GEOLOGY OF A PART OF THE ROSAMOND HILLS AREA, KERN COUNTY, CALIFORNIA

by

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ABSTRACT

An erosion surface of low relief was developed on the granitic complex of the Rosamond Hills area during the early part of the Tertiary period. Sometime during the Miocene epoch, faulting and volcanic activity formed a series of shallow lakes in which pyroclastic debris accumulated to a maximum depth of 900 feet to form the lower part of the Rosamond series. Deformation and volcanic activity culminated with the elevation of a mountain range of considerable relief, the outpouring of a comparatively large amount of rhyolite, and the ejection of much pyroclastic debris. A series of alluvial fans or bajada deposits with intercalated layers of pyroclastic debris accumulated along the margin of this mountain range to a maximum thickness of about 500 feet to form the upper part of the Rosamond series. The area was subsequently tilted southward, and erosion removed the Rosamond series from the tilted block except for a narrow strip along its southern margin. Hillocks formed by erosion of this strip of Rosamond rocks constitute the Rosamond Hills. Recent faulting along the southern margin of the Hills has probably helped to form Rosamond Lake.

INTRODUCTION

General Statement

The post-Mesozoic structural history of the western part of the Mojave Desert region is imperfectly known, owing principally to the scarcity and patchy distribution of Tertiary rocks. The Rosamond Hills just north of the town of Rosamond constitute one of the few areas in which Tertiary rocks are well exposed, and the present investigation was made in this area in the hope that it might yield information on the geologic history of the entire region. Attention, during this investigation, therefore was focused primarily on structure and stratigraphy, and only a few specimens were subjected to detailed petrographic study.

The writer devoted 35 days to field work in the south-easterly portion of the Rosamond Hills and about four days to microscopic study of rock specimens in the laboratory. The field mapping was done on aerial photographs at a scale of 1 inch equals 1667 feet, and the geology was transferred to appropriate parts of the Rosamond, Rosamond Lake, Soledad Mountain and Bissell quadrangles. These four 7½ minute quadrangles were prepared by the Army Map Service in 1947.

The work was accomplished under the guidance of Dr. Richard H. Jahns and Dr. James A. Noble of the California Institute of Technology. The writer also wishes to express his sincere thanks to Mr. Carel Otte, who tendered some helpful suggestions during a visit to the field.

Geography

The Rosamond Hills in the southern part of Kern County are in the Mojave Desert region about 65 miles north of Los Angeles (see fig.1). They are a discontinuous series of low hills that form a belt about a mile wide. This belt extends in a northwesterly direction from Rosamond Lake to the vicinity of Middle Buttes, whence it widens appreciably and curves northeasterly toward the town of Mojave. Soledad Mountain near the town of Mojave is by far the highest and most conspicuous hill of the region.

Both U.S.Highway 6 and the Southern Pacific Railroad extend northward across the Hills from the town of Rosamond. Another road extends north from the village of Willow Springs and crosses the western portion of the area mapped; it is herein referred to as the Willow Springs road. Several secondary roads penetrate the area at convenient intervals, a factor which greatly facilitates field work. There are several small gold mines in the area, but the Tropico Mine just north of Willow Springs is the only one operating at the present time. A number of small farms and ranches are located near Willow Springs.

The area mapped is that part of the Rosamond Hills extending in a belt about one mile wide and about 12 miles long from the northwest corner of Rosamond Lake to section 34 of R 13 W, T 10 N, SBM (see pl.1). Also included in the mapped area are parts of T 9 N, R 12 W and T 10 N, R 12 W, all of

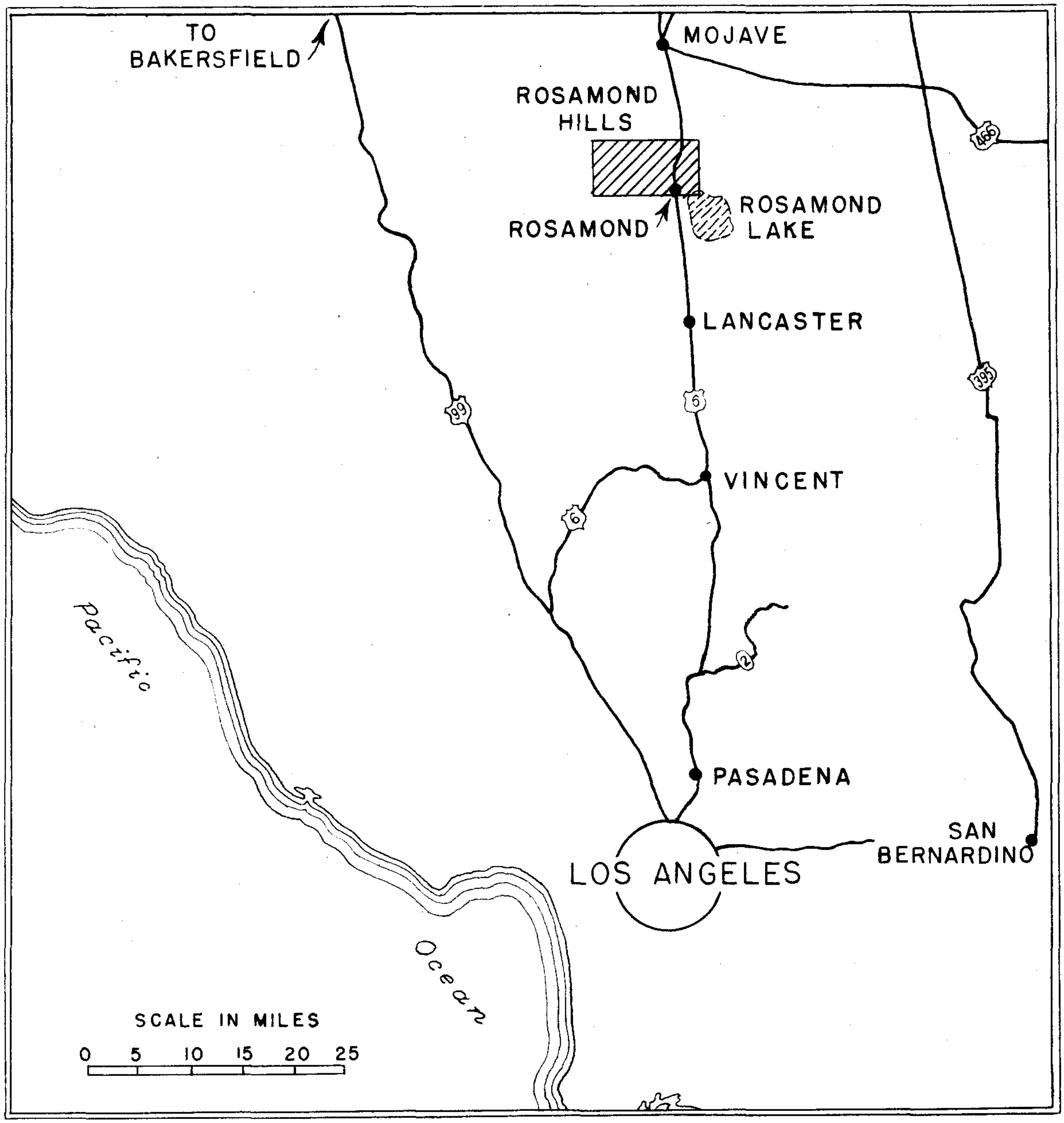

Fig. 1 Index map showing the location of the Rosamond Hills

the SBM. The Tropico Mine, which is on a prominent hill just north of Willow Springs, was not included in this investigation.

The general altitude of the rather flat country that flanks the Hills is about 2400 feet on the south and about 2600 feet on the north. The top of the highest peak in the mapped area is about 3320 feet above sea level, and hence the maximum relief is of the order of 1700 feet. Drainage of the area is into Rosamond Lake, a playa southeast of the town of Rosamond.

The climate of the region is arid. As in other desert areas of Southern California the summers are hot, and the winters are notably cool and windy. The mean precipitation is less than 10 inches a year, and vegetation is sparse. Greasewood, mesquite and a few rather picturesque yuccas are the only plants worthy of note.

Geologic Setting

The Tertiary rocks of the Rosamond Hills have been designated the Rosamond series.1/ This series comprises

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1/ Hershey, O.H., Some Tertiary formations of Southern Calif.: Am. Geol., vol. 29, pp.350-355, 1902.

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lapilli-tuffs, tuff-breccias, arkosic fanglomerates, volcanic conglomerates and volcanic sandstones. This detrital material accumulated on a surface of low relief that was developed on granite of pre-Tertiary age. Later this series was faulted, folded and tilted. Rhyolite and andesite was intruded during this period of deformation. Except where badly deformed, the Rosamond beds trend about N 70° W, and dip about 20° southwest.

Thus far the Rosamond series have yielded no distinctive fossils, so their age is uncertain, but they are lithologically similar to beds of known Upper Miocene age from the Barstow region.[2/] Simpson,[3/] in his report on the Elizabeth Lake

2/ Merriam, J.C., Tertiary mammalian faunas of the Mojave Desert: Univ. Calif. Publ., Dept. Geol. Bull., vol.11, pp. 438-585, 1919.

3/ Simpson, E.C., Geology and mineral deposits of the Elizabeth Lake quadrangle, Calif.: 30th Annual Report of the State Mineralogist, pp. 400-401, 1934.

quadrangle, notes that the Rosamond beds in this area lie on a granite erosion surface. For this reason he regards them as the basal part of the Rosamond series, and hence slightly older than the beds near Barstow. On this basis he tentatively regards the beds exposed near the town of Rosamond as Middle Miocene.

The topography of the region is striking as well as significant. The rocks of Tertiary age crop out boldly and form steep slopes. The rhyolite, in particular, forms irregular hills and knobs that locally are extremely rugged. The tuffaceous rocks form less conspicuous outcrops and the granitic rocks typically yield subdued landscapes. Thus, each major rock type forms a distinctive topography.

An impressive feature of the region is the array of bright colors displayed by the rocks. Many colors are represented, but white, green and reddish-brown are dominant.

Economic Geology

Gold and silver have been mined profitably from the hill just north of Willow Springs, and nearby Soledad Mountain has long been a center of mining activity. However, metallic mineral deposits of commercial importance have not been found within the area mapped. The granite complex exposed in parts of this area is transected by numerous aplite and pegmatite dikes, and in places these are of notable size. Some contain concentrations of coarse-grained feldspar and a little of this material is being mined on a small scale at the present time. Rhyolite has been mined from at least one locality for use as road metal, and several occurrences of perlite, though not large, might justify commercial exploration.

PRE-TERTIARY GRANITIC COMPLEX

Granite Complex

Granite is by far the commonest rock in the western part of the Mojave Desert region. In the vicinity of the Rosamond Hills, where it constitutes the platform upon which the Rosamond series was deposited, it is mainly a medium-grained adamellite with abundant dikes of aplite and pegmatite. This rock is exposed over large areas in the region north and east of the Rosamond Hills. It also crops out in several very small patches along the southern margin of the Hills. These small occurrences are very significant to the structural history of the area.

In his report on the Randsburg quadrangle, Hulin[4] describes similar rocks from areas near Atolia. He gives a petrographic description of the assemblage, discusses its field relations, regards its age as Mesozoic, and applies to it the name Atolia quartz monzonite. The granitic rocks near Rosamond correspond very closely in composition and texture to the Atolia quartz monzonite, as determined by field observations and study of two thin sections. Therefore, it is probable that the granitic rocks near Rosamond are a part of the Mesozoic ? intrusive.

4/ Hulin, C.D., Geology and ore deposits of the Randsburg quadrangle, Calif.: California State Mining Bureau Bull. 95, pp. 33-42, 1925.

A detailed study of this formation was not made, but a few of its more salient features are described herein. The term "granite" as used in this report, comprises all rocks of this formation in the Rosamond Hills, and thus includes aplite, pegmatite, adamellite and quartz-monzonite. A striking feature of these crystalline rocks is the complex of pink aplite and pegmatite dikes. Most of these are stringers, but some are as much as 15 feet thick. The granitic complex is easily recognized from a distance by its soft brown color and its subdued topography. Appreciable relief has developed in some localities owing to recent faulting and attendant rejuvenation of the streams. Even in these favored areas, however, relief of more than 200 feet is rare. The more resistant aplite-pegmatite dikes tend to form hillocks, whereas the depressions are underlain by adamellite.

Several prominent hills of this material near the Rosamond series probably have been protected from erosion by a resistant capping of Rosamond rocks. Much of the area underlain by granite is veneered with a thin layer of sandy debris. The granite itself is intensely weathered and commonly forms spheroidal masses.

Several white patches and discontinuous white arcuate strips of caliche traverse the granite just north of the east-west belt of Rosamond rocks. These are clearly shown on aerial photographs of the area. These strips are usually less than 50 feet wide, but they attain lengths of half a mile or more; in places, the caliche is nearly two feet thick. These caliche strips may mark the traces of faults, although little direct evidence of faulting is present in this area. It should be mentioned, however, that most faults transecting granite, such as the east-west faults north of Rosamond Lake, are strongly calichefied.

Erosion surface developed on the granite

An erosion surface evidently was developed on the granite prior to the deposition of the Rosamond beds. In many respects this surface was similar to the present erosion surface developed on the granitic complex just northeast of the area mapped - an undulating surface of low relief.

Many of the hillocks on this ancient surface are composed of aplite and pegmatite, and evidently were bare as they are directly overlain by Rosamond beds. The depressions along the surface were mantled with granitic debris, which in general, is not more than 25 feet thick. Most occurrences of this material are resistant to erosion, and thus stand in relief.

About one mile east of Highway 6 there is an occurrence of boulder-rich granitic debris that probably represents a small debris-choked valley which was later buried by Tertiary sediments. The boulders are subangular, are three feet in maximum diameter, and are most commonly composed of aplite and pegmatite. They are embedded in a green sandy matrix, which weathers to a brightly pink-colored soil. No bedding is discernible, and no volcanic material is present in this debris.

In most places the contact between the granite and the

Rosamond series is very sharp, and in general, it is the most easily recognized contact in the entire area. It tends to be less sharp where the granite surface was mantled with debris, but rarely does the contact exceed 20 feet in width.

The granite near the contact is generally stained red to a depth of about 25 feet. This color contrasts strikingly with the light colors of the overlying Rosamond beds. The stain may be the result of weathering or soil formation on the old granite erosion surface, as evidenced by its regional distribution. It is found associated with depositional contacts only. Thus it is helpful in differentiating between fault and depositional contacts.

TERTIARY FORMATIONS

The Rosamond series

The Rosamond series was first described by Hershey[5/] in 1902.

5/ Hershey, O.H., op. cit pp. 365-370.

He measured a section across the east flank of Hill 3091, just west of U.S.Highway 6. Hulin,[6/] in his report on the Randsburg

6/ Hulin, C.D., op. cit pp. 42-48.

quadrangle, described similar beds near the town of Red Mountain. Simpson[7/] briefly mentioned the Rosamond series in

7/ Simpson, E.C., op. cit. pp. 395-400.

his report on the Elizabeth Lake quadrangle. He compared the stratigraphic column from the type section near the town of Rosamond with two other columns measured farther west. One of these was from the hills six miles northwest of Rosamond, just west of the Willow Springs road. These hills are included within the area mapped during the present investigation. The other column was from the Fairmont Hills, which are farther west, and are not included in this investigation.

The outstanding characteristic of the Rosamond series is its high content of pyroclastic material. Nearly all of the beds contain an appreciable amount of this material, and in many beds it is the most abundant constituent. All of the beds probably are non-marine, and thus far they have yielded no diagnostic fossils despite diligent search by several investigators.

Simpson[8/] divides the series into Upper Rosamond beds and Lower Rosamond beds, a scheme favored by the present writer. In general, Lower Rosamond beds are finer grained, better stratified, and contain a higher proportion of pyroclastic material than Upper Rosamond beds. The Lower Rosamond beds consist principally of lapilli-tuff, tuff-breccia, and lacustrine volcanic conglomerates and sandstones, whereas the Upper Rosamond beds consist principally of fanglomerates with interbeds of volcanic sandstone. Welded tuff-breccia is present in the Upper Rosamond beds west of the Willow Springs road. In general, Upper Rosamond beds are thickest in the western part of the area, whereas Lower Rosamond beds are thickest in the central part of the area.

The Lower Rosamond beds comprise the white volcanic conglomerate, the pink tuff, and the green volcanic conglomerate units, as defined in this report. The Upper Rosamond beds comprise the brown fanglomerate and the welded tuff-breccia.

8/ Simpson, E.C., op. cit. p. 400.

White volcanic conglomerate

The white volcanic conglomerate is the most distinctive and conspicuous rock in the area. It is typically light gray to pale buff in color, and tends to form bold outcrops that are nearly devoid of vegetation. The formation is thickest and best exposed east of U.S.Highway 6, where it crops out to form a narrow east-west line of hogbacks. These beds lie on an erosion surface developed on granite, and dip southerly at angles of 15° to 20°. The formation terminates eastward near the northwest corner of Rosamond Lake. West of U.S.Highway 6, the formation is present along the northeast flank of Hill 3091, where it is disturbed by folding and faulting. Farther west, it thins noticeably, and disappears west of the Willow Springs road. A maximum thickness of about 300 feet is attained about two miles east of U.S.Highway 6.

The rock consists principally of pumiceous rhyolite lapillae embedded in a tuff matrix. Also included are a small amount of fragments of flow-banded trachyte, red rhyolite, and sundry granitic debris. The fragments are subangular, and are two to five mm. in average diameter, but fragments as large as 10 mm. in diameter are not uncommon. The rock generally is well layered and cleavable, although at places it is composed of unsorted fragments, and is massive. The lack of sorting is characteristic of the coarser grained varieties only. Individual beds are about two inches in average thickness, and rarely exceed 18 inches.

Westward, the particle size decreases, the degree of rounding increases, and the proportion of constituents other than rhyolite lapillae increases. These factors suggest that the source of material was toward the east.

Thinly bedded white volcanic conglomerate disintegrates to slabs, whereas the more massive facies tend to develop spheroidal boulders and cliff-like outcrops with cavernous reentrants. The basal layers of this formation are commonly silicified and are thus more resistant to erosion. This probably accounts for the line of hogbacks composed of basal white volcanic conglomerate which extends eastward from U.S. Highway 6. Interbedded fanglomerates, though rare, are conspicuous because they are dark colored, and tend to stand in relief. They are found only in the basal layers of the formation.

The white volcanic conglomerate generally is more resistant to erosion than the granite, but is much less resistant than the red rhyolite. Where white volcanic conglomerate is in contact with the red rhyolite it is generally topographically low. As a consequence, debris shed by the red rhyolite tends to accumulate on its surface, in many places obliterating it entirely.

The large, rounded, granite boulders that occur in the white volcanic conglomerate are an interesting feature. Those incorporated in the basal layers probably mantled the ancient erosion surface developed on the granite. Others are disseminated throughout the formation, and are locally abundant in certain layers. Boulders as large as four feet in diameter have been found, but the average diameter is about eight inches. They were derived from the granitic complex, but the aplitic facies seem more generously represented than the coarser grained varieties. Evidently the aplite is a more resistant rock. As weathering of the conglomerate removes the tuffaceous matrix the boulders tend to accumulate on the surface. A noteworthy accumulation of this type is on the white volcanic conglomerate just northwest of the prominent red hill near Rosamond Lake.

In general, soil produced by the weathering of white volcanic conglomerate does not support the growth of vegetatation; however, fault traces in this rock are commonly delineated by weeds and small bushes.

The white volcanic conglomerate is unconformably overlain by the pink tuff formation. The erosion surface represented by this unconformity was one of moderate relief, and there is marked discordance between the attitude of bedding in the white volcanic conglomerate and that in the overlying pink tuff. Boulders of granite scattered through the white volcanic conglomerate formed a residual accumulation along this old erosion surface in much the same manner as accumulations of these boulders are forming now wherever this formation is being eroded. These facts suggest that considerable warping and erosion took place after deposition of the white volcanic conglomerate and prior to deposition of the pink tuff.

Pink tuff

The pink tuff is principally a lapilli-tuff composed of subangular buff-colored pumiceous rhyolite lapillae embedded in a pinkish or greenish tuff matrix. Fragments of red rhyolite and granite are locally present in minor amounts. Bedding generally is poor to non-existent, but in places the basal layers are well-bedded. Typically, the rock is massive and structureless, and tends to weather into rounded, subdued outcrops yielding a debris of coarse, angular fragments.

This rock occurs on both the east and west flanks of Hill 3091, and between Hills 2638 and 2650 about one-half mile east of the Willow Springs road. East of Hill 3091, it terminates against a northwest-striking fault, which also cuts the underlying white volcanic conglomerate (see pl.1). Westward, it wedges out just east of the Willow Springs road.

The most instructive occurrence of the pink tuff is between Hills 2650 and 2638. This area is devoid of vegetation, and a badlands type of topography is partially developed. Pastel tints of pink and green impart a most unusual appearance. Here the bed is approximately 90 feet thick, poorly stratified, and composed exclusively of pumiceous lapillae embedded in a tuff matrix. The usual clasts of rhyolite and granite are not present.

The pink tuff on the east flank of Hill 3091 is approximately 120 feet thick, but its thickness on the west flank of the hill is not known. The basal layers of these occurrences are generally well stratified, but stratification is poor or non-existent in the upper layers.

Most occurrences of pink tuff are overlain by a dark green fanglomerate bed from two to ten feet thick, composed of angular cobbles of red rhyolite and granite embedded in a tuffaceous matrix. This bed is not present at this horizon on the west slope of Hill 3091. At the occurrence near Hills 2638 and 2650, this cobble bed is remarkably uniform in thickness and attitude, and it contrasts strikingly with the beds above and below. Small faults in this vicinity are clearly indicated by dislocations of this bed.

Green volcanic conglomerate

The green volcanic conglomerate includes several types of rocks. It is composed of tuff-breccia with lesser amounts of lapilli-tuff, arkosic fanglomerate, and volcanic conglomerate and sandstone.

The lithology of the green volcanic conglomerate varies considerably both laterally and vertically. In the vicinity of Hill 3091, the most abundant rock type is a poorly bedded yellowish-green tuff-breccia containing moderately abundant angular fragments of red rhyolite and rounded cobbles of granite. Interbeds of dark brown arkosic fanglomerate are locally abundant, and a few well-stratified beds of volcanic conglomerate and sandstone are also present. Locally, the tuff-breccia tends to weather to bare, rounded patinated forms which produce an unusual "knobby" type of topography.

At this locality, the formation appears to represent a series of truncated and overlapping tuff-breccia beds and fan-glomerates. The rocks at this locality have been severely faulted and brecciated, and in several places they are cut by dikes, etc. of red rhyolite. These factors have produced a terrane that is very complex in detail. At this locality, the formation is approximately 700 feet thick.

In the hills west of the Willow Springs road, the upper part of the formation consists principally of lapilli-tuff beds, and the lower part is volcanic conglomerate and sand-stone. The lapilli-tuff beds are yellowish green in color, and are fairly well stratified. The stratification is accentuated by a few interbeds of dark brown pebble con-glomerate.

The basal part of the formation consists principally of alternating layers of well-stratified volcanic conglomerate and sandstone, and at least one andesite flow and several thin chert beds occur near the base of the formation. The conglomerate layers are composed of subangular lapillae of pumiceous rhyolite embedded in a tuffaceous matrix, and the sandstone layers are composed of tuff with minor amounts of fine-grained granitic debris. Thin laminae of dark green shale are locally present, but never common. In general, these beds vary in color from gray to yellowish green.

West of the Willow Springs road, the green volcanic con-glomerate is conformably overlain by the brown fanglomerate. Fanglomerate interbeds increase in number and thickness toward the top of the green volcanic conglomerate. In the overlying brown fanglomerate, they are predominant. Thus the contact between the two formations is gradational.

At this locality, the formation has been complicated by faulting, and its basal contact is not exposed; however, measurements indicate that it is at least 800 feet thick.

The green volcanic conglomerate is not present east of U.S.Highway 6. It probably was deposited there, and later removed by erosion.

Brown fanglomerate

The brown fanglomerate comprises a series of cobble and boulder conglomerates with intercalated tuffaceous material. The conglomerate layers consist of dark-colored subangular cobbles and boulders of red rhyolite and granite embedded in a gray tuffaceous matrix. The tuffaceous layers are principally tuffaceous sandstone.

East of U.S.Highway 6, the formation crops out in an east-west belt just south of the hogbacks of white volcanic conglomerate, and terminates near the prominent red hill at the northwest corner of Rosamond Lake. Here the formation is composed of loosely consolidated cobble and boulder beds with a very few tuffaceous interbeds. Erosion removes the pulverulent tuffaceous material while the larger clasts remain behind as residual accumulations on the surface. Thus the formation crops out as a series of low rounded hills thickly mantled with dark-colored cobbles and boulders.

In this area, the boulder fanglomerate disconformably overlies the white volcanic conglomerate and, of course, overlies the thin andesite flows that poured out on the surface of the white volcanic conglomerate. The beds at this locality trend approximately east-west, dip about 20°S., and are about 300 feet thick. An unknown thickness of this material probably has been removed by erosion.

The brown fanglomerate is the most common rock unit in the hills west of the Willow Springs road. It conformably overlies the green volcanic conglomerate and composes most of the higher hills of the area. This occurrence differs from the one previously described in that interbeds of tuffaceous sandstone are more common, the bedding is better developed, and the outcrops differ in form. Instead of low rounded hills, erosion has produced a very rugged topography characterized by bizarre erosional forms. This probably results from the greater induration of the formation in this area. The formation trends approximately N 45°W and dips about 20°S. The actual thickness of the unit is about 500 feet; however, it appears much thicker because of repetition by faulting.

Small intrusive masses of red rhyolite occur in the basal layers of the brown fanglomerate, but nowhere are they abundant. It is possible that some of these masses are remnants of small flows.

The brown fanglomerate probably accumulated in an arid environment as an alluvial fan, or bajada deposit, at the base of a topographic escarpment. This escarpment probably was formed during a period of intense faulting. This event caused the profound change in regimen that marked the beginning of Upper Rosamond time.

Welded tuff-breccia

This formation comprises the layers of welded tuff and welded tuff-breccia along the southwestern flank of the hills west of the Willow Springs road. The layers of welded tuff-breccia are dark reddish brown and are composed of unstratified angular clasts of flow-banded rhyolite embedded in welded tuff. Also included are a few rounded granite boulders. The intercalated layers of welded tuff are commonly pink and locally are stratified. The welded tuff-breccia layers are extremely resistant to weathering and form rugged outcrops. The welded tuff layers weather more readily, and such forms as mushroom rocks, natural arches, and keyholes are common results.

The welded tuff-breccia formation trends about N.45°W., dips about 15°SW, and is about 100 feet thick. It unconformably overlies the green volcanic conglomerate, and northward it abuts against the brown fanglomerate along a northwest trending fault (see pl. 1). At its western extremity, it appears to be overlain by brown fanglomerate. This and other evidence suggests that it is contemporaneous with the middle part of the brown fanglomerate formation. However, it is difficult to establish the stratigraphic position of this formation with certainty because the field evidence is meagre.

Volcanic rocks

Andesite dikes, sills, and flows

Small dikes, sills, and flows of andesite are widespread, but nowhere does this material occur in abundance. Andesite dikes and sills do not exceed 20 feet in width; however, a flow, crossed by the Willow Springs road in the northwestern part of the area, is about 80 feet thick.

Where fresh the rock is easily recognized by its greenish-black color and aphanitic texture. Outcrops of fresh material disintegrate to a rubble of blocky fragments that are medium brown in color on exposed surfaces. The rock generally weathers to a greenish-brown material which is commonly calichefied.

A small dike about six feet wide occurs in white volcanic conglomerate about one mile east of U.S. Highway 6. It has a marginal selvage of dark green, flow-banded andesitic glass about a foot thick along either wall. The four-foot central zone is composed of subangular blocks of flow-banded andesite embedded in a matrix of andesitic glass. The white volcanic conglomerate adjacent to the dike is moderately silicified and bright green in color.

Microscopic examination of selvage from a small sill just west of the Willow Springs road reveals a sprinkling of angular quartz grains and deformed rhyolite lapillae elongated parallel to the sill. These are embedded in a green cryptocrystalline matrix of andesite. Another specimen from the flow about one-half mile west of the Willow Springs road near Hill 3255 consists of elongate phenocrysts of labradorite and subordinate augite. Some of the feldspar crystals are zoned. The phenocrysts are embedded in a matrix composed of plagioclase microlites, magnetite dust, and glass. The texture of the rock is microporphyritic with an andesitic groundmass. Many of the labradorite phenocrysts are riddled with vermiform intergrowths of augite and, in places, augite has altered to uralite. The index of refraction of the glass is less than 1.54, which suggests a composition very near the andesite-basalt borderline. This is compatible with the absence of olivine from the rock. For the sake of convenience, these rocks are designated herein as andesites, but it is recognized that some may well be basaltic in composition.

The occurrence of andesite flows is significant. East of U.S.Highway 6 they lie on an erosion surface on white volcanic conglomerate and are overlain by brown fanglomerate. These flows attain a maximum thickness of about 30 feet. They comprise a central layer of dense, greenish-black andesite or greenish-brown vesicular andesite, and border zones of porous, brick-red, oxidized andesite. The upper border zone generally is thicker and more persistent than the lower one. About one and one-half miles east of U.S. Highway 6, the relation between a flow and its feeder dike is well displayed. The dike begins near the granite-white volcanic conglomerate contact, transects the conglomerate diagonally, and joins a flow that lies along the unconformity. The following features suggest that these concordant masses are flows, rather than sills:

(1) Apophyses into the overlying brown fanglomerate have not been found, whereas dikes do occur in the underlying material.

(2) Andesite is not known to occur in the Upper Rosamond beds.

(3) Known andesite intrusives in tuffaceous rocks have vitreous selvages, whereas occurrences of andesite along the unconformity do not.

(4) Occurrences of andesite along the unconformity have brick-red, vesicular, oxidized border zones, but known andesite intrusives do not.

The flow in the northwestern part of the area is poorly exposed, but its general size and position can be determined by the large flint amygdules that have weathered from it. The body is about 80 feet thick and seems to be conformable with the enclosing beds. It occurs near the bottom of the green volcanic conglomerate formation.

Other flows nearby are smaller but more instructive because they are better exposed. One of these about one-half mile west is conformable with the enclosing beds, and is bordered along its upper edge by a layer of glassy material about one foot thick. The overlying tuffaceous beds are unaltered. These factors suggest that this represents a submarine flow.

Andesite does not occur in Upper Rosamond beds, nor do andesite flows occur in or below the white volcanic conglomerate. Also this material generally occurs near faults. These factors suggest that andesite was intruded and extruded during a period of deformation which took place during middle Lower Rosamond time.

Red rhyolite

By far the most abundant and conspicuous intrusive rock of Tertiary age in the Rosamond Hills is the red rhyolite. The term "rhyolite" here is used in a broad sense to include all light-colored volcanic rocks. Dacites and quartz-latites, though common, are subordinate to true rhyolite in this area. No effort was made during the present study to distinguish these rocks from true rhyolite. Hence, they are grouped under the more general term "rhyolite".

Rocks of this type occur in two intrusive centers. The smaller center is marked by the prominent red hill near the northwest corner of Rosamond Lake, and the larger center consists of scattered intrusives in the group of hills between U.S.Highway 6 and the Willow Springs road (see pl. 1). Simpson[9/] regards these rocks as extrusive flows interbedded

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9/ Simpson, E.C., op. cit., pp. 396-400.

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with the sedimentary rocks of the Rosamond series. With but few possible exceptions, all occurrences of this rock examined by the writer are intrusive.

The color of this rock varies from buff through red to purple, and a dark red is typical. Rarely it is white or gray. The texture varies from microcrystalline to glassy, and porphyritic facies are locally developed. Certain of these porphyries consist of closely-spaced phenocrysts, generally less than five mm. in diameter embedded in a vitreous groundmass. Where weathered, these porphyries closely resemble plutonic rock.

The red rhyolite is extremely resistant to weathering, and outcrops generally are very rough and craggy. Cavernous reentrants, pillars, and monuments are common. Where red rhyolite is adjacent to tuffaceous rocks, it is generally topographically high, and the contact between the two rocks is commonly marked by an escarpment. The talus derived from outcrops of red rhyolite usually consists of angular blocks; however, the more felsic, flow-banded facies shed thin chips and spalls that respond with a metallic ring when struck with a hammer.

Flow-banding is the most striking feature displayed by this rock. These flow-bands generally consist of thin sub-parallel layers of vitreous hematite-rich material, or less commonly of light green diopside crystals. They generally are steeply inclined and roughly parallel to the walls of the rock in which they occur. This feature suggests an intrusive origin for many occurrences of red rhyolite. At places, the flow-banding is intricately convoluted, and at one locality, it is so perfectly developed it closely resembles the laminations of a typical shale.

The larger intrusives of red rhyolite commonly display a rudely developed zonal structure. The peripheral zone is commonly a cogmate breccia consisting of angular fragments of flow-banded rhyolite embedded in a matrix of dark red vitreous that contains some small fragments of the invaded rock. The central portion is generally composed of normal or porphyritic rhyolite. The central zone of the large rhyolite dike at the eastern extremity of the area mapped displays a rudely developed columnar jointing, which is normal to the walls of the dike. The composite nature of the larger intrusive masses suggests successive periods of igneous activity separated by intervals of relative quiescence.

Slickensides are common within the intrusive masses, and are especially abundant near the margins. These features suggest that the magma was highly viscous and perhaps partially solid during the final stages of emplacement.

Contacts of red rhyolite intrusives and invaded rock are commonly planar. In plan, these contacts appear linear, a fact which tends to belie the intrusive nature of the rhyolite. Slickensides along these planar contacts are prima facie evidence of slippage, but since they originated during intrusion and along the margin of the intrusive, they are herein regarded as intrusive contacts. At some places, intrusive contacts of red rhyolite and tuffaceous material are gradational over a distance of as much as 50 feet. Unaltered tuffaceous material grades into perlite which, in turn, grades imperceptibly into flow-banded rhyolite. The writer suspects that considerable substance has been added to the rhyolite through digestion of xenoliths and other masses of tuffaceous material.

The small conical hill about one-fourth mile northwest of Hill 3091 is composed principally of granite, and is capped with buff-colored rhyolite. Close inspection reveals highly altered white volcanic conglomerate at the granite-rhyolite contact. It seems reasonable to conclude that this represents an erosional remnant of a lava flow that poured out over a granitic surface thinly mantled with white volcanic conglomerate. However, closer scrutiny reveals nearly vertical flow-bands in the rhyolite and a steeply inclined conglomerate-rhyolite contact. These features indicate that this is a plug, intruded into granite and the overlying Rosamond beds, upon which erosion has progressed just far enough to preserve an annular ring of altered white volcanic conglomerate.

Red rhyolite intrusives commonly occur in rocks of the Lower Rosamond beds. It occurs less commonly in granite, and a few small masses of this material occur in the basal layers of the Upper Rosamond beds. Fragments of red rhyolite are common to abundant in all formations of the Rosamond series except in the white volcanic conglomerate, where they are present either in small amounts or entirely lacking. These facts, and the composite nature of many of the larger intrusive masses, suggest that successive intrusions of red rhyolite took place throughout most of Lower Rosamond time and during at least part of Upper Rosamond time.

Aureoles of perlitic alteration

Tuffaceous material, where intruded by rhyolite, generally is altered to a vitreous substance that strongly resembles perlite. This material is light to dark gray in color and is composed principally of glass. Perlitic cracks are well developed locally, and they commonly impart a nodular aspect to the material. At several places, dark gray perlite was injected by vitreous red rhyolite to produce a rock of very striking appearance. At other places, where the alteration was less intense, the original fragmental nature of the material can be discerned.

The perlitic alteration is most intense and the zones widest where tuffaceous material is underlain by rhyolite at shallow depth, or where it is transected by a plexus of small rhyolite dikes. The zones are narrowest and weakest along the steeply inclined planar intrusive contacts. There appears to be no consistent relationship between the size of the intrusive mass and the width of the zone of alteration. Small dikes just west of the prominent red hill at the northwest corner of Rosamond Lake are encircled by zones of intensely altered tuffaceous material nearly 20 feet wide, whereas the zones associated with many of the larger intrusive masses west of U.S. Highway 6 are narrow and discontinuous.

QUATERNARY FORMATIONS

Alluvium

Alluvial fans are fairly well developed along the southern margin of the Rosamond Hills. Some of these fans have been built by streams that head in the Rosamond Hills, whereas others have been built by streams that breach the Rosamond Hills and head in the granitic highlands to the north. As might be expected, the former are composed predominantly of volcanic and pyroclastic debris, whereas the latter are composed mainly of granitic debris.

About two miles east of U.S.Highway 6, remnants of alluvial fans are preserved at levels 10 to 30 feet above the present level of the stream valleys. This differential increases to the east, and suggests that this part of the region has been uplifted within recent times.

The escarpment along the northern edge of Rosamond Lake was probably caused by movement along a fault zone (see pl. 1) that elevated the area to the north at least 50 feet, and it is probable that this movement was partially responsible for the formation of the present Rosamond Lake. It is noteworthy that the previously mentioned alluvial fan remnants are located less than a mile west of this escarpment, and their position suggests movement in the same direction and of a like magnitude.

STRUCTURE

Faults

Most of the faults in the area west of the Willow Springs road have certain features in common. Nearly all of them dip steeply to the north and trend roughly east-west. Slickensides usually indicate strike-slip movement and, in general, the Rosamond beds north of these faults have been displaced eastward and slightly downward.

It is significant that movement along the northwest trending fault in the northwestern extremity of the mapped area (see pl. 1) has elevated the area south of the fault. This caused erosion to remove part of the underlying green volcanic conglomerate prior to the deposition of the welded tuff-breccia. Also the welded tuff-breccia has been cut by this same fault. Thus it is probable that this fault was active both before and after deposition of the welded tuff-breccia, which probably took place early in Upper Rosamond time.

A broad swarm of east-west trending faults transect the Rosamond beds in the vicinity of Hills 3091 and 2796. Beds north of these faults have been displaced westward. Noble,[10/]

10/ Noble, J.A., oral communication, May 1951.

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who has recently been investigating the Willow Springs fault, finds some evidence that it trends northwesterly through the

Rosamond Hills instead of along their southern margin. Streams offset by the Willow Springs fault suggest a direction of movement which is compatible with that indicated by the displaced Rosamond beds. Noble[11] reports that recent

11/ Noble, J.A., oral communication, May 1951.

movement along the Willow Springs fault has formed a topographic scarp in the alluvium west of the village of Willow Springs. This suggests recent movement along the faults which transect the Rosamond beds in the vicinity of Hills 3091 and 2796.

The fault zone which extends eastward along the north shore of Rosamond Lake was mentioned previously in the section pertaining to Quaternary Alluvium. Several rhyolite intrusive masses are aligned along this fault zone, including the one that forms the prominent red hill at the northwest corner of Rosamond Lake. In general, the principal faults in this zone dip steeply northward, and the granite within the zone has been badly crushed and later calichefied.

The largest fault of the region trends in a northwesterly direction along the alluvium-filled valley between the mapped area and the hill just north of Willow Springs (see pl. 1). Rosamond beds occur with depositional contact on a granite erosion surface in the Tropico mine.[12] This probably

12/ Noble, J.A., oral communication, A pril 1951.

is the same erosion surface that is exposed in the hills to the north. Because the regional dip of the Rosamond series is about 20° SW, it seems necessary to postulate a fault along which the Rosamond beds to the north were displaced downward against granite to the south. This movement probably tilted the block north of the fault toward the southwest. This would explain the regional southwesterly dip of the Rosamond series.

A few very small occurrences of granite along the south side of the Rosamond Hills (see pl. 1) suggest a northwest trending fault with similar displacement which has been offset by later transverse faults. It is possible that the fault indicated by these occurrences of granite is the eastern extension of the large fault mentioned above.

In the northwest part of the area mapped, the Rosamond beds trend northwest and dip about 20° SW; however, they terminate abruptly along an east-west trending escarpment (see pl. 1). It is probable that this abrupt termination is caused by a fault buried beneath the alluvium at the base of the escarpment.

Folds

Folding, other than gentle warping, is confined to two areas in the Rosamond Hills. Just west of the prominent red hill at the northwest corner of Rosamond Lake, beds of white volcanic conglomerate with a regional east-west strike bend sharply around to the southwest to form a southwest-ward plunging syncline with an axial plane that strikes about S 65° W (see pl. 1). The overlying brown fanglomerate appears to be tightly crenulated between the two synclinal limbs of white volcanic conglomerate. Small remnants of white volcanic conglomerate flank the prominent hill of red rhyolite along its north and south margins. The field relations seem to indicate that intrusion of the red rhyolite was accompanied by folding and faulting in the adjacent beds with development of a steeply plunging syncline. More detailed work is needed, however, to demonstrate this hypothesis in a convincing manner.

The fold in the vicinity of Hill 3091 is complicated by a swarm of east trending faults and by numerous intrusive masses of rhyolite. Further, the fold seems to be compound in nature. The angular unconformity along the upper surface of the white volcanic conglomerate at this locality indicates an early stage of folding. Later, the entire Lower Rosamond sequence was folded into an anticline that plunges about 25°W and has an axial plane that strikes about N 75°W. The Upper Rosamond sequence is represented by a few nubbins of brown fanglomerate that project from the alluvium along the western flank of Hill 3091. It is difficult to determine whether or not the Upper Rosamond beds were involved in the folding. The fact that the attitude of the Upper Rosamond beds is about the same wherever found suggests that the folding antedated the deposition of these beds.

The basal white conglomerate that forms the crests of the hogbacks east of U.S.Highway 6 characteristically dips southward more steeply than the overlying beds farther south. This is caused by gentle folding along an east trending axis.

GEOLOGIC HISTORY

The details of the Tertiary history of the Rosamond Hills region are not fully understood; however, this investigation has yielded certain geologic data from which a generalized sequence of major events can be formulated with reasonable accuracy.

The events are tabulated below in chronological order.

(1) Long-continued erosion throughout the Mojave Desert region during early Tertiary time eventually developed an erosion surface of low relief on the granite complex.

(2) Volcanic activity commenced in the Rosamond Hills area sometime during the Miocene epoch and probably was accompanied by faulting. The drainage thus was obstructed, and a series of shallow lakes was formed. Lower Rosamond time began with this event. The lakes were rapidly filled with pyroclastic debris forming the white volcanic conglomerate formation.

(3) Minor earth movements folded and faulted the white volcanic conglomerate, and the region near Hill 3091 was elevated and partially eroded.

(4) Red rhyolite was both intruded and extruded and this was accompanied by the

ejection of lapilli and tuff in the vicinity of Hill 3091. Accumulations of this material formed the pink tuff formation.

(5) Deposition of the green volcanic conglomerate began with lacustrine accumulations in the west and interbedded shallow water and fanglomerate accumulations near Hill 3091. During this period, the western part of the area was faulted along east trending fractures, displacing the area to the north toward the east. This faulting was accompanied by minor intrusions and extrusions of andecite. These faults elevated the area east of U.S.Highway 6, thus causing the overlying green volcanic conglomerate to be eroded away. Also, certain localities in the western part of the area were uplifted and subjected to erosion.

(6) Upper Rosamond time began with a period of intense faulting, which elevated an adjacent area to form a mountain range. The debris shed by this mountain range formed the brown fanglomerate. Folding and intrusion and extrusion of large quantities of red rhyolite probably accompanied this

period of faulting.

(7) Movement along the northwest trending fault, situated along the southwest flank of the Rosamond Hills, tilted the entire region toward the south, thus elevating the region northeast of the Rosamond Hills.

(8) Erosion removed most of the Rosamond beds from this tilted block, and reduced the underlying granite to a group of low hills; however, a belt of Rosamond rock remained along the southern margin of this block to form the Rosamond Hills.

(9) Movement along a series of east trending faults displaced the area north of the faults toward the west. This faulting appears to be going on at the present time.