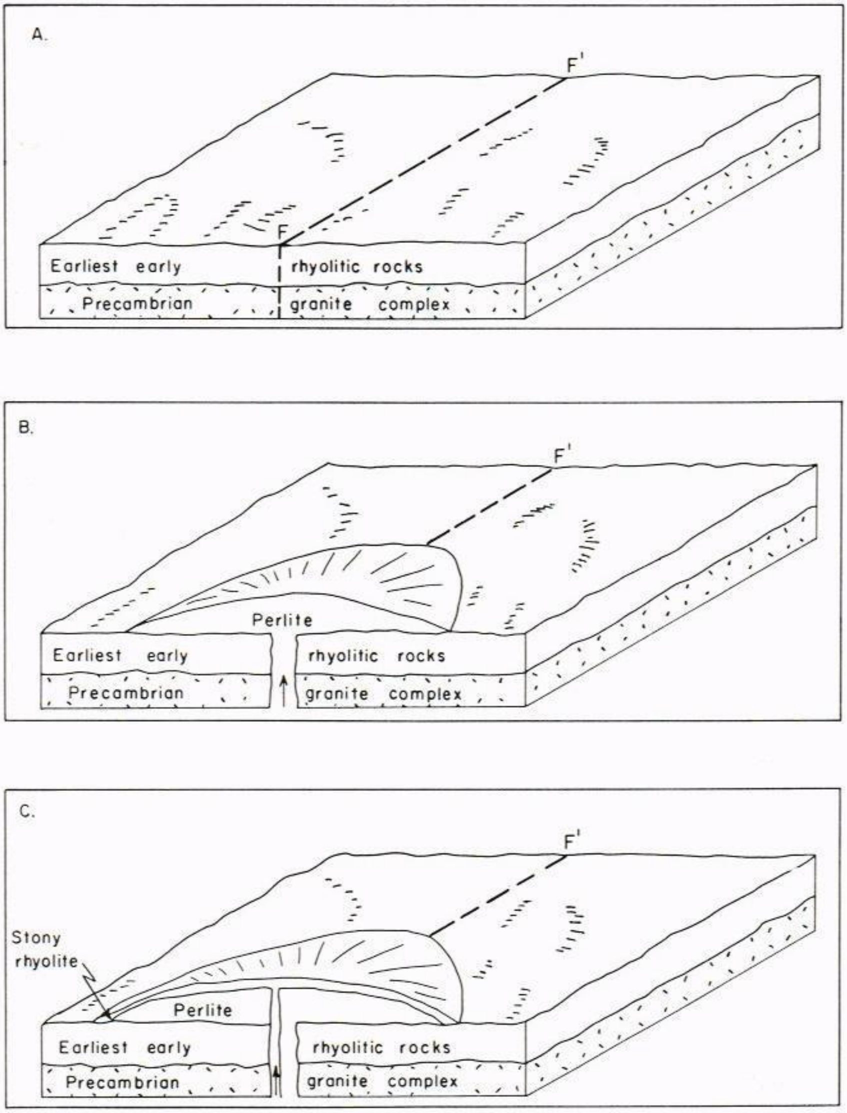

Figure 5

EVOLUTION OF PERLITE OUTCROPS

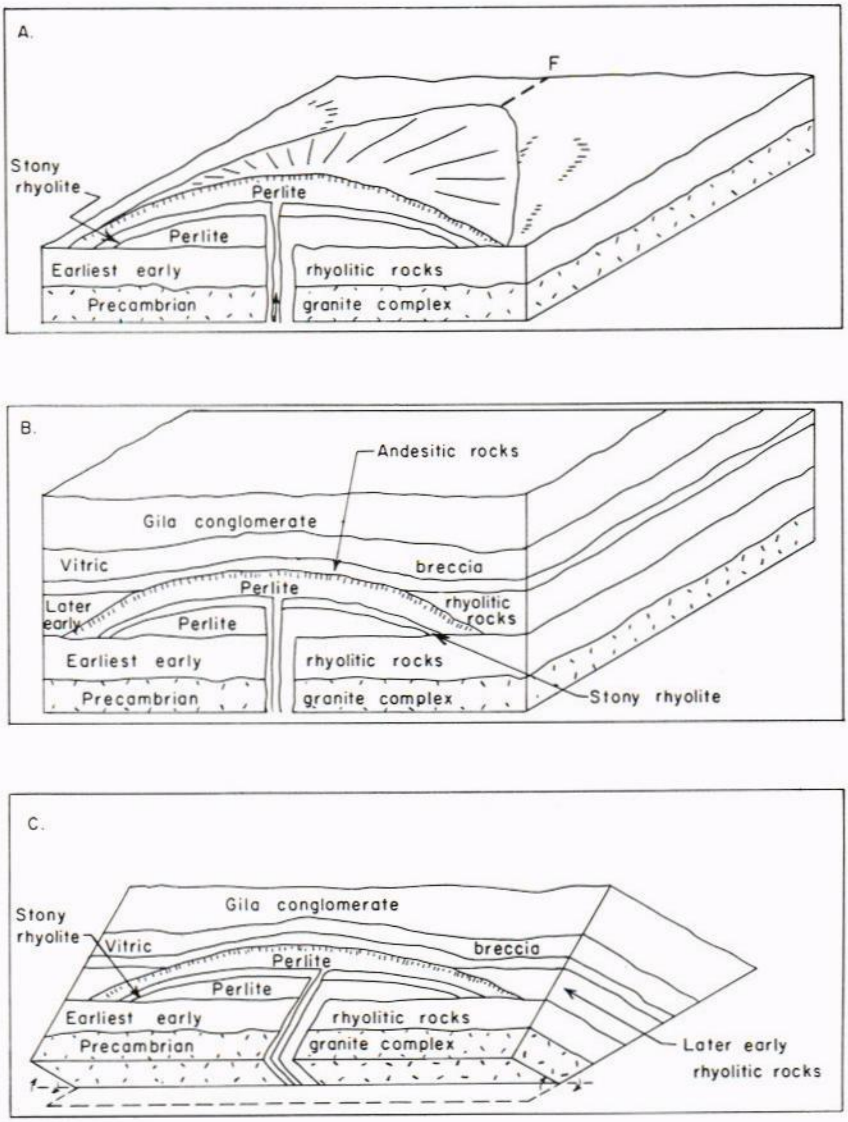

Figure 6

Evolution of perlite outcrops

PORPHYRITIC RHYOLITIC WELDED TUFF

Throughout the Knight Peak range, the agglomerate is overlain unconformably by a gray to pinkish-lavender porphyritic welded tuff. This rock is a gray chalky tuff at the bottom, with abundant sanidine phenocrysts up to 2 mm in diameter. It grades upward into a pink to lavender welded tuff, with common phenocrysts of quartz, sanidine, plagioclase, and biotite. Angular lithic fragments of rhyolite up to 8 mm in diameter are locally abundant. In some areas, the pink welded tuff grades upward into more of the chalky sanidine tuff. Elsewhere this upper unit is absent.

The lower and upper chalky portions contain up to about 20 percent phenocrysts, most of which are euhedral to subhedral sanidine in a matrix of welded rhyolite tuff. A few phenocrysts of plagioclase are present, but biotite is absent. The middle portion of this unit is conspicuous for its higher percentage of phenocrysts (40 to 60 percent), most of which are zoned euhedral sanidine up to 2 mm in diameter. Some of the sanidine crystals are embayed. Euhedral bent and shredded biotite phenocrysts are common. Anhedral to subhedral plagioclase phenocrysts (An_{37}-An_{44}) with albite and Carlsbad twinning are abundant. Granophyric phenocrysts of anhedral quartz and orthoclase are common. Euhedral to anhedral orthoclase phenocrysts with many glass inclusions are present. Some perthite occurs. A few orthoclase crystals show faint zoning and commonly contain small grains of biotite and magnetite. The groundmass of this middle unit is hypohyaline. Much quartz is present, with a very fine granophyric texture, giving the groundmass a plumose appearance. The groundmass is partially devitrified, and spherulites are common. Finely divided magnetite is present throughout the groundmass.

The porphyritic rhyolitic welded tuff is not present above the Brock perlite body. It reaches a maximum thickness of about 300 feet near the junction of C-Bar and Walking-X Canyons.

WATER-LAID TUFFS

Several thin-bedded, well-sorted, water-laid rhyolitic tuffs are present locally at the top of the lower rhyolitic series. They rarely exceed 20 feet in thickness. Their usual green color is caused apparently by the presence of finely divided green colloform grains in the tuff. X-ray analyses of this green substance were inconclusive; apparently the material is noncrystalline.

EARLY ANDESITIC ROCKS (Tea)

Andesitic flows and pyroclastic rocks unconformably overlie the early rhyolitic series continuously from Pines Canyon to within a mile of Highway 180, and for a distance of 2 miles between C-Bar and Walking-X Canyons, a mile south of the highway.

EARLY ANDESITIC LAVA

The andesite flows are dark-gray to purple aphanite, with abundant white to pink weathered feldspar phenocrysts. These lavas are concentrated on both sides of Pines Canyon and grade into andesitic tuffs southeastward along the strike. Euhedral to subhedral plagioclase phenocrysts, some as much as 4 mm in diameter, constitute about 30 percent of the rock and are contained in a cryptocrystalline matrix.

EARLY ANDESITIC LITHIC TUFF

Well-bedded gray to maroon andesitic lithic tuff overlies the early rhyolitic rocks unconformably throughout the northern third of the Knight Peak area. The same unit is present between C-Bar and Walking-X Canyons south of Highway 180. The tuff is composed of red to purple loosely packed aphanitic andesite fragments commonly less than an inch in diameter. Most of the fragments are roughly spherical, and the interstices commonly are filled with calcite.

Microscopically the unit is composed of spherical fragments of scoriaceous clear to brown glass, with a few plagioclase microlites in a fine-grained andesitic matrix. The matrix contains abundant reddish-brown globulites and cumulites. Euhedral to subhedral zoned augite phenocrysts are present in both the glassy fragments and the matrix, but are more common in the latter. Some augite crystals show twinning.

A few volcanic bombs occur in the lithic tuff approximately 0.5 mile north of Thompson Canyon. The early andesitic rocks are commonly from 10 to 20 feet thick. At Pines Canyon, however, the andesitic lava is from 1,000 to 1,500 feet thick.

VITRIC RHYOLITIC BRECCIA (Tvb)

A vitric rhyolitic breccia rests unconformably on the extrusive andesite in the northern half of the Knight Peak area. This unit attains a maximum thickness of about 2,000 feet on the east side of Gold Gulch, south of Thompson Canyon, for a distance of about a mile, and to the north between Thompson Canyon and Pines Canyon. Usually it is from 450 to 500 feet thick.

Megascopically the vitric breccia is a gray to pink volcanic breccia, with angular fragments of rhyolitic and andesitic rocks in a porphyritic pink tuff matrix. Individual lithic fragments up to 2 inches in diameter are common. Phenocrysts of biotite are visible in the matrix.

Microscopically the angular lithic fragments are set in a matrix of porphyritic welded tuff very similar in composition to the welded rhyolitic lithic tuff of the early rhyolitic rocks. Embayed euhedral and subhedral phenocrysts of sanidine with glass inclusions are common. Quartz is common as granophyric intergrowths. Euhedral plagioclase and fine-grained magnetite are present also. See Figure 7. The vitric breccia contains lithic fragments of all earlier volcanic rocks. Most of the larger

Figure 7

PHOTOMICROGRAPH OF VITRIC RHYOLITIC BRECCIA

Plane polarized light. x 22.

fragments are angular, but layers of well-sorted subrounded lithic fragments occur in a fine-grained siliceous matrix. This seems to indicate that portions of this unit are water laid.

MIDDLE RHYOLITIC ROCKS (Tmr)

South of Thompson Canyon, the vitric rhyolitic breccia is overlain unconformably by a series of tuff beds and tuffaceous breccias ranging from gray to greenish gray to white. In sharp contrast to the earlier rhyolitic rocks, this group contains almost no phenocrysts. Nearly all the units are even bedded and less than a foot thick, although some beds are as much as 6 feet thick. The estimated total thickness of the middle rhyolitic rocks is 100 feet.

This series of rocks is extremely variable. Most of the units, however, contain abundant angular to rounded pumiceous and glassy fragments up to 0.5 mm in diameter. Some units contain sparse euhedral to subhedral quartz phenocrysts up to 0.2 mm in diameter. The dense ground-mass is chocolate brown to green. The color of the groundmass is clue to the presence of abundant extremely small brownish-green globulites.

These middle rhyolites are missing above the Brock perlite. Here the vitric rhyolite breccia is overlain by the Gila conglomerate. This suggests that the area around the perlite dome, covered now by andesitic and rhyolitic rocks, was still a topographic high when the middle rhyolites were being deposited off its flanks. Undoubtedly the dome served as a source area for many of the water-laid beds of the middle rhyolites. The middle rhyolitic rocks overlie the extrusive andesite unconformably south of Highway 180 where the vitric rhyolite breccia is absent. The slabby, even-bedded units of the middle rhyolite are used extensively by the ranchers in the area as riprap for earth dams and stock tanks.

INTRUSIVE ANDESITE (Tia)

A gray to grayish-red fine-grained porphyritic intrusive andesite cuts across the bedding of the rhyolitic rocks in many places. These masses are usually dikelike, although several are plug shaped. Locally inclusions of Precambrian granite up to 6 mm in diameter are visible.

Two dikes of andesite about 30 feet wide cut the rhyolite beds perpendicular to their strike at Knight Peak. The rhyolite has a baked zone at its contact with the andesite. A north-trending andesite dike about 10 feet wide cuts through the rhyolites a mile northeast of Soldiers' Farewell Mountain. The northern extremity of this dike is a black glass. An andesite dike intrudes the rhyolites on both sides of C-Bar Canyon just above its junction with Walking-X Canyon. An arcuate andesite dike is intruded along a part of the Taylor fault and a crossfault east of Whiterock Draw near the eastern edge of the Knight Peak range. Andesite is intruded also at many places along the Malone fault. The largest of these masses is along the base of Knight Peak. Intrusive andesite is present along a strike fault on the dip slope of Knight Peak. It is intruded against rhyolitic rocks to the west and extrusive andesite to the east and contains numerous inclusions of both these rocks. This rock also intrudes many strike faults between Silver City Draw and Highway 189.

A pluglike andesite body is present a mile south of C-Bar ranch. The walls of the body are steep and cut across the bedding of the rhyolite. This mass is more than 1 mile long and nearly 0.5 mile wide. Another andesite is present between C-Bar and Walking-X Canyons just above their junctions.

Microscopically the rock is hypohyaline to holocrystalline porphyritic andesite whose major constituents are glass, euhedral corroded plagioclase, corroded olivine, and augite. Magnetite is abundant throughout the rock. Some specimens display trachytic to pilotaxitic texture (fig. 8). The estimated mode for one sample taken between Silver City Draw and Highway 189 is given in Table 3.

TABLE 3. ESTIMATED MODE FOR THE OLIVINE-AUGITE ANDESITE

MINERAL	PERCENT
Glass	51
Plagioclase	20
Olivine	7
Augite	17
Vesicles	5
Magnetite	tr
Total	100

Most of the intrusive andesite bodies are associated with faults. It is suggested that the andesitic magma found fault zones to be the easiest paths of migration. At several places, xenoliths of an earlier andesite are engulfed in a later andesite matrix, suggesting that several periods of intrusion accompanied successive movements along the same faults.

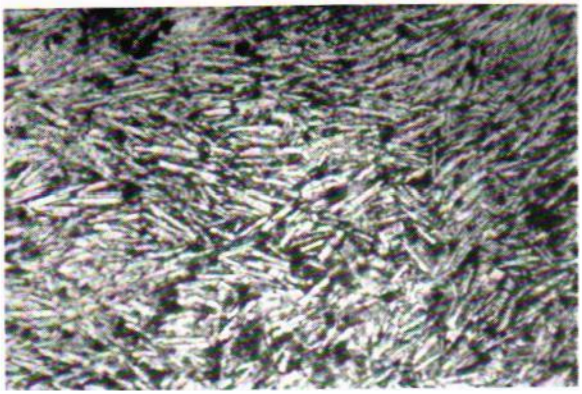

Figure 8

PHOTOMICROGRAPH OF INTRUSIVE ANDESITE

Note the alinement of minute plagioclase laths.
Plane polarized light. x 22.

Tertiary-Quaternary Rocks

The middle rhyolitic rocks locally grade upward into the Gila conglomerate. Lowermost beds of the Gila are tuffaceous and are locally apparently conformable with the middle rhyolitic sequence. At other places, an unconformity must exist between the rhyolitic rocks and the Gila, because the lowermost beds of the Gila are composed almost entirely of fragments of the rhyolites from a nearby source.

The Gila conglomerate is a variable unit. The bottom of the formation is quite different from the top. Yet individual beds are impossible to distinguish. The pebbles and cobbles at the bottom of the Gila are almost entirely fragments of the Tertiary volcanic rocks. Most of the cobbles are angular to subangular; a few are slightly rounded. These lower beds contain a few cobbles of Precambrian rocks, especially the granite. The uppermost beds, on the other hand, contain mostly Precambrian cobbles and boulders and only a small percentage of Tertiary volcanic fragments. The entire formation is poorly sorted, and boulders as much as 6 feet in diameter are common, especially in the upper beds (fig. 9). In the lower beds, most of the fragments are less than 4 inches in diameter.

The cement is calcareous and buff to pink, but in some places reddish. The lower beds are well consolidated, whereas the uppermost layers are poorly cemented. This variation in cementation is useless as a stratigraphic tool, however, since it is completely transitional.

A section of Gila conglomerate nearly 5,000 feet thick is preserved along Pines Canyon. Nowhere else north of Highway 180 is the Gila so thick. South of Highway 180, the Gila conglomerate is apparently *much* thicker. This greater thickness is doubtful, however, because the section is probably repeated by faulting. Most outcrops are badly weathered, but locally, as along Pines Canyon, exposures are fresh.

The attitude of the beds in the Gila conglomerate suggests a further reason why this unit appears so thick locally. Bedding in the upper part of the Gila conglomerate is very poor, so that accurate measurements of dip are extremely difficult. In sec. 6, T. 22 S., R. 14 W., however, just west of China Draw south of Highway 180, a dip of N. 11° E. was measured. Other less certain observations point to a gentler dip in the Gila, especially toward the top of the unit, than in the underlying volcanic sequence. This suggests that much of the Gila conglomerate was deposited after downward movement of the fault block in the Knight Peak area began along the Taylor fault. Probably much of the postfaulting Gila conglomerate was derived from the Big Burro Mountains to the northeast. Much of it, however, probably was derived from the erosion of the volcanic sequence within the Knight Peak range, as well as from the lower beds of the Gila itself.

The poor sorting, the many coarse angular to subangular fragments,

Figure 9

LARGE BOULDERS IN THE GILA CONGLOMERATE

and the numerous large boulders suggest that the Gila is a fanglomerate derived from the Big Burro Mountains to the east. As these mountains were uplifted, their cover of Tertiary volcanic rocks was stripped away; as uplift continued, their Precambrian rocks were partially eroded.

The Gila conglomerate is difficult to correlate. In the vicinity of Silver City, a similar conglomerate occurs in about the same stratigraphic position. The source of this conglomerate is a combination of Precambrian and Paleozoic rocks. Along the Gila River to the northwest, where the unit crops out, it is derived from the rocks of the Mogollon Plateau immediately to the north. In southeastern Arizona, it is reported to be of local derivation (Knechtel, 1936). The conglomerate sequence in the Knight Peak area is tentatively correlated with the Gila conglomerate of Pliocene-Pleistocene age on the basis of its stratigraphic position above the Tertiary volcanic rocks, which are generally considered to be of Miocene age (Callaghan, 1953).

Quaternary Rocks

Rocks of Quaternary age include several groups of volcanic rocks and sediments. The volcanic rocks are concentrated in the southern third of the Knight Peak area. The sediments, mostly pediment gravels and stream deposits, are found in all parts of the area.

Compared to the Tertiary volcanic sequence, these late volcanic rocks bear strikingly different structural relations to their surroundings. They are conelike masses which thin in all directions away from a center and overlie the tilted rocks of the Knight Peak area with an angular unconformity. Some of these late volcanic rocks are present only in old stream valleys and other topographic lows which were present at the time of their extrusion. Away from the cones, which were probably centers of extrusion, flow banding usually indicates that these units were poured out over the existing topography after most of the tilting of the Knight Peak range had occurred.

LATE RHYOLITIC ROCKS (Qlr)

Four prominent rhyolite cones protrude from the bajada south and southeast of Soldiers' Farewell Mountain. The rhyolite of all four is a white to buff dense porphyritic aphanite.

Microscopically the rhyolite is a felsophyric porphyry with sparse phenocrysts of granophyric quartz and euhedral corroded orthoclase. A few corroded biotite phenocrysts as much as 1.5 mm long are present. Very fine anhedral magnetite grains are common.

Along McDonald Draw on the Grant County—Luna County line, several remnants of a late rhyolite are present. These are part of the more extensive rhyolite flows of the Cow Springs Hills to the east in Luna County. Microscopically this unit is similar to the late rhyolitic felsophyre except that quartz phenocrysts are absent. Instead, zoned corroded phenocrysts of plagioclase are present.

Outcrops of this late rhyolite are restricted to the southern and southeastern margin of the Knight Peak area.

RHYOLITE DIKES AND INTRUSIVE BODIES (Qrd)

Clustered in secs. 9, 10, 15, 16, T. 22 S., R. 15 W., along the west side of the Knight Peak area 3 miles northwest of Soldiers' Farewell Mountain, is a group of rhyolite dikes, up to 100 feet wide, and of larger, more irregular, intrusive bodies. These rocks are white to pinkish-white porphyritic rhyolites. Fluidal banding parallel to the dike borders is usually present. The contiguous wall rock contains baked zones, and the dikes have glassy chilled borders.

Microscopically the rhyolite is a felsophyric porphyry with abundant granophyric intergrowths of quartz and feldspar. Altered feldspar phenocrysts up to 1 mm long are present. Abundant fine-grained anhedral magnetite is scattered throughout the groundmass.

LATE DACITE FLOWS (Qd)

Soldiers' Farewell Mountain is composed entirely of a gray to tan aphanitic dacite porphyry. This unit is found only in this peak and off its flanks to the north and east, where it overlaps the tilted earlier volcanic rocks.

The dacite is a porphyritic lava with sparse phenocrysts of euhedral plagioclase up to 0.5 mm long, euhedral hornblende, and biotite, set in a trachytic to felsophyric groundmass of plagioclase microlites and glass or quartz. In the upper portion of the flow, quartz is more abundant than near the bottom. Very fine anhedral magnetite is present throughout the groundmass.

LATE ANDESITIC ROCKS (Qla)

Remnants of thin horizontal andesitic pyroclastic rocks are present in many of the low areas around Soldiers' Farewell Mountain. The largest of these remnants lie due west of the peak in the low valleys, and to the east of Burro Cienega as a cap rock on a low ridge. Abundant smaller horizontal remnants of these beds occur along many of the streams in this southern portion of the Knight Peak area. The late andesite overlies older rocks with an angular unconformity.

Megascopically the andesite is a gray to purplish-black tuff. Andesite cinders 3 to 10 mm in diameter are loosely packed and cemented with crystalline calcite and clay.

Microscopically the andesite fragments are porphyritic vitric tuffs. Euhedral phenocrysts of altered feldspar and biotite are set in a matrix of brown andesitic glass. Abundant plagioclase microlites occur in the glass. Many of the phenocrysts are replaced and overgrown by granophyric quartz.

The late andesite is the youngest of the volcanic rocks in the Knight Peak area, inasmuch as it overlies unconformably all the other volcanic rocks.

PEDIMENT GRAVELS AND HIGH-LEVEL GRAVELS (Qpg)

The gravels of the bajada west of Knight Peak are derived from the pediment of Precambrian granite. They are rich in subangular to rounded grains of quartz and undecomposed feldspar. The majority of the material is less than 2 inches in diameter. The pediment gravels south and southeast of the Knight Peak area are derived mainly from the Tertiary and Quaternary volcanic rocks.

High-level gravels occur throughout the area and in many cases mark the location of abandoned drainage. They are compositionally similar to the pediment gravels and are distinguished from them only by their location.

The thickness of the high-level gravels is unknown, but most deposits seem to be relatively thin. The thickness of the bajada deposits to the south is also unknown. West of Knight Peak, the pediment gravels are 20 feet thick at the margin of the map area; they merge to the south and southwest with the bolson deposits of the Lordsburg bolson.

ALLUVIUM (Qal)

Nearly all the stream valleys contain deposits of alluvium. This material is predominantly of sand and silt size, but cobbles and even large boulders are not uncommon. The thickness of alluvium ranges from place to place even within a single valley. Excavations for earth dams in Thompson Canyon and other streams reveal that thicknesses of 40 feet of alluvial material are common.

Structure

The northern half of the Knight Peak range is bounded on the west by an irregular normal fault known as the Malone fault. From a point about 3 miles south of C-Bar Canyon, however, the Malone fault can no longer be traced with certainty. It is possible that it passes out into the Precambrian granite at this point. Several abandoned fluorspar mines are located along a fault zone which is in line with a southward projection of the Malone fault. No certain field evidence for such an identification could be found. The eastern boundary of the range is marked by a high-angle normal fault, also irregular in trace, named the Taylor fault in this report. It is along this fault that the major movement in the Knight Peak area occurred. This evidence establishes the Knight Peak range as a tilted fault block of the type so typical of the Basin and Range province. Hinge-type movement seems to have occurred, the northern half of the range receiving the greatest downward displacement. This is shown by the movement along the Malone fault.

The Malone fault has an extremely irregular trace. This irregularity is pronounced between Thompson and Knight Canyons, where toothlike projections into the granite are present. These indentations are from 200 to 500 feet long and may be the result of the ripping out of joint blocks of the granite by the downdropping block as it slid by. A pronounced change of the strike of the fault occurs just north of Thompson Canyon. South of Thompson Canyon, the Malone fault strikes roughly N. 25° W., whereas its strike north of the canyon is about N. 75° W.

The Malone fault is a high-angle normal fault which dips about N. 70° E. Its attitude can be measured in a roadcut along Highway 180 (fig. 10). The trace of the fault is slightly displaced toward the northeast in nearly every stream valley it crosses. The location of old mine shafts and the depths at which they are reported to intersect the fault plane also indicate a dip of about N. 70° E. (A. A. Leach, personal communication). The fault zone varies from a few feet wide to at least 80 feet.

The amount of displacement along the Malone fault is variable but never very great. No exact measurement is possible, but the early rhyolitic rocks are faulted against the granite along the entire Malone fault. The stratigraphic throw probably varies from a few feet to possibly 300 feet. South of C-Bar Canyon, where no faulting has occurred between granite and volcanic rocks, these same early volcanic rocks are deposited unconformably on the Lobo(?) formation.

The Taylor fault, along the northeast side of the Knight Peak range, was first mentioned in print by Gillerman (1952, p. 262), who gave it a vague location on his map. It is usually difficult to locate exactly because of the weathering of the Gila conglomerate, which is always present along the fault. A few good exposures occur.

The fault trace across stream valleys indicates that the Taylor fault

Figure 10

MALONE FAULT

Roadcut along Highway 180. View looking north.

is a high-angle normal fault which dips toward the southwest. Exact measurements of the angle are not possible.

The amount of displacement along the Taylor fault is great, probably on the order of several thousand feet. The whole Tertiary volcanic series and some of the Gila conglomerate have been depressed below the surface of the granite.

Intrusive andesite is present at many places along the Malone fault, as well as along the Taylor fault just east of Whiterock Draw, a few miles south of Highway 189. Chrysocolla mineralization occurs along the Taylor fault just north of Chocolate Peak.

Just north of the junction of Silver City Draw and Burro Cienega, a horst about 4 miles long and 1 mile wide is exposed by the erosion in Silver City Draw. The trends of the horst and of Knight Peak range arc parallel. The horst is bounded on the east by the Prevost fault, a high-angle normal fault which dips northeastward. The fault along the west side is poorly exposed, and its attitude is not known.

Numerous high-angle crossfaults transect the Knight Peak range. Displacement along these nearly vertical faults is from a few feet to about 100 feet. Their average trend is perpendicular to the trend of the range. A system of such faults is present along Thompson Canyon. The entire area is shattered, resulting in the uplift of the block north of the canyon. Just northeast of Knight Peak are two northeast-trending crossfaults, and 2 miles south of Highway 189, on the east side of Burro Cienega, several high-angle crossfaults occur.

A slight amount of displacement has occurred along a diagonal north-trending fault on the dip slope of Knight Peak. To the south, this fault is parallel to the Malone fault, but east of Knight Peak, it veers to the north.

As many as three sets of parallel tilted fault blocks make up the widest part of the Knight Peak range. Many of the boundary faults of these blocks are covered. No folding was discovered in the area. Dips of beds in the tilted blocks range in general from about 30 degrees to nearly 60 degrees. Gentler dips are rare except in the upper portion of the Gila conglomerate.

The faulting and tilting can be dated only as Quaternary. The Gila conglomerate is generally accepted to be Tertiary-Quaternary in age and is the youngest unit involved in the faulting and tilting.

Geologic History

Any attempt to unravel the history of the Knight Peak area must include consideration of evidence from the surrounding region as well as what is recorded in the rocks within the area.

Little is known as to the origin of the Precambrian granite. Paige and Spencer (1935, p. 60) consider that " a few small areas of schist and quartzite point to the existence of ancient seas." They worked in the region around Santa Rita about 50 miles to the northeast. Before the beginning of the Paleozoic era, diabase dikes were emplaced.

There followed a period of uplift and erosion of the granite surface, after which the area was depressed beneath the sea. The first sediments were predominantly clastic (Bliss sandstone), and by Ordovician time the sea began to clear, so that limestone became the predominant rock type. In the Knight Peak area, Upper Ordovician to Lower Cretaceous rocks are missing, but the history of the area was probably similar to that of the Silver City region a few miles to the northeast. In the Silver City region, marine deposition continued until near the end of the Permian, when the sea withdrew. After prolonged erosion throughout the Triassic and Jurassic, the sea returned in Cretaceous time, and the Beartooth quartzite and Colorado shale were deposited. After Colorado time, the Knight Peak area was uplifted, probably as a result of the beginnings of the Big Burro uplift. This uplift exposed the entire Paleozoic sequence and the Cretaceous rocks to erosion, and all but a few small remnants of these rocks were removed. Probably in late Cretaceous time, the Lobo(?) arkose was deposited in basins and valleys as a terrestrial deposit.

Volcanic activity began in the Tertiary, probably in Miocene time. Successive episodes of volcanism produced the early rhyolites, the early andesite, the middle rhyolites, and finally the intrusive andesite. Near the close of the Tertiary, the Tyrone stock was intruded under the eastern edge of the Big Burro Mountains, and these mountains began to shed their cover of Tertiary volcanic rocks. These clastic rocks were laid down to the west as the lower part of the Gila fanglomerate. In the waning phase of their uplift, the Big Burro Mountains shed great quantities of Precambrian rock to the west.

After the deposition of the lower Gila in Tertiary(?) time, the first major movement occurred along the Taylor fault. Downward movement continued here and produced a basin in which the upper Gila beds accumulated. Finally, the tilting in the northern half of the Knight Peak range became sufficient to cause the Malone fault. Several more recent episodes of faulting have produced the numerous crossfaults.

The late phases of volcanic activity followed and produced the late rhyolites, andesites, and dacites which overlap the truncated tilted beds of the earlier volcanic rocks. The cutting of the pediment which began with the Big Burro uplift is continuing. Present-day streams are cutting into older high-level gravels.

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