A MAP AREA SOUTH OF SPADRA,

TWO AND ONE HALF MILES SOUTHWEST OF POMONA, CALIFORNIA

Thesis by

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CONTENTS

INTRODUCTION

Location of the Area

The area under investigation is in the southeast corner of the Pomona quadrangle, Los Angeles County, California. It lies at the extreme north of the Puente Hills. It can be reached by the new Pomona-Brea canyon highway which cuts the map area almost in two, north and south, and is two and one half miles south-west of Pomona, California. Since these hills stand right up from the surrounding alluvium, they can be seen from a distance of at least five miles from any state highways running in and by Pomona.

The area described in detail is approximately 3850 feet east-west by 5000 feet north-south.

Purpose and Scope of the Investigation

A detailed study of the area was undertaken as partial fulfillment of the requirements for the degree of Master of Science at the California Institute of Technology, Pasadena, California.

The writer was principally interested in the geological field mapping of an igneous body and was indeed fortunate in having such an area readily accessible. The field work was supplemented with the petrographic analysis of the rocks.

In 1926 the area was mapped by W. A. English [1] on small-scale base maps (1 mile to the inch). The work was done in connection with the mapping of the Puente Hills region, and almost no work was done with the volcanics.

[1] W. A. English, Geology and Oil Resources of the Puente Hills Region, Southern California; U. S. Geological Survey Bull. No. 768, 1926.

Method of Investigation

The author was very fortunate in obtaining a topographic map from the Los Angeles Metropolitan Water District, in scale 1000 feet to the inch (which was enlarged four times, making it 250 feet to the inch), and with contour intervals of 20 feet.

The nature of the problem required accurate detailed examination because of the complicated character of the different volcanics, yet it did not appear necessary to use a plane table for this work. This method is more accurate than a Brunton compass survey, but since time is an important factor in any problem of this sort, all contacts were located by Brunton compass sight intersections and pacing wherever it was most convenient. Despite the careful mapping, the conditions of a few features are subject to more than one interpretation. Although quite a few different kinds of rock exposures could be seen from a distance, at places it was necessary to walk over and observe complicated intermixed features foot by foot.

The field work was done during the first and second terms of the academic year of 1942-43, about four weeks being spent in the field.

Acknowledgments

The writer is obligated to Dr. H. J. Fraser of the California Institute of Technology for his interest, advice and for starting him on the field work. Due to war conditions however, Dr. Fraser was transferred to the Bureau of Economic Warfare, Washington, D. C., and was unable to assist the author any further with the field mapping.

Dr. F. D. Bode of the California Institute of Technology, who supervised the work, was ever ready to discuss problems and to check field observations, and the writer owes him a debt of gratitude.

Appreciation is extended to Dr. Ian Campbell and to the Geology Department of the California Institute of Technology for the services of Mr. R. von Huene for making thin sections; to Mr. von Huene; and to Mr. Keigan of the Los Angeles Metropolitan Water District for the topographic map of the region.

GEOGRAPHY

Topography and Drainage

Most topographic features can be clearly seen on the accompanying map. The Puente Hills have moderate relief. At this point the elevation of the block averages about 950 feet. Elevations of the map area vary from a minimum of 740 feet at the west to a maximum of 1370 feet towards the southeast, giving 630 feet of relief. The slopes of the hills at the northern and eastern parts are steepest. Most of the drainage is in a westward direction.

These hills have an unusually rugged, irregular appearance, and are outstanding due to their high relief in comparison to the surrounding low lying alluviated areas.

Climate

The well known southern California climate prevails here, making it possible to carry on field work throughout the year.

Due to the moderating effect of prevailing ocean breezes, there are few extremes in temperature. In the summer maximum temperature averages about 85 degrees F. and seldom reaches 100 degrees F., which in the winter light frosts may occur early in the mornings. An average temperature of 65 degrees F. prevails throughout the winter season, occasionally going up to 85 degrees F.

The annual precipitation varies from 8 inches in dry seasons to over 16 inches in wet years, with an average of about 12 inches. The rainfall comes almost entirely in the winter, occurring in short spells, rarely over two or three days in length, starting in about November and continuing to April.

Vegetation

The hills are covered with green grass and numerous wild flowers from the middle of February to June, but by the middle of July everything turns to a monotonous brown. On reddish soil covered slopes and on steep hillsides wild walnut, live oak, poison oak, and California holly grow. Because of the semi-arid climate, only the cacti and drought-resisting shrubs survive all the year around.

Culture

All around this area the low lying alluvium is perfect for production of the famous southern California citrus fruits. Rows of orange, lemon and avocado trees, walnut orchards, and farming lands bound the area on all sides. These particular hills are used for pasturing of cattle, horses and sheep.

Railroads and good highways connect the area with near-by important towns, making access by automobile or by train a simple matter.

Rock Exposures

The rock exposures are not typical of the surrounding alluvium country, but stand up, and outcrops can be seen on most of the map area. Of course there are exceptions near the contacts of different rocks where weathering has turned the lavas into red or purplish red soil, and at places they are covered with calcareous sediments, also on occasional grassy slopes and on level low-lying ground.

DESCRIPTION OF THE ROCKS

General

Basement complex of Jurassic age is the country rock of the region. Marine sediments of Miocene age were intruded by volcanics of upper Miocene. Lavas of upper Miocene flowed over the country rock, enclosing granitic boulders along the contact with the intrusive rocks. Conglomerates of upper Miocene to lower Pleistocene were laid along the edge of the extrusive rocks. From local hot springs related to vulcanism calcareous solutions penetrated the existing rocks.

INTRUSIVE ROCKS

Basement Complex

In the eastern portion of the map area a narrow strip of intrusive igneous rocks occur. Many granitic rock types are represented, but due to lack of detailed previous work and occurrence just at the contact of the author's area, only two typical granitic rock specimens have been taken and thin sections of them made. The name "Basement Complex" was given to these different intrusive types as customarily was done by the geologists who previously worked in this area. The basement complex is composed largely of rocks that crystallized from liquid magmas. Several dike-like masses, almost biotite-free aplitic granites, pegmatites with graphic intergrowths, pegmatites, and pegmetitic quartz veins were intruded into the main body of rocks.

The age of these rocks is believed to be Jurassic on the basis of correlations with the San Gabriel mountains approximately five miles to the north. Also, they are thought to be of the same origin as the mountains to the north of the area.

No faulting could be noticed in this intrusive igneous mass.

Calcite veins in these granites that occur along the contact with a volcanic flow at the north-east of 1370 hill are discussed under the chapter on calcite.

These rocks get to be well covered by recent alluvium as they get farther away from their contact with the volcanic flow. At these outcrops, rocks have undergone extensive weathering due to jointing and fracturing in them.

Granite

Megascopis description: In general the granite is medium to coarse grained, light colored, and of typical granitic texture, and considerably altered.

Two thin sections, one of biotite and the other of muscovite-rich rocks, were made, trusting that they may represent an average composition of the granites. But green to black colored hornblende was not found in them, even though it was present in the area. These specimens are believed to act as matrix (up to 1/2 inch size mica) to mica granite and later intrusives.

Microscopic description: The following is the composition obtained from biotite granite:

Minerals	Percentage
Essential:	
Orthoclase	41
Albite	14
Microcline	12
Quartz	26
Varietal:	
Biotite	3
Muscovite	1
Accessories:	3

The primary constituents, in order of their crystallization, are apatite, magnetite (two out of the three percent of accessories), zircon, sphene, ilmenite, albite, orthoclase, biotite, muscovite and quartz. The fabric of the rock is hypidiomorphic granular, euhedral to subhedral.

Apatite has crystallized in its usual form. Magnetite is found in small grains usually associated with biotite, as are small grains of zircon, sphene, and ilmenite. Crystals of albite (up to 1 mm. in length) are unzoned and a few of them are intergrown with microcline. Orthoclase is irregularly formed (up to 2 mm. in length), and about 2 percent of it is overgrown on plagioclase. Biotite (up to 2 mm. in length), possessing strong pleochroism from dark brown to yellowish brown, has irregular crystal outlines. There are small scattered grains of muscovite. Quartz (up to 3 mm. in length), may be easily distinguished from the altered orthoclase, and about 1 percent of it is in vermicular forms with plagioclase (myrmekite).

Alteration products are: kaolinization of orthoclase, silicification of feldspar, alteration of biotite to magnetite and chlorite; and minor sericitization, chloritization and alteration of feldspars to calcite.

Remarks: All the grains, even the quartz, are cracked, corroded, and contain numerous inclusions; biotite especially is eaten up by chemical solutions and oxidized.

Microscopic description: The following is the composition obtained from muscovite-rich granite:

Mineral	Percentage
Essential:	
Orthoclase	35
Oligoclase	17
Microcline	10
Microcline Perthite	8
Quartz	27
Varietal:	
Muscovite	2
Accessories:	1

The primary constituents, in order of crystallization, are: apatite in its usual form, muscovite (up to 1.5 mm. in length), scattered and subhedral; orthoclase (up to 2 mm. in length); oligoclase (up to 2 mm. in length) overgrown around orthoclase; microcline perthite (up to 1.5 mm. in length); quartz (up to 2.5 mm. in length) and 1 percent of it anhedral; small grains of epidote, chlorite, replacement albite. The fabric of the rock is hypidiomorphic granular, and all the grains are subhedral except quartz, which are euhedral and subhedral.

Alteration products are: silicification and sericitization of feldspars, chloritization of muscovite; and minor kaolinization and chloritization of feldspars.

Remarks: the rock is extensively altered, corroded, and somewhat cracked; they are chemically eaten up grains with inclusions, except that the quartz grains are unaltered and there is only a small trace of corrosion on quartz with very few cracks. Evidence of oxidation is present.

TUFFACEOUS SEDIMENTS

Almost in the central portion of the area mapped, west of hill 1370 on the slightly sloping surface lie tuffaceous sediments with calcareous sandstone, scattered weathered pieces of granite, and fragments of a rhyolitic flow enclosed in a calcite matrix. Unquestionably this cementing material emanated from local hot springs, similar to those forming calcite in other parts of the area.

These sediments, i.e., sandstones, could be assumed to be of the same nature as the ones beyond the volcanics to the west which are of marine origin and of Miocene age. And the granite carried from the main body to the east. The evidence of marine conditions is apparent in the presence of molluscan remains.

These sediments were surrounded and intruded by rhyolitic flows. Then the calcareous solutions emanated from local hot springs into volcanic and sedimentary material, breaking the rhyolitic flows into one to two inch fragments to pieces five to six feet; cementing and acting as matrix for the whole body. Resembling limestone in its appearance, gray coated calcite stands up 2 to 3 feet higher than the surrounding width of 3 to 4 feet at the northern contact against the volcanics. This peculiar relief of the gray limestone might be due to cracks, openings, and poor intermixing of the sediments and the main body of volcanics which let the hot solutions come up freely at these contacts.

EXTRUSIVE ROCKS

Volcanic activity is represented by a series of altered flows, striking approximately north-south and dipping generally to the west. These rocks lie on the basement complex and in turn are overlain by tuffaceous sediments, and conglomerates to the west. At the granite and conglomerate contacts, boulders are found in the flows.

It seems that lava broke through the basement complex, and that a succession of flows were extruded, as is indicated by the appearance of different textures and by flow beddings. Their longest axes, or flat surfaces, coincide with the direction of flow. The strongest flow layers are found near the contacts of intrusive granite, and the measurements began here, and thence traced the structure into the interior. The orientation of flows were ascertained and different orientations were examined. Fifteen thin sections of lavas of different texture and color were made and analyzed petrographically. The following is the classification of the geologically mapped volcanic body:

I. Massive rhyolitic flow
II. Regularly bedded rhyolitic flow
III. Irregularly bedded rhyolitic flow
IV. Rhyolitic flow breccia
V. Irregularly bedded and brecciated rhyolitic flow
VI. Andesite

I. Massive Rhyolitic Flow

In the eastern portion of the southern part of the area, pinkish-gray, fine-grained, rather vesicular massive rhyolites lie.

These rocks strike approximately north-south, and dip to the west and then to the east as they extend southward. These were rapidly cooled enclosing fine air bubbles, and although they are the oldest of the flows, strangely enough they do not include any layers of silica.

Petrographically, 40 percent of the rock consists of brownish glassy groundmass with a relief less than balsam and 30 percent densely packed feldspar microlites. The brown coloring is due to opaque iron oxides from ferric minerals. Primary, euhedral, somewhat corroded, cracked and chemically eaten up scattered phenocrysts of sanidine (up to .5 mm. in length)2%; microcline (up to 1.4 mm. in length) 2%; oligoclase (up to 1.5 mm. in length) 2%; microphenocrysts of oligoclase 8%; and varietal minerals of biotite (up to 1 mm. in length) 2%; magnetite 2% in fine grains, fine grain pyrite 3%, ferric oxide 9%, compose the rock. Alteration products are: kaolinization of feldspars, and almost complete alteration of biotite to ferric oxide.

II. Regularly Bedded Rhyolitic Flow:

In the northern half of the map area, in patches, fine-grained, pink and light gray whitish, compact, less altered, regularly bedded rhyolitic flows occur. Petrographically, the rock is of the same composition (with less ferric minerals and phenocrysts), and identical to that just described. Additionally, there occur thin parallel bands of quartz 2% (up to 1 mm. in length), 12% chalcedony occurring as cavity fillings, spherulitic and fibrous chalcedony enclosed by a thin line opal, and up to 2 mm. thick, approximately one half inch apart light gray whitish parallel bands of silicification. This secondary silica was probably deposited from water originating in the parent magma.

III. Irregularly Bedded Rhyolitic Flow

The only difference between this and regularly bedded rhyolitic flow is the texture. Petrographically, it is exactly the same as the preceding one. The index of refraction increases and approaches that of balsam in the darker glassy groundmass. The darker colors in these flows represent higher percentages of opaque ferric minerals which are due to weathering and replacement.

IV. Rhyolitic Flow Breccia.

Fragments from one to six inches of whitish, light brown, gray to purplish rhyolites occur generally either in a dark gray to black fine-grained matrix, or as fragments cemented by thin bands of chalcedony and opal. The dark gray flinty rock breaks with an uneven fracture. Petrographically, all these different colored rocks were found to be of the same origin and composition, except that plagioclase feldspar is andesine rather than oligoclase, and black coloring is due to pyroxene (augite), up to .3 mm. in length with mossy irregular shapes of grains.

The making of breccia involves, or may involve, three distinct processes: fragmentation, assemblage of the fragments, and cementation by the introduction of the matrix. Flow breccias were formed by hardening and breaking of the consolidated surface of lava sheets while still flowing. The fragments were contributed by outside layers hard enough to suffer fracture. They are sharply angular, homogeneous, and show approximately their relative positions from the initial attitude of the layers before fragmentation. But at places the moving lava had partly crystallized, and records of its former motion were lost through rearrangement of the rhyolitic flow, when it came to rest while viscosity was yet low. The fragments and the matrix are of the same material, the matrix having frozen about the fragments from a molten condition.

V. Irregularly Bedded and Brecciated Rhyolitic Flow.

These rocks are just the combinations of irregularly bedded rhyolitic flow breccia as the name indicates, and occur in patches in the northern half of the area.

VI. Andesite.

In the new Pomona-Brea Canyon highway road cuts, zones of dark colored, compact, fine-grained irregular dikes and sills come up like thin tongues terminating abruptly. This is the youngest of the volcanics which were intruded into the existing lavas, and lacking exposures they are untraceable on the map. Petrographically, they are of the same composition as the foregoing ones, except that the plagioclase feldspar is andesine with a small percentage of quartz, and 10 percent pyroxene (augite) gives the dark coloring.

The andesite could be called pyroxene-andesite.

Remarks

In all the cases of the flows, the euhedral grains had already formed, while the rest of the mass was still liquid. The effects of the flow forces had rotated the longest axis, or longer axis, roughly parallel to the direction of maximum elongation.

Age of the Volcanics

E. N. Harshman[3] states, "The basaltic-andesitic flow is definitely upper Miocene in age and was extruded during the deposition of the upper Puente shale," for the flows north-east of the area near Puddingstone Dam.

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[3] E. N. Harshman, "Geology of the San Jose Hills, Los Angeles, California.": Master's thesis, California Institute of Technology, Pasadena, California, p. 32.

The writer is in agreement with Mr. Harshman and believes that late in the period of Miocene vulcanism these lavas were extruded upon the "basement complex", and existing sediments. The lavas near Puddingstone Dam and in this area belong to the same period of activity.

Source of the Volcanics

The association of pyroclastic material of similar nature to the extrusives is probably an indication of the composite type. Volcanoes located in the region gave rise to lava flows, which flowed out over land surfaces, and in part over the sea floor at the edges of the Miocene sea. The angular fragments were contributed by broken crust, and then enclosed by the advancing molten lava.

CONGLOMERATE

Along the western contact of the volcanic flows coarse conglomerates occur. Coarse granitic conglomerates, fragments from flow lava, a few small irregular dike-like calcite veins and scattered pieces of calcite up to one foot in size associated usually with coarse to medium poorly sorted gray to brownish sandstone which is occasionally consolidated with siliceous, or calcareous cementing material, make up this horizon. These rocks lie at a lower elevation than the volcanic flows. Slightly rounded cobbles averaging about four inches in diameter and coarser material is present with boulders frequently as large as two feet, but rarely over three feet. Conglomerates are composed of granites, aplites, and pegmatites of the same character as the basement complex to the east and represent a unit assemblage of the same origin. Also pieces of rhyolitic flow in it are derived from the main body of lavas from the east. Calcite is of the same origin as in the other parts of the map area.

E. C. Edwards[2], in his thesis, states that the Puente Hills

[2] E. C. Edwards, "Pliocene Conglomerates of the Los Angeles Basin and their Paleogeographic Significance"; Ph.D. Thesis, California Institute of Technology, Pasadena, California; p. 57.

conglomerate series apparently bridges the time interval from upper Miocene into and including lower Pleistocene, although many diastems and disconformities may occur in the series, effectively concealed by the irregular bedding characteristic of coarse conglomerate.

This conglomerate body includes the concentration of lava flow types, bearing a similar relation to the volcanics adjacent to them, and is roughly equivalent in age. Therefore, the oldest conglomerates are of late upper Miocene age, and may extend to lower Pleistocene.

CALCITE

Rich calcite veins follow contacts of granite with rhyolitic flows or rhyolitic flow breccias on the southeast; and occur near the contact of conglomerates and rhyolitic flows on the west. Also the southern and the central portion of the area is characterized by an abundance of calcite intrusions, and irregular veining. In the south and the southwest of the map area, individual veins of pure calcite reach approximately four feet in width, and zones averaging thirty-five feet in width can be traced for more than one half mile to the south, striking about N 70° W, and dipping generally 65° NE. Occasionally this material cuts rhyolitic bodies in the southern half of the area, tuffaceous sediments in the center, conglomerate beds in the west, and acts as a matrix for a strip of granite right at the contact between granite and rhyolites in the southeast, and fragments of rhyolite in this matrix on the south. But mostly the veins are small, scattered, and of an irregular nature; frequently contacts and veins can be traced as shows on the map. Moreover many of those in the southeast portion of the area in the rhyolitic flows and rhyolitic flow breccias have no sharp contacts and are ill defined.

The presence of calcite intrusions and veins near the contacts might be due to the fractures, joints, openings, weak planes, etc., developed in the rocks before the lavas were cooled. These planes of weakness and openings might have been produced by shear, sudden chilling, and by volume of expansion of the extrusive rocks. For the fillings of primary open spaces are limited in their distribution to the rocks in which the chambers were present; e.g., amygdules in rocks.

The calcite presents a variety of granular, fibrous and massive textures. In good crystals, tabûlar, cleavable individual crystals up to three inches are present in the veins. Most abundant are the banded structures, frequently enclosing radiated fibrous masses which occur in the widest and longest bodies. Also irregular shapes, and massive fine-grained calcite which resembles limestone in its appearance, are found scattered in the area.

As to the mode of origin: the veins must have been formed by calcareous solutions; probably some of the calcite can be classified as travertine, which is a product of chemical precipitation from hot springs. A source for calcite is the local springs related to vulcanism.

The calcite has dull milky white yellowish color and can be easily broken on cleavage faces. It is quite pure, and contains almost no quartz. In the laboratory, the specific gravity measured with a Jolly balance was found to be 2.77; it effervesces vigorously with dilute hydrochloric acid.

Remains of old quarries where calcite was mined on a small scale by the early Spanish inhabitants can be seen on the west side of the area where the veins are the widest. This lime was burned for plaster.

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(3) E. N. Harshman, Geology of the San Jose Hills, Los Angeles, California. Master's Thesis, California Institute of Technology, Pasadena, California, 1933.