Geology of the Willow Springs and Rosamond Quadrangles California

By T. W. DIBBLEE, JR.

GEOLOGIC INVESTIGATIONS OF SOUTHERN CALIFORNIA DESERTS

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The geology and mineral resources of an important part of the western Mojave Desert

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GEOLOGY OF THE WILLOW SPRINGS AND ROSAMOND QUADRANGLES, CALIFORNIA

By T. W. Dibblee, Jr.

ABSTRACT

The Willow Springs and Rosamond quadrangles cover an area of 490 square miles in the western Mojave Desert. The area, centered about 50 airline miles north of Los Angeles, takes in the northern part of Antelope Valley and a small part of the southeastern slope of the Tehachapi Mountains that bound this valley on the northwest. Altitudes range from 2,271 feet at Rosamond Lake (dry) to 6,900 feet in the Tehachapi Mountains.

The rock units of the area may be divided into three groups separated by unconformities. These groups are: pre-Tertiary crystalline rocks; Tertiary volcanic, pyroclastic, and sedimentary rocks; and Quaternary sedimentary deposits.

The crystalline rocks of pre-Tertiary age are composed of plutonic igneous rocks and metamorphic rocks that together form a crystalline complex upon which all later formations were deposited. Metamorphic rocks occur as isolated pendants within the granitic rocks in the Tehachapi Mountains. There are two series of metamorphic rocks: the Pelona schist of supposed Precambrian age, and the Bean Canyon formation of probable late Paleozoic age. The Pelona schist is confined to a half-mile wide strip between branches of the Garlock fault. In this strip about 2,000 feet of schist is exposed. The schist is highly foliated and is composed of mica, chlorite, albite, and quartz, and, locally, biotite or actinolite. The Bean Canyon formation occurs within the granitic rocks in the southern foothills of the Tehachapi Mountains as isolated pendants; in the largest pendant this formation is about 5,000 feet thick. The Bean Canyon formation consists of marble, biotite schist, hornfels, quartzite, and some metabasalt.

The plutonic rocks are probably Mesozoic, possibly Cretaceous, in age and range in composition from hornblende diorite to granite. Quartz monzonite is by far the most extensive; it occurs as a massive granitic-textured rock that underlies large areas in the Tehachapi Mountains southeast of the Garlock fault and is the main rock type of the granitic batholith that underlies the Mojave Desert. Hornblende-quartz diorite underlies the Tehachapi Mountains north of the Garlock fault, and quartz diorite form masses in the mountains south of this fault. Black hornblende diorite occurs as lenticular bodies marginal to the pendants of the Bean Canyon formation in the Tehachapi Mountains, and as other smaller bodies nearby that are elongated parallel to the pendants. Granite associated with an aplite-pegmatite dike complex is intrusive into all other plutonic and metamorphic rocks in the

Tehachapi Mountains. The sequence of intrusion of these rock types was generally from mafic to silicic.

The volcanic, pyroclastic, and sedimentary rocks crop out in isolated hills in the desert area. These rocks yielded no fossils but presumably are of Tertiary age. They were formerly mapped as the Rosamond series but are now referred to as the Tropico group. This group is 2,800 feet in maximum exposed thickness and is divided into the Gem Hill formation, the Fiss fanglomerate, and the Bissell formation.

The Gem Hill formation, which rests upon the Pre-Tertiary crystalline complex, is a series of pyroclastic sedimentary and volcanic rocks. The pyroclastic rocks constitute the major part of the formation and consist mainly of rhyolitic tuff and tuffaceous sandstone that aggregate a maximum thickness of about 1,250 feet. The associated volcanic rocks are differentiated as the Bobtail quartz latite member and form local intrusive and extrusive bodies within the Gem Hill formation. In addition, there are several small occurrences of basalt. The Gem Hill formation is correlated, on the basis of comparable lithology and stratigraphic position, with similar formations of early or middle Miocene age in other parts of the western Mojave Desert region.

The Fiss fanglomerate lies above the Gem Hill formation, in places unconformably. It is about 1,750 feet in maximum thickness and is composed of detritus derived mainly from the underlying volcanic rocks of the Gem Hill formation and its equivalent. The Fiss fanglomerate is correlated with similar coarse terrestrial sedimentary formations of late Miocene age elsewhere in the Mojave Desert.

The Bissell formation, about 800 feet thick, crops out only in the hills of the extreme northeastern part of the area and consists of conglomerate and sandstone, claystone, and dolomite, in descending order. It overlies the Gem Hill formation. It may be, at least in part, correlative with the Fiss fanglomerate, or younger. The Bissell is late Miocene or early Pliocene age.

The sedimentary deposits of Quaternary age range from coarse fanglomerate to fine clay and are of detrital alluvial origin; they underlie the desert floor and flood plains of canyons emerging from the Tehachapi Mountains. The deposits are separated into two general units: older alluvium presumably of Pleistocene age, and alluvium and surficial deposits of Recent age. At the base of the Tehachapi Mountains a maximum total thickness of 900 feet of dissected fanglomerate and older alluvium is exposed. Test holes in Antelope Valley penetrate alluvial sediments to depths of several thousand feet that may be in part of late Tertiary age.

The regional structural pattern consists of several broad uplifts and downwarps that are elongated in a general east-northeast direction. The Tehachapi Mountains constitute an uplift of pre-Tertiary crystalline rocks along the Garlock fault, a high-angle left-lateral strike-slip fault zone trending N. 70° E. through these mountains. They are flanked on the southeast by the Antelope Valley. The northwestern part of the Antelope Valley is a structural basin filled with a great thickness of Cenozoic alluvial sedimentary deposits. East and southeast of this part of Antelope Valley are isolated low hills in which are exposed quartz monzonite and the overlying Tropico group. The Tropico group is tilted, folded, and faulted, and the hills are erosional remnants of a broad uplift. The part of Antelope Valley southeast of these hills is another structural basin filled with a great thickness of Cenozoic alluvial deposits.

Intense diastrophism and batholithic invasion by granitoid rocks in this area during the Mesozoic era were followed by a long interval of erosion during Late Cretaceous and early Tertiary time. Sedimentation on the deeply eroded surface of the crystalline rocks probably started in middle Tertiary time, with subaerial deposition of ash of the Gem Hill formation. The ash was emitted from several volcanic vents within the Mojave Desert area, and was followed by the eruption of quartz latitic lava from these vents. This was soon followed by deposition of alluvial and lacustrine sediments of the Fiss fanglomerate and the Bissell formation in enclosed basins.

Crustal warping of the region, probably in late Tertiary and early Quaternary time, produced the major northeast-trending upwarp that forms the Tehachapi Mountains, a smaller parallel upwarp to the southeast, the downwarping of the intervening areas to form basins, and the deformation of the Tropico group. Material eroded from the elevated areas during and after the disturbance was deposited in the downwarping basins. Relative stability has prevailed since except for a recurrent uplifting of the Tehachapi Mountains in late Quaternary time.

Mineral resources in the area are mainly gold and some silver ore from veins in intrusive quartz latite in the Mojave Desert area. Nonmetallic resources include limestone suitable for cement, volcanic rock suitable for road and roof material, and practically unlimited amounts of common clay on Rosamond Lake. Other resources are small amounts of quartz, feldspar, perlite, magnesite, arsenic ore, and radioactive minerals.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Willow Springs and Rosamond quadrangles, California, are adjoining 15-minute quadrangles between long 118° and 118°30′ W. and between lat 34°45′ and 35° N. in Kern and Los Angeles Counties, as shown in figure 5. The area is centered about 50 miles north of Los Angeles by airline, about 100 miles by road.

PURPOSE OF INVESTIGATION

A primary objective of the U.S. Geological Survey's study of the areal geology of the western Mojave Desert was to determine whether formations of Tertiary and Quaternary age might contain hidden saline deposits of economic value such as those occurring in other parts of this region. The Willow Springs and Rosamond quadrangles are two of the twenty-three 15-minute quadrangles being mapped in whole or in part in this study.

A secondary aim was to determine the general character of the pre-Tertiary crystalline bedrock complex within the two mapped quadrangles and to investigate the relations of the complex to the depositional history and structure of the Cenozoic formations. In order to complete the geologic study, the known mineral deposits within the area are briefly described, largely from published sources.

PREVIOUS WORK

Several reconnaissance reports and maps on the geology of part or all of the Willow Springs and Rosamond quadrangles have been

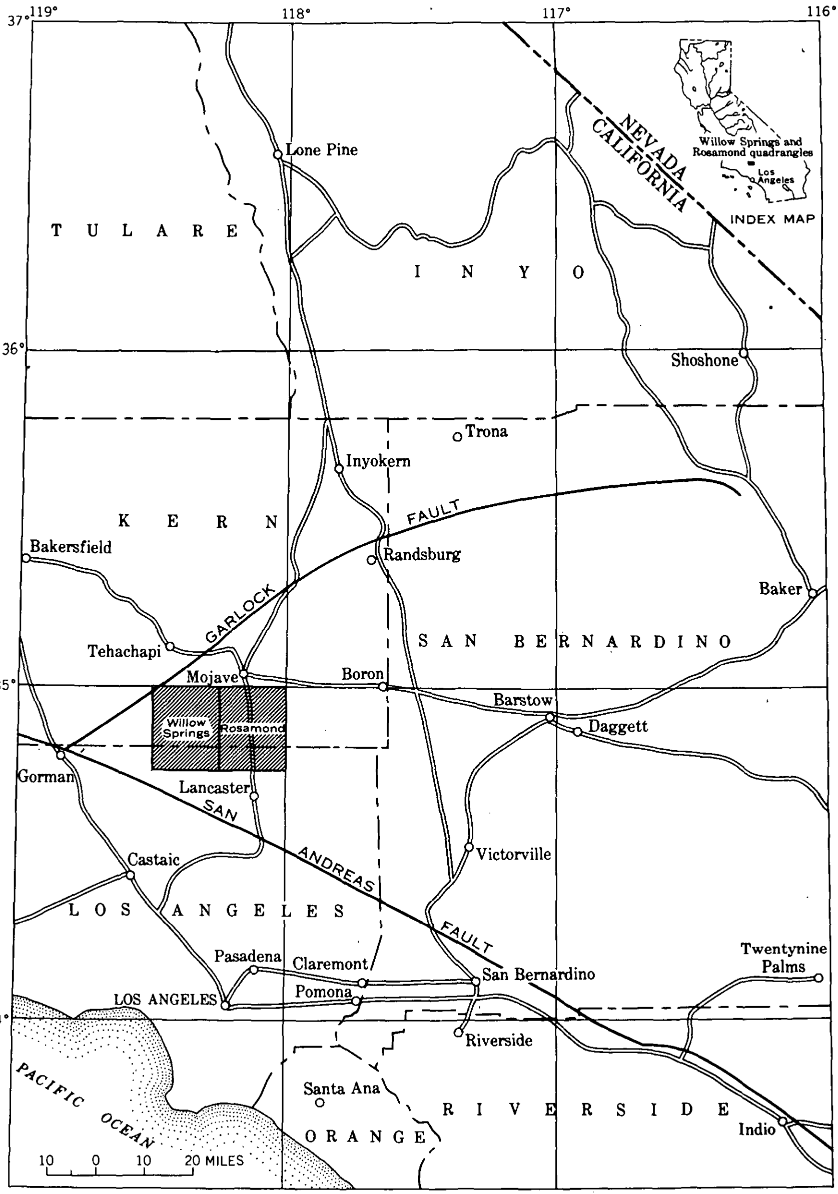

FIGURE 5.—Index map of Mojave Desert and vicinity, California, showing location of area mapped.

published. The earliest was by Hershey (1920a, p. 350–355), in which the Tertiary rocks in the Rosamond Hills were first described and named the Rosamond series. The broader structural features and ground-water conditions of Antelope Valley were outlined first by Johnson (1911) and later by Thompson (1929, p. 289–370).

The areal geology of the 30-minute Elizabeth Lake quadrangle, the north half of which includes the 15-minute Willow Springs and Rosamond quadrangles, was mapped at a scale of 1:125,000 and described by Simpson (1934). He recognized the fault at Willow Springs, mapped it eastward, and named it the Rosamond fault. He thought he recognized the Garlock fault southeast of the Tehachapi Mountains, and named the segment of the true Garlock fault within the mountains the Oak Canyon fault. His map shows the Rosamond formation and associated volcanic rocks cropping out in many places in the desert area. The report briefly describes the mineral resources of this quadrangle.

The areal geology of the 15-minute Neenach quadrangle, which adjoins the Willow Springs quadrangle on the west, was mapped and described in detail by Wiese (1950). His colored map shows the western extension of the Garlock fault system through the Tehachapi Mountains. In the same year Wiese and Fine (1950) described the broad structural features of western Antelope Valley, and their small-scale map is the first to show the Cottonwood and Tylerhorse faults.

A geologic map and report of the Rosamond Hills–Soledad Mountain area by Noble (1954) gives a more detailed account of the geology of this area.

The gold-silver deposits of Soledad Mountain, Middle Buttes, and Tropico Hill were described by Simpson (1934, p. 408–409), Tucker and Sampson (1934, p. 316–317), Tucker, Sampson, and Oakeshott (1949, p. 218–233, 234), and Gardner (1954). The Bissell magnesite deposit was described by Simpson (1934, p. 412–413) and Rubey and Callaghan (1936). A uranium prospect in the Rosamond Hills was described by Walker (1953).

PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

Fieldwork was done by the writer in the Rosamond and Willow Springs quadrangles in February–March 1953. The geology (pl. 10) was mapped on aerial photographs and subsequently transferred to the topographic base maps (scale 1:62,500) of the 15-minute Rosamond and Willow Springs quadrangles issued in 1943 by the Corps of Engineers, U.S. Army, and revised in 1957 by the Geological Survey, with new culture added.

The plutonic rocks of the area were identified by Robert D. Allen. The mineral percentages (modes) of 11 samples from the Willow Springs quadrangle and 6 samples from the Rosamond quadrangle were determined by crushing a small sample of each and identifying and counting under the microscope 200 grains of mesh size 140 by 200 immersed in oils of known index. Subsurface structural interpretations are based in part on data from a geophysical (gravitymeter) survey of the area by D. R. Mabey; frequent discussions with him have been of great help.

GEOGRAPHY AND TOPOGRAPHY

The only town of any size in the area is Rosamond with about 500 inhabitants. Mojave, population about 1,000, is just north of the area, and Lancaster, population about 2,500, is just south. Within the area are small settlements of Gloster, at Willow Springs, and at the Tropico and the Golden Queen mines. Many ranches are cultivated on the level valley lands. The Rosamond quadrangle is traversed by the Southern Pacific Railroad, by the Atchison, Topeka, and Santa Fe Railway, and by U.S. Highway 6; numerous secondary roads traverse both quadrangles. Since 1955 Rosamond Lake and vicinity have been part of the Edwards Air Force Base testing ground.

The Rosamond quadrangle and most of the Willow Springs quadrangle lie within a part of the western Mojave Desert that is mostly flat but includes some low hills and a few volcanic buttes. The northwestern part of the Willow Springs quadrangle includes a small segment of the southeastern slope of the Tehachapi Mountains. Altitudes above sea level range from 2,271 feet at Rosamond Lake to 6,900 feet in the Tehachapi Mountains, giving a maximum relief of about 4,600 feet. The topographic features and drainage of the two mapped quadrangles are shown on plate 10.

The quadrangles are in a region of arid climate. In the desert area the summers are generally hot with daily maximum temperatures usually exceeding 100°F and sometimes reaching 115°F. The winters are mild to cold, with night temperatures falling below freezing, sometimes as low as 12°F. Cyclonic storms that pass over the area in the winter and spring are generally accompanied or followed by strong westerly gales that blow over the Tehachapi Mountains into the desert. Most of these storms precipitate rain or snow in the mountains, but only the most severe yield rain in the desert, where annual precipitation averages about 5 inches.

Vegetation in the desert is of the usual sparse sagebrush type, composed largely of burro bush and creosote bush. Giant yuccas (Joshua trees) are fairly abundant over sandy flat areas west of Soledad Mountain and the Rosamond Hills and along the lower alluvial-fan slopes of the Tehachapi Mountains between altitudes of 2,800 and 4,000 feet. Between altitudes of 4,000 and 6,000 feet these mountains are covered by heavier vegetation composed mainly of scrub oak, juniper, pinyon pine, and yucca. Above 6,000 feet the mountains are partly forested with large trees, mainly price oak and sugar pine, with some cedar.

Willow Springs is the only major natural watering place within the heart of the western Mojave Desert and was the site of an early pioneer settlement and stage station prior to the routing of the Southern Pacific Railroad through this area in 1875. In Antelope Valley the ground-water resources have been tapped by numerous wells for use in irrigation of alfalfa, cotton, barley, and other crops.

REGIONAL GEOLOGIC SETTING

The area embraced by the Willow Springs and Rosamond quadrangles lies in the western part of the Mojave Desert block largely between the Garlock fault to the northwest and the San Andreas fault to the southwest. The area is centered about 35 miles east of the junction of the faults, as shown on plate 11.

The rocks of the Willow Springs and Rosamond quadrangles may be grouped into the following three main divisions, generally prevalent in the western Mojave Desert region: crystalline rocks of pre-Tertiary age; pyroclastic, volcanic, and sedimentary rocks of Tertiary age; and alluvial sedimentary deposits of Quaternary age. The rock units have not yet yielded indigenous fossils, therefore, their ages had to be inferred from geologic relations and comparison with similar rocks of known ages outside the area.

ROCK UNITS

The crystalline rocks of pre-Tertiary age are mainly of plutonic origin but include some of metamorphic origin. The plutonic rocks are largely granitic intrusions typical of the Sierra Nevada granitoid batholith of Late Jurassic or Cretaceous age. Quartz monzonite is by far the most widespread granitic rock, but hornblende diorite, hornblende-quartz diorite, quartz diorite, and granite also are present. Metamorphic rocks occur within the granitic rocks of the Tehachapi mountains and consist of a belt of mica schist of supposed Precambrian age, and pendants of hornfels, schist, quartzite, marble, and metabasalt of inferred Paleozoic age. The plutonic and metamorphic rocks together form the crystalline bedrock complex upon which assemblages of Cenozoic age rest unconformably.

Deposits of Tertiary age consist of pyroclastic, volcanic, and sedimentary rocks of terrestrial origin. These may be divided into a lower sequence of consolidated rocks, the Tropico group, and an upper sequence of weakly consolidated alluvial sediments. The Tropico group, about 2,800 feet thick and of probable Miocene-Pliocene age, crops out in the hills of the Mojave Desert. This group is divided into three formations: (a) the Gem Hill formation, which consists mainly of pyroclastic and volcanic rocks; (b) the Fiss fanglomerate of predominantly volcanic detritus; and

(c) the Bissell formation, composed of conglomerate, sandstone, and claystone and carbonate rocks. The Fiss fanglomerate and Bissell formation both overlie the Gem Hill formation in widely separated areas and may be correlative. The weekly consolidated alluvial deposits, probably of Pliocene age, crop out beyond the western border of the mapped area where they consist of about 1,600 feet of gravel, sand and lacustrine clay. They are not exposed within the mapped area but probably underlie the Quaternary alluvium of the greater part of Antelope Valley.

Wherever exposed, alluvial sediments of Quaternary age rest unconformably on the Tertiary and pre-Tertiary rocks. In the valley areas the sediments aggregate several hundred or possibly several thousand feet in thickness. They were derived from the adjacent mountains and hills and range from coarse fanglomerate to fine clay. They are divided into older alluvium of Pleistocene age, which is locally tilted, deformed, and dissected, and alluvium and other surficial deposits of Recent age that fill all the valleys and flood plains and are undissected.

PRE-TERTIARY CRYSTALLINE ROCKS

METAMORPHIC ROCKS

PELONA SCHIST

Mica schist assigned to the Pelona schist by Wiese (1950, p. 12–14, pl. 1) is exposed as a narrow strip between branches of the Garlock fault across the Neenach quadrangle, west of the Willow Springs quadrangle. The schist continues for 3 miles across the northwest corner of the Willow Springs quadrangle, in an exposure about half a mile wide that narrows northeastward and finally wedges out in Oak Canyon a mile beyond the north border of the quadrangle. The part within this quadrangle was erroneously mapped with the Bean Canyon series by Simpson (1934, pl. 5).

The Pelona schist weathers to generally rounded ridges with smooth grassy slopes. However, it forms badlands of a conspicuous blue-gray color in Tylerhorse Canyon, where the schist is cut through by a deep, youthful gorge.

The Pelona schist of Precambrian(?) age exposed in the Willow Springs quadrangle is of the same character as that in the adjoining Neenach quadrangle, the lithology and petrography of which were described in detail by Wiese (1950, p. 12–13). The dominant variety within the Willow Springs quadrangle is mica-chlorite-albite schist. Less common varieties are quartz-biotite schist and green actinolite-albite schist. The schist is fine to medium grained, highly foliated, and of a greenish- to bluish-gray color with a silvery sheen. Occasional thin layers of micaceous quartzite are parallel to foliation. Much of the formation is intensely sheared, mostly along foliation planes, and in places it is brecciated or sheared to gouge.

Small lenticular veins of white quartz, from a few inches to 2 feet thick, occur locally in the Pelona schist and are generally oriented parallel to its foliation. The quartz is invariably brecciated and is usually iron stained.

There is no determined sequence within the narrow fault sliver of Pelona schist, because the various rock types are intercalated in thin layers. The schist strikes north of east, parallel to the two branches of the Garlock fault which bound it, and dips steeply northwestward. A thickness of about 2,000 feet is here exposed, but because of the shearing this may not represent the original thickness. It is not known which side is top or bottom.

The Pelona schist appears to be a metamorphosed series of predominantly fine-grained sedimentary rocks. The quartzite layers were probably thin strata of quartzose sandstone or possibly of chert, and the quartz-mica schist was sandy shale. The mica-chlorite-albite schist may have been tuffaceous shale. The thin lenses of actinolite-albite schist were probably mafic tuff.

The high degree of schistosity is the result of regional metamorphism and was no doubt formed prior to the intrusion of the plutonic rocks of this region, as suggested by Wiese (1950, p. 14). The schistosity may have been impressed before deposition of the Bean Canyon formation of probable late Paleozoic age, as schistosity is poorly developed in that formation. This condition suggests that the Pelona schist is older than the Bean Canyon formation. The Pelona schist was considered to be of Precambrian age by Hershey (1920b), Simpson (1934, p. 380–381), and Wiese (1950, p. 13–14), but it is possibly of middle or early Paleozoic age.

BEAN CANYON FORMATION

DISTRIBUTION

A metamorphic sequence of schist, hornfels, quartzite, and marble, occurring as roof-pendants in the granitic rocks of the Tehachapi Mountains, was named and mapped as the Bean Canyon series by Simpson (1934, p. 381, pl. 5). In the present report it is designated as the Bean Canyon formation, because the term "series" is applied by the U.S. Geological Survey only to a time-stratigraphic unit and not to a rock-stratigraphic unit. Along the southeastern foothills of the Tehachapi Mountains the Bean Canyon formation occurs as a belt of isolated roof-pendants that are elongated parallel to the mountain front. These pendants extend discontinuously northeastward into the Tehachapi quadrangle to Oak Canyon, and southwestward into the Neenach quadrangle where they were mapped by Wiese (1950, p. 16–18, pl. 7) as Paleozoic(?) metamorphic rocks.

Within the Willow Springs quadrangle there are two large pendants of Bean Canyon formation. The larger western pendant, nearly a mile wide and more than 3 miles long, extends across Gamble Spring Canyon westward to Tylerhorse Canyon, and probably extends southwestward under Quaternary gravel to the outcrops of the schist and limestone in Cottonwood Canyon. The smaller eastern pendant covers about 1 square mile in Bean Canyon. Besides these two large pendants there are several very small ones in upper Tylerhorse Canyon. The field relation of these metamorphic rocks to the plutonic rocks are discussed under "Plutonic rocks" (p. 157).

The belt of metamorphic rocks stands out prominently at the base of the Tehachapi Mountains because these rocks are more resistant to erosion than the enclosing granitic rocks. The marble and the quartzite are especially resistant and form prominent strike ridges.

LITHOLOGY

The Bean Canyon formation is composed predominantly of dark-gray to nearly black fine crystalline platy rocks that for convenience will be referred to in this report as schist; the rocks generally are not schist in the strict sense of the term, however, but approach phyllite, hornfels, or even argillite in character. The average grain size is generally less than half a millimeter, and the rocks are characterized by faint to conspicuous bedding, expressed by varying shades of gray, and by platy cleavage or foliation parallel to bedding resulting from parallel orientation of mica flakes. Near granitic contacts the rocks are more coarsely crystalline and more like true schist. In places at and near granitic contacts they are partly migmatized to coarse crystalline biotite schist that approaches gneiss in character, but no true gneiss is formed. The schist of the Bean Canyon formation is composed mainly of biotite, muscovite, quartz, plagioclase and hornblende, but it also contains some aluminum silicates such as andalusite, cordierite, and sillimanite in the form of minute prisms, as reported by Simpson (1934, p. 382).

Most of the quartzite in the Bean Canyon formation occurs in Bean Canyon. The quartzite is light gray to tan, massive to faintly laminated, very fine grained, and composed almost entirely of quartz. Although this rock is extremely hard, it is closely jointed so that it does not form prominent outcrops. Individual layers 2 feet thick are common, but most layers are thinner; they are intercalated with layers of schist of about equal thickness.

The carbonate rocks of the Bean Canyon formation are limestone, in large part recrystallized to marble. The marble is composed mainly of calcite, but in places includes some dolomite. The grain size ranges from less than 1 to more than 5 mm, and at many places coarse and fine crystalline layers are intercalated. Most of the coarse marble is near contacts with granitic rocks. The limestone and marble generally occur as thin strata within the schist, but one unit attains a thickness of 1,200 feet. Most of the marble is white but it commonly contains light bluish-gray laminae which probably are graphitic. Internal bedding is generally well preserved except in the coarse marble.

Thin layers of light reddish- to greenish-brown lime-silicate hornfels are associated with the limestone and marble, especially within the thick unit in Gamble Spring Canyon. The hornfels layers are hard, brittle, and fine grained, and are composed mainly of garnet, zoisite, and some epidote.

The Bean Canyon formation contains some metabasalt and metafelsite, in the form of an occasional lenticular flow or sill. The metabasalt is black, fine to medium grained, and in places amygdaloidal. It is composed of dark plagioclase and ferromagnesian minerals, the latter largely altered to iron oxides and black antigorite, a probable alteration of olivine. One metabasalt unit east of Bean Canyon (pl. 10) is largely altered near the contact with a granitic intrusion to antigorite and iron oxides that are in part pseudomorphous after medium to coarsely crystalline actinolite. The metafelsite is aphanitic and light gray; it weathers buff, contains relict phenocrysts of feldspar, and is probably meta-andesite or metalatite.

STRATIGRAPHY

In all the pendants of the Bean Canyon formation within the Willow Springs quadrangle, the strata are vertical or dip steeply, and strike eastward to northeastward. In the Gamble Spring Canyon pendant the strata are vertical or dip about 80° S., and in the Bean Canyon pendant they dip 65° to 85° NW. The stratigraphic sequences of the two pendants are entirely different, and it is not known definitely which of the sequences is the older. In the adjoining Tehachapi quadrangle to the north, there are pendants of strata similar in lithology and sequence to the strata of the Gamble Spring Canyon pendant, and alined with it; this similarity suggests that abrupt facies changes are not common in the Bean Canyon formation. It seems likely, therefore, that the strata of the Gamble Spring Canyon pendant and the Bean Canyon pendant are different parts of a very thick sequence. In the Tehachapi quadrangle the strata dip to the southeast, in some places at low angles;

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this attitude suggests that the top of the beds is to the southeast, and by analogy, that the top of the beds in the Gamble Spring Canyon pendant is also to the southeast. The strata of the Gamble Spring Canyon pendant strike north of the Bean Canyon pendant and toward the strata in the Tehachapi quadrangle; this relation suggests that the strata of the Bean Canyon pendant are probably younger than those of the Gamble Spring Canyon pendant, and if they are part of the same sequence, are overturned to the southeast.

Simpson (1934, p. 383) assumed that the top side of the sequence exposed in Bean Canyon is to the northwest, because there the sequence dips steeply northwestward, but if the sequence is overturned as suggested above, the top side is to the southeast. The sequence, probably an overturned section, is given below (as modified from Simpson) from southeast to northwest, from youngest to oldest:

Section of Bean Canyon formation exposed in Bean Canyon

	Feet
Schist, gray-black thin-bedded fine-grained biotite-plagioclase schist; occurs as small isolated pendant in quartz monzonite on southeast side of canyon	300
Marble, white, massive; present only on west side of canyon	50
Schist, dark-gray poorly bedded fine-grained biotite-andalusite-cordierite schist	300
Marble, gray-white, coarse-grained; lenses out westward in canyon; traceable for a mile northeastward and thickens to 200 feet	40
Schist, gray thin-bedded fine-grained biotite-andalusite-cordierite schist	120
Marble, gray-white, thin-bedded, medium- to coarse-grained	110
Schist and quartzite, dark-gray fine-grained biotite-andalusite-cordierite schist and many interbeds of tan quartzite	200
Schist, black thin-bedded fine-grained biotite-hornblende-plagioclase schist	450
Metabasalt, black, massive, fine- to medium-grained, partly serpentinized; lenses out eastward in canyon	0–150
Schist, same as schist above	570
Metabasalt, same as metabasalt above, but locally amygdaloidal; lenses out westward in canyon, thickens eastward	0–300
Marble, white, thin-bedded, coarsely crystalline	30
Schist, gray thin fine-grained quartz biotite schist beds, quartz-mica schist, and quartz biotite andalusite schist beds, contains thin sill of partly serpentinized pyroxenite	170
Quartzite, hard tan massive to faintly laminated quartzite with blocky fracture; interbeds of dark-gray fine-grained quartz biotite schist	430
Schist, dark-gray thin-bedded biotite plagioclase schist; contains thin lenses of white vein quartz parallel to schistosity	200
Marble, gray-white, thick-bedded, coarsely crystalline	80
Schist, gray thin-bedded fine-grained biotite-plagioclase-andalusite schist	165

Section of Bean Canyon formation exposed in Bean Canyon—Continued

	Feet
Metafelsite, brown-gray, massive, porphyritic	300
Schist, hard black graphitic biotite schist with blocky fracture; interbeds of fine quartz mica schist; occasional thin layers of tan quartzite	500
Aggregate range in thickness	4, 015–4, 465

Contact with intrusive granitic rocks.

The sequence of strata in the large western pendant across Gamble Spring and Tylerhorse Canyon is most completely exposed at Gamble Spring Canyon. The sequence there is as follows from top to bottom (south to north):

Section of Bean Canyon formation exposed at Gamble Spring Canyon

	Feet
Schist, dark-gray thin-bedded fine-grained quartz-biotite-muscovite schist and biotite-plagioclase schist; contains about 30 feet of gray-white marble, 300 feet above base, exposed only east of canyon; schist and marble intruded by or recrystallized to hornblende diorite west of canyon	700
Marble, light bluish-gray to white, thick-bedded, medium to coarsely crystalline; contains occasional thin dark graphitic laminae; a few thin interbeds of lime-silicate hornfels; thickens to 1,200 feet east of canyon and to about 800 feet west of it	600
Schist, gray thin-bedded quartz biotite muscovite schist; subordinate interbeds of calc-silicate hornfels	200
Marble, white, thick-bedded, coarsely crystalline; lenses out along strike to east and west	110
Schist, dark-gray to black thin-bedded biotite quartz plagioclase schist	1, 400
Metatuff, rusty-tan massive fine-grained altered andesitic tuff(?)	200
Total thickness	3, 210

In Cottonwood Creek the section is composed of about 200 feet of white marble similar to and probably equivalent to that of the Gamble Spring pendant. The marble is underlain on the northwest by about 1,600 feet of dark fine-grained biotite plagioclase schist similar to and probably correlative with the 1,600 feet of schist below (north of) the thick marble member at Gamble Spring Canyon.

The two small pendants in upper Tylerhorse Canyon are composed of dark schist, with a thin layer of limestone in the northern one. In both these pendants the strata strike eastward and are vertical. Along the south branch of the Garlock fault there is a strip, as wide as 150 feet, of brecciated white marble adjacent to the Pelona schist.

As previously indicated, the stratigraphic relations of the isolated pendants of the Bean Canyon formation cannot be determined with certainty. However, as the strata within the pendants are vertical or steep with an east to northeast strike, and as there is no evidence of repetition, the pendants are tentatively inferred to be remnants of a once homoclinal section with the top side probably to the southeast; this hypotheses assumes, of course, that there was no faulting or other structural complexities between the pendants prior to the emplacement of the plutonic rocks. If so, then the marble along the Garlock fault adjacent to the Pelona schist may be inferred to be the lowest part of the Bean Canyon formation, with progressively higher beds southeastward away from the Pelona schist; the supposedly overturned section in Bean Canyon probably represents the youngest part of the Bean Canyon formation. If the pendants are remnants of a homoclinal section, then the Bean Canyon formation must have had a great thickness, possibly more than 15,000 feet, prior to the emplacement of the granitic rocks.

CONDITIONS OF DEPOSITION AND METAMORPHISM

The Bean Canyon formation is a metamorphosed sequence of sedimentary rocks, as indicated by the well-preserved stratification and the presence of marble, hornfels, and quartzite. The marble was recrystallized from limestone; the associated calc-silicate hornfels was calcareous shale; the quarzite was originally quartzose sandstone; the quartz biotite schist was probably sandy sale; the schist containing andalusite and cordierite was probably alumina-rich argillaceous shale; and the biotite plagioclase schist and hornblende plagioclase schist may have been tuff or tuffaceous shale. The formation appears to be a marine deposit, probably laid down under a widespread open sea, as indicated by the presence of thick layers of marble and by the dark, well-bedded character of the schist. The metabasalt and the metafelsite are probably submarine flows if they are not sills. The Bean Canyon formation appears to be in a much lower stage of regional metamorphism than is the Pelona schist.

PROBABLE AGE AND CORRELATION

The Bean Canyon formation has yielded no fossils, so its exact age and correlation are unknown. It is no younger than the granitic rocks of probable Cretaceous age that intrude it. The older age limit is undetermined, but the formation is almost certainly younger than the more highly regionally metamorphosed Pelona schist of supposed Precambrian age.

Simpson (1934, p. 383) concluded that the Bean Canyon series is in part Triassic and in part Jurassic, on the basis of lithologic similarity to rocks of known age in the Inyo Range, 100 miles to the north. In the adjoining Neenach quadrangle Wiese (1950, p. 18) tentatively assigned to the Paleozoic Era metamorphic rocks that are generally similar to the Bean Canyon formation, on the basis of their lithologic similarity to Paleozoic rocks in the Inyo Range and the Randsburg district. The Bean Canyon formation is also similar to the sequence of schist, slate, limestone, and quartzite strata widespread in the southern Sierra Nevada and Tehachapi Mountains to the north across the Garlock fault. This sequence was named the Kernville series by Miller (1931), and mapped and described by Miller and Webb (1940, p. 349–352) and by Dibblee (1952, p. 13–18). Miller's Kernville series is unfossiliferous but is probably Jurassic or older (possibly Carboniferous) in age.

In other parts of the western Mojave Desert there are thick sequences of similar metamorphic rocks; several of these sections have yielded fossils indicating late Paleozoic age. The middle part of the Garlock series of Dibblee (1952, p. 15–19) in the El Paso Range yielded fusilinids indicating Permian age. Another sequence, which crops out in the Calico Mountains, contains Carboniferous fossils, according to McCulloh.[1] Other rocks that have yielded late Paleozoic fossils crop out in the southern part of the Barstow quadrangle; they were mapped and described by Bowen (1954, p. 23–42) as the Oro Grande series and the Fairview Valley formation. As most of these sections have yielded fossils indicating late Paleozoic age, the Bean Canyon formation is also tentatively considered to be of late Paleozoic age.

METAQUARTZ LATITE

The only metamorphic rock within the Rosamond quadrangle is a metavolcanic rock whose mineral composition suggests metaquartz latite; it is exposed in two small outcrops less than a mile apart at the northeast base of Soledad Mountain. Both outcrops are largely surrounded by Tertiary volcanic rocks of the Bobtail quartz latite member of the Gem Hill formation and by Recent alluvium. In the northwestern exposure the metavolcanic rock is associated with quartz monzonite that probably intrudes it.

The metaquartz latite is dark brownish black, massive, and dense, with closely spaced subparallel fractures suggesting bedding or fracture cleavage, but otherwise it lacks lamination. The parallel fracturing, which causes the rock to weather into subplaty slabs, trends northwestward and dips about 45° NE. in the southeastern exposure and is nearly vertical in the northwestern exposure. The fractures are generally coated with brown to bluish-black ferruginous and manganiferous oxides.

The rock is composed of an extremely fine dark-brown groundmass and numerous minute phenocrysts of cream-white altered feldspar. Under the microscope the rock is seen as a fine-grained intergrowth of hematite, quartz, potassium feldspar, and andesine. It was not possible to make quantitative estimates because of the extremely fine grain size and the opacity of the hematite.

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[1] McCulloh, T. H., 1952, Geology of the southern half of the Lane Mountain quadrangle: Ph.D. Thesis, Univ. of California at Los Angeles, unpublished.

The age of the metaquartz latite is unknown other than being pre-Tertiary. In the outcrop northeast of Soledad Peak the metaquartz latite is intruded by quartz monzonite, so that it is older than this plutonic rock. In both outcrops it is intruded by the Bobtail quartz latite member, and in the eastern outcrop it is unconformably overlain by tuff of the Gem Hill formation.

PLUTONIC ROCKS

Plutonic intrusive rocks ranging in composition from hornblende diorite to granite make up most of the pre-Tertiary crystalline bedrock complex exposed within the mapped area. Field relations as described in the following paragraphs indicate that in the area southeast of the Garlock fault the sequence of emplacement of the intrusive rocks probably was as follows: (a) hornblende diorite; (b) quartz diorite and quartz monzonite; and (c) granite pegmatite-aplite. In the mountains north of the Garlock fault, hornblende-quartz diorite is intruded by quartz monzonite and pegmatite in areas beyond the border of the map area.

Samples of granitic rocks from seven Mojave Desert localities were determined by the lead-alpha method to range in age from about 86 to 112 million years and thus to be of Cretaceous age (W. G. Schlecht, written communication, March 13, 1957). A sample of quartz monzonite from the Rosamond Hills, 4 miles northeast of Rosamond, was determined to be about 95 million years old; another of granite from the foothills south of Antelope Valley, a mile east of the Rivera mine, Neenach quadrangle, was determined to be about 86 million years old.

In the Tehachapi Mountains the plutonic igneous rocks generally form smooth rounded slopes covered with residual sandy soil, but in the canyons the freshly exposed rocks form steep bare rocky slopes. Granite and dikes of pegmatite and aplite, however, are more resistant to weathering and form even more rugged exposures. In the desert area quartz monzonite, the most extensively exposed plutonic rock, weathers to low undulating hills. The lower slopes of these hills are covered by residual coarse sand (grüs) that blends into the alluvial sand of the adjacent valleys. In some places, however, such as in the northeastern part of the Rosamond Hills, a somewhat more coherent and consequently more resistant phase of the quartz monzonite crops out as low peaks that form the crest of the hills. In the Rosamond Hills resistant dikes of pegmatite and aplite form ridges, and detritus from these dikes commonly masks the adjacent less-resistant quartz monzonite.

HORNBLENDE DIORITE

In the Tehachapi Mountains hornblende diorite is exposed between Gamble Spring and Tylerhorse Canyons as two large bodies elongated eastward, one on each side of the large pendant of metamorphic rocks of the Bean Canyon formation. Both bodies are tabular and parallel to the vertical layers of the adjacent metasedimentary rocks. They are as much as 1,300 feet wide and are traceable for 1½ miles. The southern body of hornblende diorite is in contact with but does not transect marble to the north; in Tylerhorse Canyon it is in contact with biotite schist to the south, which it intrudes in the form of sill-like tongues, and it also contains isolated inclusions of the schist.

Farther northwest, between Tylerhorse and Cottonwood Canyons, hornblende diorite occurs as small lenticular bodies elongated eastward in quartz monzonite and quartz diorite. Contacts, which are practically vertical, are sharp and there are no apparent textural changes within the rocks up to the contact. Offshoots a few inches or feet wide of the quartz monzonite and quartz diorite that cut into the hornblende diorite indicate that the hornblende diorite is older than the granitic rocks.

In exposures east of Cottonwood Canyon the hornblende diorite is of generally uniform texture and composition and is massive. However, in the exposure west of Cottonwood Canyon it is locally gneissoid, with crude vertical foliation trending northwestward. Contacts with the adjacent rocks are generally sharp. In places near the contact with quartz diorite the dark hornblende diorite is mixed with the light-colored quartz diorite to form hybrid rocks.

The hornblende diorite is black to dark gray, medium grained, and holocrystalline, and generally is composed of equal amounts of grayish-white calcic plagioclase feldspar and black hornblende. In some exposures, such as that on the west side of Cottonwood Creek, it contains biotite as well as hornblende. Plagioclase and hornblende crystals are all intergrown, stubby, generally equidimensional, and average about 2 to 4 mm across.

HORNBLENDE-QUARTZ DIORITE

Hornblende-quartz diorite and related rocks crop out in the Tehachapi Mountains northwest of the Garlock fault, in the northwest corner of the Willow Springs quadrangle. This rock in the Neenach quadrangle was mapped by Wiese (1950, p. 21–22, pl. 1) as diorite, and he stated that the unit ranges from hornblende diorite to biotite quartz diorite. This unit extends to the north through the Tehachapi Mountains into the southern Sierra Nevada; it was described by Dibblee and Chesterman (1953, p. 22–28) in their Breckenridge Mountain quadrangle report.

The hornblende-quartz diorite is moderately coarse grained, equigranular, gray, and composed of about equal amounts of dark- and light-colored minerals. It is weakly to strongly gneissoid.

The rock ranges in composition from hornblende diorite containing little or no quartz or biotite, to biotite-quartz diorite with little hornblende. Hornblende-quartz diorite is the predominant variety in the mapped area. Samples taken from the exposure in the northwest corner of the Willow Springs quadrangle have an average percentage composition as follows: quartz, 20; orthoclase, 1; oligoclase, 35; hornblende, 40; limonite, less than 5. The average composition of the dominant variety of diorite in exposures to the west, as given by Wiese (1950, p. 21), is "* * * 50 percent andesine, 47 percent hornblende, and 3 percent magnetite, apatite, sphene, zircon and garnet, in descending order of abundance."

The hornblende occurs as long-bladed anhedra 1 to 5 mm thick by 3 to 12 mm long that form lenticular aggregates. The hornblende and biotite have parallel orientation between grains of plagioclase and give the rock its gneissoid foliation. The plagioclase occurs as subhedral to rounded grains 1 to 2 mm thick by 3 to 5 mm long. The quartz is present as interstitial grains and, according to Wiese (1950, p. 22), as tiny blebs in or around grains of plagioclase. The rock is of generally homogeneous texture, but in places it contains small xenoliths of dark fine-textured diorite. These are lenticular bodies several inches long by an inch or two thick that are oriented parallel to the gneissoid foliation of the host rock.

Near the Garlock fault the hornblende-quartz diorite is locally sheared and altered. In places the sheared rock has been mylonitized with relict augen of plagioclase and hornblende in a groundmass of chlorite, epidote, calcite, and iron oxides. Veinlets of secondary quartz and calcite are also present.

QUARTZ DIORITE

In the Tehachapi Mountains in the Neenach quadrangle, south of the Garlock fault zone, a large mass of quartz diorite extends eastward across Cottonwood Canyon for several miles into the Willow Springs quadrangle (Wiese, 1950, p. 27–28, pl. 1).

The quartz diorite is separated from the hornblende-quartz diorite to the north by the Garlock fault zone, and differs from that rock in its composition and lack of gneissoid foliation. The quartz diorite is in large part separated from the quartz monzonite to the south by a stock of granite from which apophyses of pegmatite and aplite penetrate both the quartz diorite and the quartz monzonite. Only in one small area adjacent to the Tylerhorse fault is the quartz diorite in contact with the quartz monzonite, but the position of this contact is controversial because the rocks are megascopically similar. Because of this uncertainty it is possible that the southernmost part of the rocks west of the Tylerhorse fault mapped as quartz diorite may be quartz monzonite.

The quartz diorite is light gray to nearly white, and it generally is massive, although in some places it shows weakly formed gneissoid foliation. The rock is medium to coarse grained and is composed of quartz, feldspar, and a little biotite. Two samples studied contain the following mineral percentages: quartz, 15 to 25; orthoclase, 5 to 15; plagioclase (oligoclase), 60; biotite and (or) chlorite, 1 to 15; sphene, 0 to 5. The average percentages given by Wiese (1950, p. 27) were: quartz, 35 to 45; plagioclase (andesine), 45 to 50; biotite, 10 to 15; sphene, commonly present.

The quartz occurs as clear glassy grains of irregular shape 1 to 3 mm across. The feldspar is cloudy white and in anhedral grains 1 to 5 mm across. Biotite forms small flakes, mostly less than 1 mm across, usually in clusters between or around grains of feldspar.

QUARTZ MONZONITE

Quartz monzonite, with local variations to granodiorite and granite, is the most widespread granitic rock within the two mapped quadrangles, as well as in the Mojave Desert. It is exposed on the lower slopes of the Tehachapi Mountains, extensively in the Rosamond and Bissell Hills, at Antelope Buttes, in small areas at Little Buttes, Middle Buttes, and Soledad Mountain, and in the isolated hills east of Soledad Mountain. This granitic rock probably underlies Cenozoic rocks throughout most of the two mapped quadrangles.

The contacts of the quartz monzonite with the roof-pendants of metamorphic rocks are generally sharp. Commonly the contacts are either vertical or dip steeply under the pendants. An exception is the southeastern base of the Gamble Spring Conyon pendant, which is nearly a plane that slopes westward at a very low angle. In the first canyon east of Gamble Spring Canyon this contact appears to be a fault plane marked by a few inches of sheared rock; however, in the next canyon to the east there is no shear zone, and several small apophyses of quartz monzonite cross the plane into the metamorphic rocks. This nearly flat base of the Gamble Spring Canyon pendant may be related to a similar flat base, mapped and described by Wiese (1950, p. 26), of several large pendants of metamorphic rocks to the west in the Neenach quadrangle. He indicated this base "may be the plane of a pregranite thrust fault, with the intrusion of the granite confined largely to the footwall block." The eastern base of the Bean Canyon pendant also dips westward at low angles, but it is not a flat plane as is that of the Gamble Spring pendant.

The quartz monzonite is a medium- to coarse-grained holocrystalline granitic rock, gray white when fresh but commonly buff white on weathering. It is composed of more or less equal percentages of quartz, potassium feldspar, and plagioclase, a small percentage of biotite, and locally a little hornblende. The quartz is clear and glassy, and in equant grains 1 to 3 mm across. It is anhedral and appears to fill spaces between subhedral grains of feldspar. However, in one sample the quartz grains are partly rounded. The plagioclase feldspar is cloudy and white to cream white, in subhedral grains 1 to 5 mm across; the potassium feldspar in places is faintly pink. Biotite occurs as tiny flakes or subhedral tablets as much as 2 mm across. The flakes are usually scattered singly, more rarely in clusters. Hornblende, when present, occurs as small bladed prisms usually less than 5 mm long. Muscovite, sphene, and apatite are the most common accessory minerals.

In the Rosamond Hills, in Antelope Buttes, and in most of the Tehachapi Mountains the quartz monzonite is massive and uniform. Locally in the Tehachapi Mountains it shows indistinct gneissoid foliation. The rock contains no xenoliths. The mineralogy of the quartz monzonite in the areas is fairly constant, although percentages of the mineral constituents vary locally, as indicated in table 1.

A sample of quartz monzonite from Bean Canyon at the north border of the Willow Springs quadrangle appears similar to those from outcrops a few miles to the southwest. However, a thin section of this rock shows that quartz and orthoclase form the matrix; the quartz occurs as subrounded equant grains of fairly uniform size, and orthoclase fills the interspaces. Plagioclase (oligoclase- andesine), biotite, and hornblende phenocrysts are irregularly distributed throughout the matrix. Some of the orthoclase and biotite occurs as interstitial veins. The quartz monzonite of this sample contains more quartz and more orthoclase than the normal quartz monzonite, and thus approaches granite in composition.

TABLE 1.—*Mineral content (mode) of samples of quartz monzonite and its variations, from Willow Springs and Rosamond quadrangles*

[Analyst, R. D. Allen]

Sample	Rock name and location	Mineral composition, in percent											Total
		Quartz	Potassium feldspar	Alkalic feldspar	Plagioclase (calcic oligoclase)	Muscovite	Biotite	Biotite and hornblende	Opaque minerals	Sphene	Apatite	Epidote	
1	Granodiorite,[1] Mojave-Tropico road 3 miles N. of Tropico mine, sec. 36, T. 10 N., R. 13 W.	20	18		51		7			2	2		100
2	Quartz monzonite[1] ½ mile NW. of Tropico mine, sec. 10, T. 9 N., R. 13 W.	30		40	25			5					100
3	Quartz monzonite,[2] Rosamond Hills 4 miles east of Ansel, sec. 31, T. 10 N., R. 11 W.	35.6	21.3		37.3	0.1	4		0.3	0.6		0.8	100
4	Quartz monzonite,[1] Antelope Buttes, sec. 20, T. 8 N., R. 14 W.	15	30		45		10						100
5	Quartz monzonite,[1] samples from three locations in Tehachapi Mountains between Gamble Spring and Bean Canyons, sec. 6, T. 10 N., R. 14 W.; secs. 1 and 11, T. 10 N., R. 15 W.	23–35	30–40		15–30	>1		12–20		>1			100

[1] Composition based on grain count of crushed sample.
[2] Composition based on point count of thin section.

GRANITE AND GRANITE PEGMATITE AND APLITE

White plutonic rocks of diverse textures and of the general composition of granite crop out on the southeast slope of the Tehachapi Mountains between exposures of quartz monzonite to the south and quartz diorite to the north.

Most of the granite is white to cream white, medium to fine grained, and equigranular, and is composed almost wholly of quartz and feldspar. It is massive and rarely shows gneissoid foliation. The grains are interlocking. Two samples are of the following composition by volume percentages: quartz, 25 to 30; potassium feldspar, 45 to 55; plagioclase (oligoclase), 15 to 25; biotite and hornblende, 2 to 5; muscovite, less than 1.

Associated with the granite are numerous white dikes and apophyses of aplite and pegmatite. Most of these are along the southern part of the granite exposure, where they stand out in marked contrast to the gray quartz monzonite and quartz diorite which they penetrate. There are all textural gradations between fine-grained aplite, in which the grains average about 1 mm across, and coarse pegmatite in which they average about 1 cm but reach a maximum of 4 cm across. The firm intergrowth of the grains makes the rock strongly coherent. It is composed of about 35 percent quartz and 65 percent white feldspars, mostly potassium feldspar (orthoclase or microcline) and alkali-feldspar (perthite and albite). Accessories are biotite and muscovite in small scattered flakes, and at some places hornblende.

The granite and the associated aplite and pegmatite dikes may be related to the widespread granite mapped farther west in the Tehachapi Mountains by Wiese (1950, p. 24–27, pl. 1), but they are of different texture and of slightly different mineralogic composition.

QUARTZ MONZONITE PEGMATITE AND APLITE

In the northern part of the Rosamond quadrangle, quartz monzonite is locally cut by dike swarms of pegmatite and aplite of the same mineralogic composition. The dike swarms crop out in the Rosamond Hills, mostly in the western part, in the hill east of Gloster, and in the hill east of De Stazo Ranch.

The dikes range from less than an inch to about 6 feet in width and are traceable from a few feet to half a mile. Only the larger dikes (a foot or more wide and traceable for at least 200 feet) are shown on plate 10. They are generally more or less parallel and are vertical or steeply inclined. In the Rosamond Hills they trend generally slightly west of north. In the hills east of Gloster they trend northwestward and dip steeply southwestward.

The pegmatite and aplite rock of the Rosamond quadrangle is generally similar to that in the Tehachapi Mountains except that it is cream white instead of white. The rock is composed almost entirely or quartz and feldspar in the average ratio of 1:2. Pegmatite predominates over aplite, and there are all gradations between them. The grains range from 1 mm across in the aplite to as much as 4 or 5 cm across in the pegmatite. The crystals are commonly graphically intergrown. The quartz is clear and glassy. The feldspar is cloudy cream white, and is composed of both potassium feldspar (orthoclase and microcline) and plagioclase (oligoclase). A sample from the western Rosamond Hills contains the following percentages: quartz, 26; potassium feldspar (orthoclase), 33; plagioclase (oligoclase), 41. Some pegmatites contain a few flakes of biotite and muscovite. None contain accessory minerals of economic value.

TERTIARY VOLCANIC, PYROCLASTIC, AND SEDIMENTARY ROCKS

TROPICO GROUP

NOMENCLATURE, DISTRIBUTION, AND SUBDIVISIONS

The nonmarine sequence of tuff, sandstone, conglomerate, breccia, and rhyolitic volcanic rocks that form colorful outcrops in the Rosamond Hills near the town of Rosamond was first named and described as the Rosamond series by Hershey (1902a). These rocks together with similar and correlative rocks within the 30-minute Elizabeth Lake quadrangle were later described and mapped as the Rosamond formation by Simpson (1934, p. 395–401, pl. 1). After Hershey's paper appeared, the term Rosamond series was applied to similar-appearing assemblages of strata of Tertiary age in other parts of the Mojave Desert north and east of Rosamond, on the assumption that the strata represent one great period of accumulation. This usage was followed by:

1. Baker (1911, p. 354–357; 1912, p. 117–142) for the Tertiary strata at Redrock Canyon, which subsequently yielded a lower Pliocene vertebrate fauna and which were later named the Ricardo formation by J. C. Merriam (1919, p. 443–448), and mapped and described as such by Dibblee (1952, p. 25–30, pl. 1).
2. Baker (1911, p. 342–347) for the Tertiary strata of the Barstow syncline 10 miles north of Barstow, which yielded an upper Miocene vertebrate fauna and which were later named the Barstow formation by Merriam (1919, p. 441).
3. Hulin (1925, p. 42–48, map) for the Tertiary rocks of the El Paso Mountains and of the Lava Mountains within the Randsburg quadrangle. In the El Paso Mountains the westward extension of the formation that was mapped as Rosamond series by Hulin yielded an Eocene flora and was later mapped and described as the Goler formation by Dibblee (1952, p. 19–25,

pl. 1). Still later it yielded a vertebrate fossil that according to McKenna (1955, p. 514–515) indicates Paleocene age.

4. Gale (1946) for the unfossiliferous Tertiary strata below a basalt flow separating them from the overlying borate-bearing clay unit in the Kramer borate district.
5. Gardner (1940, p. 278–281) for the unfossiliferous Tertiary fanglomerate, sandstone, tuff, agglomerate, and lava in the Newberry Mountains south of Daggett and Newberry.

Because of the confusion resulting from the indiscriminate application of the name Rosamond to so many widely separated incongruous assemblages of strata of Tertiary age within the Mojave Desert, the name Rosamond has been abandoned as a stratigraphic term by the Geological Survey. Therefore, the unit mapped by Simpson (1934) as the Rosamond formation and originally described as the Rosamond series by Hershey (1902a) was renamed the Tropico group (Dibblee, 1958, p. 136–139). The Tropico group includes similar and probably correlative rocks in the Kramer Hills.

The Tropico group includes all the sedimentary, pyroclastic, and volcanic rocks of Tertiary age exposed in the Willow Springs and Rosamond quadrangles. The most prominent exposures, designated as the type section, are in the Rosamond Hills just west of the Mojave-Tropico road, in the W½ sec. 1 and E½ sec. 2, T. 9 N., R. 13 W. Isolated outcrops occur in nearby Tropico Hill, Willow Springs Mountain, Middle Buttes, and Soledad Mountain; in the Bissell Hills; and at Little Buttes and Antelope Buttes.

In exposures the stratified rocks of the Tropico group rest unconformably on quartz monzonite and in one place on metaquartz latite, and are overlain unconformably by Quaternary alluvial sedimentary deposits.

Within the two mapped quadrangles, the Tropico group is divisible into two distinctive units. The lower unit, mapped as the Gem Hill formation, is composed of pyroclastic sedimentary rocks and intrusive and extrusive volcanic rocks. This unit is overlain, in places unconformably, by an upper unit mapped as the Fiss fanglomerate. In the extreme northeast corner of the map area the Gem Hill formation is overlain instead by an upper unit mapped as the Bissell formation that is composed of sedimentary rocks of lacustrine and stream-laid origin.

GEM HILL FORMATION

DISTRIBUTION AND GENERAL FEATURES

The light-colored sequence of lithic tuff, tuff breccia, tuffaceous sandstone, conglomerate, and associated volcanic rocks that form the lower part of the Tropico group in the Rosamond Hills was named the Gem Hill formation (Dibblee, 1958, p. 1940), after Gem

Hill, the type locality, in the S½ sec. 25, SE½¼ sec. 26 and NE¼ sec. 35, T. 10 N., R. 13 W.

The Gem Hill formation crops out in a nearly continuous belt that extends from Gem Hill, near the west end of the Rosamond Hills, southeastward nearly 8 miles to Red Hill. Other isolated outcrops of this formation are associated with intrusive quartz latite at Tropico Hill, Willow Springs Mountain, Middle Buttes, Soledad Mountain and eastward to De Stazo Ranch. Other exposures occur in the Bissell Hills, and at Little Buttes and Antelope Buttes in Antelope Valley.

The Gem Hill formation is of volcanic origin and represents a period of great volcanic activity in the western Mojave Desert. The formation is composed predominantly of rhyolitic [2] pyroclastic material emitted from volcanic vents at the sites of Soledad Mountain and Middle Buttes, and from numerous other smaller vents within 10 miles of these volcanic centers. This material accumulated in the form of volcanic ash on the deeply eroded and weathered surface of the pre-Tertiary crystalline rocks. The ash that covered most if not all the western Mojave Desert region in middle Tertiary time is now consolidated into tuffaceous stratified rocks. During the latter stages of this volcanic activity the numerous vents, through which this material was spewed out by magmatic gases, were filled with intrusive rhyolitic magma to form volcanic plugs, and in places this magma spilled out of some vents to form tongue-like wedges of rhyolitic flow breccia within the pyroclastic material. Besides these numerous rhyolitic masses the Gem Hill formation contains some basaltic flows and dikes but these are few and of small areal extent.

As shown on plate 10, the igneous rocks of the Gem Hill formation are mapped separately from the pyroclastic rocks. The pyroclastic rocks are mapped as a single rock unit, and because they constitute the bulk of the Gem Hill formation, they are described in the following paragraphs simply as the Gem Hill formation, as originally defined (Dibblee, 1958, p. 140). The numerous intrusive and extrusive masses of rhyolitic volcanic rocks are mapped as the Bobtail quartz latite member of the Gem Hill formation, and are described as a separate rock unit. The small intrusive and extrusive masses of basaltic rocks are also mapped and described as a separate rock unit.

The Gem Hill formation erodes to conspicuous light-colored exposures that are generally smooth and almost devoid of vegetation.

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[2] Throughout this report the term "rhyolitic" is used to include material or rocks of the composition of rhyolite, quartz latite, and dacite, which are generally distinguishable only by microscopic examination or by chemical analysis.

In places the formation contains thin hard resistant layers that protrude as thin ledges as shown in figure 6.

The Bobtail quartz latite member is the most resistant rock unit within the western Mojave Desert; it forms craggy outcrops within this area of generally low relief. The largest masses crop out as prominent steep-sided buttes. For example, Soledad Mountain, the most conspicuous landmark in the western Mojave Desert, is the erosional remnant of several closely spaced volcanic necks of this rock, as seen in figure 7.

LITHOLOGY

The Gem Hill formation is a generally well stratified sequence of light-colored rhyolitic, lithic, and lapilli tuffs, and tuff breccias with local facies of tuffaceous conglomeratic sandstone, volcanic conglomerate, and some chemically deposited siliceous shale, chert, and limestone. Silicified or welded layers of nearly all facies are common. White beds of fine-grained rhyolitic tuffs occur only locally, usually in the lower part.

Lithic and lapilli tuffs constitute the major part of the Gem Hill formation. They are composed of scattered to abundant small angular rock fragments and pumice lapilli generally less than 10 mm across, embedded in a white, tan, and light-green very fine to medium grained indurated matrix containing grains of quartz, feldspar, biotite, and volcanic material. The embedded fragments are poorly sorted and are mainly of white to pinkish-brown rhyolitic rocks that are either dense, flow banded, or porphyritic. Others are of granitic material, chiefly quartz monzonite. The pumice fragments are generally of pea size and are subrounded; they are devitrified to a soft white material that is commonly leached out, leaving vugs or semivugs. Some layers contain fragments of soft dense white material that appears to be fragmented tuff, redeposited by stream action. The lithic and lapilli tuffs and tuff breccias are commonly sandy and locally contain layers of massive to laminated tuffaceous sandstones or even some arkosic sandstones.

As the size of the angular fragments increases, the lithic and lapilli tuffs grade into the interbedded tuff-breccia. This in turn grades into volcanic conglomerate with further increase in size and rounding of the fragments. The fragments locally are as large as 4 feet in diameter. The breccia and conglomerate consist of brown volcanic detritus of rhyolitic to andesitic composition with subordinate amounts of granitic detritus.

In the western Rosamond Hills chemically deposited sedimentary strata in the form of siliceous shale occur near the base of the Gem Hill formation. At Little Buttes the formation contains partly silicified tuffaceous shale, and hard layers as much as 2 feet thick

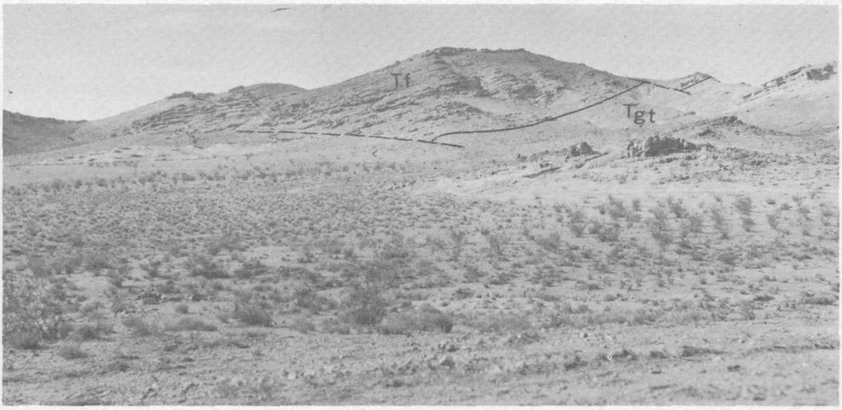

FIGURE 6.—Fiss fanglomerate overlying Gem Hill formation. View west in western Rosamond Hills; dark exposures on left and center are Fiss fanglomerate (Tf); light-colored exposures on right are tuff, sandstone, and breccia of Gem Hill formation (Tgt).

FIGURE 7.—Bobtail quartz latite member of Gem Hill formation in Soledad Mountain. West side of Soledad Mountain, showing volcanic plugs of felsite that form jagged outcrops; workings are of Elephant mines (hill on right) and Golden Queen mine (mountains in background).

of gray chert and cherty limestone of probable lacustrine origin interbedded in the softer lithic tuff.

The Gem Hill formation is unaltered except where it is intruded by volcanic plugs of the Bobtail quartz latite member, as at Soledad Mountain, Middle Buttes, Willow Springs Mountain, Tropico Hill, and in the southern Rosamond Hills. In these areas the lithic tuff is generally silicified to a hard brittle porcelaneous rock by thermal

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action of volcanic plugs. In some places the tuff is altered to a soft bentonitic clayey material, probably by hydrothermal action during or after emplacement of the plugs.

EXPOSURE AND STRATIGRAPHY IN THE ROSAMOND HILLS

Because of great lateral variations in lithology within this pyroclastic formation there is no definite sequence of beds consistent throughout its areal extent in the Rosamond Hills. The thickness is likewise highly variable and the formation thickens along strike from east to west. This westward thickening is largely the result of admixture and addition of large amounts of coarse detritus. In the western Rosamond Hills the Gem Hill formation grades upward through interbeds into the overlying Fiss fanglomerate and attains its maximum exposed thickness of 1,200 feet at Gem Hill. This exposure is therefore designated the type locality of the Gem Hill formation. At this exposure, the formation is a well-stratified stream-laid sequence of alternating beds of light-colored lithic to sandy tuff, lithic tuff-breccias, and subordinate interbeds of darker volcanic conglomerate; it contains several thin flows of basalt of limited extent. A measured section of the Gem Hill formation at its type locality is given below:

Section of Gem Hill formation at the type locality, Gem Hill, western Rosamond Hills, S½ sec. 25, 26, N½ secs. 35, 36, T. 10 N., R. 13 W.

	Feet
Fiss fanglomerate-Gem Hill formation transition zone:	
Lithic tuff-breccia, minor amount of volcanic pebble-cobble conglomerate	59
Conglomerate, cobbles as much as 1 foot in diameter	20
Lithic tuff-breccia, minor amount conglomerate	50
Conglomerate, minor amount tuff-breccia	20
Gem Hill formation:	
Lithic tuff-breccia, minor amount of conglomerate	15
Conglomerate, hard; forms prominent ledge	5
Tuff-breccia, minor amount of volcanic sandstone and cobble conglomerate	65
Cobble conglomerate	3
Lithic tuff-breccia, minor amount of pebble conglomerate	20
Conglomerate of volcanic and granitic boulders	6
Lithic tuff-breccia, minor amount of volcanic sandstone and pebble conglomerate	30
Conglomerate of volcanic and granitic boulders	5
Lithic tuff-breccia, minor amount of volcanic sandstone and conglomerate	16
Conglomerate of volcanic and granitic boulders	27
Lithic tuff-breccia and volcanic sandstone, minor amount of conglomerate	66
Conglomerate of granitic and volcanic cobbles	2
Lithic tuff-breccia and sandstone	7
Conglomerate of granitic and volcanic cobbles	5
Lithic tuff-breccia and sandy tuff; top bed hard	10

Section of Gem Hill formation at the type locality, Gem Hill, western Rosamond Hills, S½ sec. 25, 26, N½ sec. 35, 36, T. 10 N., R. 13 W.—Continued

	Feet
Gem Hill formation—Continued	
Conglomerate of granitic and volcanic boulders	2
Lithic, fine to coarse, sandy tuff, cream-white	30
Basalt, black, amygdaloidal	0–30
Lithic tuff-breccia	20
Conglomerate	3
Lithic tuff-breccia	20
Tuff-breccia and interbedded volcanic sandstone and conglomerate; forms prominent ledges	10
Lithic tuff-breccia	40
Conglomerate; caps Gem Hill	10
Basalt, black, fine-grained, with 2 ft of gray to green chert at top; crops out on south slope of Gem Hill; may be intrusive	0–10
Lithic tuff-breccia, minor amount of volcanic sandstone and conglomerate; well-bedded	40
Lithic tuff-breccia	60
Basalt, black, amygdaloidal; overlain by about 1 ft of gray to green chert and opal; crops out of northeast slope of Gem Hill on the northwest side of a small fault	0–8
Small fault.	
Lithic tuff-breccia, and intercalated tuffaceous sandstone and silicified fine-grained tuff; unit hard, well-stratified	190
Lithic tuff-brecia and volcanic conglomerate; pebbles and cobbles as much as 6 in. in diameter	5
Lithic tuff-breccia	10
Possible small fault.	
Lithic tuff-breccia, tuff, and tuffaceous sandstone; some layers partly silicified; well-bedded; some volcanic conglomerate; unit forms strike ridge between Gem Hill and Mojave-Tropico road	50±
Basalt, black, vesicular, fine-grained, friable (crossed by Mojave-Tropico road)	100±
Volcanic breccia, subangular fragments as much as 1 foot wide of quartz latite in loose sandy matrix	25±
Volcanic breccia, angular fragments as much as 3 ft wide of quartz latite embedded in very hard brown silicified tuffaceous matrix	5
Lithic-lapilli tuff, tuffaceous sandstone, and some silicified tuffaceous shale; hard, well-bedded	85
Unexposed; probably tuff-breccia	18
Lithic and sandy tuff, bedded, hard, silicified	9
Shale, tan, hard, stratified, platy, siliceous; minor thin beds of chert as much as ½ in. thick	10
Lithic-lapilli tuff-breccia, gray, sandy	22
Total exposed thickness of Gem Hill formation, and Fiss fanglomerate-Gem Hill formation transition zone	1, 293±

Base not exposed, estimated about 50 feet below lowest exposure.

It is not certain that this section gives the true thickness of the Gem Hill formation; there are several minor faults and parts of the formation may be repeated.

The lithic tuff-breccia is greenish tan to cream white, and contains numerous small fragments (1 to 20 mm in size) of pink to brownish-white altered volcanic rock, and some of granitic rock, as well as lapilli of white devitrified pumice. The cream-white to light-green tuffaceous matrix is dense to sandy and well indurated. Some layers are somewhat massive and appear to be mud-flow breccia, but most of them, especially the sandy layers, are well stratified (fig. 8), even locally cross-bedded; probable sorting and transportation by stream action is indicated.

FIGURE 8.—Gem Hill formation at type section. Exposure on east side of Mojave-Tropico road near Rosamond Uranium Prospect, showing layers of volcanic breccia and conglomerate intercalated in well-bedded tuffaceous sandstone. Thickness shown in photograph is approximately 10 feet.

There are all gradations among tuffaceous sandstone, lithic tuff breccia, and volcanic breccia and conglomerate. These rock types are commonly interbedded as shown in figure 8. The numerous interbedded layers of conglomerate are of a prevailing brown color and are well indurated to form prominent ledges. They are composed of poorly sorted subrounded fragments of pinkish-brown massive, flow-banded to porphyritic volcanic rocks ranging from rhyolite and quartz latite to andesite in composition. From 1/10 to 1/3 of the fragments are composed of quartz monzonite. These conglomerates are similar to the overlying Fiss fanglomerate but are not as coarse. They appear to lens in from the west and disappear southeastward along strike.

The base of the Gem Hill formation is not exposed in this section but crops out to the south on the upthrown side of a large fault, just east of the Mojave-Tropico road. There the lowest bed, which rests upon quartz monzonite, consists of about 20 feet of hard tuff-breccia containing large angular fragments of rhyolitic rocks.

The unfaulted, southward-dipping homoclinal section of the Gem Hill formation exposed just north of Fiss Hill, is much thinner than that of Gem Hill, but the lithology is characteristic of this formation throughout most of the mapped area. The general stratigraphic sequence, which is completely exposed, is listed below:

Section of Gem Hill formation exposed near Fiss Hill, NE¼ sec. 2, T. 9 N., R. 13 W.

	Feet
Fiss fanglomerate.	
Unconformable(?) contact.	
Gem Hill formation:	
Basalt lentil, black, amygdaloidal	90
Lithic tuff-breccia, white, with small rock fragments	13
Lithic tuff-breccia, white, with volcanic rock fragments as much as 5 in. across	27
Lithic tuff-breccia, greenish-tan, with volcanic and some granitic rock fragments as much as 2 in. across	2
Lithic tuff, greenish-white, with small (one-half in. or less) volcanic rock fragments of pumice(?) lapilli	45
Lithic tuff-breccia	5
Lithic tuff, greenish-white	23
Lithic tuff-breccia, rock fragments as much as 1 in. across	17
Lithic tuff, greenish-white	50
Lithic tuff-breccia	3
Lithic tuff, greenish-white	19
Lithic tuff, greenish-tan	95
Lithic tuff, white	55
Lithic tuff, white, hard, silicified, platy	5
Lithic tuff, white to tan, bedded, hard	27
Unexposed, probably soft white tuff. Along strike about 300 ft east this interval is probably represented by about 45 ft of white massive to bedded fine sandy tuff resting on quartz monzonite	20
Total thickness of Gem Hill formation	496
Quartz monzonite, weathered rusty yellow.	

The lithic tuffs of this section are white and tan to greenish tan, and are composed of very small (1 to 5 mm) angular fragments of light-brown volcanic rocks, a minor amount of granitic rocks, and some pieces of soft white fragmental tuff or devitrified pumice. These are embedded in a very fine to medium-grained arkosic sandy tuffaceous matrix. The lithic tuff-breccia is similar to that of the section at Gem Hill. There are no strata of coarse volcanic conglomerate or siliceous shale in the section at Fiss Hill.

The basal contact of the Gem Hill formation is well exposed just east of the Fiss Hill section and the basal white tuff, 45 feet thick, crops out conspicuously (fig. 9). This tuff layer pinches out westward along strike and thickens eastward across the Mojave-Tropico road. At the Gem Hill section it is either absent or is represented by tuff-breccia.

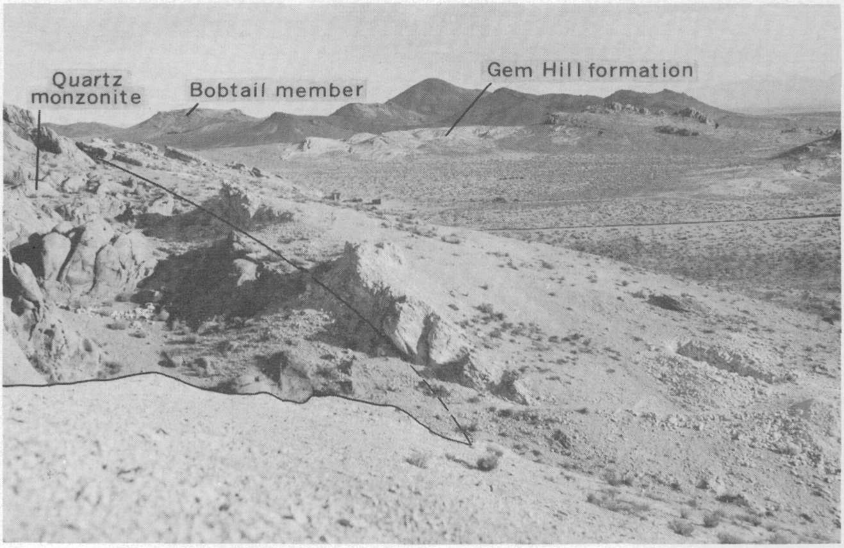

FIGURE 9.—Basal tuff of Gem Hill formation overlying quartz monzonite. View southeastward in Rosamond Hills just west of Mojave–Tropico road; quartz monzonite exposed on left; dark hills in background are exposures of Bobtail quartz latite member intrusive into and extrusive on Gem Hill formation that forms light-colored hills.

The basalt flow at the top of the Fiss Hill section is of the same lithology as are the three flows in the section at Gem Hill, and may be correlative with one of these flows. If this is so, then the strata above the flow at Gem Hill are absent at Fiss Hill, possibly because of overlap by the Fiss fanglomerate. This possible overlap is also suggested by the much lesser thickness of the Gem Hill formation at Fiss Hill as compared to its thickness at Gem Hill.

In the exposures between the Mojave-Tropico road and U.S. Highway 6, the pyroclastic rocks of the Gem Hill formation are much deformed by tectonic movements and are cut by so many volcanic intrusions of the Bobtail quartz latite member that the stratigraphic sequence is difficult to unravel. In the low hills within a mile east of the Mojave-Tropico road the stratigraphic sequence is generally the same as at the Fiss Hill section west of the road, except that the basal layer of white tuff thickens to about 100 feet. To the southeast, within 2 miles west of U.S. Highway 6, the stratigraphic sequence is largely obscured by volcanic intrusive rocks and structural complexities.

On hill 3091 northwest of Rosamond, which is the location of the type section of the Rosamond series as described by Hershey (1902a), the pyroclastic sequence of the Gem Hill formation may be divided into several units somewhat as recognized by W. B. Roberts (*in* Noble, 1954), but these units are of local extent and their thickness and lithology change rapidly along strike. This rapid change is no doubt the local effect of contemporaneous intrusion of the associated Bobtail quartz latite member during deposition of the tuffaceous sediments. The general stratigraphic sequence is roughly as follows:

Generalized section of Gem Hill formation on hill 3091, 1 mile northwest of Rosamond, S½ sec. 8, N½ sec. 17, T. 9 N., R. 12 W.

	Feet
Fiss fanglomerate.	
Probable unconformable contact.	
Gem Hill formation:	
Green lithic tuff:	
Lithic tuff, light greenish-tan, with rhyolitic fragments; minor lenses of tuffaceous sandstone and volcanic pebble conglomerate. Several discontinuous lenses as much as 30 ft thick of red rhyolitic breccia near top	400±
Brown conglomerate lentil:	
Volcanic cobble conglomerate, lensing out northwestward against a small plug of red quartz latite	0–50
Pink and green lithic tuff:	
Lithic tuff and tuffaceous sandstone, lower part pink and tan, upper part green; possible local unconformity at base	120±
White lithic tuff	200±
Approximate range in thickness of Gem Hill formation	720–770
Unconformity.	
Quartz monzonite.	

The green lithic tuff of this section is generally similar to that of the Fiss Hill section, except that the predominant rock type is massive to poorly bedded lithic tuff which in places is partly silicified or welded. The layers of tuffaceous sandstone and volcanic pebble conglomerate occur mostly in the upper part of this member.

The lentil of brown conglomerate is composed almost entirely of subrounded and angular fragments as much as a foot in diameter of brown and red to pink quartz latite or rhyolite. The fragments are similar to and were probably derived from the mass of volcanic breccia, upon which this conglomerate lentil rests in part.

The pink and green lithic tuff exposed on the east slope of hill 3091 is more prominently stratified than the overlying brown conglomerate, and it contains several layers of tuffaceous sandstone. The lower beds are pink and a slight local unconformity appears to occur at the base.

The white tuff is well exposed on the east and northwest slopes of hill 3091 where it is cut by the quartz latite intrusions. The tuff is conspicuously and evenly stratified with individual beds ranging from less than an inch to nearly 2 feet in thickness. The lapilli and volcanic rock fragments are well sorted. The stratification of this white tuff is not everywhere parallel to the basement surface upon which it rests, but in places dips at angles into this surface as on the northwest slope of hill 3091. These anomalous attitudes appear to be local initial dips or possibly foreset layers deposited by stream action. The white tuff rests on an eroded surface of quartz monzonite which is weathered rusty yellow.

Along the southern margin of the Rosamond Hills between U.S. Highway 6 and Red Hill, the Gem Hill formation crops out for 3 miles and forms an alinement of prominent light-colored hogbacks. It is composed of white to greenish-white lithic tuff about 300 feet thick. It rests on a nearly flat eroded surface of quartz monzonite which is weathered rusty brown or brick red to a maximum depth of 25 feet below the contact. The Gem Hill formation is here overlain unconformably by the Fiss fanglomerate.

In this section the lithic tuff is well stratified, and is composed of angular to subangular fragments that average about half an inch across and that are embedded in a fragmental matrix of dense white tuff. The lithic tuff is similar to that exposed near Fiss Hill in the western Rosamond Hills. Locally the tuff contains, mostly in the basal part, scattered subrounded cobbles and boulders of quartz monzonite and pegmatite as large as a foot in diameter.

At the top of the Gem Hill formation a mile northwest of Red Hill a lava flow, about 50 feet thick, is traceable along strike for about 1,000 feet and is overlapped in both directions by the Fiss fanglomerate. It appears to have flowed from a feeder dike of basalt cutting diagonally across the Gem Hill formation just to the northwest.

The stratigraphic relations of the Gem Hill formation as exposed at U.S. Highway 6 and eastward in the Rosamond Hills are uncertain, because of faulting and the presence of intrusive masses of the Bobtail quartz latite member just west of the highway. The exposure may represent the entire formation as exposed to the west in hill 3091, but more likely it represents only the lower part, possibly only the white tuff and pink and green lithic tuff of that section. If the latter is true, then the upper part of the Gem Hill formation exposed east of the highway is overlapped by the Fiss fanglomerate. Just west of the highway in the SE¼ sec. 8, T. 9 N., R. 12 W., the Fiss fanglomerate lies on progressively lower beds of the tuff northwestward along strike until it rests on the basal part at the west end of the exposure.

The northward-dipping lithic tuff associated with intrusive quartz latite just west of Red Hill is largely silicified to an opaline rock.

EXPOSURES AT SOLEDAD MOUNTAIN

The Gem Hill formation exposed in the Soledad Mountain area is a sequence of light-colored tuff and breccia generally similar to those in the western Rosamond Hills. The sequence rests on the pre-Tertiary rocks exposed in the northeastern foothills of the Soledad Mountain area, and dips at low angles in a generally southerly direction. The upper part of the sequence here is eroded so that the exposed section is incomplete, and the remaining strata are intruded by numerous volcanic bodies of the Bobtail quartz latite member.

The largest exposure of the pyroclastic sequence in this area is around the east and south sides of the large intrusive mass of the Bobtail quartz latite member that forms Soledad Mountain. The sequence there is characterized by light greenish-tan to white, poorly bedded to massive lithic tuffs and by tuff-breccia composed of angular fragments of massive to flow-banded, tan to brown felsitic and porphyritic quartz latite similar to that of the intrusive masses of this area. Lenses of tuffaceous sandstone occur locally. On the south slope of the mountain the highest strata consist of tuff-breccia and admixtures of light greenish-brown volcanic sandstone and breccia composed of subangular fragments averaging about 2 inches in diameter but reaching a maximum of more than a foot. The total exposed thickness of this sequence is estimated at about 600 feet, but irregular initial dips and abundant quartz latite talus that masks most of the exposures prevent an accurate measurement. There is little evidence of hydrothermal alteration in this exposure, despite the numerous volcanic intrusions. The tuffs and breccias are only locally silicified adjacent to the larger intrusions, and the softer tuffs are in part altered to bentonite.

In the large exposure extending southwestward from Soledad Mountain, the pyroclastic sequence is similar to that exposed around Soledad Mountain. Massive light-green lithic tuff predominates. The most southeasterly outcrop is formed by massive tuff breccia, which is about 300 feet thick, but the base is unexposed. The tuffaceous rocks are locally silicified by hydrothermal action accompanying the volcanic intrusions. A thick flow of vesicular basalt in the lower part of this section apparently pinches out westward.

In the hills extending southeastward from Soledad Mountain, the Gem Hill formation consists of light greenish-tan poorly bedded volcanic sandstone and breccia similar to that exposed on the south slope of Soledad Mountain. This unit appears to be the sedimentary phase of the volcanic flow breccia exposed to the west. In the alluvium half a mile to the southwest there are two isolated outcrops of these same rock types. In the little hill a mile west of Gloster the Gem Hill formation is light greenish-brown tuff-breccia and tuffaceous sandstone. This is overlain by about 25 feet of thick-bedded gray chert, which in turn is overlain by soft-weathering basalt barely exposed at the south tip of this hill. The chert is similar to and possibly equivalent to the chert of the lower member of the Bissell formation in the Bissell Hills.

EXPOSURES IN THE BISSELL HILLS

Near the De Stazo Ranch there are two isolated exposures of the basal part of the Gem Hill formation which here consists of medium to coarse greenish-white partly silicified lithic tuff and tuff-breccia. The Gem Hill rests on quartz monzonite and is associated with several volcanic plugs of the Bobtail quartz latite member.

In the Bissell Hills, lithic tuff of the Gem Hill formation underlies the north flank of the low hogback ridge for nearly 3 miles near the south line of secs. 2 and 3, T. 10 N., R. 11 W. The tuff is largely concealed by overburden and talus from the overlying carbonate and shale member of the Bissell formation. The tuff rests on quartz monzonite that is weathered brick red below the depositional contact. The tuff is white, conspicuously stratified, and fine to medium grained, and contains felsitic rock fragments, weathered pumice lapilli, grains of quartz and feldspar, and flakes of biotite. At the west end of the exposure the tuff is at least 140 feet thick, but eastward along strike it gradually thins to about 90 feet at the eastern border of the Rosamond quadrangle. Within half a mile of the border, the basal part of the tuff also changes laterally eastward to about 15 feet of cobble-boulder conglomerate derived from the underlying quartz monzonite. The following section exposed north of the Bissell magnesite pits is characteristic of the Gem Hill formation of this area.

Gem Hill formation exposed in Bissell Hills, north of Bissell magnesite pits, N½ sec. 11, T. 10 N., R. 11 W.

	Feet
Bissell formation, carbonate and shale member (see p. 194).	
Gem Hill formation:	
Tuff, green-white, bedded, fine- to coarse-grained; some layers are lithic and contain small white rock fragments as much as 2 mm wide	82
Tuff; same as above, but contains grit of granitic rocks	3
Tuff, white, fine- to coarse-sandy, massive to poorly bedded, arkosic; contains biotite	37
Total thickness of Gem Hill formation	122
Unconformity.	
Quartz monzonite, weathered red to about 25 ft below contact; no gouge.	

EXPOSURES IN MIDDLE BUTTES, WILLOW SPRINGS MOUNTAIN, AND TROPICO HILL

In the volcanic centers of Middle Buttes, Willow Springs Mountain, and Tropico Hill, tuff of the Gem Hill formation occurs only as small isolated remnants engulfed in intrusive rock, of the Bobtail quartz latite member. In these exposures the tuff is white, massive to bedded, fine to medium grained, and contains small volcanic rock fragments. Most of the tuff is altered or partly altered either to a hard siliceous rock or to soft clayey bentonitic material, probably by hydrothermal solutions accompanying or following the intrusions. Small veins of chert or opal, a fraction of an inch to several feet thick, are commonly present.

At Middle Buttes pyroclastic rocks of the Gem Hill formation occur only as remnants between large intrusive masses of the Bobtail quartz latite member and in most places are covered by talus and overburden from these intrusive masses. The pyroclastic rocks consist of soft-weathering gray-white tuff-breccia. Much of what is exposed is silicified and can be differentiated from the associated intrusive quartz latite only by the presence of fragments of quartz latite and altered pumice.

At the east end of Willow Springs Mountain the pyroclastic facies of the Gem Hill formation consists of conspicuously stratified white lithic tuff resting on quartz monzonite that is weathered to a deep red color. In the western part of the mountain the lithic tuff is largely silicified to a massive semiopaline rock in which stratification is largely obliterated.

At Tropico Hill pyroclastic rocks of the Gem Hill formation are massive lithic tuff and fine-grained tuff that are almost completely silicified to dense opaline rocks very similar to the enclosing quartz latite. The silicified tuffs are differentiated from the quartz latite only by the presence of fragments of quartz latite and altered pumice, and by the lack of flow laminae that occur in much of the intrusive quartz latite.

EXPOSURES AT LITTLE BUTTES

At Little Buttes about 800 feet of eastward-dipping strata of the Gem Hill formation is exposed. The base between this hill and the outcrop of quartz monzonite to the west is buried under alluvium. The top of the Gem Hill formation to the north and east is buried. The Gem Hill here consists of light greenish-tan tuffaceous sandstone and siltstone strata alternating with layers of lithic tuff, tuff-breccia, limestone, and chert. The tuff and tuff-breccia contain small subrounded to angular fragments of pumice, obsidian, and felsite in a moderately indurated tuffaceous matrix. The limestone, in beds as much as 2 feet thick, is tan to gray, is impure, and contains chert nodules. Associated with the limestone beds are layers of thin-bedded gray chert. These limestone and chert beds are of lacustrine origin.

EXPOSURES IN ANTELOPE BUTTES

The Gem Hill formation crops out in Antelope Buttes where it dips northwestward and extends southwestward a quarter of a mile beyond the southern border of the Willow Springs quadrangle. The Gem Hill formation here is about 1,250 feet thick; it rests upon quartz monzonite and is overlain by the Fiss fanglomerate. The Gem Hill is composed of well-stratified, moderately indurated white rhyolitic lithic tuff remarkably similar to that in the Rosamond Hills. The rock fragments are angular to subangular and average about half an inch in size. They are composed of brown massive to flow-banded felsitic to porphyritic volcanic rocks, and few are of granitic rocks. They are scattered and embedded in a matrix of white tuff or tuffaceous sandstones. A few layers are composed of tuff-breccia.

At the top of the formation is a lens of soft-weathering basalt as much as 20 feet thick and traceable for about 100 feet, similar to that at the top of the Gem Hill formation in the Fiss Hill section in the Rosamond Hills. The basalt is fine grained and vesicular; it weathers to a greenish-black soil and is poorly exposed.

BOBTAIL QUARTZ LATITE MEMBER

The light-colored volcanic rocks that are prominently exposed as a group of volcanic plugs and necks on Soledad Mountain and Middle Buttes, and as smaller satellite plugs within a radius of 8 miles of these volcanic centers, were named the Bobtail quartz latite member of the Gem Hill formation (Dibblee, 1958, p. 140–141). The type locality is Soledad Mountain, in secs. 6 and 7, T. 10 N., R. 12 W., and the member was named after the Bobtail mines on the west slope. This igneous rock is differentiated from the pyroclastic strata of the Gem Hill formation but is designated as a member of that formation because it occurs not only as numerous intrusive bodies but as short wedges of flow breccia within the pyroclastic strata. The igneous rocks that are mapped as the Bobtail quartz latite member have been referred to as "dacite and rhyolite" by Simpson (1934, p. 396–399) and commonly are called "rhyolite" by the local miners. They are collectively called quartz latite in this report because several samples were all determined to be of the probable composition of quartz latite (R. D. Allen, written communication, 1955). However, it must not be assumed on the basis of these few samples that all the rocks included in the Bobtail quartz latite member are of that composition only, because determination of many samples may reveal the presence of rocks of the composition of rhyolite, dacite, and latite, as well as quartz latite, which are accurately distinguishable only by microscopic examination or chemical analysis.

The satellite plugs of the Bobtail quartz latite member occur as far westward as Bean Canyon and as far eastward as the western Bissell Hills. Several others are found just beyond the northern border of the mapped quadrangles. Some 6 miles south of the volcanic centers of Middle Buttes and Soledad Mountain, the Bobtail quartz latite member crops out as a series of volcanic plugs or cores, alined generally east-west along the north margin of Antelope Valley. From west to east these plugs form Willow Springs Mountain, Tropico Hill, many small plugs in the southern Rosamond Hills, and Red Hill.

The Bobtail quartz latite member is massive to flow-laminated and ranges in color from cream-white through tan, brown, pink, red, and purplish-brown, to greenish-brown. The massive rock fractures into large irregular-shaped blocks, while the flow-laminated rock commonly splits along lamination planes into platy slabs.

Four facies of the Bobtail quartz latite member were recognized and mapped. Three were based on variations in texture: a porphyry facies; a felsite and porphyritic felsite facies; and a perlite facies. All appear to be volcanic plugs and are therefore of probable intrusive origin. Part of the fourth facies, felsite breccia, borders some of the volcanic plugs, and part occurs as wedges of flow breccia in the Gem Hill formation parallel to its stratification, so that the facies is of both intrusive and extrusive origin.

The porphyry facies is most widespread in the vicinity of Soledad Mountain, but is also present on Willow Springs Mountain and Tropico Hill. It ranges in color from pink to grayish brown and is massive to faintly flow laminated. This facies consists of 20 to 30 percent euhedral phenocrysts set in an aphanitic to fine-grained groundmass. Most of the phenocrysts are from 2 to 3 mm long, but some are as much as 5 mm. They consist of plagioclase (oligoclase), sanidine, and quartz, in order of decreasing abundance. Also present are hexagonal plates of hematite, possibly pseudomorphous after biotite, and elongated vugs lined with iron oxides, possibly formed from leaching of hornblende. The groundmass contains disseminated hematite. At Tropico Hill the porphyry contains biotite.

The felsite and porphyritic felsite together are the most widespread facies of the Bobtail quartz latite member and form most of the volcanic plugs within the mapped area. This facies is in most places cream white or tan, but locally is of the various colors previously mentioned. It is massive to conspicuously flow laminated.

In contrast to the porphyry just described, the felsite is aphanitic and in some places glassy, and contains only a few very small phenocrysts of feldspar and quartz. The porphyritic felsite is transitional between the felsite and porphyry, and is distinguishable from the porphyry only by the smaller percentage of phenocrysts. The phenocrysts are of similar dimensions and mineral content, but generally quartz phenocrysts are the most abundant. The plagioclase and sanidine phenocrysts have generally conspicuous rectangular outlines; the quartz phenocrysts are subrounded. The aphanitic groundmass of the samples tested has a refractive index of about 1.53.

The perlite facies, a variety of obsidian, is associated with the glassy phase of the felsite. The perlite is nearly always formed along the outer margins of the volcanic plugs, apparently by rapid chilling of the magma as it was emplaced in the vents. The perlite is most prominent along the margins of some of the volcanic plugs in the Rosamond Hills, as shown on plate 10, and forms marginal zones as much as 50 feet thick, but generally much less. The perlite is a steel-gray glassy rock with generally conspicuous curved fracture that gives it an "onionskin" structure. It is massive and devoid of phenocrysts. In the Rosamond Hills, a mile southeast of hill 3091, perlite borders a mass of red felsite breccia, in which the transition zone contains scattered brown rhyolitic spherulites from 1 to several inches in diameter. Each of these contains a cavity filled with white opal or clear chalcedony. The distribution of the perlite is discussed more fully under the section on "Mineral resources."

The felsite breccia facies of the Bobtail quartz latite member is found mainly on the eastern spur of Soledad Mountain and in the southern part of the Rosamond Hills. It has formed by brecciation of the felsite and the porphyritic felsite facies, and has the same composition, texture, and structure. The breccia facies commonly makes up marginal breccia zones and terminal pinch outs of many of the intrusive masses of the felsite and porphyritic felsite facies throughout the map area. Generally these zones are only a few feet wide and are too small to map. The larger masses of felsite breccia that are shown on plate 10 are either piles or wedges of flow breccia, apparently adjacent to or within pyroclastic rocks of the Gem Hill formation. The fragments of the breccia are unsorted and as large as several feet across, but generally much less.

Much of the Bobtail quartz latite member has been hydrothermally altered, especially along brecciated zones and fault zones. The flow-laminated felsite and porphyritic felsite is more severely affected than other facies, but all rocks near solution channels are affected. The most widespread alteration occurs at Middle Buttes, where much of the quartz latite is affected. At Soledad Mountain the rock is highly altered only along and near northwestward-trending fault or brecciated zones. At Tropico Hill most of the alteration occurs along fault or fracture zones trending westward and along minor ones trending northwestward. At the east end of Willow Springs Mountain there are only minor eastward-trending altered zones. In many places the tuff of the Gem Hill formation adjacent to these affected plugs is also affected to some degree, typically by hardening from impregnation of silica into the tuffaceous sediments.

The hydrothermally altered quartz latite is commonly bleached white or cream-white, and phenocrysts of feldspar are altered to a soft white kaolinitic material which is commonly leached out to leave rectangular vugs. In places even the groundmass itself is partly altered to soft kaolinitic material. In the flow-laminated rock some laminae are more altered than others, and where leached are finely vuggy. Hydrothermally altered brecciated zones and soft vuggy zones and laminae are locally replaced by chalcedony or quartz, and are rebrecciated. In places these altered zones are mineralized with sulfides of iron, silver, and disseminated gold.

The Bobtail quartz latite member that forms Soledad Mountain and its spurs occurs as volcanic plugs, with vertical or steep outer walls, intrusive into pyroclastic rocks of the Gem Hill formation and the underlying pre-Tertiary crystalline rocks. Most of these intrusive masses are of the felsite and porphyritic felsite facies and most are elongated in a northwesterly direction; the magma probably issued through fissure vents of that trend. In many of these plugs the felsite has prominent flow laminae that are vertical or steep, or are parallel to the outer walls. The largest mass forms the high peaks of Soledad Mountain and is composed of several closely spaced volcanic plugs separated by zones of sheared and brecciated rock that is in part hydrothermally altered and mineralized.

Two of the large intrusive plugs in the Soledad Mountain area are of the porphyry facies. The larger plug forms a small mountain southeast of Soledad Mountain and extends eastward to U.S. Highway 6. In the high western part of this mass the porphyry has faint flow laminae and fracture cleavage that are concentric around the central core of this mass and dip steeply inward. This indicates that as the magma moved upward through its vent it started to fan outward as it approached the ground surface. In the eastern spur of this mass the flow laminae are less regular but dip generally steeply southward. The smaller plug of porphyry is a mile south of Soledad Mountain, on its southwestern spur. It is only partly flow laminated, and much of it is brecciated. In addition, there are several small podlike masses of this rock at the end of a spur a mile east of Soledad Mountain. Other masses are found underground on Soledad Mountain in workings of the Golden Queen mine, between intrusive masses of the felsite facies.

The large greenish-tan mass of felsite breccia on the eastern spur of Soledad Mountain appears to be a flow breccia or, as suggested by its crude bedding, possibly a detrital breccia within the Gem Hill formation. The brown felsite breccia in the southern spur of this mountain is devoid of bedding, and appears to be a volcanic pile, in part intrusive.

Northward from Soledad Mountain, just beyond the north border of the quadrangle, there are satellite pods of both the felsite and the porphyry facies of the Bobtail quartz latite member. Other pods, mostly of the felsitic facies, occur eastward to De Stazo Ranch. All are intrusive into quartz monzonite and into the tuff-breccia of the Gem Hill formation.

At Middle Buttes the Bobtail quartz latite member forms several large podlike masses intrusive into quartz monzonite and the overlying tuff and tuff-breccia of the Gem Hill formation. All the quartz latite of this area is of the felsite and porphyritic felsite facies. It is generally light tan to cream white, and is massive to faintly flow laminated. The intrusive masses are elongated in a general northwesterly direction, as at Soledad Mountain, and the flow laminae are generally vertical and trend northwestward. Much of the intrusive rock is brecciated and in part altered by hydrothermal action to soft and vuggy kaolinitic material. The narrow remnants of tuffaceous rocks that separate the intrusive masses, and even some of the quartz monzonite exposed at the north end of the buttes, are so severly affected by hydrothermal alteration that these altered rocks are difficult to distinguish from the quartz latite.

Willow Springs Mountain is not a series of northward-dipping flows and flow breccias as stated by Simpson (1934, p. 397–398), but is a large mass of the Bobtail quartz latite member intrusive into both quartz monzonite and the overlying pyroclastic rocks of the Gem Hill formation. It is the largest of the volcanic plugs along the southern margin of the Rosamond Hills. The quartz latite appears to have been injected as a series of dikes and pods, trending eastward and dipping steeply southward, which merged into a single mass at the middle part of the mountain. At the east end of the mountain the intrusive relations are well displayed. Here dikelike masses of quartz latite cut both the quartz monzonite and the overlying gently northward-dipping white tuff of the Gem Hill formation.

Nearly all the Bobtail quartz latite member on Willow Springs Mountain is of the felsite facies, with only minor amounts of porphyritic felsite. Both facies range from pink to brown and tan.

The rock is massive to faintly flow laminated. Throughout most of this intrusion, platy fracture parting is very conspicuous, parallels the faint flow laminae of the rock, and strikes eastward and dips steeply southward. In places the rock is brecciated along some zones of fracture parting. On the northwest slope of the mountain there is a small exposure of massive pinkish-brown porphyry. No perlite was found on Willow Springs Mountain.

Northeast of Willow Springs Mountain the quartz monzonite is intruded by a small northeastward-trending satellitic mass of felsite. It appears to be composed of several merging dikes or pods, with marginal zones of gray perlite as much as 20 feet wide. Eastward from this pod the quartz monzonite is cut by several eastward-trending dikes of porphyry.

In the hill a mile northeast of Willow Springs Mountain there is a small pod of felsite intrusive along a steep contact or fault between quartz monzonite and tuff of the Gem Hill formation.

Tropico Hill is another intrusive volcanic center of the Bobtail quartz latite member. The member cuts both quartz monzonite and a few remnants of the Gem Hill formation. This intrusive plug is a generally pod-shaped body nearly as large as that of Willow Springs Mountain, likewise elongated in an east-west direction and inclined steeply southward. It is composed of both felsite and porphyry facies.

The felsite of Tropico Hill is similar to that of Willow Springs Mountain except that it is nearly all tan. Flow laminae and fracture parting strike generally eastward, parallel to the northern contact with quartz monzonite, and dip steeply southward, as at Willow Springs Mountain. However, there are many irregularities and local convoluted structures, because the rock was emplaced as an intricate series of dikes and pods.

The porphyry of Tropico Hill occurs as small pod- or dike-like masses within quartz monzonite and felsite. In this area it is a massive gray porphyritic rock devoid of flow layering. Several dikes trending eastward transect the quartz monzonite northwest of Tropico Hill. The occurrence of smaller masses of porphyry within the felsite facies suggests that the porphyry is slightly younger than the felsite and is intrusive into it.

In the Rosamond Hills between the Mojave-Tropico road and U.S. Highway 6, the Bobtail quartz latite member occurs as many small plugs. Most of these are pod-shaped bodies and are generally elongated in a northeasterly or easterly direction as if radiating from Tropico Hill. The quartz latite of all these plugs is of the felsite facies and is intrusive into the quartz monzonite and the overlying Gem Hill formation. All these plugs have steep or ver-

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tical walls and vary in outline from nearly circular to teardrop shaped or dikelike. The largest covers an area of about 50 acres. Hill 3091 is formed by one of these plugs. Seven of the larger plugs have peripheral zones of glassy perlite as much as 20 feet wide. Commonly the felsite is conspicuously laminated, and the laminae and fracture cleavage of each are more or less vertical and parallel to its outer wall. The rock is usually brecciated at the ends of the podlike plugs and in the dikelike bodies. Two miles northwest of hill 3091 there are three small podlike intrusions of felsite elongated northeastward. In each of these the flow laminae are vertical or locally minutely contorted, and the rock in the peripheral zones is generally brecciated.

Red felsite breccia occurs half a mile southeast of hill 3091 as an irregular-shaped mass probably in part intrusive into tuff of the Gem Hill formation, as indicated by the generally steep contact with the tuff, although it may be in part a flow breccia. In one place the breccia shows vertical grooves of movement at the northern contact, indicating that the magma was partly solidified when extruded. In places along the southern margin this felsite breccia mass has been chilled to a peripheral zone of gray perlite as wide as 30 feet.

Across U.S. Highway 6, opposite the last-described mass of red felsite breccia, there is another similar but smaller mass. This is either an intrusion or possibly a mass of flow breccia at the top of the Gem Hill formation. It contains no perlite.

The mass of pink felsite that forms Red Hill is the easternmost plug of the Bobtail quartz latite member along the southern margin of the Rosamond Hills. The Red Hill plug wedges out northeastward into a dike in quartz monzonite, apparently along an old fault. A mile east of the end of this dike there are several other small satellite dikes of felsite trending northeastward in quartz monzonite. Local flow laminae and fracture cleavages dip steeply inward from both sides. At the west end of the plug the felsite is brecciated and in part chilled to gray perlite.

In the southeastern foothills of the Tehachapi Mountains, in the vicinity of Bean Canyon and eastward, many small dikes and pods of tan to pink felsite intrude the granitic and metamorphic rocks. These are widespread along the northeastern spur of the Tehachapi Mountains nearly as far as Warren station, Tehachapi quadrangle. Although none of the felsite intrusions are in contact with any Tertiary formation, detritus from them is abundant in the Pliocene terrestrial deposits exposed northwest of Mojave. These felsite intrusions are presumably satellitic offshoots of the Bobtail quartz latite member from the main masses that form Middle Buttes and Soledad Mountain.

BASALT IN GEM HILL FORMATION

Basalt occurs as several flows in the Gem Hill formation in the Rosamond Hills and near Soledad Mountain, and as a very small flow in Antelope Buttes. In the Rosamond Hills it occurs also as a single dike in this formation.

The largest exposure of basalt is in a hill 1⅓ miles south of Soledad Peak. This basalt is a southward-dipping flow about 200 feet thick that is traceable along strike for about half a mile and that forms a dip slope covering about 50 acres. It is within tuff-breccia of the Gem Hill formation. Mention has been made of the several thin flows of basalt at and near the top of the Gem Hill formation in the Rosamond Hills, the three at Gem Hill, the one at Fiss Hill, and the one northwest of Red Hill (p. 169–174). At Antelope Buttes black basalt occurs only as a poorly exposed lentil about 20 feet thick at the top of the Gem Hill formation.

The basalt is only moderately resistant to weathering and does not form conspicuous outcrops. It forms black exposures which contrast sharply with the light-colored tuffaceous rocks of the Gem Hill formation. Where the lava is highly vesicular, it breaks down to a greenish-black soil.

The basalt is black, fine-grained, and commonly vesicular. The rock is generally massive, but fracture parting, parallel to the top and botton of each flow, is common. The vesicles range from 1 to 10 mm in diameter and average about 3 mm. They are commonly alined or flattened parallel to flow layering, are commonly present in the rock, and are filled with secondary calcite, opal, or chalcedony.

The rock is composed of more or less equal amounts of plagioclase feldspar and ferromagnesian minerals. The ferromagnesian minerals are in part altered to secondary greenish- to rusty-brown oxidation products, chiefly iron oxides.

Under the microscope, samples from the Gem Hill area are seen to be microporphyritic, with phenocrysts of labradorite and subordinate augite in a groundmass of plagioclase, magnetite, and glass (index of refraction 1.54). The labradorite phenocrysts are riddled with vermiform intergrowth of augite. The augite is partly altered to uralite. There is no olivine. This composition indicates the rock to be basalt but close to andesite.

Two miles northeast of Rosamond there is a black dike as much as 20 feet wide of basalt or diabase that cuts diagonally across white tuff of the Gem Hill formation. The dike does not cut the underlying quartz monzonite; its truncation by the Fiss fanglomerate that lies unconformably on the tuff indicates that this dike is younger than the tuff but older than the fanglomerate. The dike rock is finely diabasic, unaltered, and nonvesicular. It is composed of plagioclase, augite, and iron oxides.

Half a mile southeast of the black dike there is a red flow at the top of the tuff of the Gem Hill formation, overlain unconformably by the Fiss fanglomerate. The flow is as much as 50 feet thick and is traceable along strike for about 1,000 feet. The flow rock is brick red and appears to be basalt or andesite-basalt that is highly oxidized, presumably by weathering prior to deposition of the overlying Fiss fanglomerate. This flow probably erupted from a fissure now filled by the black dike just described. The flow rock is composed of a groundmass of plagioclase (largely altered to kaolinitic material), iron oxides (mainly hematite and limonite) formed by oxidation of ferromagnesian minerals, and scattered small phenocrysts of feldspar weathered to a white powdery kaolinitic material.

PROBABLE AGE AND CORRELATION

The Gem Hill formation is unfossiliferous, so its age within the Tertiary period is uncertain and can only be inferred by comparing it to formations of similar character and stratigraphic position outside the mapped area.

Simpson (1934, p. 400–401) correlated the Rosamond formation, which includes rocks now called the Gem Hill formation, with the Escondido formation that he mapped in the vicinity of Sierra Pelona south of the San Andreas fault zone; he considered both to be of probable middle Miocene age. The Escondido series, originally named by Hershey (1902a, p. 350–355), referred to the Sespe formation of Oligocene age in the San Fernando quadrangle by Kew (1924, p. 38–39, map), and renamed the Vasquez series by Sharp (1935) because the name Escondido was preoccupied, is a sequence of unfossiliferous terrestrial strata, andesitic and basaltic lavas, and tuff. It rests conformably on marine strata of Eocene and Paleocene age and unconformably on pre-Tertiary crystalline rocks, and is overlain unconformably by terrestrial strata of the Tick Canyon formation of Jahns (1939, p. 821) of early or middle Miocene age and the Mint Canyon formation of Kew (1923) of late Miocene age. The correlation of the Gem Hill formation with the Vasquez is only a possibility that cannot be verified, the only evidence being that both are overlain by conglomeratess containing volcanic detritus. Data given in the following paragraph indicates that the Vasquez is older than the Gem Hill formation.

The Gem Hill formation is similar in lithology and in stratigraphic position to: (a) the Kinnick formation of middle Miocene age (Buwalda and Lewis, 1935, p. 147–148) in the mountains northeast of Tehachapi Valley north of the Garlock fault; (b) the Pickhandle formation, considered, though unfossiliferous, to be prelate Miocene in age, in the Calico Mountains,[3] in the Mud Hills, and in the Opal Mountain–Black Canyon area. Because all these formations are similar lithologically, are the only pyroclastic units in their respective areas, and appear to occupy about the same stratigraphic position, they are believed to be about the same age. Thus the Gem Hill formation is tentatively inferred to be of middle Miocene age, with the possibility that it may be in part of early Miocene age.

FISS FANGLOMERATE

DISTRIBUTION AND GENERAL FEATURES

The brown volcanic fanglomerate that overlies the Gem Hill formation in the Rosamond Hills and that forms the upper unit of the Tropico group was named the Fiss fanglomerate (Dibblee, 1958, p. 141) after Fiss Hill, the type locality, 2 miles north of the Tropico mine, in the west-central part of sec. 1, T. 9 N., R. 13 W.

The Fiss fanglomerate is well exposed at the west end of the Rosamond Hills. From there it extends discontinuously southeastward along the southwestern margin of the Rosamond Hills nearly to the town of Rosamond. It is again exposed a mile north of Rosamond and is traceable eastward to Red Hill. To the southwest across Antelope Valley the Fiss fanglomerate also crops out in Antelope Buttes.

At the west end of the Rosamond Hills the Fiss fanglomerate is well indurated and forms bold dark reddish-brown clifflike outcrops with prominent ledges (fig. 6). These commonly weather with small cavernous re-entrants. In other areas where the fanglomerate is weakly consolidated, it does not form prominent outcrops but weathers to generally rounded hills with smooth slopes strewn with loose boulders and cobbles. At Antelope Buttes it forms a prominent 2-mile long hogback with smooth cobbly slopes.

LITHOLOGY

The Fiss fanglomerate in both the Rosamond Hills and Antelope Buttes is composed of coarse, crudely stratified, poorly sorted material, characteristic of coarse alluvial fans depositel at the base of rugged mountains. Fragments in the Fiss fanglomerate are subrounded and vary greatly in size. They average between 6 and 15 inches, but in the western Rosamond Hills some are as large as 8 feet in diameter. They are generally composed of brown, reddish to pink massive to flow-laminated felsite and porphyry mainly of probable quartz latite composition, but including some of the composition of rhyolite, dacite, latite, and andesite. The fragments are embedded in a poorly sorted fragmental to sandy matrix of the

[3] See footnote 2, p. 155.

same volcanic detritus. The fragments and matrix alike impart a prevailing pinkish-brown color to this volcanic fanglomerate. In addition to these, there are minor admixtures of granitic fragments, mostly of biotite quartz monzonite, and some of pegmatite. In the extreme eastern exposures of this formation in the Rosamond Hills, granitic fragments locally exceed the volcanic fragments; the matrix, also, is composed largely of granitic detritus. The granitic facies of the fanglomerate is light-gray in contrast to the volcanic facies which is brown.

EXPOSURES IN THE ROSAMOND HILLS

The Fiss fanglomerate attains its greatest thickness in the Rosamond Hills in the extreme western part southwest of Gem Hill, where it forms the spectacular clifflike outcrops mentioned. In this area the Fiss fanglomerate is about 900 feet thick. It appears to be thicker than that because of repetition by several northeastward-trending faults. It is reddish to greenish brown, crudely stratified, and well indurated. It contains volcanic fragments as large as 8 feet in diameter. The base is difficult to map because the coarse fanglomerate grades downward through roughly 150 feet of strata into the underlying Gem Hill formation. To the south the top is eroded or buried under Recent alluvium.

The Fiss fanglomerate exposed in the unfaulted southward-dipping section at Fiss Hill, just west of the Mojave Tropico road, is fairly typical of this formation and is therefore designated the type section. Here the fanglomerate rests with a sharp, possibly unconformable contact on both the lithic tuff of the Gem Hill formation and the basalt flow at the top of that formation. The fanglomerate is about 400 feet thick but the top is eroded or concealed under Recent alluvium. The sequence of the Fiss fanglomerate at the type section is given below:

Section of Fiss fanglomerate exposed at the type locality, Fiss Hill, 1½ miles north of the Tropico mine, W½ sec. 1, T. 9 N., R. 13 W.

	Feet
Fiss fanglomerate (top of section buried under Recent alluvium):	
Loose cobbles, brown felsitic and porphyritic	40±
Fanglomerate, greenish-brown, massive; composed of subrounded cobbles as much as 1 foot in diameter of felsitic and porphyritic rocks in poorly sorted, moderately indurated greenish-brown matrix of rhyolitic detritus	60±
Fanglomerate, brown, massive; composed of subangular to subrounded cobbles and boulders of brown quartz latite and rare ones of granitic rock in soft to partly indurated matrix of felsitic and porphyritic detritus	200±
Felsite breccia, reddish-brown, massive, aphanitic, brecciated into large blocks; occurs as three discontinuous lentils along same horizon	0–40

Section of Fiss fanglomerate exposed at the type locality, Fiss Hill, 1½ miles north of the Tropico mine, W½ sec. 1, T. 9 N., R. 13 W.—Continued

	Feet
Fiss fanglomerate (top of section buried under Recent alluvium)—Con.	
Fanglomerate, light-green, massive; composed of angular to subangular cobbles and boulders of brown felsitic and porphyritic rocks, a few of granitic rock in matrix of soft light-green tuffaceous gritty sandstone	95
Approximate total thickness of Fiss fanglomerate exposed	400±
Gem Hill formation: basalt and tuff-breccia.	

The discontinuous lentils of felsite breccia 95 feet above the base are lithologically similar to the felsite breccia of the Bobtail quartz latite member of the underlying Gem Hill formation. They may be flow breccias, but since they occur as disconnected lentils in the fanglomerate and parallel to its stratification they are more probably landslide breccias derived from some nearby volcanic pile of felsite breccia, from which the detritus of the fanglomerate was also derived. For this reason these felsite lentils in the Fiss fanglomerate are not included in the Bobtail quartz latite member.

Between the Mojave-Tropico road and U.S. Highway 6 only the lower part of the Fiss fanglomerate is seen in isolated exposures. The two largest exposures are on the southwestern slope of hill 3091 and a mile west of hill 3091. At these outcrops the Fiss fanglomerate is about 300 feet thick and consists of both volcanic and granitic fragments as large as 2 feet in diameter in a moderately indurated gray-brown fragmental matrix. The Fiss rests on the Gem Hill formation, probably unconformably. Halfway between hill 3091 and Fiss Hill are two exposures of flat-lying(?) weakly indurated brown volcanic fanglomerate, resting unconformably on northwestward-dipping tuff of the Gem Hill formation. The basal part of what is questionably the Fiss fanglomerate crops out at the southeastern base of hill 3091, where the formation consists of light-brown volcanic and granitic conglomerate and sandstone that dip southeastward. On the northeast base of hill 3091, northwest of a fault, the basal 150 feet of the Fiss fanglomerate is exposed; it consists of loosely indurated brown volcanic detritus resting unconformably on the basal part of the Gem Hill formation.

The Fiss fanglomerate exposed along the south margin of the Rosamond Hills between U.S. Highway 6 and Red Hill is about 300 feet thick and rests unconformably on both the tuff and the felsite breccia of the Gem Hill formation. The fanglomerate is composed of rounded volcanic fragments, as much as 2 feet in diameter, embedded in a weakly indurated brown volcanic fragmental matrix. Stratification is apparent only in fresh exposures. Granitic fragments become increasingly abundant eastward, and in the exposures within a mile northwest of Red Hill the lower part of the formation is composed of light-gray granitic fanglomerate. The Fiss fanglomerate is there overlain unconformably by granitic gravel of the old alluvium.

EXPOSURES IN ANTELOPE BUTTES

The Fiss fanglomerate crops out in Antelope Buttes where it forms a 2-mile-long strike ridge. The fanglomerate, about 1,750 feet in thickness, dips northwestward. It rests on the Gem Hill formation with a sharp, possibly unconformable contact, as in part of the Rosamond Hills. The rounded volcanic fragments, as large as 3 feet in diameter, are similar to those in the Fiss fanglomerate of the Rosamond Hills and are predominantly pink, tan to brown felsite and porphyritic felsites. They are similar to the rhyolitic felsite that crops out 8 miles southwest in Pine Canyon, Neenach quadrangle, from which they were probably derived. The fragments are embedded in a poorly stratified and weakly indurated brown fragmental matrix of volcanic material. The top of the fanglomerate to the northwest is concealed under Quaternary alluvium.

About 500 feet above the base of the fanglomerate a lentil of red to green felsite breccia is exposed at the top of the ridge. The lentil is about 50 feet in maximum thickness and is traceable for about 150 feet along strike. This breccia is similar to that in the lower part of the Fiss fanglomerate at Fiss Hill, and although it may be flow breccia, it is more likely landslide breccia within the fanglomerate, as at Fiss Hill.

PROBABLE AGE AND CORRELATION

The Fiss fanglomerate has yielded no fossils, so its age is uncertain and can only be inferred by comparison with similar fanglomerate formations outside the mapped area.

In the hills south of the Neenach school, Neenach quadrangle, on the southwest side of Antelope Valley, or 8 to 11 miles west of Antelope Buttes, there is an exposure of fanglomerate of volcanic and granitic detritus. This fanglomerate was mapped by Wiese (1950, p. 33–35) as part of his Miocene(?) continental deposits, and correlated with brackish marine strata that he mapped as the Santa Margarita formation of late Miocene age. This fanglomerate is very similar to the Fiss fanglomerate of Antelope Buttes and rests on a mass of extrusive and intrusive felsitic volcanic rocks generally similar to those of the Bobtail quartz latite member of the Gem Hill formation. An unconformity is here indicated between the fanglomerate and the underlying mass of volcanic rocks, because the fanglomerate overlaps the volcanic rocks eastward onto quartz monzonite. This unconformity must be of regional extent and probably contemporaneous with that generally present at the base of the Fiss fanglomerate. On the basis of these stratigraphic relations, the Fiss fanglomerate may be correlative with the lower part of the Miocene(?) continental deposits as mapped by Wiese (1950, p. 33, pl. 1).

Another fanglomerate of volcanic detritus similar to the Fiss fanglomerate occurs at Soledad Pass just across the San Andreas fault, south of Palmdale. This brown volcanic fanglomerate is at the base of the Punchbowl formation of late Miocene age as mapped by Noble (1953). The fanglomerate is composed of detritus derived from the andesitic volcanic rocks of the Vasquez formation (Escondido of Simpson, 1934, p. 391–395) of Oligocene and early Miocene(?) age, which lies unconformably below it.

Formations containing facies of volcanic fanglomerate in part similar to the Fiss fanglomerate are the Barstow formation of middle and late Miocene agê, as exposed in the hills east and north of Harper Valley near Barstow, and the Bopesta formation of late Miocene age (Buwalda and Lewis, 1955, p. 148) exposed in the Tehachapi Mountains. Both formations in these widely separated areas rest unconformably on pyroclastic formations similar to the Gem Hill formation and associated felsitic volcanic rocks similar to the Bobtail quartz latite member.

On the basis of the above comparisons, the Fiss fanglomerate is tentatively assigned to the middle or upper Miocene.

BISSELL FORMATION

DISTRIBUTION AND GENERAL FEATURES

The Bissell formation is a sequence of carbonate rocks, shales, and claystones of lacustrine origin, and sandstones and conglomerates of fluviatile origin, exposed only in the Bissell Hills in the northeastern part of the Rosamond quadrangle. It is named from outcrops in the N½ sec. 11, T. 10 N., R. 11 W. (Dibblee, 1958, p. 141–142). The Bissell formation, about 800 feet in thickness, conformably overlies tuffs of the Gem Hill formation and is overlain unconformably by fanglomerate and older alluvium of Pleistocene age. The Bissell formation, originally mapped as part of the Rosamond formation by Simpson (1934, pl. 5), constitutes the upper unit of the Tropico group in this area, and may be at least in part the equivalent of the Fiss fanglomerate.

The carbonate and cherty shale strata in the lower part of the Bissell formation are highly resistant to erosion and consequently form a prominent 2-mile-long strike ridge, part of which is shown in figure 10. These hard strata crop out as prominent ledges; detrital material weathered from these strata conceals the softer intercalated shales. The overlying soft clays and sandstones are eroded to a nearly flat surface covered largely by Quaternary gravel.

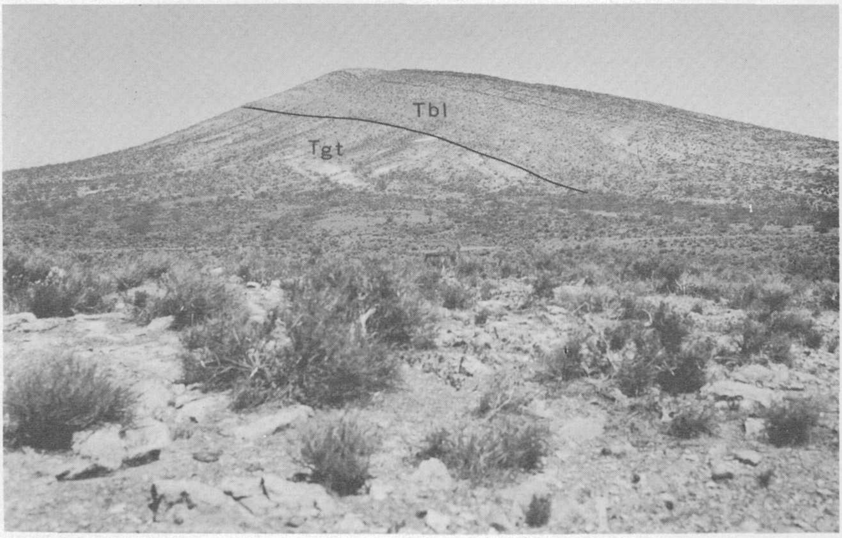

FIGURE 10.—Bissell formation overlying Gem Hill formation. Strike ridge in Bissell Hills viewed from west; crest and upper slopes formed by resistant carbonate and shale member of Bissell formation (Tbl); lower slopes showing white exposures by less-resistant tuff of Gem Hill formation (Tgt).

STRATIGRAPHY AND LITHOLOGY

The Bissell formation is divisible into the following three members in ascending order: carbonate and shale member, claystone member, and a sandstone member. The most complete section of the Bissell formation is exposed at the type locality and is generalized below:

Bissell formation exposed at type locality in N½ sec. 11, T. 10 N., R. 11 W.

	Feet
Quaternary gravel.	
Unconformity.	
Bissell formation:	
Sandstone member, alternating layers of light-gray friable arkosic sandstone, gray granitic conglomerate, gray sandy siltstone and claystone	475+
Claystone member, gray argillaceous claystone and thin layers of white magnesite	140±
Carbonate and shale member, light-gray dolomite and limestone interbedded in white platy tuffaceous and siliceous shale and gray chert	145±
Total thickness of Bissell formation	760±
Gem Hill formation (tuff and basal conglomerate).	

CARBONATE AND SHALE MEMBER

The carbonate and shale member of the Bissell formation is the oldest and most extensively exposed member of the formation; it forms a nearly continuous 3-mile-long outcrop. This member is thickest and most conspicuously exposed in the large hill near the north line of sec. 10, T. 10 N., R. 11 W., where it is 300 feet thick. From here the member thins along strike both westward and eastward to about 150 feet in thickness, and the carbonate strata decrease in abundance.

Shales constitute about 75 percent of this member and range from soft and argillaceous to hard and siliceous. The argillaceous shale is rarely exposed, and its presence is indicated only by soft clay soil. The siliceous shale is white, tuffaceous, moderately hard, thin bedded, and fractures parallel to bedding; it forms layers from 1/8 inch to 5 inches thick. It crops out conspicuously and resembles the platy siliceous marine shale of the Monterey formation of Miocene age in the Coast Ranges. Layers of dark to light-gray translucent chalcedonic chert from a fraction of an inch to 4 inches thick are common in the siliceous shale. The siliceous shale and chert are best exposed in the hill near the north line of sec. 10, T. 10 N., R. 11 W. Along strike to the east and west they give way to softer tuffaceous and argillaceous shales.

The carbonate strata constitute about 25 percent of this member and, because they are resistant to weathering, form prominent ledges. These strata range from an inch to about 14 inches in thickness and are interstratified with the shale layers throughout the member. The carbonate strata are gray to brown, weather to gray white or tan, and are dense and massive to faintly laminated. They range in composition from limestone to dolomite, with dolomite predominating. Some beds contain lentils or layers of dark-gray chacedonic chert, from 1/4 to 2 inches thick.

Two sections of the carbonate and shale member of the Bissell formation, together with the underlying Gem Hill formation, were measured. One of these is just north of the Bissell magnesite pits at the type locality of the Bissell formation, and the other is a mile west where this member attains its maximum thickness.

Carbonate and shale member of Bissell formtaion exposed in the Bissell Hills, north of Bissell magnesite pits, S1/2 sec. 3 and N1/2 sec. 10, T. 10 N., R. 11 W.

	Feet
Bissell formation, carbonate and shale member:	
Top eroded or buried.	
Siliceous shale 65 percent, chert 10 percent, and dolomite 25 percent, interstratified; unit forms south-facing dip slopes	55
Siliceous shale	7
Siliceous shale, chert, and carbonate rocks; form crest of ridge	5
Siliceous shale	24
Siliceous shale, carbonate rock, and chert	5
Siliceous shale	10
Siliceous shale, carbonate rock, and chert	25
Siliceous shale, few thin layers of chert, and carbonate rock	34
Carbonate rock	2

Carbonate and shale member of Bissell formation exposed in the Bissell Hills, north of Bissell magnesite pits, S½ sec. 3 and N½ sec. 10, T. 10 N., R. 11 W.—Con.

	Feet
Bissell formation, carbonate and shale member—Continued	
Unexposed; probably clay shale, tuffaceous shale, and some siliceous shale	95
Carbonate rock, siliceous shale, and chert	16
Unexposed; probably clay and siliceous shale	45
Carbonate rock, bedded	5
Siliceous shale; thin cherty layers	5
Total thickness of carbonate and shale member of Bissell formation	333
Gem Hill formation, tuff. (See p. 176.)	

Carbonate and shale member of Bissell formation, north of western magnesite pit in NE¼ sec. 11, T. 10 N., R. 11 W.

	Feet
Bissell formation:	
Claystone member.	
Carbonate and shale member:	
Interbedded siliceous shale and thin dolomite	9
Claystone	15
Clay shale and dolomite; dolomite in layers as much as 10 inches thick	10
Siliceous shale and dolomite	3
Unexposed; probably shale	10
Siliceous shale, chert, and layers as much as 1 ft thick of dolomite	15
Unexposed; probably shale	10
Dolomite or limestone	5
Unexposed, but soil is largely clay, and contains some granitic cobbles	73
Shale and dolomite layers as much as 1 ft thick	20
Dolomite and siliceous shale	5
Total thickness of carbonate and shale member of Bissell formation	175
Conformable(?) contact.	
Gem Hill formation.	

CLAYSTONE MEMBER

The claystone is the middle member of the Bissell formation; it is transitional between the carbonate and shale member below and the sandstone member above. The claystone member is about 130 feet thick and is traceable along strike for about a mile. It is poorly exposed and weathers to a soft clay soil. However, quarrying operations at the Bissell magnesite pits have produced fresh exposures (fig. 11).

The claystone exposed in the pits is poorly to well stratified, moderately indurated, but crumbly. It has a greenish-gray tingle but several layers are slightly reddish gray. In some of the claystone, minute flakes of mica can be seen. Some thin bands are dark brown, probably from the presence of inorganic plant remains. Gypsum and some free sulfur, in the form of secondary coatings of minute crystals, are formed in fracture planes. Magnesite occurs

FIGURE 11.—Claystone member of Bissell formation. View east in Bissell magnesite pits, showing white layers of magnesite (m) in the claystone.

in the lower part as soft white layers from 1 to 10 inches thick and is conspicuously exposed in the pits (fig. 11). A measured section of the claystone member just east of the shaft in the western part of the Bissell magnesite pits is given below.

Claystone member of Bissell formation exposed in Bissell magnesite pits, NE¼ sec. 11, T. 10 N., R. 11 W.

Bissell formation:	
Sandstone member.	
Claystone member:	*Feet*
Claystone, containing several thin layers as much as 5 in. thick of fine sandy limestone	35±
Claystone	17
Magnesite, containing 3-in. claystone layer at middle	2
Claystone, containing a few thin layers of magnestite	1
Claystone, slightly reddish	10
Claystone	6
Claystone, containing several thin layers as much as 6 in. thick of magnesite	5
Claystone, containing several thin layers as much as 4 in. thick of hard fine tuffaceous sandstone	2
Claystone	6
Magnesite	½
Claystone	14
Magnesite	1
Claystone	7
Claystone, containing conspicuous interbeds, as much as 10 in. thick, of magnesite and hard white dolomite	7
Claystone, some reddish brown	10
Claystone	5
Total thickness of claystone member of Bissell formation	128±
Carbonate and shale member.	

SANDSTONE MEMBER

The sandstone member of the Bissell formation is a sequence of alternating strata of claystone, arkosic sandstone, and conglomerate. This member is exposed just south of the Bissell magnesite pits where it is about 470 feet thick and is traceable along strike for about a mile. It is unconformably overlain by fanglomerate and older alluvium of Pleistocene age.

Crumbly gray claystone predominates in the lower part of this member. It is similar to that of the underlying claystone member, but ranges to soft gray sandy siltstone. It is invariably poorly exposed and weathers to a greenish-gray clay soil. A 6-foot-thick lentil of white siliceous tuff occurs near the middle of this member.

The sandstone is soft, friable, well stratified, and light gray; it is weather buff. It is composed mainly of fine- to medium-grained detrital quartz, feldspar, and biotite. It does not form prominent outcrops.

The conglomerate or pebbly sandstone is light gray and composed of subrounded pebbles and cobbles from ½ to about 5 inches in diameter, set in a friable matrix ranging from clayey siltstone to coarse-grained arkosic sandstone. The pebbles and cobbles are mostly aplite, pegmatite, and quartz monzonite, but some are Tertiary felsitic and porphyritic volcanic rocks.

A typical section of the sandstone member, as exposed in the canyon just west of the road leading to the western Bissell magnesite pit, is given below:

Sandstone member of Bissell formation, in N½ sec. 11, T. 10 N., R. 11 W.

Granitic fanglomerate (Pleistocene).	
Unconformable contact.	
Bissell formation (Tertiary):	
Sandstone member:	*Feet*
Sandstone	3
Unexposed; probably sand and silt	50±
Sandstone, hard	5
Unexposed, probably sand and silt	15
Sandstone; upper part white, silty, tuffaceous; lower part gray-white, medium to coarse	12
Silt, sandy, and granitic pebbly sand	25
Silt, sandy, pebbly	20
Claystone	5
Sandstone, gray, medium-grained, arkosic	1
Claystone	15
Tuff, white, fine, hard, siliceous, with platy fracture	6
Claystone	53
Limestone, sandy, nodular	½
Conglomerate	10
Claystone	18
Caliche	5

Sandstone member of Bissell formation, in N½ sec. 11, T. 10 N., R. 11 W.—Con.

	Feet
Bissell formation (Tertiary)—Continued	
Sandstone member—Continued	
Claystone	33
Siliceous shale and sandstone	1
Claystone and minor interbeds of pebbly sandstone	35
Sandstone	20
Claystone	2
Shale, white, tuffaceous	4
Claystone, containing a few thin layers, as much as 1 ft thick, of arkosic and calcareous sandstone	25
Sandstone, pebbly, gritty, arkosic	20
Siltstone, sandy	8
Sandstone, pebbly	20
Siltstone, sandy	5
Sandstone, pebbly	1
Claystone	19
Sandstone, pebbly	1
Siltstone, sandy	10
Sandstone, pebbly	17
Sandstone	15
Total thickness of sandstone member of Bissell formation	480±
Claystone member.	

PROBABLE AGE AND CORRELATION

The Bissell formation is unfossiliferous, so its exact position in the Tertiary is unknown. It was carefully sampled for diatom remains but none were found (K. E. Lohman, written communication, 1953). The stratigraphic position of the formation indicates that it is of either Miocene or Pliocene age, because it lies conformably above the Gem Hill formation of Miocene(?) age and unconformably below Quaternary fanglomerate.

The large amount of siliceous and of tuffaceous shale present in the carbonate and shale member of the Bissell formation suggests that this member may be a lacustrine facies of part of the Gem Hill formation. The lacustrine facies is also suggested by the much lesser thickness of the Gem Hill formation in the Bissell Hills as compared to that in the Rosamond Hills.

The stratigraphic relation of the Bissell formation to the Fiss fanglomerate is not known because the two formations are not in contact and their exposures are widely separated. However, as both overlie the Gem Hill formation, they may be in part correlative. This correlation is suggested also by the moderate amount of conglomerate in the sandstone member of the Bissell formation. If this postulated correlation is true, then both the Fiss fanglomerate and the Bissell formations are sedimentary strata of probable late Miocene age; the Fiss fanglomerate is the torrential detrital facies and the Bissell formation is the lacustrine and flood-plain facies

The only age determination of strata similar to those in the Bissell formation is from an exposure of bedded limestone resting on tuff 2 miles west of Castle Butte, in the Castle Butte quadrangle, northeast of the Rosamond quadrangle. The tuff is similar to that of the Gem Hill formation, and the limestone beds are similar to the carbonate strata of the lowest member of the Bissell formation. The limestone of the Castle Butte locality yielded a diatom assemblage which K. E. Lohman (oral communication, 1959) considers to suggest Pliocene age. If the carbonate and shale member of the Bissell formation correlates with this limestone, then the Bissell formation may be of early Pliocene rather than late Miocene age. If this hypothesis is true, then the Bissell formation may be younger than the Fiss fanglomerate of Miocene(?) age, and there may be a hiatus or possible unconformity between the Bissell formation and the underlying Gem Hill formation.

UNNAMED PLIOCENE(?) FORMATION

There are no sedimentary deposits of known Pliocene age exposed within the two mapped quadrangles. However, in the west end of Antelope Valley in the Neenach quadrangle, a formation of alluvial gravel, sand, and lacustrine clay of probable Pliocene age lies unconformably above marine and terrestrial deposits of late Miocene age and unconformably below several hundred feet of dissected and locally deformed Quaternary alluvium. About 1,600 feet of this Pliocene(?) formation crops out and was mapped by Wiese (1950, p. 35, pl. 1) as Pliocene(?) lake deposits. However, examination of this formation revealed that it is composed mainly of alluvial gravel and sand (in part mapped by Wiese with Quaternary older alluvium) derived from granitic and metamorphic rocks; and that lacustrine clay and shale constitute only a facies in the middle part. The alluvial deposits of the Pliocene(?) formation are difficult to differentiate from those of the adjacent formations. They differ from those of the overlying Quaternary alluvium by more uniform sorting and greater rounding of fragments; they differ from those of the underlying Miocene series by less induration, less rounding of fragments, greater admixtures of metamorphic detritus, and less felsitic detritus. The Pliocene(?) formation is strongly deformed and locally upturned, and dips under Antelope Valley.

This alluvial and lacustrine formation of Pliocene(?) age is suspected to lie concealed beneath the Quaternary alluvium under the greater part of Antelope Valley, where it may attain a thickness of several thousand feet. Three deep oil-test holes in Antelope Valley may have been drilled into or through this formation, but as it is composed largely of alluvial deposits it could not be differentiated from the Quaternary older alluvium.

Within the Willow Springs quadrangle there are only two exposures, mapped as part of the Quaternary older alluvium, that may possibly belong to the Pliocene(?) formation. One is the coarse arkosic sand exposed in the core of the Sand Hills anticline, which was mapped with the Quaternary older alluvium because it is conformably overlain by the clay unit of that formation. However, the sandstone may be the top of the Pliocene(?) formation that is exposed in the west end of Antelope Valley. The other exposure of Pliocene(?) age is the westward-dipping gravel that lies unconformably on the tuff of the Gem Hill formation at the west end of the hill a mile north of Willow Springs Mountain.

QUATERNARY SEDIMENTARY DEPOSITS

Deposits of Quaternary age within the two mapped quadrangles consist of loose to weakly indurated alluvial sediments ranging from coarse fanglomerates to argillaceous clays. They were derived from the mountains bordering the western Mojave Desert and the hills within it, and were deposited in the valley areas of the desert. They fill Antelope Valley to a considerable depth, possibly several thousand feet. The Quaternary deposits are divided into two main units: older alluvium, of Pleistocene age, that is locally deformed and dissected, and alluvium and surficial deposits of Recent age that are undeformed and undissected.

OLDER ALLUVIUM

On the northwestern margin of Antelope Valley older alluvium of Pleistocene age forms a dissected piedmont fan of detritus derived from the pre-Tertiary crystalline rocks of the Tehachapi Mountains. From Cottonwood Canyon this fan extends westward into the Neenach quadrangle, where the sediments that compose it were mapped by Wiese (1950, p. 36–37, pl. 1) as terrace deposits and older alluvium. At its upper edge this fan laps onto a pediment carved on the pre-Tertiary crystalline rocks at the foot of the Tehachapi Mountains. Downslope toward Antelope Valley the older alluvium thickens rapidly to at least 700 feet exposed in the Sand Hills.

On the northwest side of Antelope Valley the older alluvium of Pleistocene age is divisible into at least three mappable units. These are, starting at the bottom: sand, clay and silt, and alluvial gravel and sand. Of these, the alluvial gravel and sand unit is by far the most extensive at the surface; it conceals the other two, which are exposed at only one or two places. In the Bissell Hills and east of Rosamond Lake erosional remnants of the older alluvium

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are differentiated into two mappable units: fanglomerate, and alluvial gravel and sand. The fanglomerate is older and may be correlative with either the clay and silt unit or the sand unit on the northwest side of Antelope Valley.

The sand unit is the oldest unit of the older alluvium exposed and crops out only in the core of the Sand Hills anticline. Only the uppermost 200 feet is exposed, with an unknown thickness lying buried. The part exposed consists almost entirely of gray-white soft friable massive to poorly bedded medium- to coarse-grained locally pebbly arkosic sandstone. This unit grades upward into the overlying clay and silt.

The clay and silt unit is exposed in only two places, one in the Sand Hills anticline and the other in Gamble Spring Canyon. In the Sand Hills anticline it is about 300 feet thick and is composed of soft light-red massive silty to sandy clay containing several interbeds and lentils of gray-white arkosic sand and gray pebble gravel. This unit grades upward into the overlying alluvial gravel and sand unit through interbeds of cobble gravel.

In the area east of Gamble Spring Canyon the clay and silt unit is about 300 feet in maximum thickness; it rests on quartz monzonite and is overlapped along strike in both directions by the overlying alluvial gravel and sand unit. In this exposure the clay and silt unit is composed largely of soft massive greenish- to reddish-gray sandy clay, gritty silt, and a lesser amount of interbedded gray arkosic sand and some sandy conglomerate. The basal part is composed of about 30 feet of gray-white arkosic sand overlain by 1 or 2 feet of white marl.

The alluvial gravel and sand unit is a coarse alluvial fan deposit whose top is a surface of deposition. Northward this unit wedges out against the crystalline rocks of the Tehachapi Mountains. Along the base of the Tehachapi Mountains it is composed of coarse boulder gravel or fanglomerate, grading downslope into cobble gravel and thence into pebble gravel and sand under Antelope Valley. The deposit is composed of unsorted subrounded fragments as large as 1 or 2 feet in diameter, mostly of gneissoid hornblende quartz diorite now exposed in the Tehachapi Mountains north of the Garlock fault. Other detrital fragments include quartz monzonite, granite, aplite, pegmatite, hornblende diorite, limestone, marble, schist, hornfels, and quartzite derived from exposures of these rocks south of the Garlock fault. The fragments are embedded in a reddish-gray matrix of the same detritus, with no stratification. In Cottonwood Canyon, the alluvial gravel and sand unit is superbly exposed, especially on the west wall, where it is composed of at least 400 feet of well-sorted stratified cobble and pebble gravel of a prevailing gray color. This unit is completely exposed on both flanks of the Sand Hills anticline, where it is about 400 feet thick; the basal part is composed of cobble gravel that grades upward into pebbly coarse sand at the top.

The generally flat upper surface of the older alluvium slopes about 3° SE. from the base of the Tehachapi Mountains, and is probably the initial dip. However, in places along its upper margin, slopes and dips as high as 20° indicate local uplift. West of Cottonwood Canyon the older alluvium is elevated to form a mesa some 400 feet above the level of Antelope Valley and Cottonwood Canyon. Much of this uplift has occurred along the Sand Hills where the older alluvium is arched into an asymmetric anticline with dips as high as 50° on the southeast flank. In these hills the elevated older alluvium is being rapidly eroded, and elsewhere it has been severely dissected. With the exception of the Sand Hills anticlinal arch, the top surface of the older alluvium becomes progressively less dissected downslope and eventually grades into the Recent alluvium of Antelope Valley. The contact between these two units thus becomes difficult to map and is dashed in arbitrarily on the map.

On the south side of Antelope Valley near Antelope Buttes only the uppermost part of the older alluvium is exposed. It is slightly dissected, less than 100 feet thick, and consists of pebbly coarse arkosic sand.

In the Bissell Hills the fanglomerate occurs as erosional remnants and rests on the beveled surface of quartz monzonite and deformed strata of the Bissell formation. This fanglomerate is much dissected and is apparently overlain to the west by the younger unit of alluvial cobble gravel, sand, and silt. The maximum thickness of the fanglomerate is about 200 feet. It is composed of unsorted subrounded cobbles and boulders, as large as 3 feet in diameter, almost entirely of granitic detritus with minor admixtures of pegmatite, aplite, and Tertiary chert and dolomite. These fragments are embedded in a weakly consolidated granitic matrix.

About a mile east of Rosamond Lake there is a small outcrop of granitic fanglomerate. Just east of this outcrop is a larger one in the Rogers Lake quadrangle. These are erosional remnants of a probably once extensive exposure of fanglomerate along the south margin of the eastern Rosamond Hills; the remnants are now surrounded by Recent sediments. The fanglomerate of both these outcrops is composed entirely of granitic detritus, in subrounded boulders as large as 3 feet across, and was derived from a nearby source area of probable high relief that presumably lay to the north.

The dissected unconsolidated fanglomerate exposed at the south base of the Rosamond Hills between U.S. Highway No. 6 and Red Hill is composed of granitic detritus and is similar to that in the

Bissell Hills, although the fragments are generally less than a foot in diameter. Minor admixtures of volcanic fragments reworked from the underlying Fiss fanglomerate are also present.

At the west end of a hill a mile north of Willow Springs Mountain, there is an erosional remnant of partly indurated cobble gravel of volcanic and granitic detritus. The gravel dips 15° W. and rests unconformably on the Gem Hill formation, which dips 60° NW. This gravel was mapped as the base of the Quaternary older alluvium, but its moderate tilt suggests that it may be an older formation of possible late Tertiary age.

Under Antelope Valley the total thickness of the Quaternary alluvium is uncertain, but several test wells indicate a great thickness of fill. The Meridian well drilled at the mouth of Cottonwood Canyon reportedly passed through 3,300 feet of alluvial sediments and then through quartz diorite (Simpson, 1934, p. 415) to bottom at 3,970 feet. The Andrews well 4 miles southeast of Little Buttes was drilled entirely through alluvial sediments to bottom at 2,063 feet. At Rosamond Lake, the deep Colgrove well went from soft clay and fine sands into coarse pebbly granitic sand at about 100 feet. Granitic sand, possibly all older alluvium, was apparently drilled through to bottom at 5,576 feet. No cores were taken but the entire section from top to bottom drilled easily, and ditch samples taken every 10 feet were all granitic sand. The sand was coarse and pebbly in most samples from depths of 100 to 500 feet.

The soft sandy alluvial sediments encountered in the above-mentioned deep drill holes may be in part Tertiary, possible in part equivalent to the unnamed Pliocene(?) formation, or even to the Miocene(?) continental deposits mapped by Wiese (1950, p. 33–35, pl. 1). However, no variations within the sections have been reported in the drill holes.

ALLUVIUM AND OTHER SURFICIAL DEPOSITS

Unconsolidated and undissected alluvium and associated surficial deposits of Recent age fill practically all of Antelope Valley, the plain north of the Rosamond Hills, and the flood plains of canyons emerging from the Tehachapi Mountains and from the hills throughout the mapped area.

In the valley areas the Recent alluvium is probably several hundred feet thick, but its thickness can not be determined in water wells because there is no definite break between the Recent alluvium and the Pleistocene alluvium. Along the margins of the valleys the Recent alluvium thins out upslope against older alluvium or Tertiary or pre-Tertiary bedrock.

The Recent alluvium and associated surficial deposits are divisible into at least five mappable facies based on mode of deposition and lithology. All are contemporaneous and grade into each other laterally. These are alluvium, playa clay, windblown sand, playa clay and windblown sand, and bars of wave-deposited sand.

Alluvium.—The stream-laid alluvium, composed of gravel, sand, and silt, is of two types: fan alluvium and valley alluvium, with gradations from one to the other.

The fan alluvium in the form of piedmont or apron fans fringes the foothills of the Tehachapi Mountains and all the hills throughout the two quadrangles. The surfaces of these fans slope into the valleys at grades ranging from 50 to 200 feet per mile. The fans are composed of poorly sorted gravel and sand derived from formations exposed in the mountains or hills that the fans fringe. The alluvium at the foot of the Tehachapi Mountains is in large part derived from the dissected older alluvium upslope. The fragments are embdedded in a soft matrix of weathered sandy soil. The thickness of the fan alluvium is not known because few wells have been drilled into it, but the maximum is probably several hundred feet.

The valley alluvium fills the nearly level parts of Antelope Valley and the plain north of the Rosamond Hills. Commonly the valley alluvium slopes 50 feet per mile or less. It is composed of weathered soil material and mixtures of tan to gray poorly sorted sand, silt, and clay. It is probably several hundred feet thick, but only the upper 60 feet is exposed at the scarp of the Willow Springs fault. Water wells drilled in Antelope Valley penetrate loamy sand, silt, and clay from the surface to a depth of roughly 100 feet, then coarser, locally pebbly water-bearing sand layers that extend down to several hundred feet in most places. In the part of this valley within the Rosamond quadrangle this sand interfingers into blue clay that predominates over the sand.

Playa clay.—Playa clay fills the bed of Rosamond Lake, which has a level and smooth surface devoid of vegetation. The playa clay is composed of light- to tannish-gray massive argillaceous to silty clay and micaceous silt. It is plastic when wet but quite hard when dry. The clay and silt contain only a minor amount of alkali, mostly in the form of chlorides, carbonates, and sulfates of sodium and potassium, insufficient to form a surface crust on the playa. The thickness of the playa clay is known only at a few places where wells have been drilled in the lakebed. Thompson (1929, p. 317) reported blue clay at a depth of 200 feet west and south of Rosamond Lake that may be part of the playa clay facies rather than the valley alluvium.

Windblown sand.—Loose windblown sand occurs as a series of dune ridges around the east and south sides of Rosamond Lake. The sand is well sorted and fine grained, and is composed of subrounded grains of feldspar and quartz. The dune ridges parallel the shore line and rise to crests as high as 70 feet. Eastward beyond the marginal shoreline dunes, there is a series of generally crescent-shaped dunes concave westward toward the direction of the prevailing wind. Both the shoreline and crescent dunes have long gentle windward slopes facing westward and comparatively short, steep leeward slopes facing eastward. The sand in some of the dune ridges is cross-bedded with generally eastward dips as steep as 35°.

The dunes are accumulations of drifting sand on a platform of playa clay or valley alluvium. The sand is being deposited by the frequent westerly gales blowing down Antelope Valley and across Rosamond Lake, and the dunes are moving slowly eastward. The drifting sand appears to have been caught and held by moist ground and vegetation around Rosamond Lake; the trapped sand in turn became moist and trapped additional sand to form the dunes.

Other deposits of windblown sand occur as thin veneers on alluvium or older formations. These sheets of sand are probably not more than 50 feet thick, and the surface is flat or gently undulating, usually covered by vegetation including Joshua trees. The most extensive sheet of sand is that between the western Rosamond Hills and the west base of Soledad Mountain. In the Rosamond Hills thin streamers of sand from this sheet extend southeastward onto the surface of the quartz monzonite; they were apparently deposited by northwestern gales blowing from Tehachapi Pass. Windblown sand is banked against the western base of these hills and also of Middle Buttes and the Bissell Hills. Smaller deposits of windblown sand occur on the Sand Hills and in Antelope Valley south of Little Buttes.

Playa clay and windblown sand.—East of Rosamond Lake there is a belt of little playas, valley alluvium, and innumerable little piles of windblown sand. It was not practical to map the sand separately from the clay and silt, so here they are shown as one unit. This sand was probably deposited by the prevailing wind on a platform of playa clay or valley alluvium.

Bars of wave-deposited sand.—On the west and south sides of Rosamond Lake there are old shoreline bars of sand, gravel, and silt just below the 2,300-foot contour. They trend parallel to the shoreline of the present playa and the largest ones rise as high as 30 feet above their bases. The bars are composed of loose wave-sorted medium to coarse sand.

The shoreline bars were deposited by wave action along the shores of Rosamond Lake when it was flooded nearly to the 2,300-foot contour. The dune ridges of windblown sand around the east side of the dry lake may have formed along similar bars, now buried.

STRUCTURE

Structural features now seen within the Willow Springs and Rosamond quadrangles reflect three episodes of crustal deformation and igneous activity. These three episodes are briefly summarized at this point; they are described somewhat more fully in the section "Geologic history."

The first episode took place late in Precambrian time after the deposition of the rocks now known as the Pelona schist. At that time the rocks were metamorphosed to schist, presumably prior to the deposition of the Bean Canyon formation. During the second episode the Pelona schist and the Bean Canyon formation were severely deformed, metamorphosed at depth, and later invaded by widespread batholithic igneous rocks, presumably during the Mesozoic era.

The third period of deformation began in the Cenozoic era and is still continuing; it has resulted in broad warping movements of the crystalline basement, accompanied and followed by faulting.

The structural features of the pre-Tertiary metamorphic and plutonic rocks and of the exposed Tertiary and Quaternary formations have been broadly treated in the preceding descriptions of these units. In the following pages only the faults, folds, and broad warp features that resulted from Cenozoic deformation are described.

TEHACHAPI MOUNTAINS AREA

The Tehachapi Mountains are an uplifted block of crystalline rocks on the Garlock fault zone. The uplift is probably the result of compressive stress during Quaternary time, and the range formed as two separate blocks, one on each side of the Garlock fault zone. The block southeast of the fault zone was elevated and tilted southeastward with the maximum uplift adjacent to the fault. The block northwest of the fault zone was probably elevated in the same manner and was tilted northwestward. The strip of Pelona schist within the Garlock fault zone was itself apparently elevated by compressive squeezing and shearing between the two relatively rigid blocks.

Garlock fault zone.—The Garlock fault is a major structural break trending roughly N. 70° E. from its junction with the San Andreas fault near Lebec some 22 miles beyond the west border of the map area. Only a 3-mile segment cuts across the northwest corner of the Willow Springs quadrangle. As indicated by Wiese (1950, p. 39), the Garlock fault zone comprises two faults that bound the Pelona schist. In the Neenach quadrangle they are less than a half a mile apart, and eventually they merge in Oak Canyon a mile beyond the north border of the Willow Springs quadrangle. The Garlock fault is a high-angle shear zone along which the main movement is strike slip with the north block having moved westward relative to the south block; the movement may be defined as "left lateral" according to Hill (1947, p. 1672). In this area the amount of lateral displacement is unknown, because there is no means of measuring it, but it is no doubt great, as indicated by the dissimilarity of the crystalline rocks and structures on opposite sides of the fault zone.

The north branch of the Garlock fault separates the Pelona schist on the south from hornblende-quartz diorite on the north. Within the Willow Springs quadrangle the fault follows a straight course and is probably vertical. It is well expressed topographically; it is marked by more than 100 feet of crushed rock and gouge that erodes readily to form a trenchlike rift through the mountains. Several springs issue from this fault. Three southward-draining canyons are offset slightly to the east as they cross this fault; this offset indicates Recent left-lateral movement. Beyond the western border of the quadrangle sag ponds and some offset stream channels show that movement took place during the Quaternary period, and the fault may have been active during Tertiary time.

The south branch of the Garlock fault separates the Pelona schist on the north from quartz diorite on the south. The schist is highly sheared adjacent to the fault, and in most places is separated from the rocks to the south by a narrow strip of partly brecciated white marble as much as 100 feet wide. The fault dips steeply northward. Unlike the north branch, the south branch does not follow a straight course, and it shows practically no topographic expression nor any real evidence of Recent movements.

Tylerhorse fault.—The Tylerhorse fault is well exposed in Tylerhorse Canyon, where it cuts the pre-Tertiary rocks, and is traceable southeastward through the older alluvium to the mouth of Gamble Spring Canyon, a distance of about 4 miles. It is not traceable with certainty northwestward to the Garlock fault. The Tylerhorse fault is nearly vertical where it crosses Tylerhorse Canyon, and is marked by several tens of feet of sheared rock. On the east side of the canyon this fault cuts diagonally across eastward-trending vertical beds of the Bean Canyon formation and across the adjacent hornblende diorite, and it displaces all these rock units on the southwestern block 1,000 to 1,500 feet northwestward. Southeastward toward Gamble Spring Canyon the fault forms small scarplets in the older alluvium and slightly offsets some washes in the same manner. It also offsets Tylerhorse Canyon, and may have caused the bend in Gamble Spring Canyon. These offsets indicate clearly that this is a strike-slip fault with Recent right-lateral displacement.

Cottonwood fault.—The Cottonwood fault crosses Cottonwood Canyon and is traceable southeastward for more than 3 miles through the older alluvium. Wiese (1950, pl. 1) mapped this fault northwestward through granitic rocks to the Little Oak Canyon fault, a branch of the Garlock fault. On the west side of Cottonwood Canyon the Cottonwood fault is vertical and cuts across vertical schist and marble of the Bean Canyon formation. The marble on the southwest block is offset nearly 1,000 feet to the northwest; this offset indicates right-lateral displacement on this fault as on the Tylerhorse fault. The fault has been active in Recent time because it cuts through the older alluvium east of Cottonwood Canyon. Its straight course through the older alluvium is marked by scarplets and trenches. Several minor washes are slightly offset to the west where the fault crosses them. The fault is alined with the Recent fault scarp at Willow Springs.

Sand Hills anticline.—In the Sand Hills south of lower Cottonwood Canyon the older alluvium is arched into an asymmetrical domed anticline about 3 miles long elongated northeastward with the axial plane dipping northwestward. On the southeast flank, strata of the older alluvium are tilted as much as 50°; this flank is broken by a minor reverse fault that dips 45° to 60° NW. with a vertical displacement of not more than 200 feet. This fault, which Simpson (1934, p. 404, pl. 5) mistook for the Garlock fault is traceable on the surface for only about a mile. On the northwest flank, the older alluvium is tilted 10° or less. The asymmetry of this fold indicates that it resulted from a local compressive stress from the northwest.

BISSELL HILLS AREA

In the Bissell Hills in the northeastern part of the Rosamond quadrangle, there are two broad exposures of quartz monzonite separated by an eastward-trending, half-mide-wide exposure of strata of the Tropico group. These strata are deformed into the eastward-trending Bissell syncline. This fold appears to have resulted from upwarping of the adjacent areas of quartz monzonite from which the overlying Tertiary strata were stripped by erosion.

Only the north flank of the Bissell syncline is prominently exposed; there the beds are tilted as much as 45° and in a minor subsidiary fold as much as 80°. The south flank is either buried under Quaternary alluvial sediments or is faulted out. The west end of this fold is partly exposed in the NW¼ sec. 9, T. 10 N., R. 11 W., and the east end is exposed 2 miles beyond the east border of the quadrangle. Simpson (1934, pl. 5) mapped a fault along the contact between the Tertiary strata and the quartz monzonite on the north flank of the syncline, but did not describe it. However, the writer found no conclusive evidence of such a fault, because the depositional contact of the Gem Hill formation on the underlying quartz monzonite can be seen at two places north of the prominent ridge northwest of the Bissell magnesite pits. No gouge is present at either place, and the quartz monzonite is weathered red for about 20 feet below the depositional contact.

The narrow alluviated valley between the exposure of quartz monzonite of the southern Bissell Hills and that of the eastern Rosamond Hills was either formed as a local downwarp or carved by erosion. The latter origin is considered to be more likely, for there are no Tertiary rocks in this valley.

ROSAMOND HILLS AREA

The Rosamond Hills consist of a large eastward-trending uplifted area, possibly an upwarp, of quartz monzonite. The quartz monzonite is fringed along the southwest margin by overlying Tertiary pyroclastic and sedimentary strata of the Tropico group that once may have covered the entire area. The exposed Tertiary strata are deformed by tilting, folding, and faulting.

Folds.—The Tertiary formations now exposed in the Rosamond Hills dip generally to the southwest at an average angle of about 20° but with local variations from 5° to 45°. East of the Mojave-Tropico road the Tertiary strata are compressed into several shallow folds, all of which plunge gently westward. One of these is an anticline plunging westward from hill 3091, flanked on the north by a shallow syncline. These structures are cut by plugs of the Bobtail quartz latite member of the Gem Hill formation. At the south edge of the Rosamond Hills, just north of Rosamond, the Gem Hill formation is compressed into a shallow syncline that plunges gently westward and is much broken by faulting.

Faults.—The Rosamond Hills are cut by many minor high-angle faults that trend either north of west or north of east. Most are normal faults, although some are probably vertical.

Probably the largest fault within the Rosamond Hills is one trending north of west within quartz monzonite just east of Ansel. On aerial photographs this fault shows for a distance of some 5 miles in the quartz monzonite, and appears to extend another mile northwestward through the Recent alluvium. The course of the fault is marked by a zone of pulverized quartz monzonite covered by a white caliche-like crust on the surface. East of Ansel the northeast block is topographically higher and is therefore probably the upthrown side.

In the southwestern part of the Rosamond Hills the Tertiary formations and underlying quartz monzonite are broken by many minor faults. Most are normal faults trending north of east and dipping steeply northwestward; they probably formed in the Quaternary period, but some may have formed in Tertiary time prior to or during emplacement of the quartz latite magma. In places the magma appears to have issued from fissure vents along faults. None of these faults shows evidence of Recent activity.

The most southeasterly of the minor faults in the Rosamond Hills is the one on the north side of the volcanic plug forming Red Hill. It appears to have been an old fault trending N. 70° E., along which the magma forming Red Hill may have been emplaced originally as a dikelike mass which subsequently swelled into a plug with the emplacement of more magma. Evidence for this emplacement is the fact that the Tertiary formations strike into the volcanic plug of Red Hill from the northwest but quartz monzonite crops out on the southeast side. Some movement may have recurred along this fault in late Tertiary or Quaternary time. The eastward-trending dikes of quartz latite east of Red Hill and the basalt dike a mile northwest of Red Hill may have been emplaced in parallel faults.

A fault trending N. 60° E. crosses U.S. Highway 6 about a mile northwest of Rosamond. The southeast block is displaced relatively upward, because quartz monzonite and quartz latite on the southeast block are in contact with Tertiary tuff on the northwest block. The outcrops of red quartz latite breccia on both sides of the highway are on opposite sides of this fault; if they were once part of the same mass they are offset laterally by the fault, with the southeast block having been displaced to the northeast. The fault appears to dip steeply northwestward; it is marked by brecciated rock. A small spring issues from the fault west of the highway.

In the western Rosamond Hills in the vicinity of the Mojave-Tropico road, the Tertiary rocks and underlying quartz monzonite are cut by several parallel normal faults that trend N. 65° E. and dip steeply northwestward. Most are marked by polished planes of slippage. On each fault the northwestern block is displaced relatively downward. The largest of these faults are the southeastern one and the large central fault half a mile northwest. Both are traceable 2 miles across the hills, and vertical displacements increase northeastward to roughly 1,000 feet. The central fault is well exposed three-quarters of a mile west of the road, where it dips 58° NW. and the fault plane contains grooves that dip 75° E.; these grooves indicate the major movement to be dip slip. A minor fault nearly half a mile farther north dips 60° N. and grooves in the fault plane dip 72° E. Other faults, such as two very minor ones at the uranium prospect adits just west of the Mojave-Tropico road, dip 70° N. and grooves in each fault plane dip 30° W.

The large southeastern fault and the central fault just described extend for an unknown distance northeastward, concealed under Recent sediments. There is some scant geologic evidence that one or both may extend as far as Gloster, as inferred on plate 10. Only quartz monzonite crops out in the area southeast of the supposed extension, whereas only the Gem Hill formation, dipping generally southward toward this supposed extension, crops out in the area to the northwest, in the vicinity of Gloster. There is also geophysical evidence that this fault may extend that far, as suggested by the results of the gravity survey of the western Mojave Desert (Mabey, 1960). There is a difference in Bouguer gravity valves observed on opposite sides of the known part of this fault zone and its supposed northeastward extension. The Bouguer gravity values northwest of the known part of the fault zone and its supposed northeastward extension are considerably lower than the values to the southeast. This difference in gravity values indicates that the granitic bedrock, which crops out on the southeastern block, is overlain on the northwestern block by several thousand feet of Cenozoic rocks with a density lower than that of the granitic bedrock.

SOLEDAD MOUNTAIN AREA

In the Soledad Mountain area the pyroclastic sequence of the Gem Hill formation is cut by so many intrusive masses of the Bobtail quartz latite member that little remains of its original structure. However, available attitudes indicate that the overall structure is that of an anticline plunging southeastward from the pre-Tertiary crystalline rocks exposed northeast of Soledad Mountain. Stratification in the pyroclastic rocks dips at low angles, generally less than 30°. Whether these attitudes are initial dips of a volcanic cinder cone or are the result of crustal movement could not be definitely determined. The structure of the intrusive masses is described on page 181. Some of these masses are cut or bordered by northwestward trending faults or shear zones, along which hydrothermal alteration and mineralization have occurred.

MIDDLE BUTTES AREA

The structure of the intrusive masses of the Bobtail quartz latite member in the Middle Buttes area is described on page 182. Mine workings at the Cactus Queen mine indicate that the contact of the quartz latite with quartz monzonite to the west dips steeply eastward. The structure of the pyroclastic rocks of the Gem Hill formation is obliterated by hydrothermal alteration. Both the igneous and pyroclastic rocks are cut by numerous minor zones of faulting and brecciation, most of which trend northwestward.

TROPICO HILL-WILLOW SPRINGS MOUNTAIN AREA

At Tropico Hill the Bobtail quartz latite member was apparently injected as a series of steeply southward-inclined dikes and pods into quartz monzonite and some overlying pyroclastic rocks of the Gem Hill formation, presumably along an ancestral fault or zone of faults of that attitude. The presence of quartz monzonite north of these volcanic injections and of the Gem Hill formation south of them as encountered in mine workings, suggest that this ancestral faul zone had normal displacements. Many minor faults within this volcanic intrusion and the associated rocks indicate that faulting continued to recur after emplacement of the volcanic rocks. As seen in the Tropico mines, most of the faults dip steeply southward (Gardner, 1954). These faults are associated with southward-dipping mineralized veins described under "Mineral resources" (pp. 234–235).

The structure of the intrusive mass of the Bobtail quartz latite member of Willow Springs Mountain is similar to that of Tropico Hill (see p. 182). Tuffaceous rocks of the Gem Hill formation that are preserved as small remnants within this intrusive mass dip gently, presumably into a shallow syncline that is partly preserved at the west end of the mountain. However, the white tuff at the east end of the mountain overlies quartz monzonite and dips gently north, and the contact is displaced downward on the south along several of the quartz latite dikes; this displacement indicates that the dikes were injected along normal faults. It is possible that this whole intrusive mass was emplaced along a zone of eastward-trending southward-dipping normal faults as at Tropico Hill.

The small hill northeast of Willow Springs Mountain is composed of tuff dipping about 50° NW. and separated from quartz monzonite to the southeast by a wedge of glassy felsite. The felsite is either an intrustive mass or a basal flow breccia.

Possible fault north of Tropico Hill.—A buried fault may lie under the small alluviated valley between the exposures of quartz monzonite northwest of Tropico Hill and exposures of the Fiss fanglomerate in the western Rosamond Hills to the north, where the Tertiary formations dip southwestward toward the quartz monzonite exposures. This condition indicates either that there is a fault northeast of the quartz monzonite outcrops, or that the Tertiary formations may be synclinally folded under the valley. As there are no outcrops of Tertiary rocks anywhere in the valley area to support the latter interpretation, it is more likely that the Tertiary rocks of the western Rosamond Hills dip into a concealed fault that probably trends northwestward and is alined with the Tylerhorse fault, as implied on plate 10. Noble (1954) also postulated a fault at this position and suggested a strike-slip displacement of several miles. This displacement is highly speculative, but it is possible that the contact between the quartz monzonite and the overlying northwestward-dipping Gem Hill formation exposed in secs. 3 and 4, T. 9 N., R. 13 W., may have been offset from this same contact (now faulted) exposed three-quarters of a mile northwest of Rosamond. If so, a right-lateral displacement of some 4 miles would be indicated.

Willow Springs fault—Near Willow Springs there is a conspicuous 3-mile-long southward-facing cliff of nearly 100 feet maximum height in Quaternary alluvium. This is the scarp of the Willow Springs fault, designated by Simpson (1934, p. 406) as the Rosamond fault. This scarp was formed in early Recent time with vertical displacement equal to the height of the cliff. The alluvium on the elevated block is now dissected by gullies. The original scarp must have either been nearly vertical or sloped steeply southward; this attitude indicates that it is the scarp of a steep normal fault. Numerous springs issue from the eastern part of this scarp; Willow Springs at the east end of the scarp is the largest. The scarp trends about N. 75° W. and is alined with the Cottonwood fault. As both these faults break the Quaternary alluvium, this is no doubt an active line of movement.

As shown by Simpson (1934, p. 406, pl. 5) the Willow Springs (Rosamond) fault may extend eastward under Quaternary alluvium along the southern bases of Willow Springs Mountain, Tropico Hill, and the Rosamond Hills to Rosamond Lake. This eastward extension is inferred from the generally straight southern base line of the hills, which are on the elevated block. The minor faults at the southern base of the Rosamond Hills north of Rosamond and at Red Hill may be branches of this supposed fault. The alinement of volcanic plugs from Willow Springs Mountain to Red Hill also suggests the presence of an ancestral fault along this line.

The amount of total vertical displacement on the Willow Springs fault is not definitely determinable, but is apparently not great. The data from a gravity survey over this area indicate no great vertical displacement. Indeed this data suggests that, in the area west of Rosamond, the buried surface of the pre-Tertiary granitic(?) bedrock is closer to the surface south of the fault than north of it; the data suggests also that this buried granitic(?) structural high extends farther west on the south side of the fault (Mabey, 1960). From this condition it may be inferred that the southern block was either elevated relative to the northern block, or was displaced by right-lateral movement, as was the southwest block of the Cottonwood fault. If the southern block was vertically elevated, this displacement is opposite of that of the most recent vertical displacement as indicated by the Willow Springs fault scarp.

ANTELOPE VALLEY AREA

Antelope Valley is for the most part a depressed area filled with Quaternary alluvial sediments. However, within it are Antelope Buttes and Little Buttes, in which are exposed Tertiary and pre-Tertiary rocks. These buttes are apparently eroded remnants of a probably once extensive a northeastward-trending uplifted area that divided Antelope Valley into two parts. Antelope Buttes is eroded from strata of the Fiss fanglomerate and tuff of the Gem Hill formation that dip 20°–45° NW. off quartz monzonite exposed to the southeast. Little Buttes is eroded from strata of the Gem Hill formation that dip about 30° E., apparently away from quartz monzonite which is exposed as a small outcrop a mile to the southwest.

From these isolated outcrops it may be inferred that the base of the Gem Hill formation at Antelope Buttes strikes under Quaternary alluvium northeastward around the quartz monzonite outcrop near Little Buttes and thence southwestward (pl. 10). The southwesterly trend of this concealed contact is suggested not only by the attitude of the Gem Hill formation at Little Buttes, but by data from a water well located nearly 2 miles southwest of Little Buttes, which according to Thompson (1929, p. 351), penetrated "tufa rock" that may be the Gem Hill formation, from 165 feet to bottom at 252 feet. The inferred position of the contact implies that the structure of the Gem Hill formation is that of an anticline plunging northeastward.

Some fragmentary information on the concealed geology of Antelope Valley may be gained from several deep drill holes. All water wells, including the deeper ones drilled to depths below 300 feet, bottom in coarse gravelly sand. Three deep test holes drilled for oil penetrated a great thickness of alluvial sediments that are of Quaternary and possibly in part of Tertiary age. The Meridian test hole at the mouth of Cottonwood Canyon passed through 3,300 feet of sandy alluvial material, then entered quartz diorite and bottomed in it at 3,950 feet, according to the drillers' log. Both the O. G. Andrews test hole, located 4 miles southeast of Little Buttes, and the C. W. Colgrove test hole, in the south margin of Rosamond Lake, supposedly bottomed in weakly consolidated sandy alluvial sediments at 2,063 feet and 5,576 feet, respectively.

The general configuration of the Cenozoic sedimentary fill of Antelope Valley is revealed by the gravity survey of the western Mojave Desert by D. R. Mabey (1960). The survey results reveal the presence of a gravity high that extends northeastward across Antelope Valley from Antelope Buttes through the Rosamond and the Bissell Hills. This gravity high is in an area where the pre-Tertiary high-density crystalline basement is exposed or is near the surface, and confirms the presence of the uplift area of which Antelope Buttes and Little Buttes are a part. Antelope Buttes and Willow Springs Mountain are at the northwestern border of this gravity high which is some 11 miles in width. Adjacent to this anomaly on each side, there is a gravity low, or area in which the pre-Tertiary crystalline basement is deeply buried under a great thickness of Cenozoic low-density sedimentary or pyroclastic material. These gravity lows are probably caused by sedimentary basins that underlie the completely alluviated parts of Antelope Valley.

The sedimentary basin northwest of the uplifted area described above underlies practically all of western Antelope Valley and will be referred to as the western Antelope basin. The western half of this basin lies in the Neenach quadrangle and the eastern half in the Willow Springs quadrangle. The gravity data (Mabey, 1960) indicate that the crystalline bedrock surface slopes gradually into this basin from all directions, and that the deepest part, in which the crystalline bedrock surface is estimated to be from 7,000 to 10,000 feet deep, is about 4 miles north of the southwest corner of the Willow Springs quadrangle. The axis of maximum depth of this sedimentary basin trends roughly eastward in the Neenach quadrangle and thence curves northeastward in the Willow Springs quadrangle to a subsidiary basin just south of Middle Buttes.

The sedimentary basin lying southeast of the uplifted area described above underlies the central part of Antelope Valley and will be referred to as the central Antelope basin. This basin extends through the southeastern part of the Rosamond quadrangle and southwestward into the Lancaster quadrangle. Gravity data indicate that the deepest part is probably near the southeast corner of the Rosamond quadrangle, and that the sedimentary fill may be as deep as that of the western Antelope basin.

GEOLOGIC HISTORY

PRE-TERTIARY HISTORY

Within the map area the earliest record of the geologic history is the Pelona schist. This accumulated probably in Precambrian time as argillaceous sediments, along with lesser amounts of volcanic ash and sand.

It is not clear what happened in the Tehachapi Mountains immediately after accumulation of the deposits now represented by the Pelona schist. It is apparent that the argillaceous sediments of this formation became deeply buried, metamorphosed to mica schist, and folded. This diastrophism occurred probably in late Precambrian time.

The next recorded episode, probably during regional subsidence in late Paleozoic time, was the marine accumulation of the Bean Canyon formation as a great thickness of calcareous, argillaceous, arenaceous, and tuffaceous sediments.

After deposition of the Bean Canyon formation and probably during the Mesozoic era the Pelona schist and the Bean Canyon formation were severely deformed, metamorphosed, and intruded by magmas that formed the widespread granitic rocks in the area. The result of this great diastrophism was a stabilized complex of crystalline rocks that reacted to later stresses as a rigid or semirigid mass.

LATE MESOZOIC AND EARLY TERTIARY EROSION

Events of late Cretaceous and Eocene time left no record in the Willow Springs and Rosamond quadrangles. During this long interval this area as well as the surrounding region must have been undergoing erosion, and the eroded material was probably carried outward. The nearly planed surface of the crystalline rocks below the base of the Tertiary stratified rocks within the mapped quadrangles, as well as in other parts of the western Mojave Desert, indicates that the mountains formed during the preceding orogeny were eventually reduced to low relief by middle Tertiary time.

MIDDLE(?) TERTIARY DIASTROPHISM, VOLCANISM, AND DEPOSITION

During middle(?) Tertiary time, the area underwent crustal movements. This disturbance probably began with violent eruption of ash, fragments of pumice, and other volcanic and granitic material through volcanic vents at the site of Soledad Mountain and probably through other vents within a radius of about 10 miles. The pyroclastic material settled over the surrounding eroded surface of the crystalline bedrock to form the Gem Hill formation. Much of this material was reworked and redeposited in the form of tuffaceous sandstone and conglomerate. During the later stages of the volcanism viscous masses of flow breccia issued from some of the vents and in places this breccia became locally interbedded with the pyroclastic strata. During the final stage viscous lava was erupted from the vents of Soledad Mountain and perhaps from several larger vents, including some in the Rosamond Hills and in the Neenach quadrangle southwest of Antelope Buttes. The viscous lava formed piles of volcanic rocks over and around the vents, plugged the vents, and built up volcanic mountains.

Erosion of the volcanic mountains shed coarse volcanic detrital material into the adjacent valley areas to form the Fiss fanglomerate. This was deposited over the Gem Hill formation, which in places was partly eroded prior to deposition of the fanglomerate.

During the middle Tertiary, the Garlock fault as well as the San Andreas fault to the south, may have formed or become active. Uplifts of areas adjacent to these faults resulted in erosion, and clastic detritus was shed into the intervening wedge-shaped plain that is now the western Mojave Desert. Part of this clastic detritus was deposited contemporaneously with the volcanic Fiss fanglomerate and part later. It formed a thick accumulation of continental sediments that underlie western Antelope Valley and that are now exposed west of the mapped quadrangles. Deposition of these alluvial sediments probably began in late Miocene time and continued well into Pliocene time.

The carbonate and shale member of the Bissell formation is a lacustrine deposit, in which the shale beds were laid down as fine ashy siliceous and argillaceous muds and the carbonate strata as chemically deposited sediments on the bottom of a shallow lake. The tuffaceous and siliceous shaly sediments were probably formed in the lake from fine ash emitted during some local volcanic activity that persisted after the great volcanism of Gem Hill time. The claystone member is a playa deposit laid down as the lake became filled with argillaceous mud. This mud-filled lake thus became a playa that contained a few feet of water only after heavy rains. The sandstone member is a stream-laid deposit. The claystone of the lower part of the sandstone member represents the final stages of intermittent playa deposition at this locality. The sandstone and conglomerate of this member were deposited by streams on a broad flood plain or valley; the arkosic character of these strata indicates that they were derived from nearby granitic exposures.

LATE TERTIARY AND QUATERNARY DIASTROPHISM AND DEPOSITION

Probably in late Tertiary or early Quaternary time, after deposition of the Tropico group, the region was uplifted again. This caused elevation of the Tehachapi Mountains along a northeastward-trending axis that may have resulted from activity on the Garlock fault zone. In the Mojave Desert to the southeast, this stress caused deformation of the surface of the crystalline rocks and of the overlying stratified rocks of the Tropico group. This deformation resulted in formation of normal faults trending north of east, as in the Rosamond Hills, and of folds with axes trending north of west in the Tropico group. The overall effect of crustal movement of this part of the western Mojave Desert was the formation of a broad upwarp, generally parallel to the northeastward-trending Tehachapi Mountain uplift. The Tehachapi Mountains were probably elevated to high relief, and the upward in the Mojave Desert probably rose to moderate relief.

During this time the parts of the Mojave Desert northwest and southeast of the upwarp no doubt continued to subside and they received alluvial sediments of the unnamed Pliocene(?) formation.

These events were followed in the Pleistocene epoch by recurrent crustal disturbances that caused renewed uplift of the Tehachapi Mountains. Coarse detritus eroded from these mountains accumulated along their southeastern base as a piedmont alluvial fan that is now the older alluvium.

It is uncertain whether this recurrent disturbance affected the upwarp formed during the preceding disturbance across the western Mojave Desert. The presence of coarse fanglomerate of the older alluvium in the Bissell and Rosamond Hills indicates that those areas were affected to some degree.

During the final stage of this episode, the Tehachapi Mountains were reduced to subdued relief, or to the late-maturity stage of that erosion cycle. The upwarp across the western Mojave Desert no doubt was reduced to very low relief. Parts of it, such as that between Antelope Buttes and the Rosamond Hills, may have been planed.

In late Pleistocene time renewed activity of the Garlock fault caused re-elevation of the Tehachapi Mountains in several stages to their present heights. The range southeast of the fault was tilted southeastward, and this tilting caused dissection of the piedmont alluvial fans along its base. The Sand Hills anticline, and the scarps along the Cottonwood, Tylerhorse, and Willow Springs faults were formed during this late disturbance. The Mojave Desert within the mapped quadrangles was apparently not affected by this disturbance, and the areas upwarped during the preceding episodes were reduced to their present low relief. Alluvial sediments derived largely from the Tehachapi Mountains continued to accumulate in Antelope Valley and over the previously planed parts of the upwarped area between Antelope Buttes and the Rosamond and Bissell Hills. This episode is still continuing.

GEOMORPHOLOGY

The geomorphology of the area within the Willow Springs and Rosamond quadrangles is that of alternate low relief and rocky protrusions typical of the western Mojave Desert. The present physiography is not only the result of events during the Quaternary period but also of those during the Tertiary period as described under "Geologic history." During the Quaternary period the Tehachapi Mountains, as well as the other mountains that border the western Mojave Desert, have been undergoing continuous erosion from recurrent uplifts. During this period the desert region has been less affected by crustal movements than the mountain areas. The present physiography has resulted from continuous differential erosion of bedrock composed of homogeneous granitic rocks that readily disintegrate mechanically in the arid desert climate, and of hard coherent rocks that resist weathering. The weakly resistant rocks are worn down to low relief, while the strongly resistant ones stand out as rocky protrusions.

The detritus that has been continually eroded during the Quaternary period from the rising mountains bordering the Mojave Desert and from the highland areas within the desert has accumulated on the lower parts of the desert. It has accumulated to great thicknesses particularly in the downwarped parts of the desert region. The erosion and contemporaneous deposition of the eroded material is continuing and has progressed so far that the desert highlands are partly buried and largely isolated from each other, so that they now form islands of bedrock within a sea of alluvium that fills the greater part of the western Mojave Desert.

TEHACHAPI MOUNTAINS AND VICINITY

Within the Willow Springs quadrangle, the elevated area of plutonic rocks that forms the Tehachapi Mountains has been eroded to narrow steep-walled canyons separated by ridges with generally rounded crests. In the southern foothills the nearly vertical layers of metamorphic rocks are differentially eroded to form parallel strike ridges and intervening swales. The zone of shattered rocks along the Garlock fault (north branch) is eroded to a line of notches that forms a depression separating the two main crests of this range.

The subdued rounded crests of the mountains southeast of the Garlock fault, of which the highest is over 6,000 feet altitude, are clearly remnants of an old erosion surface. The streams that drained this old surface were graded to the heads of the old dissected alluvial fans of older alluvium that are now at altitudes of about 4,500 feet. These streams are now rejuvenated and entrenched in narrow steep-walled V-shaped canyons graded to the much lower present base level of Antelope Valley. They have deepened their channels as the mountain area was re-elevated, perhaps in several stages, during late Pleistocene time. In their lower courses they are starting to carve narrow flood plains that widen as the streams emerge from the crystalline basement complex of the mountains into the dissected heads of the alluvial fans at the base of the mountains.

The uplift of the part of the Tehachapi Mountains within the Willow Springs quadrangle in late Pleistocene time was due to southeastward tilt away from the Garlock fault. This tilting is indicated by the gradual southeastward slope of the old erosion surface preserved on the summits of the crest of this range, and by the southeastward tilt of the old dissected alluvial fans at the base of the range to which this old erosion surface was graded.

The severe dissection of the piedmont fans of older alluvium at the southeastern base of the Tehachapi Mountains, as shown on plate 10, is also the result of uplift of this range in late Pleistocene time. In the vicinity of lower Cottonwood Wash the older alluvium has been elevated so that it rises westward to a mesa whose surface is now about 400 feet higher than the present level of Antelope Valley. This mesa of older alluvium is partly dissected and is cut through by the narrow corridorlike canyon of Cottonwood Wash that is graded to the present level of Antelope Valley. The anticlinal uplift that forms the Sand Hills at the southeast margin of this elevated mesa is intensively dissected to badlands by narrow youthful canyons that drain into Antelope Valley.

MOJAVE DESERT AREA

The two large exposures of quartz monzonite in the Bissell Hills are each eroded to broad low hills that rise to crests only about 300 feet above the surrounding desert floor. The flanks of both these domelike features slope gently and blend into the alluviated surface of the adjacent desert floor.

The eastward-trending ridge northwest of the Bissell magnesite pits is a prominent 2-mile-long cuesta at the southern margin of the area described above; it rises to about 200 feet above its base. This cuesta is a strike ridge etched from resistant southward-dipping carbonate strata of the Bissell formation and consequently has a gentle dip slope on the south and a comparatively steep abrupt escarpment slope on the north.

The Rosamond Hills form a 15-mile-long eastward-trending highland area whose highest points rise to about 900 feet above the level of the adjacent part of Antelope Valley and separate the valley from a higher plain to the north. Near U.S. Highway 6 these hills are transected by a wash, apparently antecedent to them, that drains southward into Antelope Valley.

The major part of the Rosamond Hills is a broad low pyramidal domelike feature like the two of the Bissell Hills, and it is similarly eroded from weakly resistant quartz monzonite. The crest of the northeast part of these hills is a series of rather prominent pyramidal hills eroded from a more resistant phase of the quartz monzonite.

The southwestern and western parts of the Rosamond Hills are differentially eroded from Tertiary volcanic, pyroclastic, and sedimentary rocks of varying resistance. The topographic effects of the various Tertiary formations are described under "Rock units," and are shown on plate 10.

The topography of the Bissell and Rosamond Hills described above, indicates that the hills are in the late-maturity to old-age stage of the present erosion cycle. In contrast to the Tehachapi Mountains, these hills show no evidence of recurrent uplift or rejuvenation; all washes that drain them are graded to the present desert floor and none are entrenched in narrow youthful canyons as are those in the Tehachapi Mountains.

Soledad Mountain, Middle Buttes, Willow Springs Mountain, Tropico Hill, and other isolated small buttes nearby are eroded from resistant volcanic rocks of the Bobtail quartz latite member of the Gem Hill formation. All are surrounded by alluvium that covers the desert floor. The less resistant tuff of the Gem Hill formation and the quartz monzonite are invariably eroded nearly to the level of the surrounding desert valleys, and are largely buried by alluvial detritus derived from the Tehachapi Mountains and from the buttes. Erosion of these resistant buttes has progressed only to the early or middle maturity stage of the present cycle.

The summit of Middle Buttes is a gently undulating surface, as compared to its moderately steep flanks, and is 300 to 400 feet above the surrounding desert floor. A similar but less distinct undulating surface appears on the summit of Soledad Mountain, as noted by Noble (1954). It is possible that these surfaces may be remnants of one eroded to the late-maturity stage of an earlier erosion cycle and may be correlative with the surface on the summit of the Tehachapi Mountains.

The physiography of Antelope Buttes in the southwestern part of Antelope Valley is generally similar to that of the Rosamond and Bissell Hills. The eastern part of Antelope Buttes has a gently undulating late-maturity surface cut on plutonic rocks. A low gap separates this surface from that of the western part of these hills, which is a 2-mile-long cuesta or strike ridge of northwestward-dipping Fiss fanglomerate. This cuesta rises about 300 feet from the desert floor.

Little Buttes are two isolated outcrops surrounded by alluvium in Antelope Valley, nearly midway between Antelope Buttes and the Rosamond Hills. These outcrops are probably the protruding tops of isolated hills buried by alluvial fill of this valley.

Exclusive of the elevated and dissected alluvial fans that fringe the Tehachapi Mountains, Antelope Valley is an alluviated plain that is undissected, except at Willow Springs where it is broken by the Willow Springs fault. Activity on this fault during Recent time has produced a 3½-mile-long southward-facing scarp as high as 100 feet, and the alluvium of the elevated northern block is now dissected by narrow youthful gullies.

The lowest part of Antelope Valley contains two large dry or playa lakes, Rosamond Lake in the southeastern part of the Rosamond quadrangle and Rogers Lake to the east, and numerous small ones in between. Rosamond Lake is a large nearly circular level mud flat covering some 20 square miles at an altitude of 2,271 feet, which is the same as that of Rogers Lake. All the mud flats of Antelope Valley have smooth level surfaces devoid of any vegetation. They contain a few inches or feet of water only after an occasional heavy rainstorm.

Loose windblown sand is accumulating around the eastern and southern margins of Rogers Lake as ridges and dunes as much as 60 feet high. The most prominent are the long ridges of sand parallel to the eastern and southern shorelines of the dry lake.

DRAINAGE HISTORY

The drainage system formed during late Pleistocene time within the Willow Springs and Rosamond quadrangles was probably about the same as it is now.

At times during late Pleistocene time, the lower part of Antelope Valley may have been flooded by a large lake, as indicated by the presence of blue clay beds of supposed lacustrine origin found in water wells drilled in the alluvium in this part of the valley. The flooding resulted either from subsidence of this part of Antelope Valley or from accumulation of alluvial-fan material across the drainage outlet area.

At the end of Pleistocene time, perhaps during the last glacial stage (Tioga of Blackwelder, 1931), when precipitation in this region was much greater than it is now, the lower part of Antelope Valley was flooded by waters of a large shallow lake. Evidence of this ancient lake was recognized by Thompson (1929, p. 302–303); the lake was named Lake Thompson in his honor by Miller (1946, fig. 1, no. 19). This lake appears to have once covered Antelope Valley below the 2,330-foot contour and to have extended as far south as the town of Lancaster; it included what are now Rosamond Lake, Rogers Lake, and the numerous intervening playas. The approximate extent of Lake Thompson in the Rosamond quadrangle is shown on plate 10. Whether this lake persisted from the one formed earlier in late Pleistocene time, or whether there was an intervening interval of evaporation is uncertain. The existence of Lake Thompson is indicated by the soil of Antelope Valley downslope from the 2,330-foot contour and by the presence of strand-line deposits and wave-cut banks, as described in the following paragraphs.

The surface soil of Antelope Valley downslope from the 2,330-foot contour is soft gray to bluish-gray clay with admixtures of silt and fine sand. This material is like the bluish-gray clay in water wells in this area and is also similar to that now being deposited in Rosamond Lake. Even where sand dunes are being formed on parts of the valley area once flooded by Lake Thompson, the soil in the areas between the dunes is always fine argillaceous clay and silt. The soil of the valley area upslope from the 2,330-foot contour is generally sandy rather than argillaceous. The surface soil below the 2,330-foot contour contains much alkali, as pointed out by Thompson (1929, p. 298), which is not generally present in the more sandy soil above this contour. The limits of the alkali soil, as shown by Thompson (1929, pl. 19), correspond closely with the area of artesian flow at the time he surveyed the ground-water level and also with the 2,330-foot contour as shown on the detailed topographic maps of Los Angeles County. Although most of the alkali in the soil of this area may be the result of evaporation of ground water, it may be in part the result of evaporation of waters of ancient Lake Thompson.

The western and southern shorelines of Lake Thompson are barely discernible on aerial photographs and are marked only by the change of soil indicated above, for there are no shoreline bars. The northern strandline, however, is well marked. The most prominent feature is the low bank as high as 70 feet that faces Rosamond Lake; the Rosamond-Edwards road follows the bank eastward from Red Hill. For 4 miles the bank is cut into volcanic and plutonic rocks, thence for a mile it is cut into Quaternary alluvium. This bank was almost certainly cut by wave action of ancient Lake Thompson, because it follows an even curve parallel to the present north shoreline of Rosamond Lake.

The shoreline of Lake Thompson is clearly discernible on aerial photographs for 4 miles west of Red Hill; it passes directly through the town of Rosamond. The old shoreline, together with several retreating shorelines, shows faintly as parallel light-colored deposits of fine sand and silt across the small piedmont alluvial fans that slope southward from the Rosamond Hills. Similar deposits of fine sand extend due eastward from the point where the wave-cut bank ends nearly 5 miles east of Red Hill. In both areas the highest shoreline deposit follows close to the 2,330-foot contour. This ancient shoreline can be followed at the same contour at most places around Roger Lake.

As the altitude of the playa surface of both Rosamond and Rogers Lake beds is 2,271 feet, the maximum depth of Lake Thompson when filled to the 2,330-foot contour was about 60 feet.

Northwest of Rosamond there is suggestive evidence of an even older shoreline above the 2,330-foot contour. A faint light-colored line which might have been part of an old shoreline appears on aerial photographs. It lies near the 2,400-foot contour and extends across piedmont alluvial fans for nearly 4 miles from a point a mile northwest of Rosamond to a point a mile south of Tropico Hill.

The waters of Lake Thompson may have once overflowed from the north end of Rogers Lake either northward some 20 miles to Koehn Lake (altitude about 1,920 feet) or eastward to the Mojave River, as suggested by Thompson (1929, p. 303). He indicated that the former is more likely, as the altitude of the outlet north of Rogers Dry Lake is 2,360 feet, whereas that eastward through the valley area at Boron and Kramer is 2,485 feet.

Two series of bars of well-sorted coarse sand, as much as 300 feet wide and 10 to 15 feet high, are present, one a mile west of the present shoreline of Rosamond Lake, the other about a mile south (pl. 10). They are at or near the 2,290-foot contour and some bars are more than a mile long. These bars were probably deposited by long-continued wave action when much of the waters of Lake Thompson evaporated and the shoreline retreated and stood for a long time at or near this contour.

In late Recent time precipitation in this region diminished and Lake Thompson eventually evaporated. As the prevailing westerly gales sweep across the dry lake bed they pick up fine sand from it and deposit it as a series of dunes. The long ridges of sand around the east shoreline of what is now dry Rosamond Dry Lake may have accumulated along old wave-deposited sand bars; this accumulation caused Rosamond Lake to come into existence and isolated it from other playas to the east.

MINERAL RESOURCES

The mineral resources of proved value within the Willow Springs and Rosamond quadrangles include gold, silver, arsenic, radioactive minerals, limestone, magnesite, feldspar, quartz, ornamental stones, roofing material, and clay. The value of gold produced far exceeds the combined value of the other mineral products.

HISTORY

In 1894, gold was discovered in veins associated with the volcanic rocks of Soledad Mountain and in the isolated hills to the north. This area became known as the Mojave mining district. From 1894 to about 1909, extensive prospecting and exploratory work led to the development of the Elephant, Echo and Gray Eagle, Queen Esther, and Karma groups of mines on Soledad Mountain, and of the Exposed Treasure mine on Bowers Hill just beyond the north border of the Rosamond quadrangle. The production of gold and some silver from these mines was substantial. Many other prospects and small mines were developed in the Soledad Mountain area, but production from them was small. In all the mines of Soledad Mountain, production was from the readily accessible oxidized zone. When this was worked out, the mines were shut down because operations at depths below the water table were unprofitable.

From 1910 to 1931 there was very little activity, except in 1922 when the Yellow Dog mine was developed in Bowers Hill. In 1931 there was increased leasing activity and some 50 to 70 lessees were operating at the Exposed Treasure, Yellow Dog, Elephant, Echo, and Gray Eagle mines. Ore from these mines was hauled 17 miles to the Tropico mines where it was milled by the Burton Bros. custom mill. In 1931, 1,358 tons of ore was mined, from which was recovered gold valued at $28,270, with an average value of $20.81 per ton; in 1932, 3,381 tons was mined, with $70,000 worth of gold recovered at an average value of $20.70 per ton.

In 1933, activity was revived on Soledad Mountain with the discovery at the Queen Esther claim of a new high-grade vein containing gold and silver. This discovery was developed by the Golden Queen Mining Co., which eventually acquired most of the properties of the former Queen Esther, Echo, Gray Eagle, and Elephant mines, and installed a mill and a cyanide recovery plant. The Golden Queen mines were operated until 1940. Since that time the mines of the Soledad Mountain area have been largely shut down.

The other volcanic buttes beyond the immediate vicinity of the Soledad Mountain area have been extensively prospected. These include the small buttes near DeStazo Ranch, Middle Buttes, Willow Springs Mountain, Tropico Hill, and Red Hill. This activity resulted in finding gold at Middle Buttes and at Tropico Hill. Discoveries at Middle Buttes led to development of the Cactus Queen mine, and at Tropico Hill to development of the Tropico mines. The Cactus Queen and Tropico mines have been steady producers for many years.

During World War II (1941–45) all the actively operated gold mines were shut down by War Production Board Order L208. Since that time there has been practically no production from any of the mines except the Tropico mines which were reopened in 1946 and which produced gold ore until 1952.

The search for uranium minerals led to the discovery in 1948 of small deposits of autunite in the tuffaceous rocks of Tertiary age in the western Rosamond Hills, but prospecting indicated that the ore is of subcommercial grade.

A small deposit of magnesite in Tertiary lake beds in the Bissell Hills yielded small tonnages from 1915 to 1923. Small tonnages of feldspar, quartz, volcanic rock, and pottery clay have been quarried and shipped sporadically from the Rosamond Hills. In the Tehachapi Mountains there are large deposits of limestone but these have not been quarried.

GOLD-SILVER DEPOSITS

Gold occurs in numerous brecciated and sheared zones of the Tertiary intrusive quartz latite of Soledad Mountain, Middle Buttes, and Tropico Hill. All these shear zones have been heavily prospected and are honeycombed with numerous workings. With the exception of some rich ore shoots that led to the development of the Golden Queen, Cactus Queen, and Tropico mines, the shear zones are either barren or of low grade, and most of these have been abandoned since the early part of the century. There are no available figures on the total production of gold and silver.

Deposits described by Gardner (1954, p. 52) as epithermal veins containing gold and silver occur within or adjacent to the intrusive masses of the Bobtail quartz latite member of the Gem Hill formation. The veins of this type range from a few inches to about 40 feet wide, and consist of brecciated, sheared, or kaolinized rock. The vein minerals are quartz, chalcedony, calcite, sericite, and sulfides of iron and of silver that are largely oxidized above the water table. The texture of the gangue minerals is fine grained to drusy. Adularia is present locally. Alunite and kaolin are the major constituents of some of the veins at Middle Buttes. Finely disseminated free gold and sparse to abundant pyrite or its oxidation product, limonite, occur in local shoots along persistent vein zones. Some veins contain silver in the form of cerargyrite, argentite, and proustite.

In Soledad Mountain the veins occur within intrusive masses of felsitic and porphyritic quartz latite, commonly near or at their margins. Nearly all the veins trend roughly N. 30° W., parallel to the general trend of the large elongated intrusive masses of the volcanic rock in which they occur, and dip steeply in either direction. The richest veins occur on the west slope of Soledad Mountain (fig. 7), where they were mined extensively. Others of lower grade occur on the northeast slope. The numerous volcanic plugs forming the lower hills that extend southward and eastward from Soledad Mountain contain shear zones and small veins, but none of these yielded commercial quantities of gold and silver. In this mountain the vein material consists of kaolinized brecciated and sheared quartz latite mineralized with quartz, calcite, iron and manganese oxides, disseminated free gold, and silver in the form of cerargyrite and argentite.

At Middle Buttes several veins containing rich ore shoots were mined on the west slope of the complex intrusive mass of quartz latite. The veins trend roughly N. 30° E. and dip gently southeastward. They occur at and near the contact of quartz latite with quartz monzonite to the west. Other veins of subcommercial grade were prospected on the east slope of Middle Buttes. The vein material consists of kaolinized quartz latite with jarosite, alunite, and quartz in varying proportions, and contains both gold and silver.

At Tropico Hill the ore is in one main vein and several minor ones that all trend eastward and dip about 60° southward. The vein material apparently occurs along fault fissures that cut wallrocks composed of granitic rock, felsitic quartz latite, intrusive felsite breccia, and porphyritic quartz latite. The veins are themselves cut by many later minor faults. The vein material is chemically about the same as the wallrocks. The only difference is the presence in the veins of gold-bearing quartz and traces of pyrite and manganese carbonate and their oxidation products. No silver minerals have been found.

The veins throughout the volcanic centers of Soledad Mountain, Middle Buttes, and Tropico Hill probably formed along fracture or fault zones. The ore minerals were deposited from hydrothermal or magmatic waters that worked up these fracture zones soon after the emplacement of the plugs. The ore shoots differ greatly in size. According to Gardner (1954, p. 52) their location and formation are controlled largely by faulting. The degree to which the vein zones could be permeated by solutions carrying gold and silver was the dominant factor that localized the ore shoots. Some ore shoots are at the intersection of veins or fractures. Others occur where veins are cut by minor faults; these occurrences suggest that such faults acted as barriers to hydrothermal solutions.

The hydrothermal solutions were probably initially acid, for sericitization and kaolinization are characteristic and alunitization is locally conspicuous at Middle Buttes. The presence of calcite in some veins at Soledad Mountain indicates a probable change there from acid to alkaline solutions during ore deposition. At Tropico Hill, according to Gardner (1954, p. 52), several stages of gold-bearing quartz are present in the altered wallrocks; in general the early quartz is dense and the later is drusy. The latest stage is represented by strong kaolinization of the quartz latite and introduction of a dark-red iron-bearing material that locally contains silica and coarse gold. No alunite has been recognized here.

MINES OF SOLEDAD MOUNTAIN AREA

Elephant mines.—The Elephant mines, also known as the Bobtail mines, were on claims totaling about 100 acres in the western part of sec. 6, T. 10 N., R. 12 W., in the northwest foothills of Soledad Mountain. The mines were developed prior to 1910 by the United Mines Co. of Chicago.

Three parallel veins, the Hope, Excelsior, and Elephant, have been explored; they strike northwestward and dip 50° to 80° NE. in quartz latite. The Hope vein was mined from a tunnel driven southeastward for 400 feet on the vein; a 100-foot ore shoot, 160 feet from the portal, was stoped to the surface. The Excelsior vein was developed from a crosscut tunnel driven N. 30° E. At 20 feet from the portal it cut the vein, which was followed for 100 feet by a drift and which was stoped to the surface. The Elephant vein was developed from a 75° inclined shaft sunk 120 feet on the vein; on the 50-foot level the vein was followed southeastward for 60 feet by a drift; on the 100-foot level, drifts followed the vein southeastward for 350 feet and northwestward for 210 feet and the vein was stoped. The ore was treated at a mill near the Elephant shaft. There are no available production figures.

All the veins are composed of highly brecciated material containing quartz and iron-stained silicified porphyritic rock. The Excelsior vein strikes N. 20° W., dips 55° E., and averages 3 feet in width. The Hope vein strikes N. 20° W., dips 70° E., and averages 2 feet in width. Ore from the Elephant vein was valued from $25 to $200 per ton (Tucker, 1923, p. 159).

Echo and Gray Eagle mines.—The Echo and Gray Eagle mines are on six claims totaling 60 acres that diagonally crossed the west-central part of sec. 6, T. 10 N., R. 12 W., on the west slope of Soledad Mountain; they adjoin the Elephant mines on the northeast. The Echo and Gray Eagle mines were developed in early years by the Echo Consolidated Mining Co. and later by A. Asher and B. Fisher of Mojave. The properties were acquired in 1935 and further developed by the Golden Queen Mining Co.

Development was on three parallel veins, the Echo, Starlight, and Gray Eagle, all trending northwestward and dipping northeastward, with widths averaging 3 or 4 feet. At latitude 3,200 feet, No. 1 Echo tunnel was driven N. 25° E. 240 feet to the Echo vein, with drifts northwestward and southeastward for 500 feet on the vein. At altitude 3,400 feet, No. 2 Echo tunnel was driven southeastward on the Echo vein for about 500 feet. The veins were stoped to the surface above these tunnels. At altitude 3,450 feet, the Gray Eagle tunnel was driven southeastward for 450 feet on the Starlight vein. At this point a crosscut extended northeastward for 40 feet to the Gray Eagle vein, which was followed by a drift for 400 feet. From this level a shaft was sunk 350 feet on the vein; drifts followed the vein on the 100-foot level for 510 feet, on the 200-foot level for 650 feet, and on the 300-foot level for 1,040 feet.

The ore was treated in a 10-stamp mill, which was dismantled in 1906, after which the ore was treated at the Elephant mill. These mines are reported to have produced $200,000 to $400,000 worth of gold. (Tucker, 1923, p. 158–159; 1929, p. 31–32.)

Queen Esther mines.—The Queen Esther mines were developed on a group of 10 claims totaling 160 acres in the east-central part of sec. 6, T. 10 N., R. 12 W., on the upper west slope of the peak of Soledad Mountain; these claims adjoin the Echo and Gray Eagle claims on the northeast. The Queen Esther mines were operated from 1894 to 1910 by the Queen Esther Mining and Milling Co. of Los Angeles. In 1935 the property was acquired and redeveloped by the Golden Queen Mining Co.

The Queen Esther vein trends northward, dips 40° eastward, and consists of iron-stained quartz averaging 4 to 8 feet wide in silicified quartz latite. The vein was mined from several tunnels about 500 feet long and from several thousand feet of drifts. The ore shoot in the vein was reported to be 500 feet long. The ore was treated at a mill that was dismantled in 1918. Production of gold prior to 1910, when operations were suspended, was reported to be valued at $200,000. Some silver was also produced (Tucker, 1923, p. 162).

Golden Queen mine.—In 1933 a rich ore shoot was discovered by George Holmes on the former Queen Esther claim on the northwest slope of Soledad Mountain. After this discovery the Silver Queen mine was developed by Holmes, and in 1935 the mine was acquired by the Golden Queen Mining Co. of Los Angeles, after which it was known as the Golden Queen mine. From 1935 to 1940 the company operated and further developed the property, and acquired other idle mines formerly operated by the Queen Esther Mining and Milling Co. and the Echo Consolidated Mines, Inc. The claims operated by the Golden Queen Mining Co. totaled about 600 acres covering much of sec. 6 and the westernmost part of sec. 7, T. 10 N., R. 12 W., on Soledad Mountain.

The Silver Queen vein, which strikes N. 20° W. and dips 55° NE., was the first vein to be explored. According to Tucker and Sampson (1934, p. 317), this vein was mined in 1934 from two shafts 45 feet apart sunk on the vein on the lower northwest slope of Soledad Mountain. The southeast shaft was 100 feet deep with drifts driven northward 100 feet and southward 100 feet. The northwest shaft was 200 feet deep with drifts at the bottom driven northwestward 180 feet and southeastward 190 feet. All these workings were reported to be in ore. Later that year a crosscut tunnel was driven southward 140 feet to the vein, with a drift southeastward 150 feet to an incline shaft on the 200-foot level, and thence a drift southeastward 600 feet.

After the property was acquired by the Golden Queens Mining Co. in 1935, the Silver Queen vein and 2 footwall branches and 3 other principal veins southwest of the Silver Queen were explored. From northeast to southwest these are the Golden Queen, Lodestar (Starlight), and Soledad Extension. All three trend about N. 40° W. and dip southwestward. The description in the following paragraphs of these veins and their development is abstracted from Tucker, Sampson, and Oakeshott (1949, p. 220–222).

The Silver Queen vein was mined from three adits driven southeastward, the 200-, 400-, and 600-foot levels. The greatest length of development is 1,700 feet, on the 200-foot level. The 600-foot level at an altitude of 3,155 feet is 8 by 8 feet in section and is the main haulage way for all the mines. It has a total length of 4,600 feet, and connects with ore passes from each of the levels in the various mines. At a point 1,500 feet from the portal it intersects the supply shaft from the 200-foot level. At a point 600 feet southeast of this intersection a crosscut was driven southwestward for 1,200 feet to connect with the 600-foot level of the Lodestar mine, thence southward for 400 feet to connect with the 600-foot level of the Soledad Extension, thence southeastward for 900 feet to a winze. This winze has 200 feet of development on the 700-foot level and 2,400 feet of workings on the 800-foot level; the 800-foot level connects with the Soledad Extension. Two footwall branches of the Silver Queen vein have been stoped for 500 feet along strike above the 300-foot level to their junctions with the Silver Queen vein.

The Golden Queen vein was explored and mined for 1,800 feet along its strike and stoped part way to the surface. The average stope width is 15 feet. This development work is on or above the 200-foot level of the Golden Queen, which is 400 feet below the surface.

The Lodestar vein was mined from four levels. The No. 1 adit at an altitude of 3,638 feet was driven southeastward 800 feet on the main Lodestar vein. No. 2 adit, at an altitude of 3,538 feet, was driven eastward 200 feet to the Gray Eagle vein, thence southeastward for about 2,800 feet. About 2,000 feet from the portal an ore shoot 900 feet long and 13 feet wide was found. At 2,100 feet from the portal a winze was sunk 250 feet on the hanging wall of this vein. No. 3 adit, at an altitude of 3,355 feet, was driven southeastward 2,500 feet. The last 950 feet was in ore. No. 4 adit, at an altitude of 3,170 feet, was driven southeastward 1,500 feet and was developed from winzes. It connects with the main haulage (600-foot) level of the Golden Queen Mine.

The Soledad Extension vein was mined from an adit driven southeastward 1,200 feet, which is connected by a raise to the Golden

Queen 200- and 400-foot levels. A 600-foot winze was sunk 400 feet from the portal. A level from this winze, 200 feet below the adit, connects with the Golden Queen 600-foot haulage level. Another level, 400 feet below the adit, was driven southeastward 1,400 feet to a winze sunk from the southeast end of the Golden Queen haulage level and thence southeastward 1,000 feet.

From the main workings described above there are numerous crosscuts, raises, and parallel drifts amounting to a total of several miles of additional underground workings.

The ore was milled and the gold and silver were recovered in a cyanide plant on the property. These mines produced large amounts of gold and a moderate amount of silver while in operation, but production figures are not available.

The four principal veins occur within a 1,000-foot-wide zone of shattered quartz latite that forms the gap between the intrusive masses forming the higher peak of Soledad Mountain and the lower peak and spur to the west. The veins occur along brecciated or sheared zones in intrusive rock. The veins are composed of quartz and iron-stained altered rock, all intensely brecciated and sheared. Ore shoots in these veins contain finely disseminated free gold, and silver in the form of cerargyrite (horn silver) and argentite.

The Silver Queen vein dips 55° NE. and occurs along a contact between separate quartz latite intrusive bodies. This vein is as much as 50 feet wide, but averages 10 to 30 feet. Sixty percent of the values are gold, and 40 percent are silver.

The Golden Queen vein dips 70° SW. and is about 300 feet southwest of the Silver Queen vein at the surface. It averages about 15 feet wide. This vein has two footwall branches striking N. 20° W. and dipping about 70° NE.

The Lodestar vein dips about 70° SW. and is about 200 feet southwest of the Golden Queen vein. It ranges from 8 to 20 feet in width and averages 13 feet. The ratio of silver to gold in this vein is about 20 to 1 by weight.

The Soledad Extension vein dips 53° SW., and is about 500 feet southwest of the Lodestar vein at the surface. It occurs at the contact of felsitic and porphyritic quartz latite. The vein averages 15 feet in width and contains two ore shoots.

Eureka mine.—The Eureka mine consists of one claim adjoining the Queen Esther mine in sec. 6, T. 10 N., R. 12 W., on the northeast slope of Soledad Mountain, at an altitude of 3,600 feet. It is owned by the Golden Queen Mining Co.

The vein is a brecciated zone in quartz latite, strikes N. 40° W., dips 60° NE., and ranges from 5 to 10 feet in width. It has been mined from tunnels, the lowest of which was driven southeastward for 200 feet on the vein.

The ore was treated at the Golden Queen Mill. Production was well over $100,000. The mine is now idle (Tucker, Sampson, and Oakeshott, 1949, p. 218).

Karma mine.—The Karma mine was developed on 4 claims totaling 70 acres on the east edge of sec. 6 and SW¼ sec. 5, T. 10 N., R. 12 W., on the northeast slope of Soledad Mountain, at an altitude of 3,200 feet. The mine was worked by the Karma Mining Co. from 1898 to 1904.

Mine workings were along two parallel veins striking N. 10° W. and dipping 60° E. The veins can be traced at the surface for a thousand feet; they consist of iron-stained sugary quartz 4 to 15 feet wide in silicified quartz latite. One vein was followed by a drift for 1,800 feet, and from a point 100 feet in from the portal the vein was stoped to the surface for 200 feet. The ore shoot in the tunnel was said to be 240 feet long and 15 feet wide. On the same level as the tunnel a shaft was sunk for 160 feet and the ore was mined from drifts and stopes. The gold was found free, with small amounts of pyrite (Tucker, 1923, p. 161; 1929, p. 37). There is no record of production figures for this mine, and workings have caved since it was abandoned years ago.

Monarch mine.—The Monarch mine (Extension Ajax) consists of one claim in the west edge of sec. 5, T. 10 N., R. 12 W., on the lower northeast slope of Soledad Mountain. The mine was owned by the Wilcox Estate, Bakersfield, Calif., and leased during 1938–40 to the Golden Ace Mining Co., Inglewood, Calif. The property adjoins the Karma mine on the east. The mine was idle in 1957.

Mine workings are in two roughly parallel veins, the Ajax and Karma, trending N. 10° W. and dipping 60° E. Workings consists of a crosscut tunnel driven S. 74° W. for 587 feet; 294 feet from the portal, the tunnel intersects the Ajax vein, which at this point is 18 feet wide; 542 feet from the portal it cuts the Karma vein, which has a width of 45 feet. About 400 feet north of the crosscut, a tunnel, trenches, and open cuts along the Ajax vein exposed 18 feet of quartz, which is reported to average $5.00 per ton of gold and silver. Figures on the output are not available but production was small.

The Ajax and Karma veins are brecciated siliceous zones in the intrusive felsitic quartz latite that forms Soledad Mountain. The veins are probably cut off on the south by a minor fault (Tucker, Sampson, and Oakeshott, 1949, p. 230).

MINES OF MIDDLE BUTTES AREA

Cactus Queen mine.—The Cactus Queen mine comprises about 500 acres in sec. 17, T. 10 N., R. 13 W., on the west side of Middle Buttes; it is owned by the Cactus Mines Co., Los Angeles. The following account of this mine is abstracted from Tucker, Sampson,

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and Oakeshott (1949, p. 216–217), and Gardner (1954, p. 54–55).

The Cactus vein strikes about N. 30° E. along and near the western base of Middle Buttes and dips about 35° SE. It has been extensively explored. Workings consist of a 700-foot inclined shaft sunk on the vein and a winze, 350 feet from the shaft, that extends from the 300- to the 1,000-foot levels. Development on the vein is in two ore bodies that are rich in silver. The vein has been mined continuously for a distance of 900 feet, and explored for a distance of 4,000 feet.

Other workings are on the Winkler vein that crops out about 1,500 feet southeast of the Cactus vein and is nearly parallel to it. This vein was developed from a shaft and several levels. High-grade ore was found between the 250- and 350-foot levels and stoped from the latter.

The ore was treated at a mill on the property. Figures on the output of this mine are not available. The mine was shut down during World War II and only sporadic exploration work was carried on afterward.

The Cactus vein is 7 to 15 feet wide and consists of brecciated and kaolinized quartz latite adjacent to the contact with quartz monzonite that in most places forms the footwall rock. The vein strikes N. 30 E. and dips gently southeastward. It contains two ore bodies, both rich in silver as well as gold. The ore shoots contain finely disseminated gold associated with arsenopyrite, marcasite, and silver mostly in the form of prousite ($3Ag_2S \cdot Ag_2S_3$).

The Winkler vein is about 5 to 15 feet wide, strikes roughly N. 15° E., and dips about 40° SE. It contained three high-grade ore shoots, one at the surface and the other two between the 250- and 350-foot levels. These shoots were comparatively small, but according to Gardner (1954, p. 55) some were as much as 100 feet long and 10 to 15 feet wide.

According to Gardner (1954, p. 55) the ore in the Cactus Queen mine is of two types:

1. Kaolinized rhyolite broken and interlaced with jarosite and goethite(?) that form a red gouge with gold. This ore contains little alunite and quartz.
2. Strongly kaolinized rhyolite with abundant pink alunite, minor quartz, and traces of manganese. Free gold occurs as dust or powder, and rarely as larger, though still minute, particles.

Middle Butte mine.—The Middle Butte mine, consisting of 160 acres in the SW¼ sec. 16, T. 10 N., R. 13 W., is on the east slope of Middle Buttes, at an altitude of 3,000 feet. The mine is owned by Middle Butte Mine, Inc., c/o E. L. Morris, Santa Ana, Calif., and was leased in 1935 to W. E. Trent of Tonopah. Workings consist of more than 5,000 feet of shafts, drifts, and crosscuts.

Tucker, Sampson, and Oakeshott (1949, p. 229) stated:

> The vein, which occurs in rhyolite, strikes N. 26° W., dips 35° E., and has a width of 6 to 8 feet. The ore shoot was 150 feet long. The gold was free, finely disseminated through the brecciated vein quartz. The ore shoot was mined from the surface to 80 feet on the dip, 150 feet in length, and 8 feet in width. It is said to have averaged $70 per ton. Production was in excess of $150,000.
>
> Considerable exploration work below this stope failed to disclose downward extension of the ore shoot. * * * The mine is now idle.

Burton, Brite, and Blank mine.—The Burton, Brite, and Blank mine comprises 160 acres in the NW¼ sec. 16, T. 10 N., R. 13 W., on the east slope of Middle Buttes, at an altitude of 3,000 feet. It also is owned by the Middle Butte Mine, Inc., Santa Ana, Calif.

The following account of this mine is quoted from Tucker, Sampson and Oakeshott (1949, p. 215–216):

> The country rock is rhyolite, which in places is highly silicified. Near the crest of the hill is a slide, which apparently carried some of the vein down the east slope of the hill in a northerly direction for a distance of 300 to 400 feet. Some very high-grade quartz was found, all of it carrying visible free gold. The float carried from $50 to $2,000 per ton. Discovery of high-grade float on the property led to the developments of Middle Butte, and some $10,000 was recovered from the material.
>
> An intensive search, which included a 400-foot tunnel, a 165-foot tunnel, and a 65-foot shaft, finally resulted in the discovery of a vein 4 to 6 feet wide. This vein, trending N. 26° W., dipping 40° E., was badly broken by faulting. The displacement was in an easterly direction. Some very high-grade ore was encountered, but mineralization was irregular and spotty. No continuous ore shoot was developed. The property is now idle.

MINES OF WILLOW SPRINGS MOUNTAIN

Milwaukee mine.—The Milwaukee mine comprises 160 acres in the NW¼ sec. 16, T. 9 N., R. 13 W., on the southeast slope of Willow Springs Mountain, at an altitude of 2,850 feet. The owner is Milwaukee Mining Co., Milwaukee, Wis.

The vein is an altered fracture zone in quartz latite; it strikes eastward, dips 60° S., and has a width of 4 to 6 feet. Development consists of 5 shafts and about 1,000 feet of drifts and crosscuts. Four of these shafts are caved. The most recent workings consist of an inclined shaft 250 feet deep, and a crosscut to the north on the 200-foot level. This shaft is west of the old workings (Tucker, Sampson, and Oakeshott, 1949, p. 230). The workings were idle at the time of the present investigation and previous production is not known.

MINES OF TROPICO HILL

Tropico mines.—The Tropico mines are located in Tropico Hill and include the Tropico, Fairview, and Lida mines comprising 11 claims covering 220 acres. The property is owned by the Burton Bros., Inc., and H. C. Burton of Rosamond.

Development and production.—The Tropico mine workings explore four closely spaced parallel veins striking east-west and dipping about 60° S. Principal development is on the Tropico or Home vein which crops out on the south slope of Tropico Hill. In a total length of 2,000 feet, four faulted segments of this vein have been mined for a length of about 400 feet each. The vein is developed from three shafts. The easternmost is the Fairview shaft, sunk down the vein to about 770 feet. The Tropico shaft, 1,000 feet west of the Fairview, was sunk on a 60° incline to 775 feet. The vertical Kid shaft, 1,000 feet west of the Tropico, is 850 feet deep. About 1,200 feet west of the Kid shaft is a small prospect, the Occidental shaft, on the west end of the vein. Eight levels have been driven on the vein from the three main shafts. The 600- and 700-foot levels extend from the Fairview shaft to the Kid shaft. Total development on this vein approximates 1,800 feet.

The Lida vein, which is parallel to the Tropico vein and about 600 feet north of it, crops out locally near the crest of Tropico Hill, and was developed mainly from the Lida shaft. This shaft is north of the Kid shaft and was sunk on the Lida vein to 300 feet. Two other shallow-prospect shafts were sunk on this vein, one north of the Home shaft and the other northeast of the Fairview shaft.

The 750-foot and 800-foot levels are below the water table. During mining operations the water was boosted to the surface by centrifugal pumps at the rate of 190 gpm (gallons per minute).

The mined ore was treated at the Tropico mill located on the property. The Tropico mines produced gold steadily from the time the veins were discovered in 1895 until 1942. During this period about 25 tons of ore was produced per day and the total value of the gold was about $3,000,000. During World War II the mines were shut down, then sporadically produced a small output from 1946 until 1958, when they were made into a tourist attraction.

Geology and ore deposits.—The productive zones of Tropico Hill occur as ore shoots mainly along the two main parallel fissure veins, the Tropico (or Home) vein and the Lida vein, and along two less important parallel ones in between. The veins occur in intrusive felsitic quartz latite with closely spaced fracture cleavage that dips steeply south in most places, in massive porphyritic quartz latite, and in some places in granitic rock. The vein material consists of brecciated and silicified quartz latite, but west of the Kid shaft some of the best ore is in altered brecciated granitic rock. The ore shoots range from 3 to 10 feet wide, although in places widths of 50 or more feet have been mined. The wallrock is less altered but not everywhere sharply defined from the vein rock so that in places the wallrock has to be determined by assaying.

The four productive veins trend nearly due eastward and dip about 60° S., parallel to the general attitude of the intrusive mass and to the fracture cleavage developed in the felsitic rock. The veins were formed probably during fault movements along certain fracture cleavage planes during or soon after emplacement of the intrusive rocks. The productive veins are possibly along normal faults with displacements estimated to be as much as 800 feet. These fault-fissure veins are themselves displaced a few feet by later minor northwestward-striking normal faults dipping steeply southwestward, and also by northward-striking faults dipping 60° W.

A notable feature of this mine is the fact that on the 800-foot level (about 1,080 feet down dip from the surface) the ore is of better grade than that which was mined from the levels above (Tucker and Sampson, 1933, p. 330–332; Tucker, Sampson, and Oakeshott, 1949, p. 234–235).

ARSENIC ORE

A small amount of arsenic ore has been reported mined from sec. 10, T. 10 N., R. 15 W., at the Contact mine, which comprises three claims in Tylerhorse Canyon.

Development consists of a vertical shaft 50 feet deep and a drift westward for 20 feet. A tunnel was driven eastward for 50 feet on the vein. It is reported that 27 tons of arsenic ore with an average assay value of 40 percent arsenic was shipped in 1923. There is no record of any production since that year and the mine has been idle since 1929 (Tucker, 1924, p. 368).

The ore is arsenopyrite associated with pyrite, and occurs in small irregular veins 6 to 12 inches wide. The veins are in the contact zone between the thick limestone and schist units of the Bean Canyon formation on the south where the schist is intruded by diorite.

RADIOACTIVE MINERALS

ROSAMOND HILLS AREA

ROSAMOND URANIUM PROSPECT

Small quantities of secondary uranium minerals composed of autunite and another unidentified radioactive mineral have been discovered in the western Rosamond Hills 5 miles northwest of Rosamond. This prospect, in the S½ sec. 25 and N½ sec. 36, T. 10 N., R. 13 W., close to the Tropico-Mojave road, was leased and operated until 1957 by the Verdi Co., c/o Clifford Gillespie, Hollywood, Calif. The prospect was studied by Walker (1953), from whose report the following data are largely taken.

The radioactive minerals were first discovered in the small cliff-like outcrop of tuffaceous sandstone near the crest of the small grade

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of the Mojave-Tropico road and just west of the road. Workings in this outcrop consist of a short adit, a 20-foot shaft, and numerous shallow pits. In this outcrop and in the next small hill to the west are 15 test holes, 15 to 19 feet deep, in addition to numerous pits. Since this discovery the area within a mile west, south, and east of the original discovery has been prospected with numerous open pits and shallow drill holes, particularly along and near the many generally eastward-trending faults that abound through this area. There have been no underground mining operations.

In 1955 the Verdi Development Co. leased the gold ore stamp mill of the Golden Queen mine on Soledad Mountain, and converted it to a uranium ore concentrating mill. Ore from the Rosamond prospect was hauled to and refined at this mill. However, efforts to concentrate the radioactive material to a grade sufficient to meet the requirements of the U.S. Atomic Energy Commission failed.

The Rosamond uranium prospect is in outcrops of light-colored lithic tuff and tuffaceous conglomeratic sandstones of the Gem Hill formation. The stratigraphic sequence of this formation at Gem Hill just west of this prospect is described on page 169, under "Rock units." The clifflike outcrop containing the first discovered occurrences of radioactive mineral is in strata 30 feet thick immediately overlying the basalt flow exposed on the Mojave-Tropico road.

Strata of the Gem Hill formation in this area strike northwestward and dip at low angles to the southwest. The formation is broken here by two large normal faults about half a mile apart. These faults trend N. 70° E. and dip steeply northward, with quartz monzonite containing pegmatite dikes exposed south of the southern and the northern faults east of the road. Vertical displacement on both these faults is more than 1,000 feet. Within this area are many minor high-angle faults generally parallel to the two main faults and with displacements of only a few feet or few tens of feet. Only the more important ones are shown on the map. Those at and near the original discovery are shown by Walker (1953, p. 4).

Radioactive minerals are erratically distributed throughout an area of nearly a square mile. The original discovery is in the most northeasterly part of this area which is not yet completely prospected.

Practically all the radioactive minerals are in the Gem Hill formation, but they are not confined to it. They occur as thin coatings along fault planes and fracture surfaces in the tuffaceous strata near the fault planes. The coatings are paper-thin and not more than 1 mm thick. The radioactive minerals also occur as sparsely disseminated minute crystals in the tuffaceous beds adjacent to the faults. The greatest concentrations to date have been found along the minor faults of the original prospect (Walker, 1953, p. 6–7), a quarter of a mile south along the northern main fault and again along the southern main fault and just east of the Mojave-Tropico road half a mile south of the original prospect. Along this fault some of the radioactive coatings are in fracture surfaces of the pegmatite dikes and quartz monzonite just south of the fault as well as in the tuff to the north.

The disseminations of radioactive minerals in the tuffaceous sediments of the Gem Hill formation and the thin coatings on surfaces of faults and fractures within or adjacent to this formation suggest one of two modes of origin. The radioactive material, which may occur in minute quantities throughout the rhyolitic tuffaceous sediments of the Gem Hill formation, was dissolved by ground water and redeposited on fault and fracture surfaces mainly as autunite, or it was introduced by hydrothermal solutions that ascended along faults, and then was deposited as autunite on the fault surfaces and as fine disseminations in the somewhat porous tuffaceous sediments of the Gem Hill formation. The first hypothesis seems more probable, because the radioactive material is present in rhyolitic tuffaceous sediments generally and not in other rock types.

Walker (1953, p. 7) indicated that in view of the sparse uranium content and the erratic distribution of uranium minerals in the tuffaceous rocks in the Rosamond prospect, it seems unlikely that a uranium deposit of economic grade exists. However, further exploration may be justified. The areas most favorable for prospecting are along and near the faults.

STILLWELL PROPERTY

The Stillwell property is in sec. 35, T. 10 N., R. 13 W., in the Rosamond Hills about a mile southwest of the Verdi Development property. Development in 1954 consisted of three trenches about 2 feet wide and 15 feet long.

The area is underlain by the Gem Hill formation and the Fiss fanglomerate, with bedding in both formations striking northwestward and dipping about 15° SW. The beds are cut by several faults striking N. 70° E. and dipping very steeply northward. Autunite is erratically distributed as joint and fracture coatings and as disseminations in the tuffaceous strata in and adjacent to some of the faults. An assay from a mineralized fault indicated a uranium content of 0.14 percent (Walker, Lovering, and Stephens. 1956, p. 17).

MIDDLE BUTTES AREA

At the old Middle Butte gold mine in sec. 16, T. 10 N., R. 13 W., on the east side of Middle Buttes, autunite occurs as sparse coatings on fracture surfaces in kaolinized quartz latite on the workings of the adit level. A selected sample of autunite-bearing rock contained 0.025 percent uranium. High radioactivity readings were noted in the mine, but samples of rock from points of high radioactivity readings were not anomalously radioactive when removed from the mine, and no radioactive minerals were visible, these facts suggest that the source of radioactivity was radon gas (Walker, Lovering, and Stephens, 1956, p. 17).

SOLEDAD MOUNTAIN AREA

On the Mamie claim in sec. 18, T. 10 N., R. 12 W., near the former Double Eagle mine south of Soledad Mountain, anomalous radioactivity amounting to 12 times background count was measured in a shear zone striking N. 32° W. and dipping 70° NE. in rhyolitic rock. Radiation intensity of the rhyolitic wall rock was about three times background count (Walker, Lovering, and Stephens, 1956, p. 17).

TROPICO HILL-WILLOW SPRINGS MOUNTAIN AREA

Section 10 anomaly.—The U.S. Atomic Energy Commission on an aerial survey of the Mojave-Rosamond region in 1954 discovered abnormally high radioactivity at a location about 1,100 feet west of the east quarter corner of sec. 10, T. 9 N., R. 13 W., just north of Tropico Hill. A ground check of the anomaly by private individuals resulted in the discovery of a deposit of autunite. Exploratory work in 1954 consisted of a 30-foot inclined shaft.

Bedrock in the vicinity of the anomaly consists of a brownish-gray quartz latite dike in quartz monzonite. The dike is as wide as 100 feet, strikes eastward for about 2,000 feet, and dips steeply southward. Autunite occurs as coatings on fracture surfaces in the dike rock and in the adjacent quartz monzonite at and near the shaft. A sample of the autunite-bearing dike rock assayed 0.41 percent U_3O_8 (Walker, Lovering, and Stephens, 1956, p. 15).

In the central part of this low ridge near the quartz latite dike, radioactive biotite was found in quartz monzonite near a quartz vein exposed in a small pit. In this pit the radioactive biotite flakes are larger than normal, with some as large as 7 mm across, and are locally concentrated along zones 1 or 2 inches thick. The radioactivity is believed to result from minute deposits of an unidentified radioactive mineral between the biotite flakes (R. D. Allen, oral communication, 1955. The radioactive mineral is not in sufficient amounts to be of economic value.

Jumpin claim. The Jumpin claim is in secs. 9 and 10, T. 9 N., R. 13 W., at Hill 2888 northeast of Willow Springs Mountain. In 1954, exploratory work consisted of a 25-foot trench, a 10-foot pit, and a shallow bulldozer cut.

The workings are in an irregularly shaped mass of felsite and perlite of the Bobtail quartz latite member of the Gem Hill formation, intrusive into quartz monzonite. Autunite, gummite(?), and iron oxides coat fractures in the quartz latite. Assays of chip samples of uranium-bearing rhyolitic rock range from 0.002 to 0.037 percent and indicate an average uranium content of about 0.02 percent (Walker, Lovering, and Stephens, 1956, p. 15).

Goldenrod claim.—The Goldenrod claim is in the SE¼ sec. 4, T. 9 N., R. 13 W., half a mile north of Hill 2888. It had not been explored as of 1954. An undetermined radioactive mineral is sparsely disseminated in a mass of felsite or quartz latite, and in hydrous iron oxides on the surface of a fault fracture. A sample of the country rock (dacite) contained 0.001 percent uranium, and a sample of the iron-stained material contained 0.041 percent uranium (Walker, Lovering, and Stephens, 1956, p. 15).

MAGNESITE

Bissell magnesite deposit. A small deposit of sedimentary magnesite crops out in the Bissell Hills, a mile northeast of the former railroad siding of Bissell, in the NE¼ sec. 11, T. 10 N., R. 11 W. It was discovered in 1915 on property owned by the Southern Pacific Railroad Co.

The magnesite has been quarried in a shallow open pit for 2,800 feet along strike. This large pit is 20 to 60 feet wide at the bottom and 12 to 25 feet deep. Near the west end of this long pit there is a 6 by 6 foot vertical shaft 14 feet deep. A thousand feet beyond the east end of this pit there is another shallow pit or quarry in the NW¼ sec. 12, T. 10 N., R. 11 W. This pit is about 1,000 feet long, 20 to 70 feet wide, and 5 to 10 feet deep. It exposes less magnesite than does the larger one to the west.

Partial production figures, according to the Southern Pacific Railroad Co., indicate that about 6,625 tons of magnesite rock was quarried in 1916, 1,135 tons in 1917, 284 tons in 1918, and 26 tons in 1923. Rubey and Callaghan (1936, p. 117) reported that a total of 15,737 tons was quarried.

The magnesite occurs as thin white layers in the claystone member of the Bissell formation, mostly in the lower part, which dips steeply southward from 30° to 90°, with an average dip of 50°. Just south of the west end of the quarry there is a small monocline, in which the strata flatten to about 2°, then steepen southward to 85°. The 14-foot shaft mentioned above was sunk on the flat part of this monocline.

The magnesite layers are less than an inch to about 10 inches thick, somewhat soft but coherent, and very fine grained. The surface weathers to a soft white powder. The magnesite layers are composed of about 50 percent magnesite and 50 percent dolomite. The clays that contain the magnesite layers crop out for a length of about 4,200 feet along strike and the magnesite layers pinch out both westward and eastward along strike. The stratigraphic sequence of the magnesite layers as given on page 195 under "Rock Units" is typical for the deposit as a whole, although individual magnesite beds do not persist over great distances. The magnesite layers are distributed through about 90 feet of claystone, but because they are thin, usually less than 6 inches, the aggregate thickness of magnesite of the entire exposure averages only about 5 feet.

Rubey and Callaghan (1936) estimated the reserves of magnesite in the Bissell deposit to exceed 100,000 tons. This is based on an average aggregate thickness of 5 feet of workable magnesite along the length of the outcrop for 100 feet down dip.

CLAY

Deposit near Tropico Hill. Pottery clay has been quarried from a deposit in a knoll at the northeast margin of Tropico Hill in the SE¼ sec. 11, T. 9 N., R. 13 W. The deposit is hydrothermally altered platy-fractured quartz latite. The fracture parting dips southward at varying angles and some "layers" are bleached to a soft white material. This is a pottery clay of good quality (Simpson, 1934, p. 414). The quarries have been idle for many years.

Rosamond Lake.—A large deposit of clay suitable for use as drilling mud covers Rosamond Lake for an area of some 20 square miles. This is a finely silty to argillaceous clay deposit extending to depths of 100 feet or more in places. The clay contains very little saline materials.

The clay of Rosamond Lake has been quarried in sec. 19, T. 9 N., R. 11 W., by the O. L. Riley Co. of Ventura, Calif., for use as oil-well mud. The clay was excavated to a depth of 18 inches and hauled to a mill 1½ miles (Tucker, Sampson, and Oakeshott, 1949, p. 246). The quarries were idle from 1953 to 1955.

LIMESTONE

Deposits in Tehachapi Mountains. In the foothills of the Tehachapi Mountains the thick limestone member of the Bean Canyon formation that is exposed eastward from Tylerhorse Canyon is a possible source of lime for cement manufacture. The limestone member stands vertically and is 600 to 1,200 feet thick. It is almost devoid of interbeds of other rocks types and, moreover, it is free from overburden. Although this deposit is easily accessible from Antelope Valley, it is 7 miles from the nearest paved road and roughly 15 miles from the nearest railroad.

Just east of Bean Canyon there are small deposits of limestone in vertical beds of possible commercial grade, but the thickest of these beds is only about 300 feet thick. A bed exposed in Cottonwood Canyon is about 200 feet in maximum thickness.

FELDSPAR

Large quantities of coarsely crystalline feldspar occur in the Rosamond Hills in the vicinity of U.S. Highway 6, in numerous pegmatite dikes cutting quartz monzonite. The dikes consist largely of cream-pink orthoclase, microcline, and lesser amounts of white plagioclase (albite and oligoclase) and quartz. The dikes are most abundant within 2 miles east of the highway.

Rosamond feldspar deposit.—Feldspar has been mined from a 12½ acre claim in the SE¼NW¼ sec. 6, T. 9 N., R. 12 W., 2 miles northwest of Rosamond. The owner is N. W. Sweetzer of Rosamond. This deposit was formerly known as the Townsend feldspar and silica deposit (Simpson, 1934, p. 411).

The feldspar is mined from a large pegmatite dike striking N. 45° W. in biotite quartz monzonite. Development consists of a vertical 75-foot shaft and 200 feet of drifts. The ore is dried in the sun and then milled to 20-mesh size. The high potassium and sodium content of the feldspar renders it particularly suitable for glass making. This mine has produced sporadically for many years, and 2,500 tons of feldspar has been shipped from this property (Tucker, Sampson, and Oakeshott, 1949, p. 247).

The pegmatite dike crops out as a small knoll on the nearby flat desert surface, and covers an area 100 by 200 feet. The dike consists of coarsely crystalline cream-pink potassium feldspar (orthoclase), in places graphically intergrown with quartz, and minor amounts of white sodium feldspar (albite). The dike contains two large lenses of commercial spar. One lens, 25 feet wide, has been mined for a length of 125 feet and to a depth of 75 feet. The feldspar is thoroughly fractured and in mining operations cleaves to about ¼-inch fragments. Analysis of the feldspars, as given by Tucker, Sampson, and Oakeshott (1949, p. 247), showed SiO_2, 65 percent; Al_2O_3, 17.5 percent; K_2O, 12 percent; Na_2O, 4 percent; Fe_2O_3, 0.08 percent.

QUARTZ

Large amounts of quartz occur with the feldspar in the pegmatite dikes in the Rosamond Hills near U.S. Highway 6. However, operations would necessitate hand sorting of quartz from the feldspar, and quartz could be exploited only as a byproduct of feldspar.

On the low ridge extending northwestward from Tropico Hill there are several veins of pure quartz in quartz monzonite. These veins are as much as 5 feet wide and about 30 feet long. In recent years small tonnages of quartz from these veins have been quarried by hand and sold for use in oil refineries.

VOLCANIC ROCK

The numerous volcanic plugs of the Bobtail quartz latite member of the Gem Hill formation are a potential source of crushed material for use on roads and also on roofs of houses. The rock in readily accessible places has been quarried extensively for use on roads of the area—for example, on the north side of Soledad Mountain, in Middle Buttes, in Willow Springs Mountain, and in the Rosamond Hills northwest of Rosamond, and at Red Hill. In many of these places the rock in the talus aprons bordering the rock in place is already of the proper size.

For use as roofing aggregate the quartz latite is available in various colors, including tan, brown, pink, red, and green. A small amount of the pink rock forming Red Hill 2 miles east of Rosamond has been quarried. The maroon quartz latite a mile north of Rosamond has not been quarried. A plug of tan rock 2 miles northwest of Rosamond is being quarried, and crushed at a mill a mile north of Rosamond. The quarry and mill are operated by Thomas Murray of Rosamond and the crushed material is sold for use as roofing aggregate.

The green porphyritic quartz latite on the east spur of Soledad Mountain a mile south-southwest of Fleta is being quarried; it is crushed at a small mill near Gold Town. This material is likewise used as roofing aggregate.

PERLITE

Deposits of perlite potentially suitable for the manufacture of lightweight insulating material (perlite expands 20 times its original volume under controlled heating to a lightweight frothy substance) occur in the Bobtail quartz latite member in the Rosamond Hills, at Soledad Mountain, and near Willow Springs Mountain. All these deposits (p. 180) occur as marginal zones as much as 50 feet thick on the walls of the felsite plugs. The perlite is a steel-gray opaque glassy rock with curved fracture, and can be easily quarried.

The most abundant perlite deposits are in the hills within 2½ miles northwest of Rosamond. In this area seven of the felsite plugs are partly surrounded by marginal zones of perlite as much as 30 feet wide, but with an average width of about 7 feet. Although these deposits are easily accessible none have been quarried.

The felsite body on Hill 2888 northeast of Willow Springs Mountain contains a zone of perlite as much as 20 feet wide and about

150 feet long. This body occurs on the southwest slope of the hill. It has not been quarried.

Soledad Mountain contains very little perlite. A small deposit about 10 feet wide borders the west side of a small plug of felsite a mile southwest of Fleta. A mile and a half southeast of Soledad Peak there is an outcrop of perlite about 15 feet wide on the desert floor; this is in part buried by alluvium. The only other occurrences of perlite are in the vicinity of the former Double Eagle mine. One of these is at the mine on the north side of a small plug; three small deposits occur three-quarters of a mile northwest along the margins of several plugs of felsite. None of these are more than 15 feet wide and none have been quarried.

ORNAMENTAL STONE

Small deposits of colored siliceous rocks suitable to cut and polish into ornamental specimens occur in the Rosamond Hills 5 miles northwest of Rosamond. The hill containing these siliceous deposits is known by local mineral collectors as Gem Hill, and the deposits were described by Ransom (1954, p. 16–18). The siliceous material is semiclear chalcedonic chert containing numerous rusty-yellow, green, and occasional red streaks of iron oxides, which form a handsome array of colors on cut and polished specimens. The rusty-yellow streaks commonly occur as numerous intersecting planes. The chert is in the form of thin irregular veinlets as much as 2 inches wide in tuffaceous rocks of the Gem Hill formation at and near the basalt outcrops. Associated with the chert veins there are veinlets of a deep-green impure opaline rock ("plasma agate") which locally contains a waxy brown unidentified radioactive mineral. Common white opal is also associated with these rocks. These colored siliceous rocks have been picked over by "rockhounds" for many years so that now good material can be had only by digging.

A mile north of Rosamond there is a limited amount of agate-filled nodules in the perlite at the west edge of the mass of red felsite breccia west of U.S. Highway 6. The nodules are irregular shaped, brownish pink, felsitic, and as much as 5 inches in diameter; they are filled or partly filled with clear chalcedony and white opal. Some are suitable for polished specimens.

SALINE DEPOSITS

The only indication of saline deposits within the two mapped quadrangles is the small amount of surface alkali in the clay of Rosamond Lake and in the soil for several miles around its western and southern margins. This surface alkali is deposite by evaporation of ground water that reaches the surface in this part of Antelope Valley. The alkali consists of bicarbonates and chlorides of sodium potassium, minor admixtures of carbonates and sulfates of sodium and potassium, minor admixtures of carbonates and sulfates of calcium and magnesium, and minor nitrates, as indicated by dissolved solids in the ground water immediately below the surface in this area (Thompson, 1929, p. 343). The salines decrease with depth in water wells. None of the saline deposits are in commercial quantities.

Johnson (1911, p. 57) indicate that the soil alkali consists of three varieties: one known as "white alkali" is sodium sulfate; another, known as "black alkali" from its darkening effect on vegetation, is sodium carbonate; a third is sodium chloride or salt. Of the first two, the more injurious to plant life is "black alkali," as it tends to hydrolize to form harmful sodium hydroxide which disintegrates organic tissue. The most effective method of treating "black alkali" is by use of gypsum (hydrous calcium sulfate), which reacts with sodium carbonate to form less injurious sodium sulfate and calcium carbonate.

The thick Cenozoic sedimentary sequence underlying Antelope Valley may contain lakebed clay at depths below that reached by water wells. These may be clay or shale beds similar or equivalent to those exposed at the northwest margin of Antelope Valley as described by Wiese (1950, p. 35). Such buried lake beds(?) might contain saline deposits of economic value, like those in the Quaternary clay of Searles Lake, or like the buried borate deposits in the Pliocene(?) lakebeds near Boron. However, this is not very likely, for no lakebeds were reported in any of the deep test holes drilled for oil within the two mapped quadrangles, and the sediments penetrated are generally too coarse to contain saline deposits.

The occurrence of lakebed clay or shale in the thick sedimentary sequence underlying Antelope Valley could be determined only by deep drilling. Lakebeds would most likely, though not necessarily, occur in the deepest parts. The deepest parts of the two deep sedimentary basins indicated by the gravity survey (Mabey 1960) are believed most favorable for prospecting for buried saline deposits by deep drilling.

Depths to possible lakebeds are unpredictable, as each of the two basins supposedly contains 10,000 feet of sedimentary fill, in any part of which lakebeds could occur. However, the lakebed clays in the Pliocene(?) formation cropping out at the northwest end of Antelope Valley may extend eastward under Antelope Valley where they might somewhere contain saline deposits of economic value. The lakebeds should be looked for in the Pliocene(?) or upper part of the sedimentary fill, possibly at depths between 1,000 and 4,000 feet. It is most remotely possible that lakebeds containing saline deposits may occur in the Miocene sequence, but if so they would probably be too deep to mine profitably.

PETROLEUM AND NATURAL GAS

Test holes.—Several deep test holes have been drilled for oil or gas in the part of Antelope Valley within the two mapped quadrangles, but no showings that can be verified have been found. All appear to be unfavorably located structurally, based on the geology of the area as known to date. Correlations of the drill-hole sections with each other and with surface sections are not possible because adequate logs were not recorded, no cores were taken, and the test holes are many miles apart.

The deepest test hole drilled in the area is the C. W. Colgrove-Hughes well on the southern margin of Rosamond Lake. Although no cores were taken, this test hole penetrated nothing but "granitic wash" that drilled easily from top to bottom at 5,576 feet (D. K. Bickmore, written communication, 1957). Ditch samples taken every 10 feet and examined by the writer verified this lithology and showed no cuttings of hard granitic rock nor of sedimentary, tuffaceous, or volcanic rocks of the Tropico group. The entire sequence penetrated by this well, and probably that in the Andrews well 10 miles west-southwest, is considered to be the thick alluvial fill of Quaternary and late Tertiary age that underlies Antelope Valley.

Table 2 summarizes the known data from the test holes drilled within the Willow Springs and Rosamond quadrangles.

TABLE 2.—*Test holes drilled for oil and gas in Willow Springs and Rosamond quadrangles*

[Data from Oakeshott and others, 1952, and Jennings and Hart, 1956, unless otherwise noted]

Test hole	Location			Year drilled	Total depth (feet)	Geology
	Section	Township	Range			
Regina Oil Marsh 1	SW¼ 26	10 N.	14 W.	1934	3,312	Granite at bottom.
Meridian Oil 1	SE¼ 11	9 N.	15 W.	1935	3,970	Sandy alluvial sediments to 3,300± ft; quartz diorite from 3,300± ft to bottom (Simpson, 1934, p. 415).
Unidentified well	NE¼ 7	9 N.	13 W.	Pre-1934	150±	Granite at bottom (Simpson, 1934, p. 415).
California Metal Products Scott 10-1.	10	8 N.	15 W.	1950	3,015	Sandstone and shale at bottom.
Solar Oil Singer 1	13	8 N.	15 W.	1950	2,090	
H-K Exploration (Los Angeles Leather) Ben Hur 87-21.	NE¼ 21	8 N.	15 W.	1950–53	3,427	Miocene at bottom.
O. G. Andrews and Sons Andrews 1.	NW¼ 23	8 N.	13 W.	1928	2,063	Alluvial sediments to bottom (Simpson, 1934, p. 415).
Morris B. Marks Gloria 1	2	8 N.	12 W.	1950–51	1,204	
Geo. A. Denison 1	24	8 N.	12 W.	1921, 1932	1,000	
C. W. Colgrove Hughes 9-11.	NW¼ 9	8 N.	11 W.	1952	5,576	10–100 ft, clay and sand; 100–1,000± ft, granitic gravelly sand; 1,000±–5,576 ft, medium to coarse granitic sand.

Prospects.—Within the map area the marine Paleozoic(?) rocks of the Bean Canyon formation, of which only remnants are present as pendants engulfed in plutonic rocks, are too severely metamorphosed to contain oil or gas or even act as source rocks. Although the thick Cenozoic stratified sequence that underlies Antelope Valley within the map area contains many porous reservoir sandstone strata and perhaps some impervious clay and shale strata, it is not known to contain any known marine source beds capable of yielding petroleum and gas. There are no surface indications of oil or gas in this sequence. These factors, as well as the lack of showings in the test holes, suggest that commercial accumulations of oil or gas are unlikely within the map area.

The desert area northward from the Rosamond Hills and Willow Springs Mountain is unfavorable for prospecting for oil and gas because in most of this area the granitic basement is probably only a few hundred feet below the surface. The alluviated parts of Antelope Valley offer some possibilities but test holes drilled to date have not been encouraging. However, much of this valley area is untested. With the exception of the three test holes drilled in the northern part of the Willow Springs quadrangle, the crystalline basement has not been reached. If either of the two major basins indicated by the gravity survey contains any structural or stratigraphic traps, these would make petroleum and gas accumulations possible.

Of the two major sedimentary basins in Antelope Valley as revealed from surface geology and the gravity survey, the western Antelope basin is the most favorable to prospect for oil and gas because of the presence of marine sediments at its west end, beyond the western border of the map area, and of at least one surface structural closure. The entire Cenozoic sequence within the map area is probably terrestrial. However, there is a possibility though not a likely one, that this thick sequence may contain marine source beds at depth. It is also possible that oil and gas migrated eastward into the terrestrial sequence from the marine sequence into which it grades at west end of Antelope Valley. This sequence, described and mapped as the Santa Margarita formation of late Miocene age by Wiese (1950, p. 32, pl. 1), by Wiese and Fine (1950, p. 1650), and by Crowell (1952, p. 12–13, pl. 1), consist of some 3,300 feet of marine sandstone and brown organic shale.

At the northwestern margin of Antelope Valley, the Miocene terrestrial sedimentary sequence is overlapped by the unnamed Pliocene(?) formation (p. 198), which there contains a lakebed clay member (Wiese, 1950, p. 35) and which dips southeastward under the valley. This clay member may extend an unknown distance eastward into the map area and if so could act as an impervious cap rock under favorable structural conditions.

Within the mapped part of Antelope Valley, the only surface structural feature, favorable for the accumulation of oil and gas, the Sand Hills anticline, is on the north flank of the western Antelope basin. Because of its steep southeast flank, a test well on this asymmetric domed anticline would have to be located on its gentle northwest flank at least half a mile northwest of the high point of its surface axis in order to test this anticline at depth. At that location the granitic basement rock should be reached approximately 300 feet higher than it was reached in the nearby Meridian well, or at a depth of about 3,000 below the surface. The up-dip edges of the beds beneath the fault on the southeast flank of this anticline could also be a structural trap.

In order to determine the stratigraphic conditions within these basins accurately, several carefully logged deep test holes in various parts are needed. A reflection seismic survey, provided satisfactory results could be obtained, would be of value in delineating the structure of the basins and would supplement the gravity survey which outlines only the general configuration and extent of the basins.

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