A Study of Miocene Vulcanism in Southern California

A Thesis By

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Abstract

The widespread Miocene volcanic rocks of Southern California represent at least four distinct epochs of activity. Lower Miocene vulcanism is represented by the basic hypersthene andesite flows north of Soledad Canyon and east of Mint Canyon. Lower middle Miocene flows are found in the Santa Monica Mountains and the Verdugo Hills; they are olivine poor basalts. Upper middle Miocene intrusives are abundant in the Santa Monica Mountains; they are usually olivine rich basalts. Upper Miocene siliceous andesite and dacite flows occur in the San Jose Hills. It is found that the distinction between the lower, middle, and upper Miocene volcanics is sharp, but that the two epochs of middle Miocene vulcanism resulted in quite similar rocks. The latter rocks are the most abundant in this region, and volcanics of lower or upper Miocene age are rare.

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Introduction

In the Tertiary section of the Los Angeles basin and nearby mountainous areas, volcanic rocks are widespread, Within some areas it has been possible to recognize more than one epoch of vulcanism, but all the rocks are generally referred to Middle Miocene time. The purpose of this research has been to determine, in so far as possible, the number of volcanic outbursts which have occurred in the neighborhood of Los Angeles, to examine representative specimens from each of these periods, and to see if there is any correlation between the age of the volcanic rock and its composition. It is realized that the possibility of a distinct correlation is not great, and that examples are on record of basalt and rhyolite extrusions from the same vent at about the same time (1). But if such a correlation does exist, a knowledge of it would be valuable. Moreover, a study of the areal extent of the different rock types may have value for the sedimentary petrologist in determining the sources of detrital material.

In order to carry out the plan, a review of the literature has been made, and previously mapped areas in which the age of the sediments enclosing the volcanics is well established have been selected for study. Since the period of Tertiary vulcanism was quite short, much difficulty has been experienced in dating many of the rocks. This is especially true where volcanics do not occur in association with foraminiferal deposits. It has been found that the usual zoning of the Miocene epoch based upon megafossils is not very satisfactory. In the later phases of the work, an attempt has been made to use the foraminiferal zones given by R. D. Reed at a

Plate I

A division of Miocene time with the correlations used in this report.

	FAUNAL ZONES		CORRELATIONS				VULCANISM
	FORAMINIFERA	MEGAFOSSILS	Santa Monica Mts.	San Jose Hills	Verdugo Hills	Northwestern Sierra Madre	Flows or intrusions
	1 Bolivina seminuda		MODELO	Upper Puente Shale	MODELO	?Modelo	
M	2 Bolivina hughesi					??????????	
I	3 Buliminella uvigerina formes					MINT CANYON	Puente Hills
	4 Baggina californica						
O	5 Valvulineria californica		Hiatus		??????		Santa Monica Mts.
C	6 Baggina robusta	Turritella ocoyana	TOPANGA				
E	7 Siphogenerina hughesi				TOPANGA	??????????	Santa Monica Mts.
	8 Uvigerina obesa					Hiatus	
N	9 Plectofrondicularia miocenica				??????	VASQUEZ	
E	10 Haplophragmoides trullisata	Turritella inezana	VAQUEROS				Northwestern Sierra Madre
	11 Bolivina marginata						
	12 Siphogenerina transversa						
	13 Cibicides americanus						
	14 Cancris sagra						

recent meeting of the Geological Society of America (2). This division of the Miocene, together with an approximate correlation with the megafossil zones is shown on Plate I. At least four periods of Miocene vulcanism resulting in flows or intrusions have been recognized within a distance of thirty miles from Los Angeles, but since there is no one locality at which all these periods are represented, the Miocene volcanic section given here is, in a sense, arbitrary. An index map of the Los Angeles area, showing the regions which have been studied is in the pocket (Plate II).

The author is indebted to Dr. J. H. Maxson for suggesting the problem. Dr. Ian Campbell has been of great assistance in the petrographic studies. The map of a part of the Lang Quadrangle is a result partly of the author's own work and partly of the work of L. F. Uhrig and C. A. Dawson. The maps of parts of the Burbank and Topanga Quadrangles are taken from United States Geological Survey Professional Paper 165c by Harold Hoots. The map of parts of the Las Flores and Dry Canyon Quadrangles is taken from a manuscript by Lawrence Bolles. The map of the San Jose Hills is taken from a manuscript by E. N. Harshman. It is hoped that full credit is given in the text to those whose publications have been useful in preparing this report.

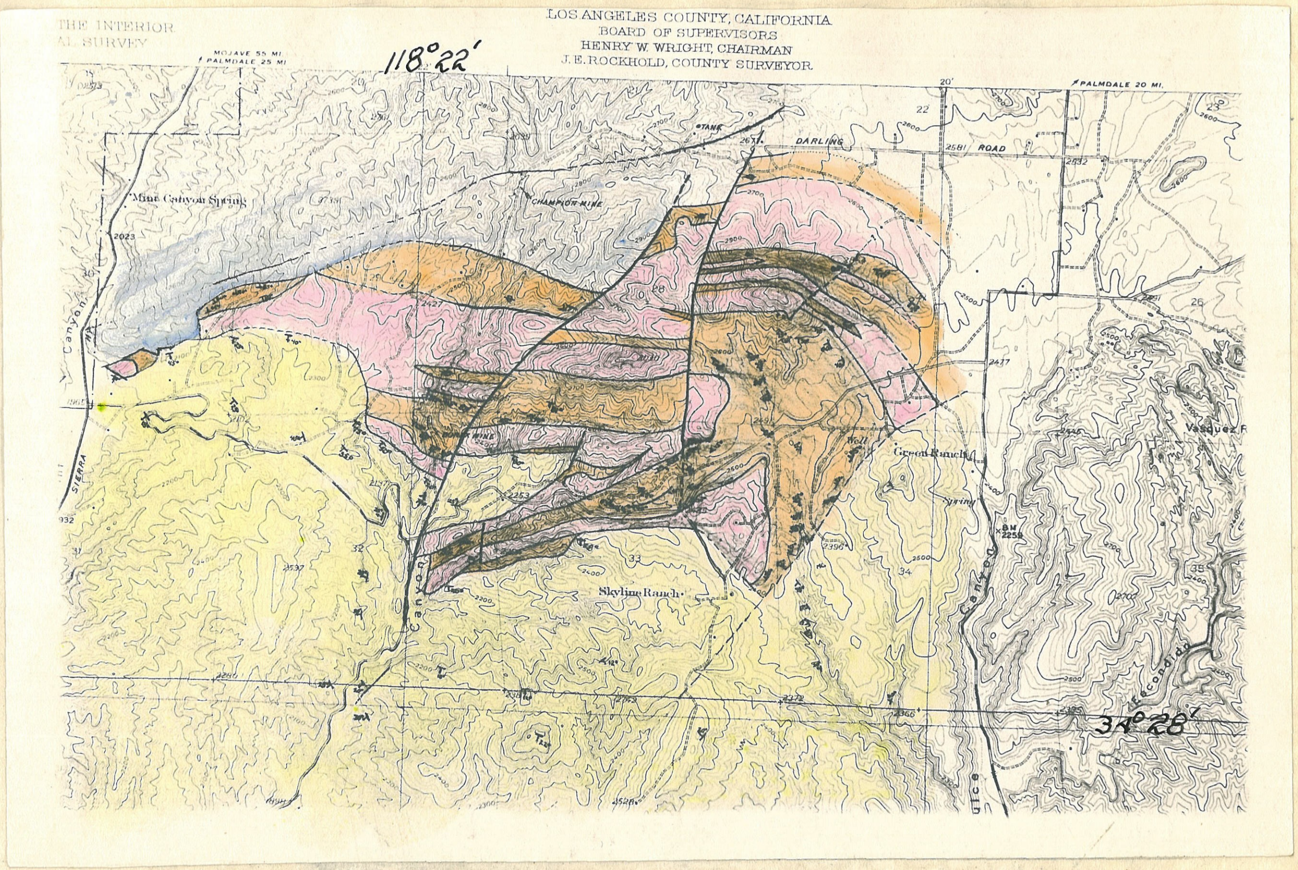
Extrusive Igneous Rocks of the Lang and Ravenna Quadrangles

In the region of Tick Canyon volcanic rocks occur interbedded in sandstones, tuffs, shales, and colemanite-bearing beds. These deposits, according to Foshag, represent deposition in a playa or desert basin (3). In the Ravenna Quadrangle, to the east and north, the sediments change in character, becoming fanglomerates and representing deposition around the edges of the basin. These beds were first described by Hershey(4) who named them the Escondido Series. In 1924 they were again described by Kew (5), who correlated them with the Sespe, which he considered of questionable Oligocene age. Kew also stated the lavas to be the oldest within the area he studied. In 1935 the sediments were renamed Vasquez by Sharp (6), since the term Escondido was preoccupied.

Recent researches by Chester Stock on mammalian remains entombed in the so-called Sespe of South Mountain, Simi Valley, and Las Posas Hills indicate that the Sespe ranges in age from Upper Eocene to Lower Miocene and "that the name Sespe, unless definitely restricted to a stratigraphic unit in the type section, loses its significance as a formational designation" (7). Hence Kew's tentative correlation, if it were true, would not mean much.

Since the Vasquez Series is deposited upon the ancient metamorphics of the Sierra Pelona, and since the beds have not as yet yielded any fossils, an important clue as to their age is found in the relations with the superjacent fossiliferous Mint Canyon beds. In the vicinity of Tick Canyon, at the type locality of Hershey's

Plate III



Geology of a Portion of the Lang Quadrangle

miles

1 0 1

Contour interval = 25 feet

Mint Canyon

Vasquez sediments

Vasquez lavas

Basement complex

"Escondido", these beds are folded into a tight east-west trending syncline, broken by numerous faults. The geologic conditions are shown on Plate III. Dips of eighty degrees or more are common in the Vasquez beds. The syncline has been eroded, and then covered by the basal conglomerates of the Mint Canyon. A fauna from the Mint Canyon is described by Maxson (8), who determined its age as middle upper Miocene, just above the Barstow of the Great Basin Section and between the Cierbo and Briones of the Pacific Coast section. However Maxson states: "The stratigraphic occurrence of a primitive *Merychippus*, *Parahippus?* near *mourningi*, and *Miolabis californicus* in the lower portion of the exposed Mint Canyon section might be considered as adequate paleontological evidence for assigning an older age for these beds, in which case an unconformity [within the formation] must be assumed." In view of the great thickness of the Mint Canyon section -- four thousand feet -- it may not be necessary to assume an unconformity, and in view of the imperfect knowledge of this formation, such a hiatus might exist without our knowing it. Recently obtained mammalian remains found at a very low horizon within the Mint Canyon but as yet undescribed indicate a probable mid-Miocene age for the base of the Formation.

In view of the fact that mammalian remains now found in abundance in the Sespe formation of the Ventura Basin indicate a rather moist climate for the upper Eocene and Oligocene, the Vasquez, decidedly an arid type deposit, cannot possibly belong to these times. That arid conditions did not obtain during Sespe time has also been pointed out by Reed (9). Oreodonts found in the upper Sespe and interbedded with lower Vaqueros strata indicate a moist wooded environment for that period (10). Actually "the evidence concerning the climate of Vaqueros and Temblor land areas is very meager. . . Probably the best guess that can be made at present . . . is that it varied from time to time and from place to place between semihumid and semiarid" (11). Unless very special circumstances existed in the Vasquez basin, conditions seem to have been more favorable for assuming its deposition during Miocene time than during the moister Oligocene, and the Eocene seems ruled out entirely on a climatological basis. It seems from a study of the Vasquez that the beds were deposited in a rather small basin whose center was approximately in the vicinity of Tick Canyon. The basin was encircled by mountains. It may have been a particularly dry area, thus explaining the lack of mammalian remains. The last bit of evidence available is the presence of the volcanic rocks. These are practically if not totally unknown elsewhere in the Tertiary of Southern California of any age but Temblor or younger. The nearest Vaqueros lavas occur at the south end of the San Joaquin Valley (12). W. J. Miller (13) considered these rocks middle Miocene in age because of the presence of lavas. However, it seems evident that this author did not take into consideration the structural relations of the Vasquez and the Mint Canyon and the evidence of the Mint Canyon fauna. In order that the time of extravasation of the Vasquez lavas should not be too far removed from that of the greater part of Tertiary vulcanism in this region, it is considered that the marked hiatus between the Vasquez and the Mint Canyon does not represent a long period of time. That such a diastrophic cycle might take place quite quickly is well illustrated in the Hollywood Hills, and is shown in figure 1. The age of the Vasquez must be considered lower Miocene (hence approximately equivalent to the Vaqueros) on a basis of the mid-Miocene age of the basal Mint Canyon supplemented by climatic evidence and the history of vulcanism. It is considered by Schenk (14) that the Vaqueros may be an Oligocene formation. This idea does not fit in well with the evidence of lower Miocene mammals from the base of the Vaqueros in Tecuya Canyon (32), but aside from this point, it is desired in this paper to abide by the common terminology of California geologists by calling the Vaqueros lower Miocene.

In Bulletin 753 of the United States Geological Survey, Kew says: "The oldest [Tertiary] igneous rocks occur as flows of andesite near the base of the Sespe (?) formation in the region north of Soledad Canyon and east of Mint Canyon. This andesite is nearly everywhere vesicular and contains amygdules of chalcedony as much as three inches in diameter. Specimens of this rock submitted to C. S. Ross of the United States Geological Survey, showed that it was a typical andesite in which euhedral crystals of andesine form about one-third of the rock and augite about five percent. The groundmass is composed of a brown glasslike material and small euhedral crystals of andesine."

Detailed studies of volcanic rocks from the vicinity of Tick Canyon and of six thin slices of rocks in the Ravenna Quadrangle kindly loaned by R. P. Sharp show that the rock is much as described by Kew, but with this difference: the phenocryst feldspars are quite uniformly mediam labradorite (measurements indicate a maximum of An65, a minimum of An58, with an average of An61), and the pyroxene is largely hypersthene, with smaller amounts of pigeonite. No augite was found. The feldspars are usually quite fresh, but have been corroded by the last solidifying magma, producing irregular external outlines and sometimes peculiar graphic textures analogous to those of pegmatites. Where the feldspar has been corroded its place is taken by the glassy and chloritic materials of the groundmass. The effects are quite similar to those shown in figure 3.

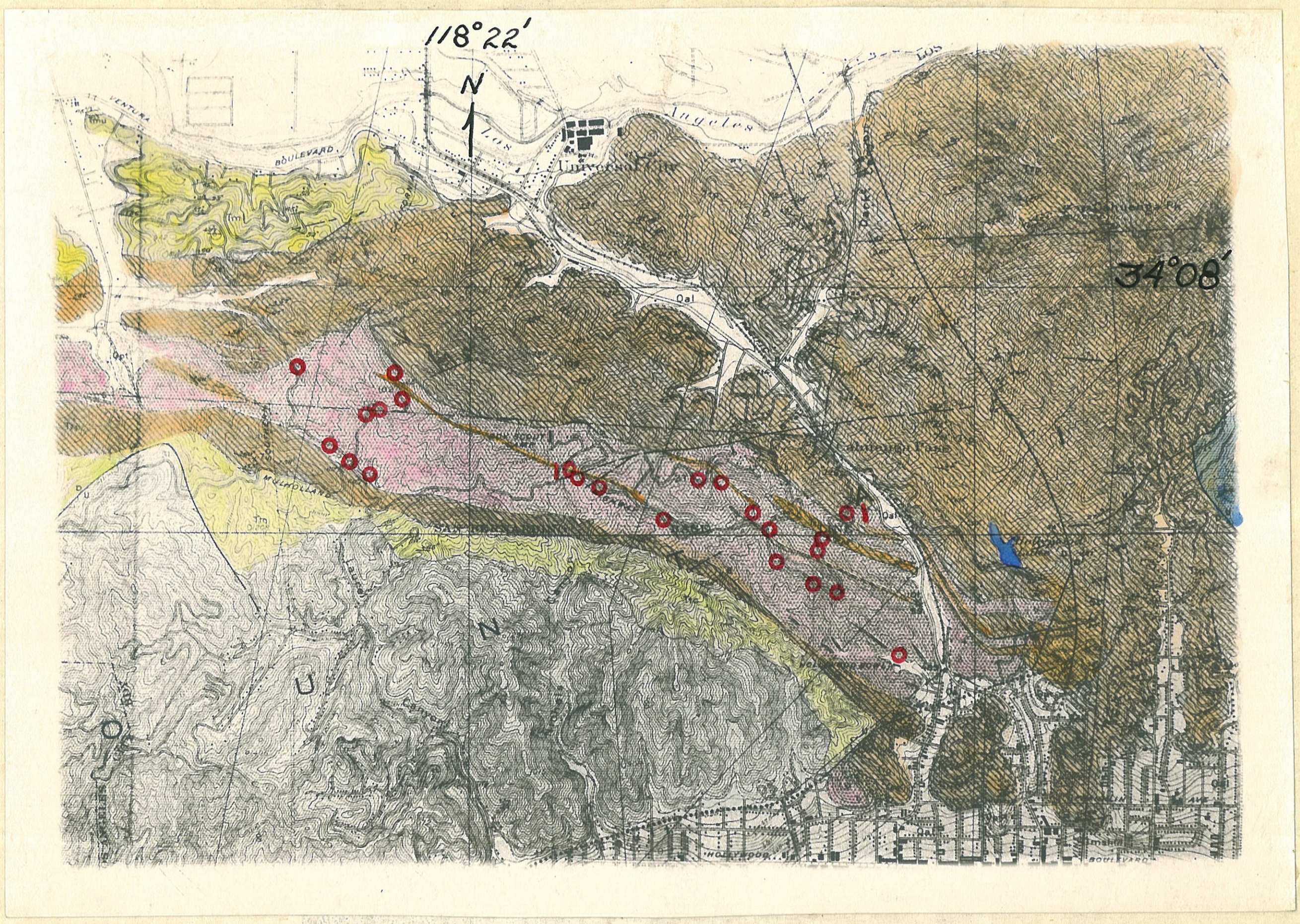
Although almost a dozen thin sections, selected at random, were studied, no other rock type than the basic hypersthene andesite just described was encountered, and the flows seem to form a distinctive group. Miller has recorded olivine basalt from northwest of Ravenna, (13), but he does not state whether these more basic rocks belong with the Vasquez flows. This is an important point inasmuch as it is known that later intrusives cut the flows in some places (6). Most of these flows are not very vesicular, often showing in the outcrops a highly trachytic arrangement of the large feldspar phenocrysts. In places there is a marked development of concentric tension fractures, probably a result of forces engendered during consolidation. These spheroidal structures are often of large size, the diameter being measurable in terms of a few fives or even tens of feet. Occasional highly vesicular flows contain chalcedony and calcite amygdules, and the microscope reveals the additional presence of bright green chloritic cavity filling material.

Extrusive and Intrusive Rocks of the Burbank Quadrangle

In the hills north of Hollywood and west of Cahuenga pass is a mass of basalt which trends west by north and pinches out to the east and west. This basalt is described by Hoots (15) as occurring near the base of the Topanga formation, in a series of sandstones and conglomerates containing a Turritella ocoyana fauna. The stratigraphic position of the basalt is diagramatically given in figure 1, which is adapted from Reed (2). Referring to the foraminiferal zones given in plate I, it can be seen that the flows correspond in age to lower middle or upper lower Miocene. The intrusives occurring with the flows probably correspond to the Valvulinaria californica (or fifth) zone.

As shown in Plate IV, most of the basalt is confined to a single stratigraphic horizon, suggesting that the major part of it is extrusive. However, as stated by Hoots (15) intrusives occur with the extrusive rocks, particularly in the region near Cahuenga Pass. But it does not seem that as much of the rock is intrusive as Hoots believes. Sandstone stringers described and figured by him as inclusions in intrusives resemble much more beds laid down upon a surface of basalt during the intervals between extravasation. The fairly well developed pillow structure developed in these rocks tends to show that they were extruded under water. The interpretation of the lavas as intrusives rests upon the evidences of baking. All such effects are very slight and usually somewhat doubtful, and cannot be backed up by positive indications of intrusion, since no dikes cutting across the sandstone lenses,

Plate IV



Geology of a Portion of the Burbank Quadrangle

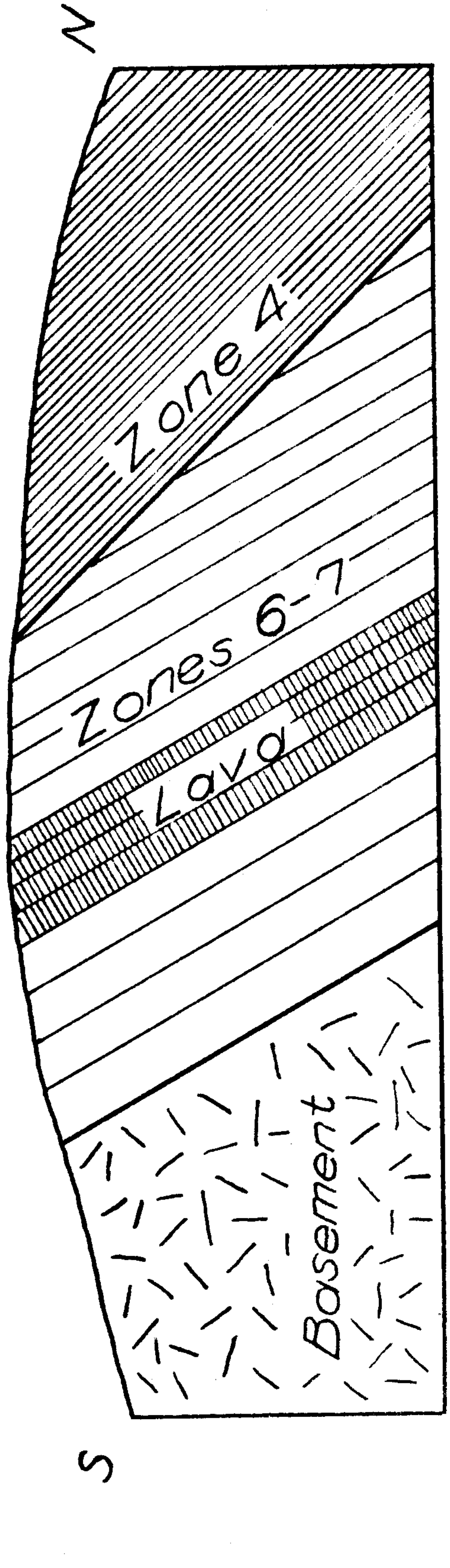
miles

1 0 1

Contour interval = 25 feet

- Modelo
- Topanga
- Extrusive and intrusive igneous rock
- Lower conglomerate member of Topanga
- Basement

Figure 1



GENERALIZED SECTION THRU THE REGION WEST OF CAHUENGA PASS nor even apophyses projecting into them could be found, although such were looked for. It does not seem possible that intrusion on a large scale could occur without greatly deforming the sands and shales and producing unmistakable metamorphism, inasmuch as they were completely surrounded by the magma if the intrusive theory is correct. At a few localities near the eastern end of this basalt mass some intrusives certainly occur. Their contacts are irregular and steep, and they contain fragments of the older igneous rock. These inclusions are not distinctly metamorphosed. In the western part of the mass, in the region north of Laurel Canyon, the rock is all extrusive, consisting largely of agglomerate and breccia. (In this report the term agglomerate is used to include all coarsely clastic rocks made up largely of somewhat rounded fragments of volcanic rock, and no genetic connotation is implied.) Much of this rock is described by Hoots as a "typical autoclastic rock", but the presence side by side of rocks of many different textures and structures refutes the idea. In many of the agglomerate and breccia layers the matrix is composed largely of sandy material; probably the rock was initially a volcanic mud. Interbedded with the agglomerate are flows, sometimes showing pillow structures with radiating hexagonal cloumns within the pillows. Some highly vesicular flows are present, usually in a more altered condition than the solid rock, as though the excess of contained gasses had played an important part in their alteration. The vesicles are often filled with chalcedony, chabazite, natrolite, thompsonite, or some variety of chlorite. In some slides a glassy material -- probably chlorophaeite -- can be seen filling cavities or replacing

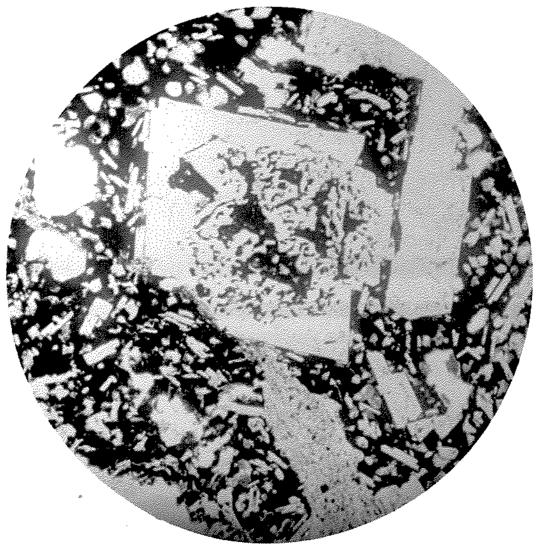
Figure 2

A. Cross-cutting magnetite needles. 48x

B. Graphic intergrowth in a feldspar phenocryst. 15x olivine. Tomkieff (16) discusses the discontinuous de-basification and hydration series leading from olivine through iddingsite to chlorophaeite and chloropal, but there is no indication here that iddingsite has been formed, and the rocks are too badly altered to determine the possible presence of chloropal.

The rocks themselves are basalts with plagioclase feldspars of an average composition of slightly sodic labradorite. (The microscope reveals a range from An65 to An52, with an average of An57.) Olivine is sparsely developed, appearing in about one-half the thin sections and never forming more than ten percent of the area of a single slice. This olivine is usually present as irregular anhedrous rather than as well formed crystals. Pigeonite is present in about half the slides, but is not always found in association with olivine. Biotite occurs in about one-fourth the slides. The groundmass is generally abundant, consisting of microcrystalline material, mostly chlorite, and glass. Magnetite is an abundant constituent, and from its long slender forms and its cross-cutting relationships seems to be a late crystallizer. Figure 2 A is a photomicrograph of a section from locality 10 in the Burbank Quadrangle. It shows the elongate magnetite needles cutting across grain boundaries, and clearly appearing to be a very late mineral in the paragenetic sequence. Broderick and Hohl have shown that in the Michigan traps iron may be carried as or by a gas during consolidation (17). It seems quite possible that this is the case in these basalts. However, the tendency of magnetite to form skeleton crystals which when sectioned would show apparent needles must be kept in mind when interpreting

Figure 3



Black = opaque tachylite; white = feldspar. The photograph illustrates the corrosion of a feldspar phenocryst by the groundmass glass, with the production of graphic textures. Burbank Quadrangle, locality 1, specimen b. Ordinary light, 17x.

these structures.

Because of the degree of alteration and the sparcity of mafic phenocrysts in these rocks, it is not possible as yet to divide them into any definite groups. The rocks seem to be intermediate in composition between the olivine basalts and the olivine-free types, inasmuch as the olivine is only rarely developed. This is the only character which would separate them from the slightly younger intrusive and highly oliviniferous diabases and basalts of the central and western Santa Monica Mountains. Because of the uncertainty which prevails as to the intrusive or extrusive nature of much of this rock, it is not possible to state any differences between the two, but since no two distinctive sets of rocks have appeared from the microscopic study, it is concluded that they are much the same.

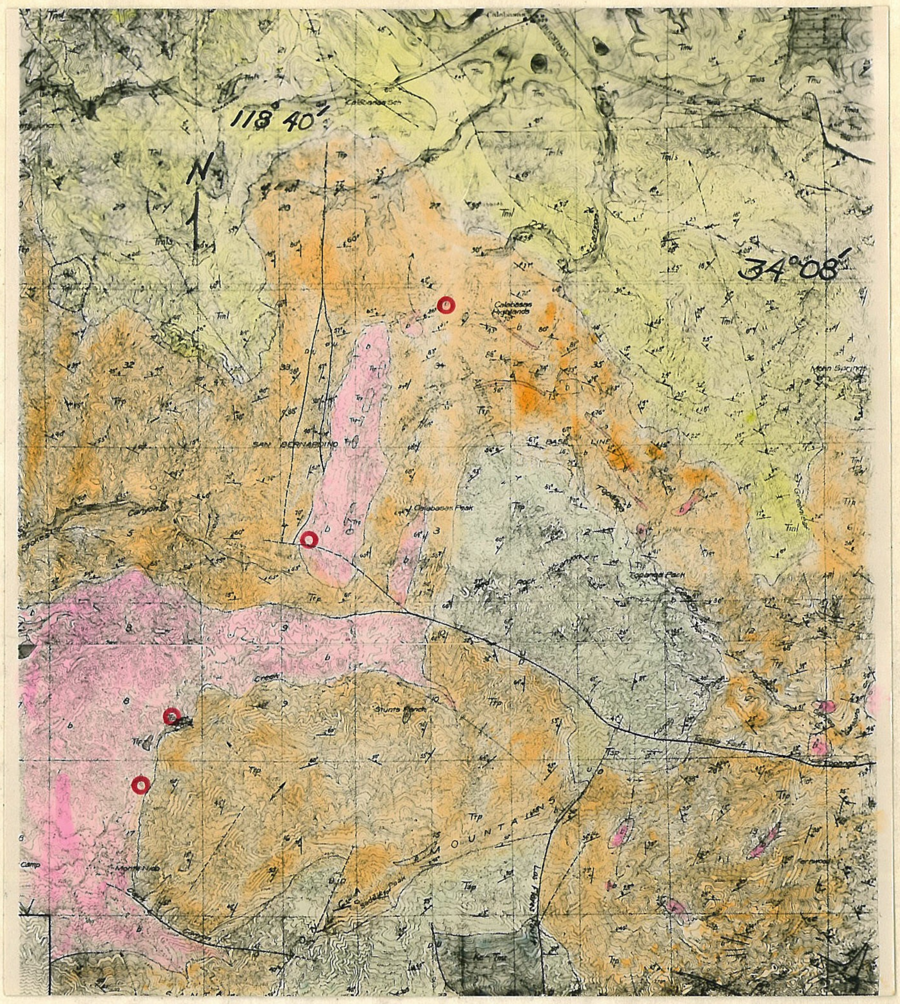
In the later stages of consolidation of these rocks the feldspars were often partially redissolved by the magma. The process was sometimes quite selective, only the cores of the feldspars being affected. This corrosion of the feldspars seems to be especially characteristic of flows and may be due to rapid loss of volatiles, resulting in changed equilibrium conditions. Figure 3 is a photomicrograph showing the corrosion of a feldspar phenocryst by the glassy groundmass. In figure 2 B, which is from a more crystalline flow (locality 10) the same graphic texture is produced, but the material within the feldspar is composed of definite mineral species, as pyroxene and chlorite. By analogy with the case seen in figure 3, one might expect that the texture was produced by the same means -- corrosion by the liquid magma, but as this flow cooled more slowly, there was an opportunity for this material to crystallize.

Intrusive and Extrusive Igneous Rocks of the Las Flores and Dry Canyon Quadrangles

In the west central Santa Monica Mountains, between Malibu Creek and Topanga Canyon and north of the axis of the range are a number of flows interbedded in the Topanga formation. The flows and surrounding sediments have been invaded by later basalt, and probably some of the vents thru which the flows were exuded have been exposed by erosion. The greater part of the igneous rocks now appearing at the surface are intrusives. The geologic conditions of the area have been described by Bolles (18).

Since most of the surface rocks of the area are very greatly altered, rendering them unsuitable for petrographic examination, and in fact making it impossible to obtain good hand specimens, merely a cursory investigation of the area was made. Only a few localities were found at which the relations of the lavas are well illustrated. (The more important of these localities, to be described below, are indicated on the accompanying map, Plate V. They will be described in order from north to south.)

Three eighths of a mile west of Calabases Highlands is a small intrusive pipe. The rock is composed very largely of clear yellow glass with numerous labradorite (An_{62}) phenocrysts and minor amounts of augite, olivine, and chlorite. In places greenish rounded spherulites composed of radially arranged, fine chlorite fibers have developed. The whole rock is cut by a network of anastomosing veinlets of calcite or dolomite in which a small amount of quartz can be seen. This mass is intrusive into the Topanga formation and probably coincides



Geology of Portions of the Las Flores and

Dry Canyon Quadrangles

miles

1 0 1

Contour interval = 25 feet

Modelo

Topanga

Extrusive and Intrusive Igneous rock

Sespe

Chico - Martinez

in age with the Topanga Canyon intrusives; the composition of the two rock masses is quite similar.

Near the south end of the long, north-trending basalt member one-half mile west of Calabasas Peak, a road cut exposes several thin flows with vesicular tops. The rock is almost completely crystalline, with only about ten per cent glass on the average. Labradorite (An65) constitutes about 75% of the rock; other minerals are pigeonite, biotite, and magnetite. Irregular areas occur in which a greenish chloritic material of rather high birefringence is well developed. The elongation is positive, and the index is greater than Canada Balsam; no other optical data can be obtained. It is probably a late-crystallizing chlorite which filled the cavities or pores in the rock.

Just south of the last locality is a very large area probably underlain almost entirely by intrusive rocks. About one-quarter mile west of Stunts Ranch, a recent road cut shows a fine laminated shale lying with gently arched depositional contact upon a lava. Two hundred yards south, on the same road, one can see the intrusive contact of the lava with the Topanga sandstone. This probably represents the same condition that one sees at Mohn Springs in Topanga Canyon, where the Modelo shales lie upon the eroded surface of the Topanga formation and its contained intrusives. This igneous rock is a highly oliviniferous diabase. The olivine is considerably altered, being replaced by a variety of chlorites or serpentines. The usual alteration to serpentine in which the orientation of the fibers is determined by the direction of the crack or fissure in which they form is present, but there is also an alteration product which orients itself within the olivine crystal with the fibers parallel to the b axis of the olivine. It is a dark green pleochroic mineral of low birefringence, positive elongation and parallel extinction. Other alteration products have small optic angles or are uniaxial, and may be of positive or negative optical character.

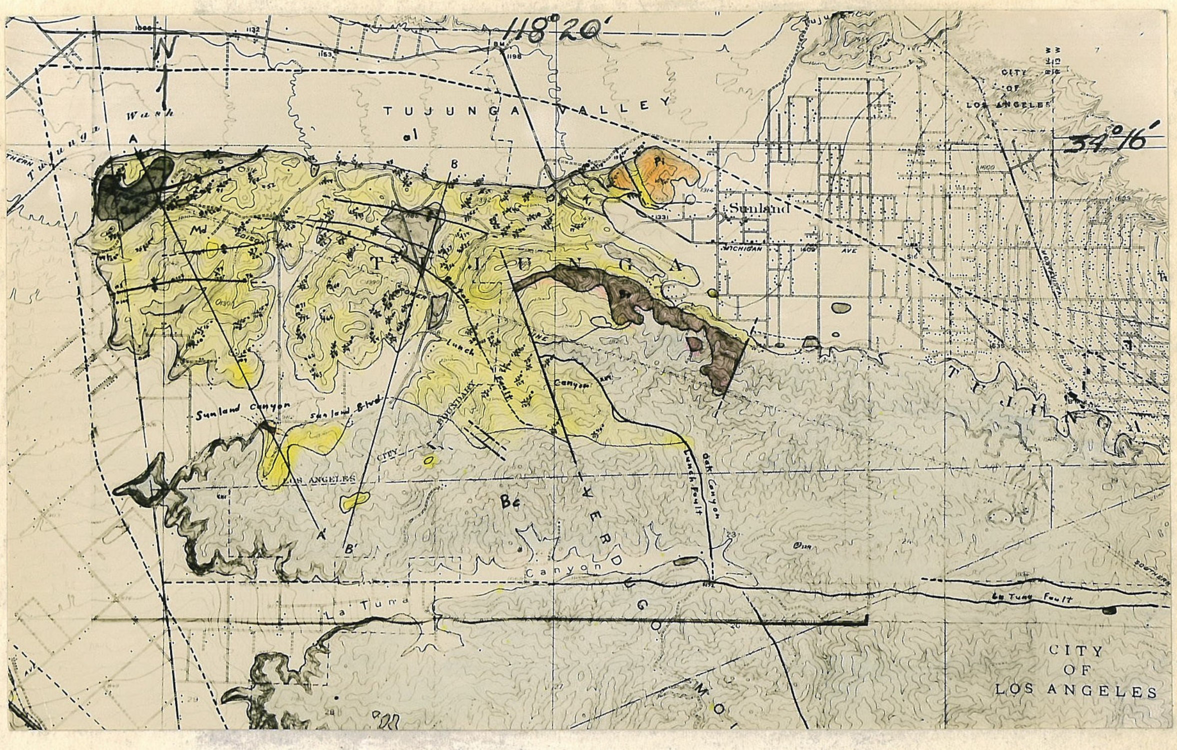
Somewhat south of the last locality, in a small canyon east of the road, is an outcrop of massive, very probably intrusive lava. Within the lava are small angular inclusions of highly amygdaloidal extrusive rock. This probably represents the condition seen in the Hollywood Hills, where the early Topanga flows are intruded by slightly younger volcanics.

Extrusive Igneous Rocks of the Sunland Quadrangle

West and slightly south of the town of Sunland, in the Verdugo Hills, are outcrops of basic lava flows interbedded with sandstone and conglomerate. Kew (5) considered the sediments to be a part of the Modelo formation, but detailed mapping by California Institute field parties has led to the belief that they are to be correlated with the Topanga formation of the Santa Monica Mountains. The flows are then roughly contemporaneous with those of the Burbank and Dry Canyon Quadrangles.

These flows are very fine grained green rocks with marked platy cleavage. Under the microscope they show a trachytic arrangement of fine feldspar needles averaging 0.25 to 0.5 mm. in length. Scattered plagioclase phenocrysts are strongly zoned, with a variation in composition in a single crystal from median bytownite to sodic labradorite. Iron rich olivine occurs rarely, and then as isolated

Plate VI



Geology of a portion of the Sunland Quadrangle

miles

1 0 1

Contour interval = 25 feet

Pico

Modelo and Topanga

Lava flows

Basement complex

phenocrysts or glomeroporphyritic groups of anhedrons. Pigeonite, augite, and magnetite also form phenocrysts. The mesostasis is microcrystalline with much chlorite. The rock is an olivine poor basalt similar to that of the Hollywood Hills.

In some sections a very interesting bright red mineral of high relief can be observed. It occurs as small patches not easily visible in the hand specimen but showing a bronzy luster and a micaceous cleavage. Under the microscope a second, slightly irregular cleavage is seen normal to the principal one. Pending observation with a universal stage, only the following data can be obtained; The optic plane is perpendicular to both cleavages and the obtuse bisectric (X) emerges in the center of the field from a cleavage fragment lying on the principal cleavage face. The mineral is slightly pleochroic; absorption $X > Y$; disperion distinct, $v > r$ (over X), with abnormal dispersion colors = green and red. The optic angle is variable but so small that the mineral appears uniaxial in some section. In all orientations there is parallel or symmetrical extinction; hence the symmetry is orthorhombic. From the mode of occurrence, the mineral appears to be a replacement of olivine. This mineral is probably a form of iddingsite, but differs from hitherto described species. Other iddingsite has been recorded with small to large negative optic angle, and with a large positive optic angle. This variety completes the series by giving a small positive optic angle. The optic relations with respect to a cleavage fragment are shown in figure 4.

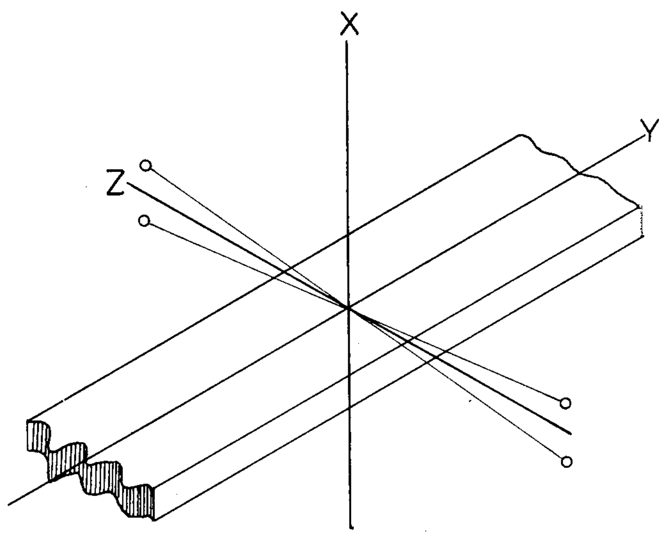


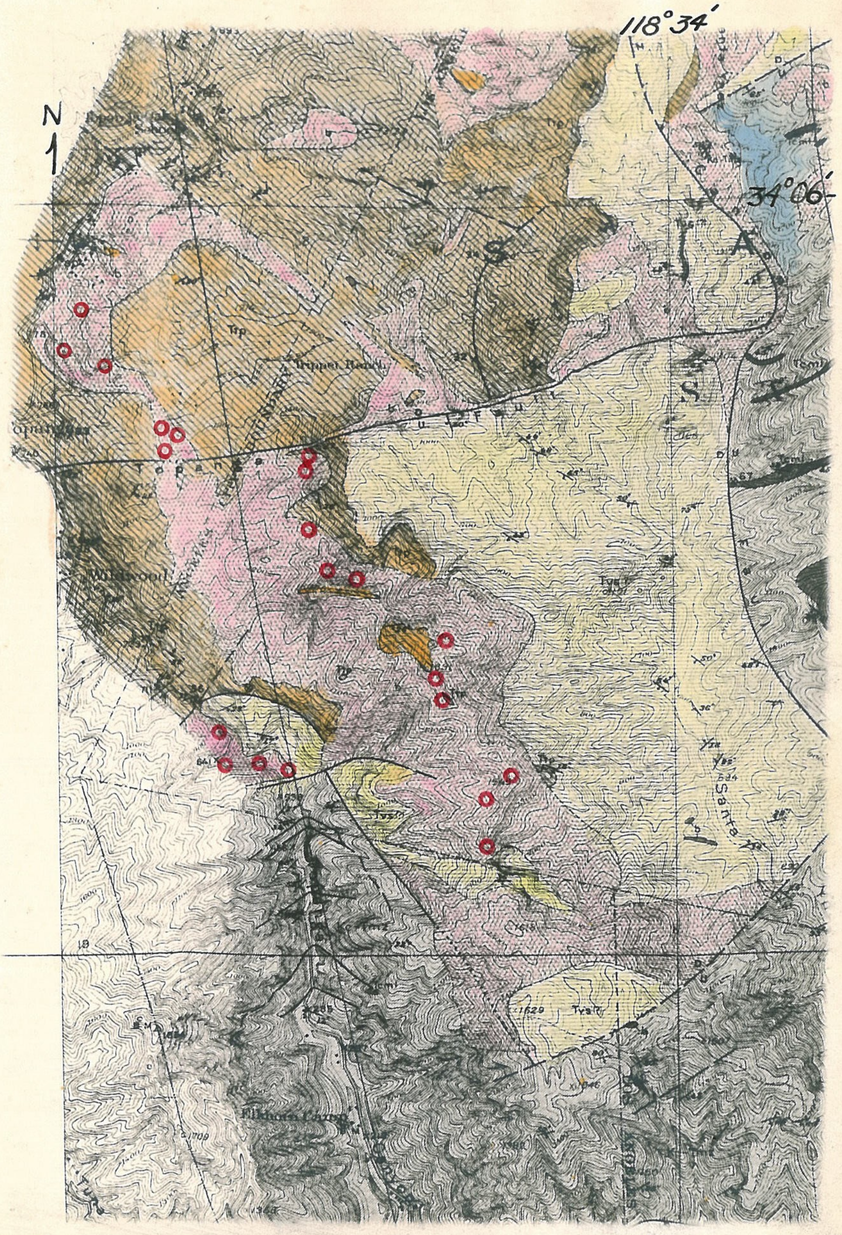
FIGURE 4

Optical relations of a new type of iddingsite

Intrusive Igneous Rocks of the Topanga Quadrangle

In the vicinity of Topanga Canyon occur several bodies of basalt and olivine gabbro intruded into the Topanga formation. These have been mapped and described by Hoots (15). Since the Modelo formation was deposited upon the eroded surface of the gabbro, the period of intrusion can be estimated with some accuracy. Marine fossils collected in the Topanga show these beds to belong to the Turritella ocoyana zone. Megafossils from the overlying Modelo indicate the formation to be older than the Briones of San Francisco Bay and younger than the Monterey of that region (19). According to Reed (2) the Modelo in the eastern Santa Monica Mountains includes zones 1, 2, 3, and four. This is shown in Plate I. It is at variance with data given by Hoots and Rankin (15) indicating the base of the Modelo near Mohn Springs to belong to the Bolivine hughesi or second zone. However, both G. L. Richards (20) and F. W. Bell (21) state that zones lower than the B. hughesi zone are to be found in the region about Mohn Springs. In all probability Reed's statement is true for this locality. Since the Temblor or Turritella ocoyana stage extends up through foraminiferal zone 6, it is probable that the period of intrusion is to be correlated with the Valvulinaria californica zone. Corroborative evidence is the fact that the period of Miocene disturbance recorded in the Hollywood Hills also falls into this zone, as has been shown in figure 1.

The igneous body located in the Topanga Quadrangle with which this report is concerned is irregular and elongate, extending about three miles northwest-southeast and averaging about one-half mile in width. The minimum vertical dimension of the mass is one thousand feet,



Geology of a Portion of the Topanga Quadrangle

- Intrusive igneous rocks
- Topanga
- Vaqueros (?)
- Chico - Martinez

Contour interval = 25 feet

miles

1 0 1

since that much is exposed. Its actual depth range cannot be estimated. Though most of the basic igneous bodies in this region are intruded along post-Topanga faults with which they are probably genetically related, this mass does not show much relation to major faults along its periphery. It is true that most of the igneous contacts of the region are slickensided, but this probably represents minor adjustment of the rigid igneous masses and the more yielding sediments during later compressive forces, occurring long after the consolidation of the magma.

The rocks at the contacts of the igneous mass are usually sandstones which show no great effects of intrusion. Occasionally they are hardened and baked, developing a red color. At one locality limestone was observed at the contact, but even on this rock the exomorphic effects are very slight. The basalt itself generally shows a well defined chilled border zone from a few feet to a few tens of feet thick, being widest where the intrusive mass is thinnest. The microscope shows the chilled rock to be composed of a felted mass of fine feldspar needles set in a mesostasis of dense opaque glass. Occasional calcic labradorite phenocrysts as much as 1.6 mm. in length occur, but seventy to ninety per cent of the rock is composed of feldspar measuring 0.1 to 0.05 mm. in length. Scattered grains of pigeonite and hypersthene occur as phenocrysts and in the groundmass. Magnetite occurs chiefly as a fine dust distributed through the glass.

Occasionally the chilled border facies is light colored and cut by numerous chalcedony veinlets. Under the microscope the rock appears texturally and mineralogically like the common black variety, except that the glass is lighter in color, and in place of the pyroxenes a bright red to yellow mineral appears. The mineral sometimes exhibits a pyroxene-like cleavage with inclined extinction; at other times it has developed without the form of the pyroxene and has even invaded the feldspars along fractures. It resembles iddingsite in some characters, but it shows inclined extinction and low birefringence. It is biaxial and positive with high refringence. Probably it is an alteration pyroxene of deuteric or magmatic origin and related to the iddingsites, which are similar replacements of olivine.

Within the main mass of the intrusive, plagioclase feldspar makes up fifty to seventy-five per cent of the rock. It is a very calcic labradorite (measurements show an average of An69, with very little range). Generally this labradorite is not greatly altered, so that it appears clear and colorless under the microscope. A slight alteration to a light-colored, only slightly pleochroic, and hence probably iron and magnesia poor and aluminum rich chlorite is often present. Kaolinization of feldspars is developed only within a surface zone sometimes less than three inches thick. Winchell (22) states that kaolinization of very calcic plagioclase is rare, and the evidence here would indicate that only the most extreme type of surface weathering can produce it.

Olivine is not present in the fine grained rocks at the contacts of the intrusives. It is present in varying amounts in all sections of the coarse grained rocks, and is most abundant in the central part of the intrusive. Olivine composes twenty to thirty per cent of the interior of this rock mass, and in an associated intrusive exposed along the Topange Canyon road three-quarters of a mile south of Wildwood, this mineral makes up fifty per cent of the rock. The olivine shows a variation in optical character indicating a variation in iron content, but most of it is the ordinary magnesian variety. It has not yet been possible to work out the sequence of crystallization of the various types of olivine, because of the difficulty of identifying them and because of their occurrence as isolated grains. Olivine has suffered more alteration than any of the other minerals. In some cases the alteration has been so selective that the presence of olivine can only be inferred from the form of the alteration products, while the pyroxenes are still fresh. Various types of serpentine result from the breakdown of olivine; antigorite is most common, but chrysotile also occurs. In several sections bowlingite was recognized, often completely replacing the olivine. These alteration products are themselves frequently broken down to more stable chlorites, and magnesian carbonate, often of a fibrous nature, is formed.

Pyroxenes are abundant within the intrusive. Pigeonite is by far the most plentiful; hypersthene is common, augite is present in minor amount. Usually pigeonite was the last pyroxene to crystallize, and often all the other minerals are present as inclusions in large pigeonite anhedrons (poikilitic texture). Other evidence indicates that pigeonite started to crystallize with the other pyroxenes; intergrowths of pigeonite and hypersthene are found. Evidently it is quite possible for two or more different types of pyroxene to crystallize side by side. Pyroxene forms only a small part of the chilled border selvage; it is more plentiful in the interior where it may form 25% of the rock, but usually less. The pyroxenes are not so altered as the olivine. Uralitization is quite rare; incomplete replacement of crystals of hypersthene or pigeonite by single crystals of bastite is fairly common; usually a variety of chlorites is produced within the pigeonite -- a common type has distinct pleochroism and a positive sign and is probably related to clinochlore.

Biotite occurs sparingly within this intrusive; it was discerned in only four sections out of fourteen. It forms irregular shreds or may be intergrown with pyroxene. Being easily altered, it may have once been more abundant, but this cannot easily be determined, since its alteration products are not distinctive. The biotite is normally brown, but usually assumes a green color and then alters to chlorite. The change in color is not accompanied by any noticeable change in optical properties.

An opaque mineral which is probably magnetite but may be titaniferous iron ore is a ubiquitous constituent of the rocks, though it forms only a minor part of them. In the contact selvage it is present as a dense swarm of very small crystals, making the tachylite opaque. In the coarser grained rocks it is segregated into larger grains. A small amount of the magnetite crystallized very early, before the olivine, but the majority of it finished crystallization after most, if not all, of the feldspars. Hence in the fine grained rocks at the contact the majority of the magnetite was still in solution just before consolidation, in spite of the fact that a considerable amount of feldspar had crystallized already. Rapid chilling prevented the formation of large crystals so that magnetite appears as a dust evenly distributed through the tachylite, making it opaque.

The distribution of mineral species within this rock mass indicates that either there has been a remarkable differentiation by crystal settling, or there has been a multiple intrusion. Rocks from near the contacts with the sediments (the chilled border zone) are very rich in feldspar, very low in pyroxene, lacking in olivine. The content of ferromagnesian minerals is much greater in the center of the mass, where feldspar may make up only 25% and olivine all of 50% of the volume. Converted to units of mass, the discrepancy would be even greater. Shand (23) describes the occurrence of olivine rich cores within large bodies of olivine poor or olivine free gabbro, and he accounts for them by differentiation. The case is not exactly similar here, since the olivine free or olivine poor rocks constitute only a very small part of the mass. In order to account for the concentration of olivine within the center of the mass by abstraction of olivine from a thin border zone of apparently olivine free rock would necessitate the assumption of an initial upward extention of the rock mass of thousands of feet, in order that there should be a sufficient volume of magma from which to derive the olivine. A more reasonable assumption seems to be that there were two or more intrusions, and that the magmas were of decidedly different compositions. In order to test the theory it will be necessary to sample the rock mass at small intervals in order to determine whether the changes in composition are gradational or sharp, and it will be of value to study some of the smaller intrusives in the neighborhood to determine whether they have compositions corresponding to the olivine free and the olivine rich types. Since there is no indication of assimilation of country rock along the borders of the intrusive, such as rounded and partially absorbed inclusions, it does not seem likely that the olivine free facies can be accounted for in this manner.

Extrusive Rocks of the San Jose Hills

In the eastern part of the San Jose Hills is a series of flows and agglomerates interbedded with the upper Puente Shale. The area was first described by English (24), whose examination of the volcanic section was rather cursory. He stated: "Most but not all of the igneous rocks in the vicinity of the San Jose Hills are flows and are older than the middle sandstone of the Puente Formation." More detailed work by Harshman (25) has shown that the lava section is contemporaneous with the upper Puente Shale. This is shown by the relations of the lava and shale near Puddingstone Dam. Foraminifera collected by Harshman and identified by F. W. Bell show that the Upper Puente shale ranges through zones 2, 3, and 4. The lavas evidently correspond to the upper and middle parts of the series. Since the Bolivina hughesi or second zone fauna is recorded by Hoots (15) from the Mohn Springs area, these lavas are in part equivalent in age to the Modelo formation in the Santa Monica Mountains.

At the base of the Lava section as exposed in the southern part of the San Jose Hills are flows of hypersthene andesites, some of which are quartz-bearing. They contain scattered calcic labradorite and hypersthene phenocrysts imbedded in a trachytic groundmass of andesine and hypersthene laths and glass, with small shreds of chlorite. Near the top of this series the hypersthene is surrounded by reaction rims of opacite which replace the hypersthene pseudomorphously. The smaller hypersthene grains are completely replaced. Figure 5 shows a photomicrograph of a reaction rim. It is thought that quite possibly this effect is due to the same causes which have produced similar

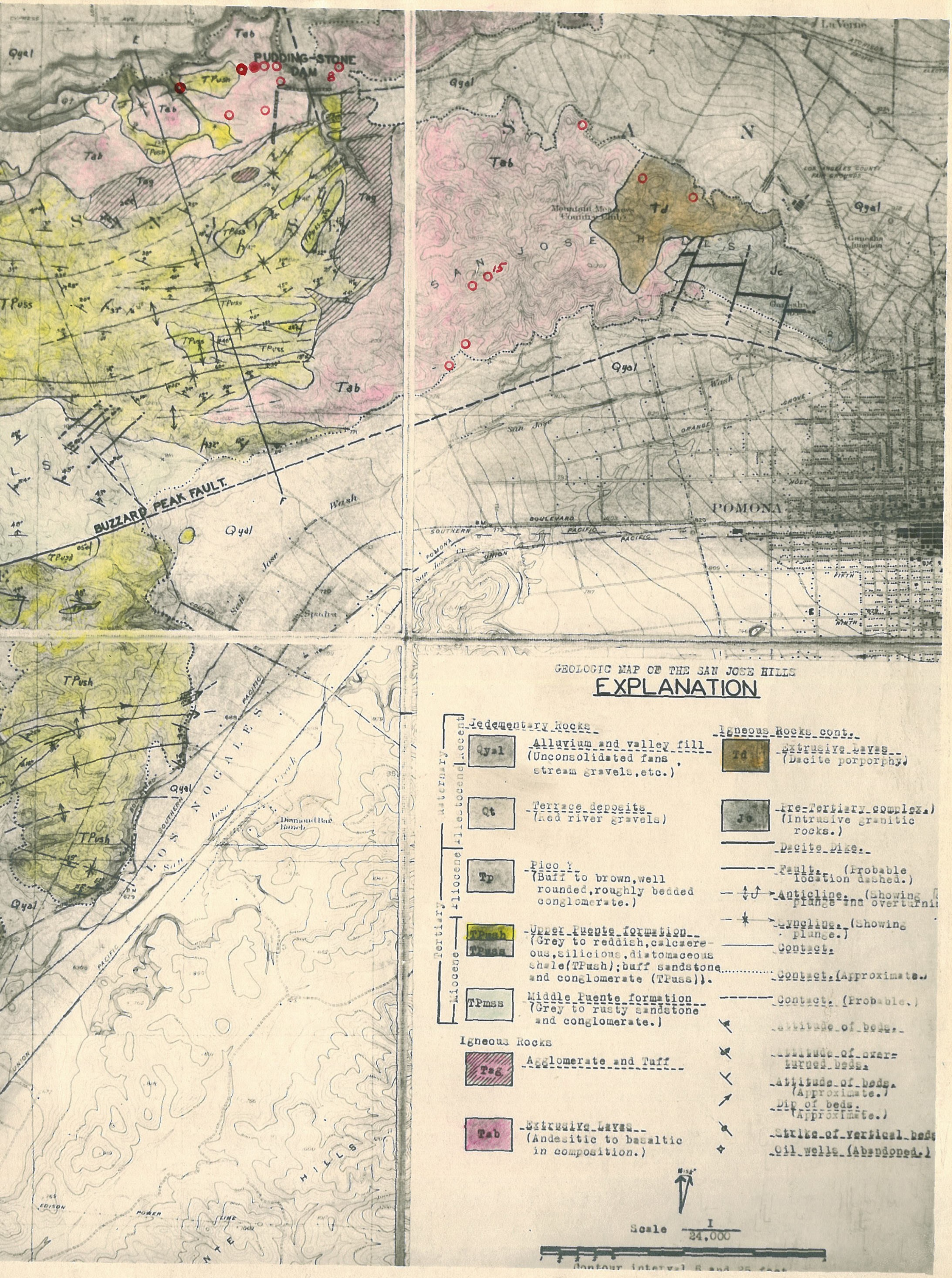

PUDDING-STONE DAM
La Verne
BUZZARD PEAK FAULT
POMONA
SAN JOSE HILLS
LOS NOGALES
Diamond Bar Ranch
Qyal
Tab
Tag
TPush
TPuss
Td
Jc
GEOLOGIC MAP OF THE SAN JOSE HILLS
EXPLANATION
Sedementary Rocks
Quaternary
Recent
Pleistocene
Pliocene
Tertiary
Miocene
Qyal
Alluvium and valley fill
(Unconsolidated fans, stream gravels, etc.)
Qt
Terrace deposits
(Red river gravels)
Tp
Pico ?
(Buff to brown, well rounded, roughly bedded conglomerate.)
TPush
TPuss
Upper Puente formation
(Grey to reddish, calcareous, silicious, diatomaceous shale (TPush); buff sandstone and conglomerate (TPuss)).
TPmss
Middle Puente formation
(Grey to rusty sandstone and conglomerate.)
Igneous Rocks
Tag
Agglomerate and Tuff
Tab
Extrusive Lavas
(Andesitic to basaltic in composition.)
Igneous Rocks cont.
Td
Extrusive Lavas
(Dacite porporphy.)
Jc
Pre-Tertiary complex.
(Intrusive granitic rocks.)
Dacite Dike.
Fault. (Probable location dashed.)
Anticline. (Showing plunge and overturning)
Syncline. (Showing plunge.)
Contact.
Contact. (Approximate.)
Contact. (Probable.)
Attitude of beds.
Attitude of overturned beds.
Attitude of beds. (Approximate.)
Dip of beds. (Approximate.)
Strike of vertical beds
Oil wells (Abandoned.)
Scale 1/24,000
Contour interval 5 and 25 feet

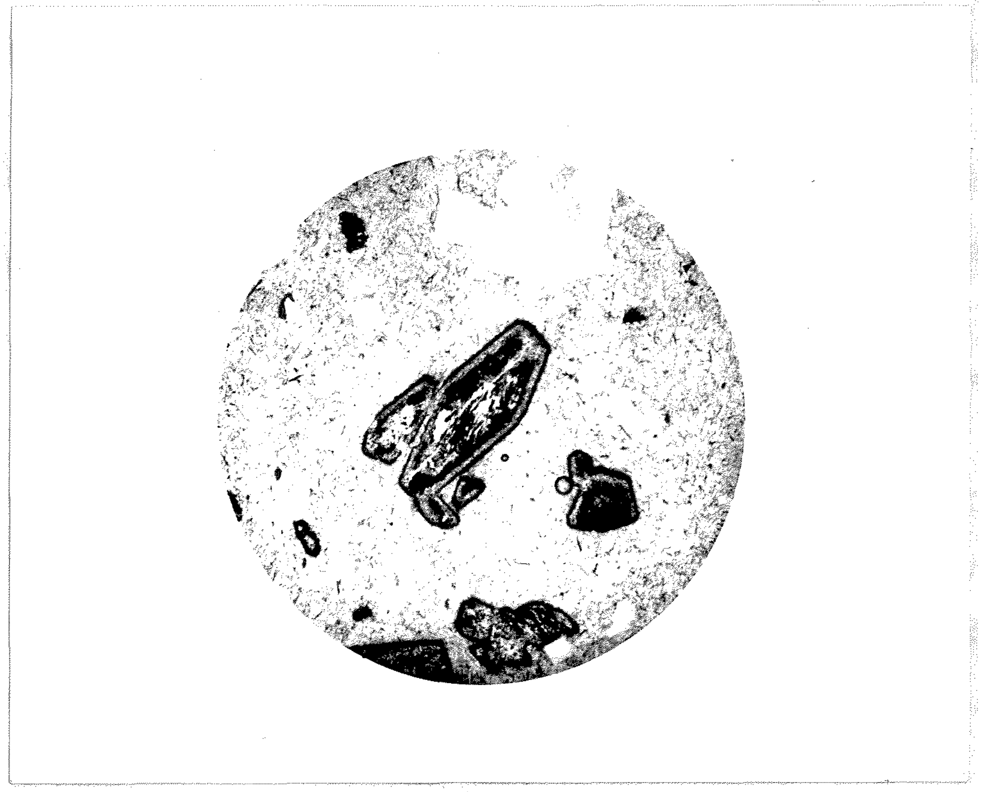
Figure 5

A rim of opacite (most probably magnetite) around a hypersthene crystal. This is analogous to the reaction rims formed about hornblende by re-heating, and is probably due to the same cause. The apparent veinlet is a crack in the section. Specimen from near the base of the lava section of the San Jose Hills, at locality 15. Magnification 19. Ordinary light.

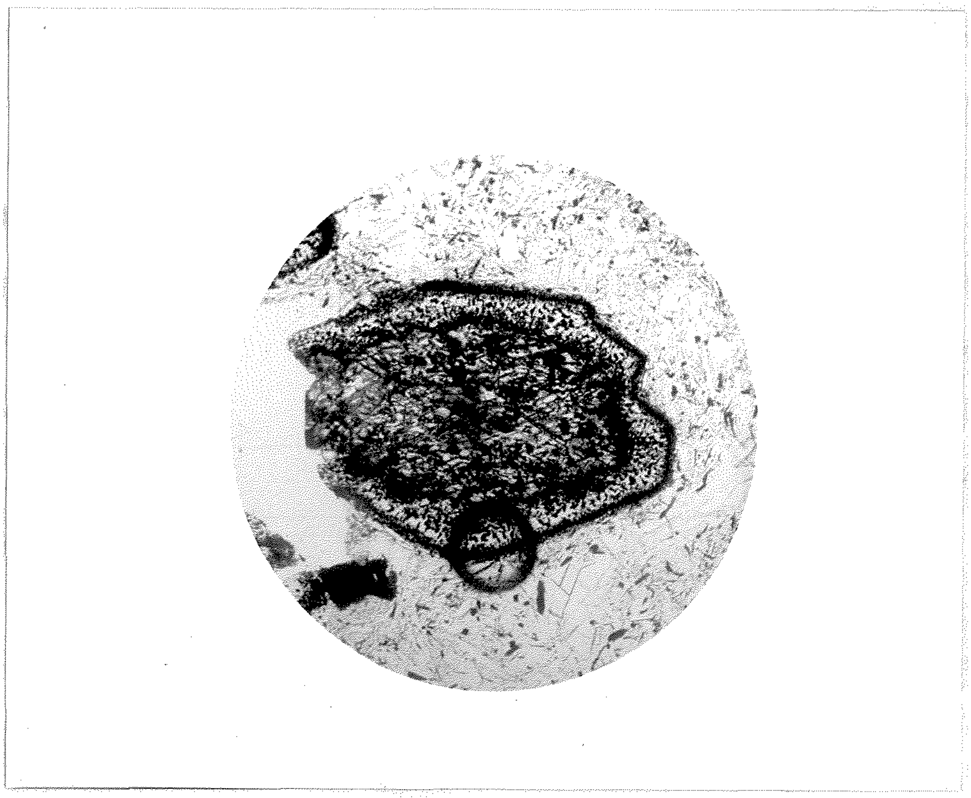
reaction rims (to be described below) on the hornblende of higher flows.

Immediately overlying this basal quartz-bearing hypersthene andesite, one finds one of the numerous and characteristic agglomerate layer of the area. The rocks are light green to violet in color, depending upon the amount of hematite which has developed upon the magnetite grains. These rocks are andesites or quartz-bearing andesites with labradorite phenocrysts and andesine groundmass feldspars. The agglomerates show interesting re-heating effects upon the hornblende. It is thought that the rocks must have originated through explosive activity during which rocks already solidified in a volcanic neck were strongly heated and finally shattered and thrown out of the vent. The rounding of the fragments is anomalous, but explicable if there was a partial remelting of the rock or if sufficient friction between the fragments is assumed. The basis for assuming re-heating is this: the original hornblende is a green mineral with extinction angle of about seventeen degrees. As re-heating progressed the hornblende became brown, the extinction angle approached zero, the birefringence and pleochroism increased, and a rim of ilmenite or titaniferous magnetite formed around the periphery. In extreme cases the hornblende has completely disappeared. The titaniferous opacite of the reaction rim is occasionally replaced by leucoxene, often by hematite. Figure 6 shows two photomicrographs of reaction rims on hornblende in a specimen from locality 8 in the San Jose Hills. This phenomenon has been observed by Howell Williams (26) in products of explosive action at the Marysville Buttes, and he has conducted laboratory experiments which show that artificial heating of normal hornblende produces similar results. Graham (27) has also discussed the problem and presents data

Figure 6



A



B

Reaction rims on hornblende due to re-heating.

A x15 B x48

showing an increase in ferric iron as the process goes on. He also carried on experiments proving that atmospheric oxygen is not necessary for the oxidation of the iron. The similar effects observed on hypersthene in the lower flows may be due to the same causes, but to the best of my knowledge no experimental work has been done along these lines. A small amount of diopside is present in some of the agglomerate.

Interbedded with the agglomerates particularly near the top of the section, more siliceous rocks appear. Just northwest of the small hill west of Puddingstone Dam is exposed a thin green flow of fine grain. The green color is due to chlorite. Other minerals are limonite or goethite, andesine, and oxyhornblende. Occurring abundantly all through the rock is tridymite. The indications are that it chilled rather rapidly from a high temperature. Still higher in the section dacites containing rather abundant quartz appear. These are termed dacite since no potash feldspar can be determined, but the grain size is so small that one cannot be sure of its absence. The presence of a considerable amount of crystalline material with index less than Canada balsam indicates the probable presence of orthoclase. A chemical analysis seems necessary to determine the true character of the rock.

This group of rocks is markedly more siliceous than any others described in this report. Within the group there is a marked increase in silica and a probable increase in potassium as the rocks become younger.

Conclusions

In the descriptions of the individual areas the correlation of the lavas has been discussed. This information is condensed in figure 7. It indicates that vulcanism of some sort was probably going on during most of Miocene time in the Los Angeles area, and that at least four distinct periods are distinguishable. It is interesting that the Miocene was an epoch of world wide vulcanism in which the predominant eruptive rock was of a basic character. Flows are found in the Miocene of all the western United States, in Germany, in India, in South America, and in Alaska. Perhaps many more instances could be cited. In the western United States as a whole, vulcanism increased from comparatively small beginnings in early Miocene to a peak in middle Miocene and decreased to small proportions in upper Miocene; there is a tendency for the volcanics to be predominatly acidic in the early and middle stages, with a distinct late phase of basic flows (28).

In the Los Angeles area much the same history is found. In the early Miocene there was a small initiation of vulcanism exemplified by the andesitic flows of the Northwestern Sierra Madre. This was followed by a double period of activity of great magnitude. In this middle Miocene period two distinct phases of vulcanism can be recognized on structural relations. The composition of the two resulting rock masses is everywhere quite similar, but there is a tendency for the second phase to be richer in olivine. In upper Miocene time we find that vulcanism has almost died out; the break is quite sudden. The siliceous flows of the San Jose Hills were erupted in this period.

It can be seen that there is a sharp division between the

Figure 7

	Faunal Zones	INDIVIDUAL AREAS					
		Lang and Ravenna	Sunland	Las Flores and DryCanyon	Burbank	Topanga	SanJose
M I	1 2 3 4						Siliceous andesite & dacite
O C	5			Olivine rich intrusion	Olivine poor intrusion	Olivine rich intrusion	
E N	6 7 8 9		Olivine poor extrusion				
E	10 11 12 13 14	Hypersthene andesite flows					

compositions of the lower, middle, and upper Miocene lavas, but that the distinction between the two phases of mid-Miocene activity is difficult and obscure. Moreover, it is seen that in contrast to the Western region as a whole, the most basic rocks here occur in middle Miocene strata, and the last phase of activity resulted in more siliceous rocks. Whether this apparent time distribution is to be correlated directly with time or with geographic distribution cannot be stated.

It is also of interest to note that the greatest period of volcanism corresponded with a period of widespread and often intense diastrophism. Whether or not there is any connection or genetic relation between diastrophism and vulcanism is not known. Though the relation just stated might indicate such a genetic relation, it is interesting that in this same area wide-spread vulcanism occurred several times without any accompanying mountain building or faulting. Examples are seen in the Northwestern Sierra Madre, the Hollywood Hills, and the San Jose Hills. In a recent article (29) the theory is brought forward that basalts at depth always follow tectonic fractures. It seems from a study of the distribution of intrusive masses in the Topanga Canyon region, where certainly a considerable amount of erosion has occurred since intrusion, that even at considerable depths basalts may make their own way into the overlying rocks and produce irregular patterns of intrusion.

Further work on the stratigraphic and areal distribution of Miocene igneous rocks should involve the study of all other exposures in this region. In particular, the 13,000 feet thick, post-Temblor lava section of the Western Santa Monica Mountains should be carefully studied and used as a control or type section for further studies.

An interesting sidelight of these studies is the widespread and abundant occurrence of pigeonite. This pyroxene has been fully discussed by Tom Barth (30) who considers it the most abundant mafic mineral in nature, regarding it as the typical pyroxene of all basalts. Recent studies (31) of the physical chemistry and phase relations of pigeonite indicate it to have somewhat the same unstable relations as clinoenstatite. This would tend to discredit the notion that pigeonite is so abundant. However, the occurrence of a pyroxene of small axial angle in large quantities in coarse grained intrusive rocks, in which presumably cooling has been slow enough that equilibrium conditions have been approximated leads one to the belief that pigeonite is not a transitory mineral of the type of clinoenstatite.

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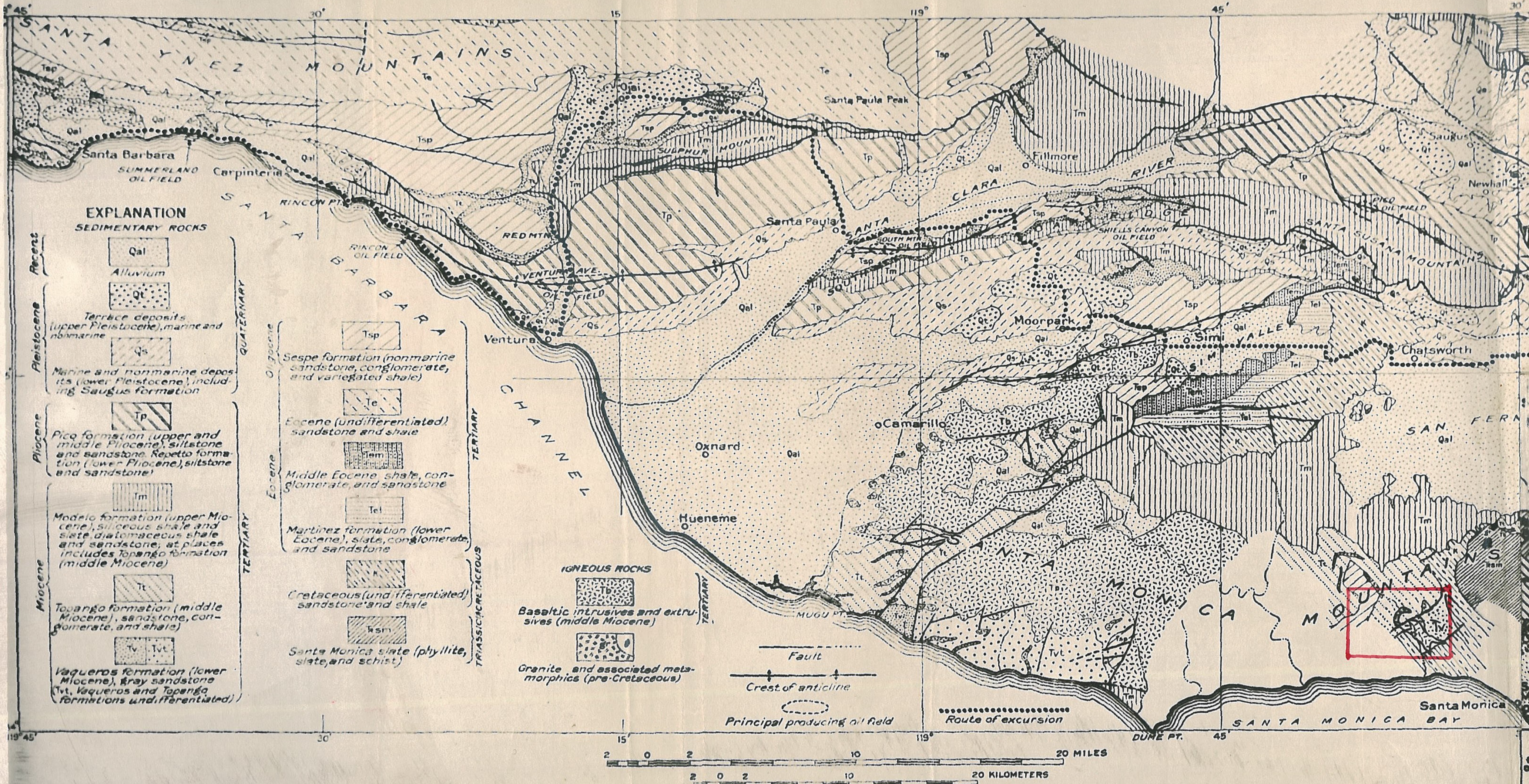
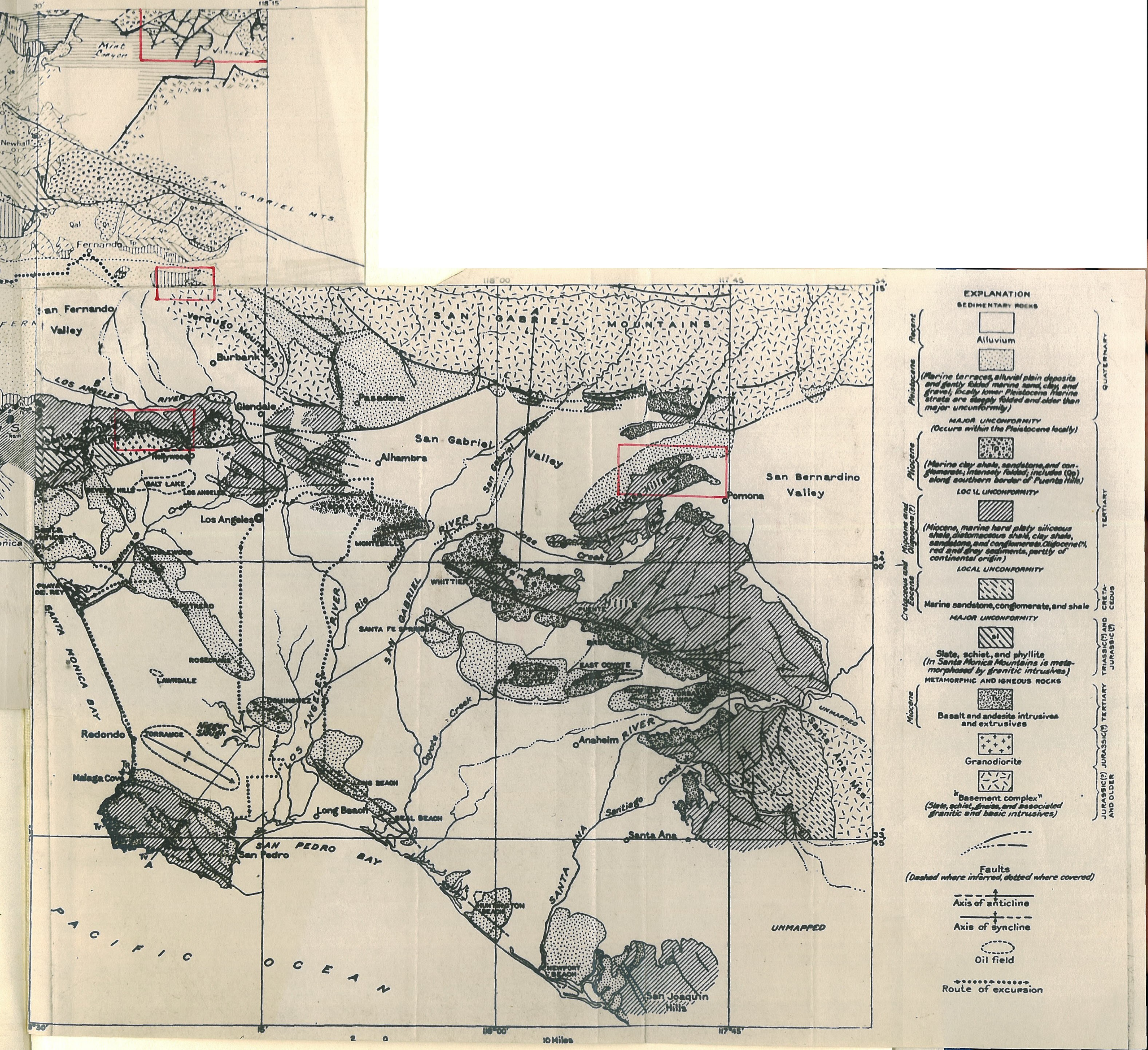


GEOLOGIC MAP OF ROUTE OF EXCURSION, LOS ANGELES TO SANTA BARBARA

The eastern part of the area northwest of Hollywood marked Ʀsm is intrusive granite.

PLATE 11


SAN GABRIEL MTS.
Newhall
Fernando
San Fernando
Valley
Verdugo Mountains
Burbank
LOS ANGELES RIVER
Glendale
Pasadena
SAN GABRIEL MOUNTAINS
San Gabriel Valley
Alhambra
San Bernardino Valley
Pomona
Hollywood
SALT LAKE
Los Angeles
San Jose Creek
Rio Hondo
SAN GABRIEL RIVER
WHITTIER
SANTA FE SPRINGS
EAST COYOTE
ROSECRANS
LAWNDALE
DOMINGUEZ
SANTA MONICA BAY
Redondo
TORRANCE
Malaga Cove
Long Beach
SEAL BEACH
San Pedro
SAN PEDRO BAY
Anaheim
Santa Ana
SANTA ANA RIVER
Santiago Creek
Coyote Creek
Santa Ana Mts.
UNMAPPED
PACIFIC OCEAN
HUNTINGTON BEACH
NEWPORT BEACH
San Joaquin Hills
118°15′
118°00′
117°45′
34°15′
34°00′
33°45′
10 Miles
EXPLANATION
SEDIMENTARY ROCKS
Recent
Alluvium
Pleistocene
(Marine terraces, alluvial plain deposits and gently folded marine sand, clay, and gravel; locally lower Pleistocene marine strata are steeply folded and older than major unconformity)
QUATERNARY
MAJOR UNCONFORMITY
(Occurs within the Pleistocene locally)
Pliocene
(Marine clay shale, sandstone, and conglomerate; intensely folded; includes (Qp) along southern border of Puente Hills)
LOCAL UNCONFORMITY
Miocene and Oligocene(?)
(Miocene, marine hard platy siliceous shale, diatomaceous shale, clay shale, sandstone, and conglomerate. Oligocene(?), red and gray sediments, partly of continental origin)
TERTIARY
LOCAL UNCONFORMITY
Cretaceous and Eocene
Marine sandstone, conglomerate, and shale
CRETACEOUS
MAJOR UNCONFORMITY
Slate, schist, and phyllite
(In Santa Monica Mountains is metamorphosed by granitic intrusives)
TRIASSIC(?) AND JURASSIC(?)
METAMORPHIC AND IGNEOUS ROCKS
Miocene
Basalt and andesite intrusives and extrusives
TERTIARY
Granodiorite
JURASSIC(?)
"Basement complex"
(Slate, schist, gneiss, and associated granitic and basic intrusives)
JURASSIC(?) AND OLDER
Faults
(Dashed where inferred, dotted where covered)
Axis of anticline
Axis of syncline
Oil field
Route of excursion