GEOLOGY AND MINERAL RESOURCES

OF

A PORTION OF

TOWNSHIP 10 NORTH

RANGE 1 EAST

SAN BERNARDINO MERIDIAN

SAN BERNARDINO COUNTY

CALIFORNIA

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Date: May, 1956

INTRODUCTION

Reconnaissance geological investigations for mineral deposits in Township 10 North, Range 1 East was conducted for the possible occurrence of mineral deposits on Southern Pacific lands. McCulloh (1954) geological maps of the Nebo and Yermo quadrangles were used as an aid in the field mapping.

The Calico colemanite deposits in the southeastern portion of Twp. 10N., Rge. 1E. opened in 1884 were worked on a large scale until 1907 by the Pacific Coast Borax Company when the easily recoverable reserves were depleted. The company continued to purchase borates from other operators until the mid-twenties. During the most active period, the Calico colemanite mines were the world's principal source of borate, having a total production value of over $9,000,000.

Recent tourist interest in the area has prompted a drive for the creation of a park in the borax district.

Location

The southern portion of Twp. 10N., Rge. 1E., SBM., lies east of Barstow, California, and includes 14 square miles. The area lies about six miles east of Barstow and 1/2 mile north of Yermo, California. The area is readily accessible by auto over the Yermo-Camp Irwin Road and the Mule Canyon Road. These roads are maintained by the county.

Previous Work

Gardner and Irwin (1940) mapped the Calico Mountain area on a scale of 1:63,360. McCulloh (1954) mapped the Yermo and Nebo quadrangles, which includes the area, on a scale of 1:24,000. The location of the borax mines were included on a map compiled by Wright (1953). A history of the borax operations was also included in the report.

Climate and Topography

The climate is arid, the annual precipitation being about five inches. The vegetation is the typical desert variety, desert holly and mesquite, which grow south and west of the Calico Mountains. This portion of the township is bounded on the northeast by the Calico Mountains and on the southwest by a low range of hills to the east of Lead Mountain. The altitude ranges from about 1,930 feet to 3,500 feet.

Most of the southeastern Calico Mountain area is drained by way of Mule Canyon, which flows southward to the alluvium valley. A southeasterly main drainage drains the area north of Yermo. All the streams in the area are intermittent.

FIELD WORK

Reconnaissance geological mapping on a scale of 1:2,000 on aerial photographs (Fig. 1) was started on April 26, 1956 and completed on May 8, 1956. Five field days were spent in reconnaissance mapping, while one field day was spent in cutting samples for assays. Three days were spent in writing the report.

Southern Pacific Company Ownership

Sections 25 (except SE¼) and 29 (except 3/4 of the S½).

GEOLOGICAL SETTING

The rocks which are exposed in the area are essentially Miocene lake bed deposits and Pliocene intrusives, Quaternary gravels and recent sands.

The rock units and their relationship to one another are shown on the map and discussed below.

Tertiary (Miocene)

Miocene waterlain sediments are widespread in the area. The area was a part of the Calico basin, within which the sediments contain a wide variety of materials.

These rocks in the area have been separated into two formations, the Barstow formation and the Daggett formation.

Barstow Formation

The Barstow formation in the area is exposed north of the Calico fault. Only a small segment crops out south of the fault. The formation is separated into the Mule Canyon member, the Borate Andesite member and the Sunrise Canyon member.

Mule Canyon Member

The Mule Canyon member of the Barstow formation is the lowest member exposed in the area. It ranges in composition from sandstones to shaly borax beds (Fig. 2).

Limestone unit. The limestone unit is exposed in Sections 13, 23 and 24. The unit is composed of cream to white fine grained tuffaceous sandstones, shales and limy shales. These layers are thin bedded and there is a slight suggestion of cross bedding in several places.

Near the top of the unit, two one to three foot beds of dark brown, cherty limestone crops out. A six inch bed of chalcedony lies interbedded with the limestones. It is a dense black to brown chalcedony. The unit generally strikes N 80° E and dips 40° to the south. It has been broken by small folds which parallel the strike of the beds. It has a total thickness of about 100 feet.

Cream sandstone unit. Light colored sandstones, shales, limy shales, and mudstones are exposed throughout the Mule Canyon member. The unit is slightly tuffaceous and generally is very fine grained. The unit generally strikes N 80 E and dips 30° to the south. It has a total thickness of about 200 feet.

Figure 1:

AERIAL PHOTO INDEX

T10N, R1E

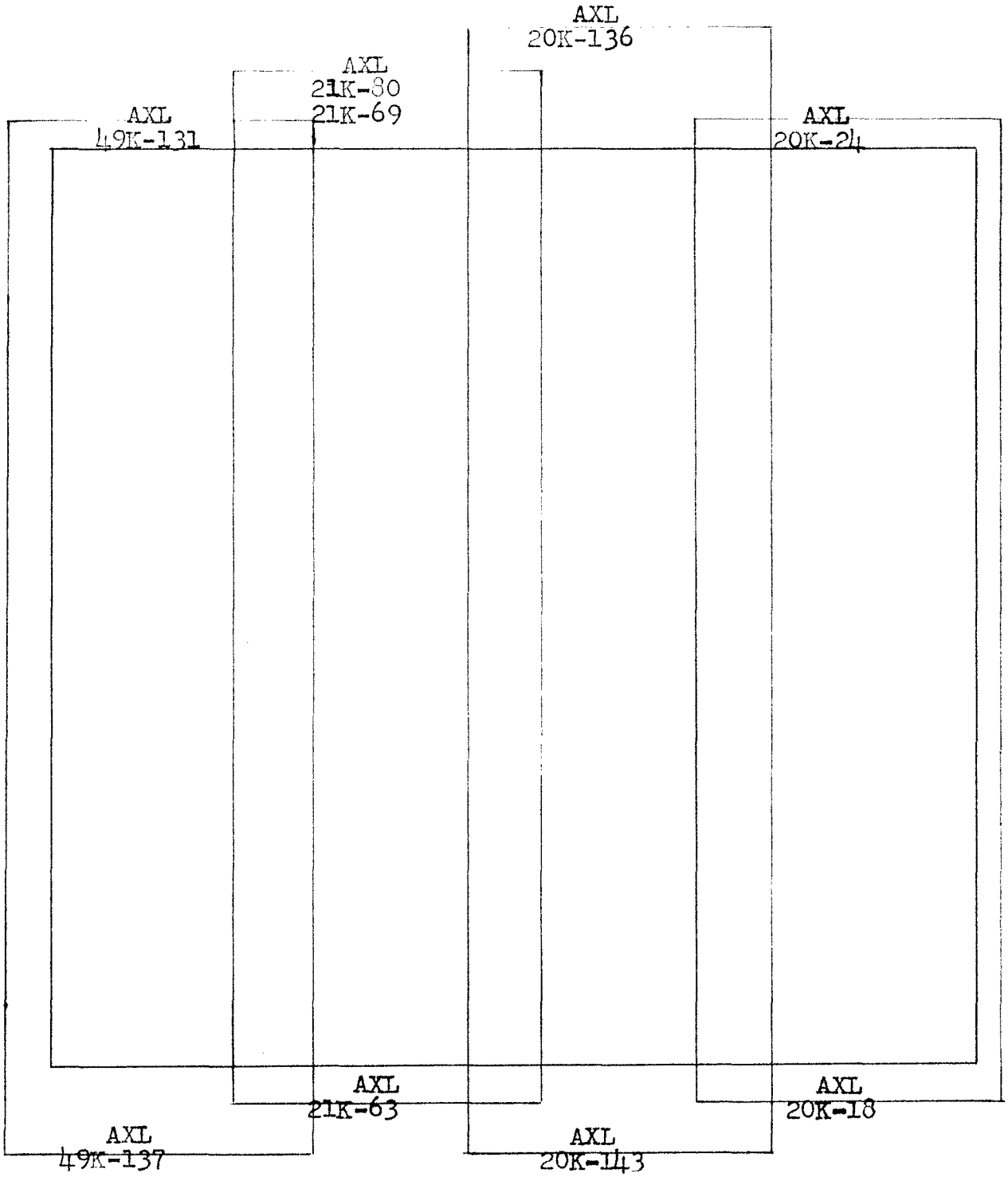
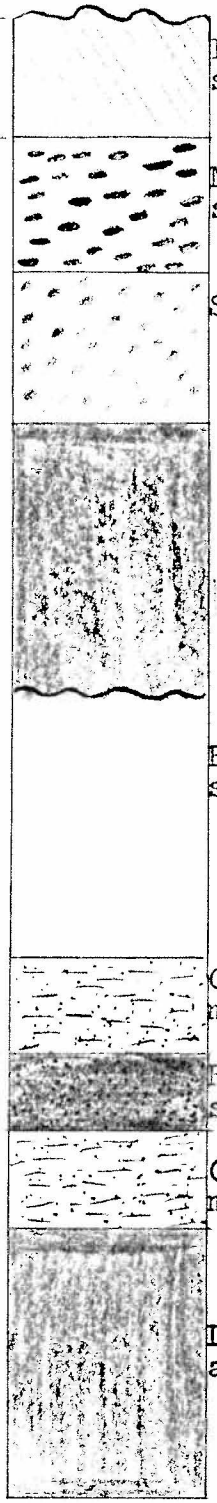


Figure 2:

STRATIGRAPHIC COLUMN

BARSTOW FORMATION

T10N, R1E



SUNRISE CANYON MEMBER	Upper Unit	50'	Limestones, sandstones, shales, chert beds.
	Middle Unit	100'	Massive sandstones, limestones, shales.
	Lower Unit	70'	Sandstones, limestones, shales.
BORATE ANDESITE MEMBER		50'-200'	Andesite flows and breccias.
MULE CANYON MEMBER	Borax Unit	70'	Borax beds, cream sandstones, shales, limestones.
	Cream Sandstone Unit	25'	Cream sandstones, shales, mudstones.
	Reddish-brown Sandstone Unit	20'	Reddish-brown sandstones, shales, mudstones.
	Cream Sandstone Unit	25'	Cream sandstones, shales, mudstones.
	Limestone Unit	100'	Limestone, shales, ash beds, sandstones.

Red-brown sandstone unit. The reddish brown sandstones, shales and mudstones lie near the middle of the Mule Canyon member of the Barstow formation. The unit is separated from the limestone unit by about 50-75 feet of cream sandstones and shales. These beds are separated from the borax unit by about 50-100 feet of cream sandstones and shales. The beds are exposed in the core of an anticline. The general trend of the beds is N 80 ^{E}, dipping 35° to the south and east.

Borax unit. There are four main borax beds near the top of the Mule Canyon member. The unit is separated from the borate andesite member by about 30 feet of cream to brown colored sandstones, shales and mudstones. The borate minerals occur in sedimentary beds of different kinds, mostly clay and shale largely derived from volcanic ash and associated with limestone and shale.

The borax and ulexite mineralization resulted from the repeated evaporation of intermittent shallow lakes or playas that received saline-rich drainage from considerable areas. These deposits, including the borax marshes, began to accumulate in late Miocene time. The mineral matter in the lakes was augmented in places by the boron-containing products from solfataras and hot springs, which represent the last stage of the Tertiary volcanic activity. Much of the boron was probably in the form of boric acid. It first became fixed as ulexite by the reaction of boric acid with the lime and soda derived from volcanic ash and clays as a result of the decomposition of the ash. The unit grades out to the west.

The upper bed of borax mineralization is about five feet thick and has interbedded gypsum stringers in shales. The borax shales are laminated and are strongly contorted in several areas. The shales are black beneath the surface, but were bleached white on the weathered portion.

The second bed of borax mineralization is about 8 feet thick and is an alteration product of the boric acid reacting with limestone. This bed is separated from the upper bed by a series of thin bedded shales and sandstones about 15 feet thick. The bed is associated with a dark green mudstone which underlies it. This bed was used as a marker guide to locate the exact borax bed being observed in the district. The borax bed had several good areas of borax mineralization in it.

The third borax bed lies about 10 feet stratigraphically below the second borax bed. This bed is about two feet thick. It is a massive borax bed.

The lower borax bed, averaging about 5 feet, has not been extensively prospected. The bed is about 15 feet stratigraphically below the third bed. It is a shaly borax bed with laminated shales interbedded with the borax mineralization.

Several other localy shaly borax beds cropped out in Sections 23 and 24, but they were only local and did not contain borates in large quantities. Some (petroliferous-smelling when broken) concretions occur in a 2 foot bed just below the second borax bed.

Colemanite, howlite, hydroboracite (?) and seamanite borax minerals are associated with gypsum in the borax unit. The borax unit generally trends N 80 E dipping 30 to 50 degrees to the south. Generally the beds pinch out to the west but become thicker to the east.

Borate Andesite Member

During the deposition of the borax unit of the Mule Canyon member, the Calico basin was very marshy. After the borax beds were covered by about 20 feet of sandstones and shales, the general area was uplifted and probably some of the lake beds were stripped off. There is a slight

suggestion of an unconformity between the Mule Canyon member and the Borate Andesite Member (Fig. 3).

The lower bed is a lavender to violet hornblende dacite-andesite flow. It is about 30 feet thick and flowed over the Mule Canyon member. The direction of flow appears to be to the south.

A small 20 foot bed of andesite porphyry breccia lies above the lower unit. It is composed of angular to subangular fragments and suggestive of landslide breccia rather than a flow breccia. The fragments range in size from a pebble to a small boulder. The unit is only found in scattered localities, thus suggesting that it is only local in character.

A small bed of cream colored andesite porphyry lies above the breccia, but no fragments of the breccia were observed in this unit. It is not extensive and averages only six feet thick.

The remainder of the member is composed of a dark green to gray andesite-latite porphyry which is about 100 to 150 feet thick in Section 24.

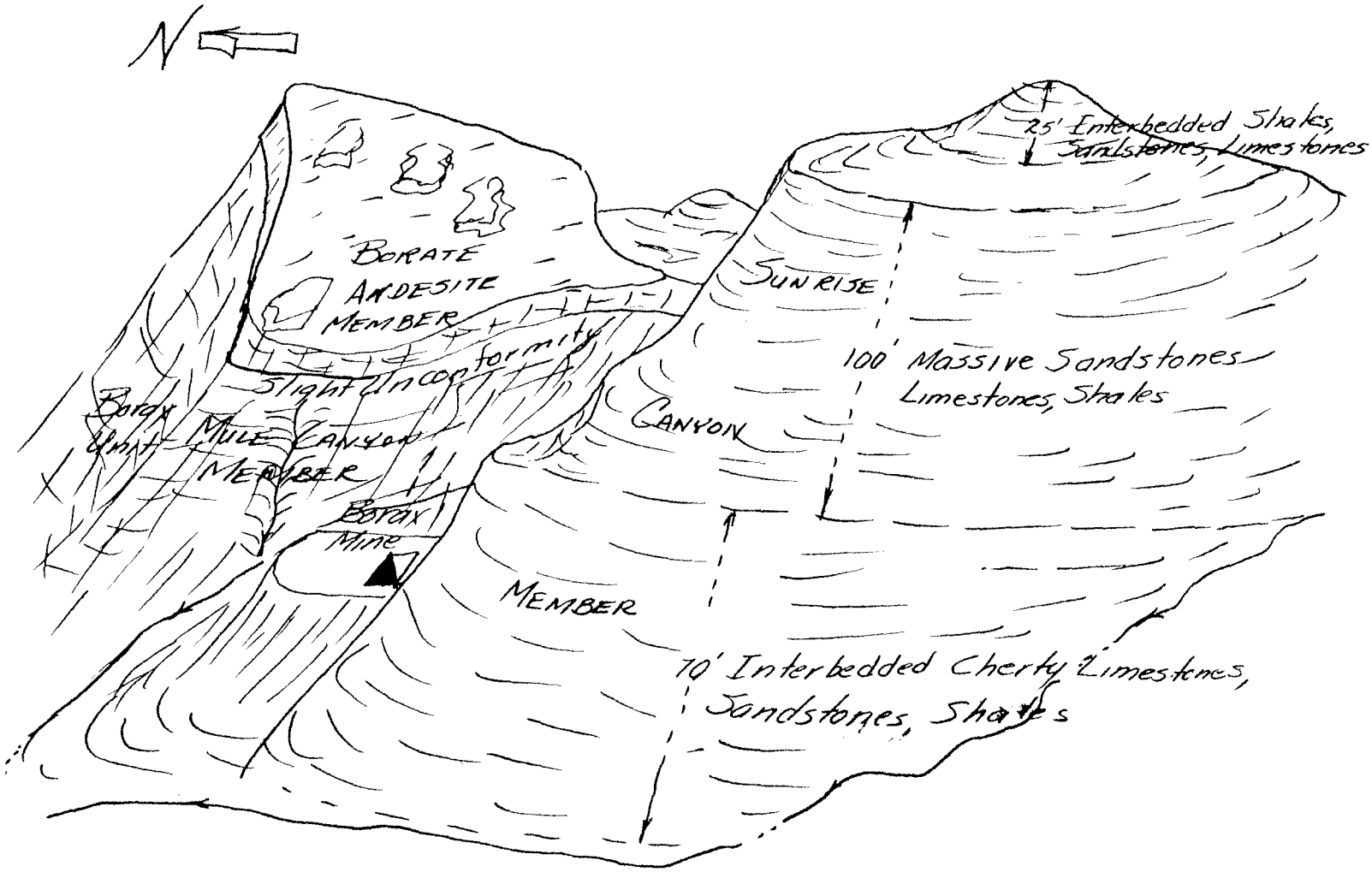
Sunrise Canyon Member

After the flows of the Andesite Borate member were laid down, the Calico basin again subsided. The time interval between the last lava flow and the deposition of the Sunrise Canyon member was very short as there are no fragments of andesite in the lowest bed of the Sunrise Canyon member (Fig. 2). The basin was deepest east of the area as the units in Mule Canyon are near shore type sandy sediments. In Twp. 10N., Rge. 2E. the units are more tuffaceous and less sandy, indicating that there was volcanic activity during the close of the Miocene.

Lower Unit (west facies). The best exposures of the lower unit are

FIGURE 3:

ISOMETRIC VIEW OF RELATION OF MULE CANYON MEMBER, BORATE ANDESITE MEMBER, AND SUNRISE CANYON MEMBER



in Sections 24 and 25. The lower unit is comprised of 70 plus feet of interbedded dark brown, cherty limestones and cream to brown, slightly tuffaceous sandstones and shales. A siliceous limestone bed rests directly on the Borate-Andesite member. Overlying this is about 20 feet of shales and tuffaceous sandstones. A 1 foot, cream colored tuffaceous sandstone and a 1 foot siliceous limestone separated by three feet of shales and tuffs overlie the lower shales and tuff. A series of limestone and sandstone beds 40 feet thick comprise the remainder of the unit.

Middle unit. About 100 to 125 feet of massive tuffaceous sandstones with interbedded thin limestones and arkosic sandstones overlie the lower unit (see Fig.3). The tuffaceous sandstones are light brown in color. About 30 feet from the base of the unit are scattered 1 foot beds of brown, cherty limestone which contain casts and molds of palms (?). These molds range in size from small roots to 8 inch trees. Overlying the limestone is a marker bed of quartzose sandstone. In Section 23, where the lower unit has been removed by pre-quartzose erosion, this bed marks the contact between the Mule Canyon and the Sunrise Canyon members. The andesite borate member is absent in Section 23.

Upper unit. The upper unit of the Sunrise Canyon member is exposed in Section 24 near the southern border where it is about 50 feet thick. In this area the top of the unit is an erosional surface and the total thickness is unknown. The unit consists of interbedded sandstones, cherty limestones and shales. A thin, tan tuff bed lies directly above the highest exposed limestone bed while a 6 inch, black colored chalcedony bed underlies the limestone.

Correlation

The sedimentary rocks of the Barstow formation are in large part of fluviatile or lacustrine origin. Many of the rocks are comparable to sediments being deposited in present-day desert playas.

McCulloh (1952) has found fossils dating the formation as Upper Miocene. These fossils are fresh water mollusks with macerated vegetable.

The fossil environment suggests standing bodies of water of more or less permanence and a climate somewhat more humid than that of the present Mojave region. Thus, the deposition of sediments occurred in a relatively large inland basin in a semi-arid climate.

A local angular unconformity separates the base of the Barstow formation from the underlying rocks. The top of the formation is not exposed as it is an erosional surface. Near the Pliocene intrusives in Sections 24 and 25 the beds lap upon the intrusive due to the resulting arching of the Barstow formation.

Daggett Formation

The Daggett formation in the township is exposed south and west of the Calico fault. A small portion of the andesite porphyry flow crops out north of the fault in Sections 23, 24 and 25. The formation ranges in composition from a white rhyolite to a hornblende andesite flow and from an andesitic to granitic conglomerate to a dark brown, cherty limestone. The formation has been subdivided into members based upon mineral composition.

Rhyolite tuff member. Outcrops of rhyolite tuff occur in Section 31. It is a whitish to grayish colored, fine grained welded rhyolite tuff. The rhyolite tuff is exposed in the cores of anticlines and as small hills rising above the alluvium.

Limestone member. The limestone member is also exposed in Section 31. It is a dark brown to black, cherty limestone. Chevron folds are probably a result of the folding being done while it was still fairly plastic. The member is a series of limestone beds about 20 feet thick.

Granitic sandstone member. The granitic sandstone member can be separated into four units. The lower unit is composed of red sandstones, shales and limestones. This unit is exposed in Mule Canyon.

The second unit is a cream colored, granitic sandstone, shales and light brown, cherty limestone. The beds are also exposed in Mule Canyon and trend N 20 E, dipping 20 to 30 degrees to the west.

The third unit is composed of interbedded, cream colored sandstones, conglomerates and shales. The lower portion of the unit is massive brown colored, granitic sandstone.

The upper unit is a coarse, purple andesitic cobble conglomerate. It tends to be confined to the troughs of the synclines in Section 31, but is exposed in a broad anticline in Mule Canyon conformably overlying the granitic sandstones and conglomerates.

Andesite member. This member, exposed north of the Calico fault, is suggestive of an intrusive andesite. South of the Calico fault it appears to be a flow which dips 30-40 degrees to the south. This flow is in fault contact with the Sunrise Canyon and Mule Canyon members of the Barstow formation in one area in Sections 23 and 24, but is not in Section 25.

The member ranges in color from a purple, red, yellow to a white color. The bleached area is near the fault contact.

Andesite flow breccia member. Hornblende andesite breccia crops out in Sections 25 and 26. It is a flow breccia as flow banding was observed.

This bedding strikes N 70 W, dipping 60 degrees to the south. The breccia is composed of angular boulders of andesite porphyry, red dacite porphyry and green latite porphyry.

Pebble conglomerate member. Pebble conglomerate is exposed in Section 25. It is a conglomerate composed of well rounded red dacite pebbles.

Correlation. The Daggett formation is largely sedimentary in the southwestern portion of the township, while it is largely volcanic in the eastern portion. It is younger than the Barstow formation as the andesite member intrudes the Sunrise Canyon member. McCulloh (1954) places the Daggett formation as part of the Miocene series. The formation is older than the Pliocene intrusives as the rocks do not contain any of the intrusive debris.

Tertiary - Quaternary

Overlying the Daggett formations in the southwestern portion and in Section 26 are the Western Borax limestones and the Lead Mountain basalt.

Western Borax Formation

In Section 26, about 100 feet of cherty, black to brown limestone is exposed. It is resting on the andesite member of the Daggett formation. In this section the beds strike N 60° E, and dip 55 degrees easterly.

Near the Odessa Canyon road in Section 22, the cherty limestone beds are about 25 feet thick. Thin beds of mudstone are interbedded in the limestone. These beds generally strike N 40 E and dip 40 degrees westerly. In Section 30, the shales and limestones are striking N 10 E and dip 50 degrees westerly.

Correlation. The beds rest unconformably on the andesite member of the Daggett formation in the eastern portion of the township. They dip away from the intrusives in the west. Thus, they are probably of early

Quaternary or late Tertiary age.

Lead Mountain Basalt

Basalt is exposed in the western portion of the area. It overlies the Daggett formation and is a dark green to black basalt. It has olivine and augite crystals set in a black matrix. The basalt generally forms the low hills in Section 31, but also forms a capping on a small hill. The basalt is very susceptible to erosion, leaving the limestone member of the Daggett formation to form the ridges. It is very possible that the basalt flow came after the deformation of the limestones; thus, it filled the low areas of the topography at that time. The flow movement was from the west and flowed to the northeast.

Correlation. The basalt is termed Lead Mountain Basalt as it caps Lead Mountain. It is probably early Quaternary in age as it unconformably overlies the Daggett formation.

Pliocene (?)

The resistance to weathering and erosion of the Tertiary intrusive rocks which occur as plugs and domes in the higher portions of the Calico Mountains accounts for much of the rugged topography of that part of the area.

Intrusive Rocks

Most of the intrusives are small plugs, probably averaging between 2,000 and 3,000 feet in maximum dimension. Four of them are in contact at the surface with Tertiary formations.

The intrusive rocks are andesites, dacites, and latites which are predominantly bluish green, green, gray and massive to thinly flow banded. The usual types are markedly porphyritic, the phenocrysts of feldspar and usually quartz, biotite and hornblende set in a hyaline groundmass composing 50 to 70 per cent of the rock volume. Andesite is most abun-

dant, through dacite and latite are common.

Correlation. The intrusives are later than the Miocene lacustrine and fluviatile sediments. These formations have been strongly distorted by the intrusion of the plugs and domes, thus placing the time of intrusion as post-Miocene. McCulloh (1954) believes the intrusives of the Calico Mountain area are Pliocene.

Quaternary

Quaternary alluvial deposits underlie nearly 3/4 of the area. Fine grained sediments of recent drainages and gravels and conglomerates of Recent dissected alluvium are the ordinary lithologic types.

Older Dissected Alluvium

Terraces capped with a variable thickness of conglomerate are found throughout the area. The remnants are deeply dissected. The debris (conglomerate) is composed of rubble from all the rock types in the area.

Recent Alluvium

There are numerous types of Recent alluvium exposed in the township, but no attempt has been made to differentiate between them.

The alluvium constitutes the stream beds and the bulk of the trough between the Calico Mountains and the Lead Mountain area. The alluvium thickness is unknown beneath the trough. The detritus is composed of poorly sorted angular to subangular fragmental material.

STRUCTURAL GEOLOGY

The structure of the rock units is very closely related to the geology. The structures in the sedimentary units are treated separately from the faults and intrusive areas.

Structures Related to the Barstow Formation

The underlying Pickhandle formation probably underwent no important deformation prior to deposition of the Barstow formation.

Folds

The limestone stratum of the Mule Canyon member consists of a series of chevron and fan folds, anticlines and synclines. These structures trend N 80° E and plunge 10 to 20 degrees to the west. Dips on the limbs range from 40 to 70 degrees. The intense deformation is due to the upper stratum sliding over the lower stratum, crumpling it severely. One cross fold, striking N 15 W, plunging 20 degrees southerly, cuts the belt and toward the east the structures align themselves with it. This is probably due to a small, elongated Pliocene intrusion just below the surface.

The rest of the Mule Canyon member is exposed on the crest and flanks of a broad anticline-syncline where the beds dip 30 to 40 degrees on the limbs.

Intrusives

Near the Pliocene intrusives in Mule Canyon, the Barstow formation lapped upon them, dipping 70 to 80 degrees away from the borders of the intrusive. The beds in this region have been so contorted that in several places the Mule Canyon member is exposed underlying the Sunrise Canyon member. As the Borate andesite member is more resistant, it probably was broken and eroded away and the outcrop covered by debris. If the Borate member has disappeared, the overlying Sunrise Canyon member has slumped to some degree.

Faults

Several faults cut the Barstow formation. The drag associated with the movement on the faults is well exposed in the hanging side. There the beds are dipping 30 degrees to the north and northeast. In some places the beds are overturned next to the Calico fault.

Calico Fault system. Movement along the Calico fault occurred after

the deformation of the Barstow formation and the intrusion of the Pliocene volcanics. This northwesterly trending fault is actually a series of faults near the eastern edge of the township with related cross-faults. It generally forms the frontal portion of the Calico Mountains with the magnitude of movement about 3,000 to 4,000 feet westerly on the south side. It is a right lateral fault.

This fault separates the Daggett formation from the Barstow formation for all practical purposes as the drainage areas were completely different for the two formations.

Sunrise Canyon Fault

Large scarps with slickensides denote a fault system running from Mule Canyon through Sunrise Canyon. The most recent movement on this fault is dip-slip and the fault has generally raised the northern block relative to the southern portion. The fault dies out to the west, but becomes stronger to the east.

MINERAL RESOURCES

In strong contrast to the silver deposits near the town of Calico, the eastern portion of the Calico Mountains is relatively free of that type of mineralization. The main source of minerals was borax until the early 1920's.

Metallic Deposits

Silver-Lead

The silver-lead deposits occur southwest of the Calico fault. They crop out of former pre-mineral fault planes in the intrusives.

Section 25 (non-Southern Pacific ownership portion). A two foot vein of barite cropped out in the SE¼ of the section. Three prospect pits had been dug on the vein, but evidently there was no production. A sample (25a-IV) assayed 0.7 oz silver/ton, and 0/0% lead.

Section 26. Two veins of banded silver onyx (travertine) strike N 80° and dip 80° southerly. They are in two pre-mineral faults into which the hydrothermal solutions have deposited travertine and silver. Silver bromite (?) is banded with the travertine and gives the rock the silver onyx term. It is being dug by the rockhounds as curios.

Nonmetallic Deposits

Boron

Concentrations of borate minerals in the Calico district are confined to shaly beds of the Borax unit in the Mule Canyon member of the Barstow formation.

Sections 24 and 25. The principal borax occurrences lie in Section 24. They are enclosed mostly in gray shale and lie at four to five horizons separated by a stratigraphic of about 50 feet. The ore contains from 15 to 20% anhydrous boric acid (Tucker, 1953). Numerous adits, shafts and prospects claimed and owned by the Pacific Coast Borax Company (Tucker, 1953) are located throughout the area.

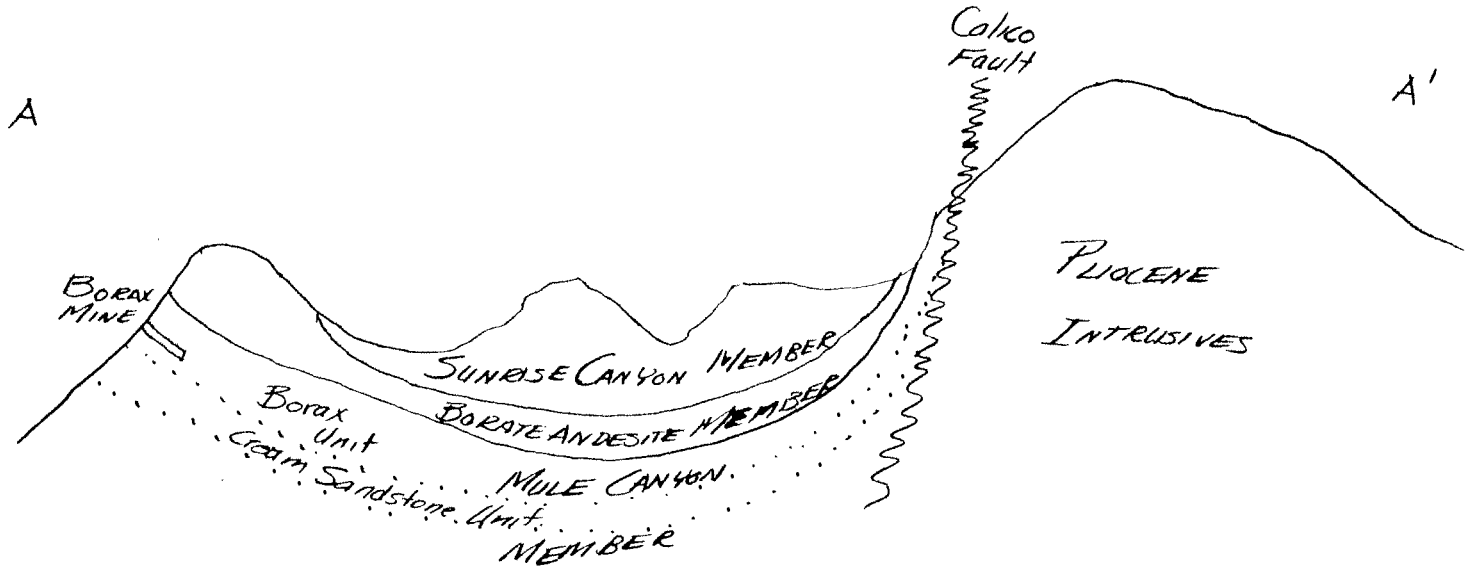
As noted in the introduction, the company's mining activity extended from 1884 to 1907, but for nearly 20 years afterward it continued to purchase small tonnages of colemanite from others who undertook scavenging operations. Small tonnages were observed on the dumps. Recent activity, probably to hold the claims, was done in the area.

By stratigraphic control (Fig. 4), it is believed that borax beds underlie the Sunrise Canyon member in the N½ of Section 25. Four samples were cut and assayed as follows:

> Sample (24-A) on the fourth bed across six feet, three inches, assayed 7.2% anhydrous boric acid and 20.3% lime.
>
> Sample (24-B) on the fourth bed on the lower portion across three feet, 1½ inches, assayed 19.9% anhydrous boric acid and 30.0% lime.

FIGURE 4:

CROSS-SECTION A-A' SHOWING RELATION BETWEEN MEMBERS OF THE BARSTOW FORMATION, SECTION R5, T10N, R1E



Sample (24-C) on the third bed across two feet, one inch, assayed 17.5% anhydrous boric acid and 30.5% lime.

Sample (24-D) on bed No. 2 across six feet, ten inches, assayed 24.1% anhydrous boric acid and 29.8% lime.

The tonnage would be quite large, but a more detailed investigation is required before an accurate estimation could be made.

Sections 28 and 30. In Sections 28 and 30 there are shafts and workings that are connected with borax production. No data are available, but it is believed that the borax was produced from the Western Borax formation.

Construction Materials

Roofing Granules

Moderate quantities of natural colored roofing granules have been produced from north of the area by the Brubaker-Mann Company and Rainbow Rock Company, Barstow, California. Rock is quarried at various localities and processed at mills near Barstow.

The various colors used are green granules, red granules and yellow granules from andesites. Numerous other shades are used also.

Section 25 (Southern Pacific ownership). There is a large area covered by andesite porphyry in the NW¼ of the section. The colors range from purple, lavender, yellow and red.

CONCLUSIONS

The area in general is well mineralized and has good possibilities of more production.

The borax deposits are quite extensive in Section 24 and underlie the Sunrise Canyon member of the Barstow formation in Section 25. The borax tonnage would be quite large in the section.

The borate deposits in Section 25, Twp. 10N., Rge. 1W. and Sections 28 and 30, Twp. 10N., Rge. 1E. should be examined for possible production

from Section 29 under the alluvium.

Roofing granules could be a principal source of income from Section 25 if the colors and composition are correct.

The lead-silver vein was not exposed in Southern Pacific's portion of Section 25; thus, there is small possibility that it might outcrop there.

RECOMMENDATIONS

In view of a possibility of the area near the borax mines in Section 24 becoming a state park, it is recommended that the area in the N½ of Section 25 (refer to map) be mapped in detail, paying particular attention to the stratigraphic control in the Mule Canyon, Borate Andesite, and Sunrise Canyon members of the Barstow formation. The borax is not economical at the present time as extraction of the element boron requires an acid lead which is cost-wise prohibitive. These deposits might become economical in the future when the large deposits at Boron, California, are exhausted.

Samples of the andesite porphyry were given to Mr. Brubaker of the Brubaker-Mann Roof Granule Company for further consideration.

The andesite porphyry outcrops within the area recommended for detail work, and this should be examined for production of roofing granules.

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