PLIOCENE CONGLOMERATES OF THE LOS ANGELES BASIN AND THEIR PALEOGEOGRAPHIC SIGNIFICANCE

Thesis by

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ABSTRACT.

The Los Angeles Basin of southern California is 50 miles long and 25 miles wide, and is bounded by the Pacific Ocean, the Santa Monica, San Gabriel and Santa Ana Mountains and the Perris Block. It contains an enormous thickness of Miocene, Pliocene and Pleistocene strata.

Physical conditions of origin and the nature of sediments are as closely related as cause and effect. Since the physical conditions of past epochs no longer persist, the sediments may bear them witness. Conglomerates are especially suited for the purpose of locating the source areas of strata, because they preserve not only the original minerals, but the texture, structure and general appearance of the original rocks.

Conglomerates contain only a partial representation of the list of formations present in a source area. The relative abundance of the various rock types occurring in a conglomerate is not proportional to their relative quantities in the original district. This is due mainly to the selective action resulting from difference in resistance to weathering and from differential destruction during transportation.

The Santa Monica Mountains furnished quantities of pholas-bored limestone breccia from the limestone lenses of the Modelo formation, to the Pliocene beds of the west side of the Los Angeles Basin. Conglomerates derived from this range are also characterized by pebbles and cobbles of igneous rocks, released by the break-down of Miocene conglomerates, reworked and recomposed in the Pliocene sea.

The San Gabriel Mountains shed conglomerate material characterized by an abundance of pink quartz-orthoclase granite, pink quartz-orthoclase pegmatite and aplite, and white spotted albiclase diorite. These mountains were emergent, but of too low relief during the Pliocene and

lower Pleistocene to be of importance as a source for clastic sediments. They were, however, a dominant source during Miocene and upper Pleistocene.

Conglomerates of Perris Block origin are characterized by large quantities of white quartz-albite pegmatite and aplite. During the Pliocene and lower Pleistocene the northwest part of the Perris Block was mountainous. From these mountains enormous quantities of coarse and fine clastic material were removed, to be deposited in the northeast quarter of the Los Angeles Basin, in the area now occupied by the Puente, Coyote, Monte Bello, and Repetto Hills. The Perris Mountains were the most important single source for the Pliocene and lower Pleistocene sediments.

The Santa Ana Mountains have been contributing terrestrial material to the Los Angeles Basin since before the advent of the Pliocene Epoch. Conglomerates from these mountains are characterized by quantities of feldspathic porphyries ranging from andesite to latite, quartzite, Triassic sandstone and siliceous slate.

In the middle Pleistocene a diastrophic revolution occurred in southern California, and the modern physiographic expression developed. The Santa Monica, San Gabriel, San Bernardino, San Jacinto and Santa Ana Mountains were thrust upward along fault planes. The rejuvenated mountains released floods of coarse and fine terrestrial material to the Los Angeles Basin, and fanglomerates began to accumulate at the mountain fronts. The Perris Block, formerly a positive and mountainous element, became depressed as a result of the structural revolution. The Santa Ana River maintained its course, became an antecedent stream, and grew headward into the San Bernardino Mountains.

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By Everett Carlyle Edwards

INTRODUCTION

LOCATION OF AREA EXAMINED

The Los Angeles Basin is limited on the south and southwest sides by the Pacific Ocean and the San Pedro Hills. On the west and north are found the Santa Monica and San Gabriel Mountains, on the east and southeast the Santa Ana Mountains and the San Joaquin Hills. These boundaries embrace an area 50 miles long and 25 miles wide.

In this basin thick series of sedimentary strata were deposited during the Tertiary, and except for those portions around the margin which have been carried away by subsequent erosion they remain preserved for study.

During the late Pleistocene and Recent Epochs, alluvial fans originating at the mountain fronts have proceeded seaward to merge with marine deposits. They effectively conceal most of the Tertiary measures previously laid down. The present exposures of these rocks are confined, therefore, to the margins of the mountainous areas and to the hills standing above the general level of the alluvial plains. Localities within the Los Angeles Basin which afford good exposures of Pliocene strata are the San Pedro Hills, the hills in the northern part of the city of Los Angeles, Repetto Hills, Puente Hills, Burruel Point, and the San Joaquin Hills. The geographic position of these may be found in Figure 1.

Because the Tertiary strata consist almost entirely of clastic deposits, the materials composing them must have originated in emergent land masses, from whence they were carried by transporting media to their place of deposition. The source of the sediments may have been any territory not now occupied by these or contemporaneous rocks. During the past year a study has been made of the region lying between the Ventura Basin on the north and the San Diego Mountains on the south, and from the Mohave Desert on the north and east to the Pacific Ocean. It is believed that this region contains the sites of the ancestral land masses which furnished the clastic material for the Tertiary formations.

PURPOSE OF INVESTIGATION

The complete story of a sediment should describe its derivation, transportation, mode of deposition, composition and subsequent alteration. It should furthermore specify the time during which these events took place; and, as Grabau [1] mentions, "the study of lithogenesis must go hand in hand with the study of paleogeography."

In this paper only the conglomerates of the Pliocene will be described in detail. However, the conglomerates offer so much information concerning the physical conditions and events of the times, that the data concerning them will be set forth. Conglomerates have a decided advantage over fine clastics in indicating their genesis, because their pebbles and boulders not only contain the original minerals, but the texture, structure and general appearance of the parent rocks as well.

Tectonic movements, physiographic forms, drainage, climate and oceanic currents influence the types of clastic sediments formed.

[1] Grabau, A.W. Interpretation of sedimentary rocks: Geol. Soc.America Bull., vol. 28, No. 4, p. 743, 1917.

Physical conditions and sediments are closely related. When the former are not observable, a study of the sediments may be useful in discerning them.

The purpose of this paper, then, is to present the facts about the Pliocene conglomerates of the Los Angeles Basin, and to draw from them such inferences regarding the paleogeography as seem reasonable; to contribute thereby to the general geologic knowledge of the Pacific coast region, and, it is hoped, to the interpretive methods used in the science of sedimentary petrology.

It is not the purpose of this paper to present new correlations, nor to affix precise boundaries to the various members which make up the Pliocene. The zoning of the individual units is now being done successfully by the use of foraminifera; and the literature already contains an abundance of formational names.

METHODS

The first operation taken in the investigation was concerned with the source of the sediments. The surrounding areas which could not have been contributory land masses during the Pliocene were eliminated. The remaining territory from which clastic material might have been derived was then examined. The formations present in each district were classified, so that if pebbles and boulders of those types were later found in the conglomerates they could be assigned to their proper source. Unusual varieties of rocks characteristic of certain areas and absent in others were given special attention, since they would have considerable diagnostic value if encountered in the conglomerates.

The Pliocene strata were then studied at their outcrop localities. Pebbles and boulders found in the strata were identified, and "pebble counts" made to obtain the relative percentage of each of the types. It was found that not only could individual pebbles with distinctive characteristics be recognized and referred to their respective source areas, but that whole assemblages of pebbles and boulders - the conglomerate beds themselves - could be treated in a like manner. The available conglomerates were diagnosed in this way, and from the data obtained the physiographic history of the region was formulated.

Pebble counts were made in the following manner. When it was desired to make a count in river gravels, a square was marked out on the surface of a gravel bed. All of the pebbles, cobbles and boulders within this square were classified and counted. The same method was used with conglomerate outcrops, except that in vertical exposures a section of the conglomerate was raked down to the base of the outcrop, and the pebbles then counted and classified.

After the pebble counts were made, larger areas of the exposures were scanned in a search for rock types not represented in the count because of their scarcity. This additional precaution proved to be very worth while in furnishing important data.

In a study of conglomerates which includes the identification and classification of thousands of pebbles and boulders of igneous rocks, it is naturally impracticable to determine microscopically the feldspars in each pebble. It has been found that when orthoclase occurs as a constituent mineral it is almost always pink or flesh colored. In the case of granites, quartz monzonites, orthoclase pegmatites and aplites, the orthoclase is present in sufficient quantity to be readily identified by its color in the hand specimen. In quartz diorites and granodiorites the plagioclase feldspar is invariably oligoclase to andesine. In granodiorites the orthoclase is inconspicuous, and the writer has no doubt classified many granodiorites as quartz diorites. However, it is believed that such errors have in no way affected the results of this investigation.

Igneous rocks were classified on the basis of their feldspar and quartz contents. The feldspars were identified by Tsuboi's[1] method, fully described in a current reference book by Winchell.[2]

In this method a feldspar anhedron is extracted from the rock and pulverized. The resulting powder consists of flakes of the crystal, most of which are parallel to the surfaces 010 or 001. Portions of the powder are immersed in different liquids of known index of refraction. The powder is examined under the microscope and the values for Ng and Np are determined by comparison with the index of refraction of the liquid in which it is immersed. The feldspar is then identified from Tsuboi's table. This is a very rapid method as it obviates the necessity of making thin sections.

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[1] Tsuboi, Mineral Mag., vol. XX, p. 103, 1923.

[2] Winchell, Alexander N., Elements of Optical Mineralogy, Part II, pp. 298-299, 1927.

W.H.Holman, Guy Miller, A.O.Woodford, William J.Miller, Frank E.Bell and Hampton Smith. Data obtained from other publications are acknowledged in the bibliography.

PLIOCENE CONGLOMERATES OF THE LOS ANGELES BASIN

POSSIBLE CONTRIBUTORY AREAS

The portion of southern California considered in this report may be subdivided into the following physiographic provinces: Ventura Basin coinciding roughly with the area drained by the Santa Clara River, Santa Monica Mountains, San Gabriel Mountains, Mohave Desert, San Bernardino Mountains, Imperial Valley, San Jacinto Mountains, Perris Block, Santa Ana Mountains, and the Los Angeles Basin. The location of these is shown in Figure 1.

Regions which were receiving sediments during the Pliocene, could not have been undergoing denudation simultaneously. Hence no regions which are now underlain by Pliocene strata could have been sources for the clastic material of that age in the Los Angeles district. For this reason the Ventura Basin and the Imperial Valley may be eliminated from the list of source areas, as they are underlain by beds of Pliocene age.

The Mohave Desert did not furnish coarse clastic material to the Pliocene deposits of the Los Angeles Basin. In that region the more prominent topographic features are due to the superior resistance to erosion of a quartz-orthoclase granite. This type of rock would be well represented in conglomerates derived from the Mohave Desert. It is not present in the Pliocene beds of the Los Angeles Basin.

In order that material from the Mohave Desert enter the Los Angeles Basin it would have to traverse the San Gabriel area or be carried around it. In either case it is probable that San Gabriel debris would be added to the sedimentary load of the rivers. The absence of San Gabriel material in the Pliocene and lower Pleistocene measures, adds support to the idea that the Mohave Desert did not contribute coarse sediments to the Los Angeles Basin during those epochs.

Prior and subsequent to the epochs under discussion, the north side of the San Gabriel Mountains was shedding sediments northward into the Mohave area. A double reversal of drainage would be necessary for the latter district to contribute material southward during the Pliocene and lower Pleistocene. These conditions are possible but not probable, especially in view of the information contained in the preceding paragraphs.

Of the provinces originally considered, there remain the Santa Monica, San Gabriel, San Bernardino, San Jacinto and Santa Ana Mountains, and the Perris Block as potential source areas. To these may be added whatever land may have existed toward the southwest now under the ocean.

FORMATIONS PRESENT IN POTENTIAL SOURCE AREAS

The surfaces of the mountains of southern California are in general covered by a deeply weathered mantle. Outcrops are numerous, but often the rocks are so badly decomposed as to make their classification difficult or impossible. Differential weathering is very conspicuous. The more resistant dikes and veins, the harder layers of the metamorphosed sediments, and the less easily weathered granitic formations form projections, ribs, and knobs above the generalized contours of the mountains. Under the continued action of weathering these more resistant formations gradually disintegrate. The fragments and blocks slide or roll down the mountain slopes.

An examination of the weathered mantle, consisting as it does of soil and fragments of the rocks just mentioned, furnishes a very unreliable estimate of the relative quantities of the various kinds of formations composing the mountains. However, the types found in the float should be well represented in any conglomerates derived from those mountains.

Journeys over the existing mountain roads, and particularly, traverses up the main canyons gave a perspective of the kinds of formations in the mountains and their relative quantitative importance. In addition to this, pebble counts were made of the gravels in the river beds of most of the important canyons near their points of contact with the alluvial fans. By these methods, it is believed, a fairly comprehensive idea was obtained of the formational content of the respective areas. Also, full use was made of previously published reports, so that the survey might be as complete as possible.

SAN GABRIEL MOUNTAINS: Adjoining the Los Angeles Basin on the north are the San Gabriel Mountains. They trend approximately east and west for a distance of 60 miles and are 20 miles wide. The highest point, San Antonio Peak (Mount Baldy), has an altitude of 10,080 feet.

Regarding the types of rock composing the western portion of the San Gabriel Mountains, Miller[1] states:

> The metamorphic rocks comprise schists, crystalline limestones and quartzites of Jurassic age or older. This old sedimentary series, more or less associated with amphibolites, has been invaded by large bodies of diorite, granite and granodiorite. Injection gneisses are very common. There are many sharply defined dikes of aplite, porphyry, and diabase.

Hill[2] describes the basement complex of a part of the western end of the San Gabriel Mountains as follows:

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1. Miller, W.J., Geomorphology of the southwestern San Gabriel Mountains: Univ.Calif.Publ., Bull.Dept. Geol., vol.17, p.197, 1927-1928.

2. Hill, M.L., Structure of the San Gabriel Mountains, north of Los Angeles, California: Univ.Calif.Publ., Bull. Dept. Geol., vol. 19, no. 6, p. 140, 1930.

Crystalline rocks outcrop in the northern part of the area under discussion. They consist predominantly of para-, ortho-, and injection gneisses. Granitic, pegmatitic, aplitic, and lamprophyric rocks also occur. Quartz-feldspar-biotite and quartz-feldspar-hornblende gneisses are the most abundant rock types. Limestones and quartz-mica schists are frequent.

Arnold and Strong[1] in a more detailed petrographic paper covering a larger area state:

> The following rocks have been found by the writers in the San Gabriel Mountains and are described in this paper: Biotite-granite, quartz-monzonite, granodiorite, hornblendite, aplite, micropegmatite, quartz-hornblende-porphyry, diabase porphyry, hornblende-diorite-gneiss, biotite-granite-gneiss, hornblende-schist, and garnetiferous schist.
>
> The Sierra Madre range consists essentially of granodiorites and gneisses, with more acid areas in which the country rock is quartz-monzonite. Large dikes or included masses of hornblendite are present at several localities, notably on the south slopes of Mount Lowe, while at other places smaller dikes of quartz-hornblende-porphyrite and diabase porphyry cut the country rock. Aplite dikes and quartz veins are of common occurrence,***.

From this same paper a list was prepared of the rock types and their constituent minerals. A sedimentational problem is not so much concerned with the origin of the minerals in a source rock as with their presence there; so minerals produced by hydrothermal or any other action will be included with the constituent minerals. The list follows;

Biotite granite:	orthoclase, microcline, quartz, plagioclase (oligoclase), biotite, muscovite, magnetite, hornblende, chlorite, epidote.
Quartz-monzonite:	orthoclase, microcline, oligoclase-andesine, quartz, hornblende, biotite, magnetite, apatite.
Granodiorite:	("commonest rock in the San Gabriels"), quartz, oligoclase-andesine, orthoclase, hornblende, biotite, titanite, zircon, magnetite, apatite, epidote, muscovite, chlorite.
Hornblendite:	hornblende, plagioclase feldspar, magnetite, ziosite.
Aplite:	quartz, orthoclase, biotite, epidote, chlorite, muscovite.

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1. Arnold, Ralph and Strong, A.M., Some crystalline rocks of the San Gabriel Mountains, California: Geol.Soc.America Bull., vol. 16, pp. 188-204, 1904.

Quartz-hornblende-porphyrite: plagioclase feldspar, quartz, orthoclase, pyroxene, hypersthene, magnetite, pyrite, ilmenite, apatite, epidote, chlorite.

Diabase porphyry: orthoclase, plagioclase, pyroxene, chlorite, enstatite.

Hornblende-diorite-gneiss: plagioclase, orthoclase, quartz, hornblende, magnetite, chlorite, epidote, hematite.

Biotite-granite-gneiss: orthoclase, biotite, quartz, oligocene, hornblende, epidote, magnetite, zircon, chlorite.

Hornblende-schist: hornblende, orthoclase, plagioclase, chlorite.

It is necessary to add further facts to the above summaries. In the northwestern portion of the mountains, between Soledad Canyon on the north and the upper reaches of Tujunga Canyon and Mill Creek on the south, there is a large body of anorthosite, of a distinct type, which has not been observed in any other locality. This rock is of a light, translucent, stone gray color. It is composed of plagioclase feldspar and occasional, irregularly distributed, bunchy, sometimes disseminated crystals of green hornblende. Individual crystals of the feldspar range from 1/4 inch to 4 inches or more in width. The feldspar is andesine ($Ng > 1.545$, $Np < 1.560$) rather than labradorite, and there may be some question as to the propriety of the use of the term "anorthosite". Hershey[1] calls attention to this occurrence in an early publication, and quotes a letter from Dr. A.C. Lawson concerning it.

> D. An allotriomorphic granular aggregate of plagioclase having symmetrical extinctions of albite lamellae ranging up to 25° and a sp.g. of 2.65. This feldspar is andesine. It is rather cloudy with the decomposition products. With the andesine there is a little green hornblende but not enough to detract from its essentially feldspathic character. The feldspar forms two kinds of aggregates in respect of texture, a fine-grained granular aggregate accompanying the coarser aggregate of anhedrons.

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[1] Hershey, Oscar H., Some crystalline rocks of southern California: The American Geologist, vol. 29, pp. 285-286.

> The rock bears the same relation to dyorite that anorthosyte does to gabbro.

Hershey then states:

> This plutonic series is unique for southern California, if not for the state at large, judging from its appearance in the field.

Pebbles and boulders of this anorthosite were found in the river gravels of Soledad Canyon, Pacoima Creek, Little Tujunga and Tujunga Canyons, but were not found in the Arroyo Seco or other canyons farther east. Its presence in conglomerates will be mentioned later.

The western half of the San Gabriel Range was found to contain a greater proportion of rocks carrying the flesh colored orthoclase feldspar than the eastern half. This statement applies also to the Verdugo and San Rafael Hills. Granite is present in considerable quantity and contains conspicuous amounts of the pinkish orthoclase. Likewise aplites and pegmatites occur in abundance, and they are of the quartz-orthoclase variety. These rocks weather less rapidly than the granodiorites and are well represented in float fragments scattered over the mountain slopes, and in the river gravels.

The eastern half of the San Gabriel Mountains contains some rock types not found in the western half. They consist of white aplites and pegmatites composed of albite and quartz, with occasional flakes of colorless mica, and frequently speckled with orange-red garnets. The albite, examined microscopically, showed indices of refraction $Ng > 1.530$, $Np < 1.540$, sign (+).

These aplites and pegmatites show unusual resistance to corrasion and corrosion. Pebbles and boulders of these rocks may be found in the river gravels of San Gabriel and San Antonio Canyons. From a casual inspection one might mistake them for vein quartz or white quartzite, especially if they are badly chatter-marked.

Another type not mentioned in the quoted summaries is one which will be spoken of in this report as the "dappled" diorite, for lack of a better name. An excellent outcrop of it in a recent road cut, is located approximately two miles northeast of the confluence of the North and West Forks of the San Gabriel River. (See loc. 17, fig. 1.) The formation crops out extensively, as numerous pebbles and boulders of it are found in the stream channels from Pacoima Creek on the west to San Antonio Canyon on the east.

The rock is medium grained, nearly white, but contains black to greenish black aggregates of biotite, sometimes hornblende. These aggregates are flat or disc shaped, about 1/4 inch in diameter. Most but not all are in parallel arrangement and give the rock a gneissic texture. From one perspective they produce a spotted or dappled appearance. When viewed parallel to the gneissic plane, they appear as thin seams or spindle shaped lenses. The light colored minerals consist of quartz and albiclase, ab 10-20, an 80-90. Microscopically the feldspar shows indices of refraction $Ng > 1.530$, $Np < 1.545$. The gneissic planes are believed to be due to primary eutaxitic flow, and the rock may represent a differentiate midway between the granodiorite and the aplite and pegmatite. This formation is found only in the San Gabriel Mountains, and is diagnostic of them.

The representative assemblages of formations occupying various portions of the San Gabriel Mountains as indicated by their classification and percentage tabulation from pebble counts, taken near the mouths of several of the large canyons, are given below:

Pacoima Creek(Loc. 12, fig. 1.)

	Percent
Granodiorite	17
Hornblende biotite gneiss	14
Diorite (hb.)	12
Anorthosite	12
Pink pegmatite	9
Crystalline limestone	8
Granodiorite gneiss	6
Pink granite	5
Biotite schist	4
Pink aplite	4
Quartz diorite	2
Rhyolite porphyry	2
Dappled diorite	2
Quartzite	2
Hornblendite	1
	100

Arroyo Seco (Loc. 14, fig. 1.)

	Percent
Pink granite	16
Granodiorite	16
Pink pegmatite	13
Dappled diorite	12
Quartz diorite	9
Hornblende biotite diorite	9
Biotite gneiss	7
Pink aplite	6
Biotite schist	3
Quartz monzonite	4
Quartzite	2
Hornblendite	2
Rhyolite	1
	100

San Antonio Canyon(Loc.17,fig.1.)

	Percent
Quartz diorite and gneiss	17
White quartzite	15
Granodiorite	11
Feldspathic porphyry	10
Biotite gneiss	6
Dappled diorite	6
Hornblende gneiss	5
White albite pegmatite	5
Dark quartzite(cf.Triassic)	4
Biotite schist	4
White aplite	4
Pink pegmatite	3
Sedimentary schist	2
Crystalline limestone	2
Pink granite	2
Vein quartz	2
Sericite schist	1
Basalt	1
	100

Tujunga Canyon (Loc. 13, fig. 1.)

	Percent
Pink granite	21
Granodiorite	16
Pink pegmatite	10
Anorthosite	10
Biotite schist and gneiss	8
Quartz diorite and gneiss	10
Pink aplite	6
Granodiorite gneiss	5
Crystalline limestone	4
Quartz monzonite	4
Hornblendite	3
Quartzite	2
Dappled diorite	1
	100

San Gabriel Canyon (Loc. 15, fig.1.)

	Percent
Granodiorite and gneiss	18
Feldspathic porphyry	15
Dappled diorite	10
Biotite schist	10
Hornblende schist and gneiss	6
Pink pegmatite	6
Pink aplite	5
Quartz diorite	5
Pink granite	5
White albite pegmatite	4
White albite aplite	3
Basalt	3
Crystalline limestone	2
Gabbro porphyry	2
Diabase	2
Quartzite	2
Chlorite schist	1
Pyroxenite	1
	100

From all of the fore-going it is evident that granodiorite forms a great preponderence of the mass making up the San Gabriel Range, especially when the related quartz monzonite and quartz diorite are included. From field work the impression is gained that probably 70 percent or more of the mountain's mass is made up of those rocks. Other types commonly found are granite, various gneisses other than those included with the granodiorite, metamorphosed sediments, anorthosite, hornblendite, quartz-orthoclase aplite and pegmatite, dappled diorite, porphyries, diabase and basalt. Evidence offered by float fragments and pebble counts is that this general order of relative quantitative abundance of the different formations is not applicable to the pebbles and boulders derived from them; the change of percentage quantity being caused by differential weathering and the destructive action of transportation.

SANTA MONICA MOUNTAINS: The northwestern limits of the Los Angeles Basin are the Santa Monica Mountains. They consist of a range of high hills about 45 miles long and of 8 miles maximum width, extending east from point Mugu on the coast to the Los Angeles River north of Hollywood. Their maximum altitude is slightly over 2,800 feet.

A varied assortment of rock formations is found in the Santa Monica Mountains. The igneous rocks consist of granite, granodiorite, diorite, basalt, trachyte, tuffs, and breccias. Regarding some of these Hoots[1] has the following to say:

> These granitic rocks are variable in character and consist of light-gray biotite granite and dark-gray diorite and granodiorite, the last consisting of green hornblende, quartz, orthoclase, and plagioclase feldspar and biotite, together with apatite, zircon and garnet in varying proportions. The granodiorite near the border of the large intrusion north of Beverly Hills is distinctly gneissic and highly micaceous, a characteristic which is well exposed in and near Franklin Canyon.

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[1] Hoots, H.W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U.S.Geol.Survey, Prof. Paper 165-C pp. 89, 90, 1930.

Schürmann[1] collected samples of igneous rock from Cahuenga Pass, Mulholland Drive and Topanga Canyon, some of which he described as follows:

> Hollywood Hills diorite:- typical granitic, hypidiomorphic crystalline structure. The maximum size of the individual crystals 6 mm, dull white feldspar, dark hornblende, brown chlorite secondary.
>
> Spec. 2,66 chiefly plagioclase, green to greenish brown hornblende, quartz and a little orthoclase. (Heavy residuals) zircon and apatite, enstatite. The diorite is cut by 2-3 cm. aplite with twinned plagioclase, some fine dark mineral and quartz.
>
> Spec. 2,68 Mostly plagioclase, little quartz, few orthoclase crystals, zircon, muscovite, apatite and hypidiomorphic crystals of enstatite.
>
> Spec. 279 Panidiomorphic crystalline structure. Fine-grained gray intrusion. Plagioclase and hornblende, garnet (spesartite). The plagioclase dull white, hornblende brown pleochroic. Also orthoclase, quartz, "ore", brookite. Decomposition products chlorite
>
> (By Horse-shoe Bend, Topanga Canyon)
> Spec. 303. Plagioclase, "ore", augite, biotite, hypersthene, hornblende, chlorite.
>
> Spec. 271. Natrolite, labradorite, augite, magnetite.

Concerning the general geology of the district he says:

> The rocks of which the Hollywood Hills of the Los Angeles District are composed may be separated into three groups.
>
> The oldest group is of Triassic age, of more or less metamorphosed rocks with deep seated intrusives. The granite and diorite intrusives are probably Jurassic, as in the Sierra Nevada. Above these follows a thick sedimentary series, which extends from the Cretaceous into the Pliocene, and which is of about 16 kilometers thickness. In them one finds the third rock group in the form of basic effusive and intrusive rocks. The Cretaceous and Tertiary sediments are very diverse; with the major types of sandstone, shale and conglomerate, one finds also limestone and diatom strata. *** The eruptives belong practically all in the Miocene, are all more or less basic, and contain tuffs, mud flows and breccias.

[1] Schürmann, H.M.E, Beitrag zur Petrographie der Hollywood Hills (Santa Monica-Gebirge) bei Los Angeles, Süd-Kalifornien: Centralblatt für Mineralogie, Abt. A Mineralogie, pp. 7-13, 1928.

The contribution by Hoots, previously mentioned is the most complete, detailed description of the geology of the Santa Monica Mountains. With its aid, the sedimentary formations of the district will be briefly summarized in the succeeding paragraphs.

Triassic (?) Santa Monica slate: A black slate which includes the more metamorphosed phases such as mica schist, dark gray phyllite, and a spotted rock containing idioblasts of cordierite.

Chico formation: Brown and gray sandstone, conglomerate and shale; also contains reefs of white algal limestone(?).

Martinez formation: Soft brown shale, sandy shale and sandstone, with hard limestone concretions containing fossils. Prominent discontinuous reefs of white algal limestone.

Vaqueros(?) and Sespe(?) formations: Light gray and red conglomerates and conglomerate sandstones.

Topanga formation: Sandstone, conglomerate and shale, intercalated with basalt and pyroclastic rocks.

Modelo formation: The lower half of the formation consists of soft light-gray to brown well-bedded shale, banded hard platy siliceous shale, thin and thick massive beds of sandstone, conglomeratic sandstone, and volcanic ash. The upper part consists of white "punky" diatomaceous and foraminiferal shale and fine sandstone, grading laterally into clay shale and sandstone. Hoots mentions that the Modelo formation contains numerous beds, concretions and concretionary lenses of hard, light-gray, yellow and brown limestone. These are believed to be represented in substantial amounts in the Pliocene conglomerates exposed in the City of Los Angeles section and elsewhere.

SAN BERNARDINO MOUNTAINS: Almost due east of the San Gabriel Range the San Bernardino Mountains are located, being separated from the former by Cajon Canyon. Like the other mountains described they trend nearly east and west. They are approximately 50 miles long and 20 miles wide at the widest part. The two highest peaks, Mount San Gorgonio and San Bernardino Peak have elevations of 11,485 and 10,630 feet respectively. The San Bernardino Mountains lie forty miles or more northeast of the Los Angeles Basin proper.

A reconnaissance of these mountains proves that by far the greatest quantity of rock composing them is pink granite, which in composition occasionally varies to quartz monzonite or granodiorite. Rocks of secondary importance are quartzite, various types of schist, crystalline limestone, aplite and pegmatite.

The most detailed reports available covering the geology of portions of the San Bernardino Mountains are those by Vaughan[1], and Woodford and Harris[2].

Vaughan separates the igneous types under three headings: Heterogeneous mass of granites, Cactus granite, and basalt. The pre-Tertiary sediments are called the Arrastre quartzite, Furnace limestone and Saragossa quartzite. The Tertiary and later sediments are separated into the Potato sandstone, Lion sandstone, Hathaway sandstone and shale, Santa Ana sandstone, Pipes fanglomerate, Deep Canyon fanglomerate, Coachella fanglomerate, Cabezon fanglomerate, Heights fanglomerate, glacial till and alluvium.

Some of the granites described in his paper may be tabulated as follows:

1. Quartz and pink orthoclase. Some albite-oligoclase is present. Other minerals present are biotite, muscovite, apatite, magnetite and garnet.

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1. Vaughan, F.E., Geology of San Bernardino Mountains north of San Gorgonio Pass: Univ. Calif.Publ., Bull. Dept. Geol. Sci., vol. 13, no. 9, Dec., 30, 1922.
2. Woodford, A.O. and Harris, T.F., Geology of Black Hawk Canyon, San Bernardino Mountains, California: Univ.Calif.Publ., Dept.Geol. Sci., vol. 17, 1928.

2. Small area of dark medium grained granite contains albite-oligoclase, a little orthoclase, less quartz; also biotite, hornblende titanite, augite, apatite, and magnetite. (Also called biotite-hornblende-diorite.)

3. North of Baldwin Lake. The granite contains quartz, orthoclase, oligoclase, biotite, muscovite, magnetite, titanite, apatite, and garnet.

4. Furnace Canyon. The granite is composed of quartz, orthoclase, biotite, a little albite-oligoclase, magnetite, titanite and apatite.

5. Round Valley. Granite contains quartz, orthoclase, biotite, a little oligoclase, muscovite, magnetite, apatite, titanite, and garnet.

6. Little Morongo Valley. Quartz monzonite composed of quartz, orthoclase, oligoclase.

Other types of rock mentioned and the minerals of which they are composed are tabulated below:

Schist: quartz, biotite, altered feldspar.

Schist: quartz, biotite, muscovite.

Pegmatite: quartz, orthoclase.

Quartzite: quartz, containing small flakes of muscovite, but no bedding planes visible.

Schist: quartz, green hornblende, small amount of biotite, titanite, apatite.

Schist: biotite (brown), muscovite, hornblende, lenticular phenocrysts of orthoclase, quartz, and altered feldspar (orthoclase). Epidotization in the black schists.

Schist: containing among other things garnet, epidote, tremolite.

Quartz-mica-schist: quartz, green and brown biotite, titanite, magnetite.

The pre-Tertiary sediments may be described in the following manner:

Arrastre quartzite: thin bedded, individual beds about 6 inches thick, varies from fairly pure quartzite to impure, containing quartz, orthoclase, biotite, titanite, hornblende, magnetite, oligoclase.

Furnace limestone: white to black, sometimes coarsely crystalline. At the contact with the granite the following minerals are frequently found: tremolite, garnet, epidote, wollastonite, pyrite, chalcopyrite, gold.

Saragossa quartzite: white to pink, yellowish-white light and dark gray. Recrystallizes to quartz-biotite schist. Sometimes has saccharoidal texture, sometimes granular, or hard and brittle like glass. Quartz, magnetite, titanite, biotite, and muscovite.

The formations just described crop out in the central half of the San Bernardino Mountains. The western end likewise contains quartz-orthoclase granite, quartz monzonite, and granodiorite, cut by stringers of quartz-orthoclase pegmatite and aplite. The pegmatite sometimes exhibits graphic intergrowth of the quartz and orthoclase.

Regarding the plutonic igneous rocks, the most striking impression gained from a reconnaissance study of the San Bernardino Mountains is the prevalence of the pink granitic types. The color is produced by the flesh colored orthoclase. This feature is in marked contrast to the other areas described, and to be described, where the prevailing formations are gray quartz diorite and granodiorite. It is noticeable, however, that the western and eastern ends of the San Bernardino Mountains contain a larger percentage of gray granodiorite than of pink granite. It is only in the central half of the mountains that pink orthoclase-quartz granite predominates.

SAN JACINTO MOUNTAINS: Approximately 50 miles east of the Los Angeles Basin the San Jacinto Mountains are found. They are triangular or wedge shaped, the wedge pointing northwest, the main mass extending toward the east and southeast. They are separated on the north from the San Bernardino Range by San Gorgonio Pass, and are bounded on the southwest side by the San Jacinto Valley and drainage area. The highest point of this range, San Jacinto Peak, has an altitude of 10,805 feet.

As in the case of the San Gabriel and San Bernardino Ranges, the San Jacinto Mountains are composed very largely of plutonic igneous rocks, ranging in composition from granite to quartz diorite, and their gneissic equivalents. However, quartz-orthoclase granite and quartz monzonite are not well represented. Quartz diorite and granodiorite greatly preponderate over the more alkaline types.

Fraser[1] examined seventeen samples of these plutonic types, collected from various localities and classified them in the following way: granite 3, quartz monzonite 2, granodiorite 3, quartz diorite 9. His determinations of the approximate mineral content of the granite, granodiorite and quartz diorite are tabulated below:

Granite.

	Percent.
Orthoclase) Microcline) Perthite)	65
Albite	2
Oligoclase	8
Biotite	8
Quartz	15
Apatite (accessory)	T
Sericite (secondary)	1

Granodiorite.

	Percent.
Oligoclase	55
Orthoclase) Microcline)	15
Quartz	15
Biotite	10
Hornblende	3
Apatite (accessory)	1
Titanite (accessory)	1
Magnetite (accessory)	T
Sericite (secondary)	T
Epidote (secondary)	T

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[1] Fraser, D.McC., Geology of San Jacinto Quadrangle south of San Gorgonio Pass, California: Mining in Calif., State of Calif., Dept.Nat.Res., Div. of Mines, pp. 525-528, October 1931.

Quartz diorite.

	Percent.
Oligoclase-andesine	55
Quartz	30
Biotite	10
Orthoclase	4
Apatite (accessory)	T
Chlorite (secondary)	T
Muscovite (secondary)	T

In addition to the plutonic formations described, the area contains occasional patches of metamorphic rocks, surrounded and engulfed by the former. These metamorphics embrace such types as quartzite, crystalline limestone, various gneisses, mica and hornblende schists, and phyllites, similar in many respects to those occurring in the San Bernardino Mountains.

The Tertiary is represented in the San Jacinto district by the Mt. Eden[1] formation (Eden[2] formation), a deposit consisting of reddish arkosic sandstone and shale, overlain by loosely consolidated, buff sandstone and shale containing vertebrate remains.

PERRIS BLOCK: The Perris Block is a long, irregularly rectangular, structural segment, trending in a northwest-southeast direction. It averages about 25 miles in width and is over 60 miles long. On the northeast side it is bounded by the San Jacinto fault zone, beyond which are the San Jacinto Mountains just described. The southwest side is limited by the Chino-Elsinore fault system and the steep scarp of the Santa Ana Mountains. The block ends towards the northwest against the base of the San Gabriel Mountains. Toward the southeast it rises gradually toward the Peninsular Ranges.

Structurally the region is at present a depressed block. Topographically it contrasts sharply with the surrounding mountainous

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1. Fraser, Op. cit, p. 512.

2. Frick, Childs, Extinct vertebrate faunas of the Badlands of Bautista Creek and San Timoteo Canyon, southern California: Univ.Calif.Pub., Bull. Dept. Geol. Sci., vol. 12, no. 5, pp. 283-288, Dec. 1921.

areas. The maximum relief between the hills and lowlands of this area is not over 1,000 feet.

Formations constituting the Perris Block are in many respects similar to those of the San Jacinto Mountains. A paper by Dudley[1] describes a part of the area as follows:

> The paper includes a geologic map covering an area of 400 square miles in western Riverside County, California, between the towns of Riverside and San Jacinto on the northeast and Corona and Elsinore on the southwest.
>
> Detailed petrographic analyses of the leading rock types are presented. The rocks, from oldest to youngest are (1) a large thickness of metamorphics (Elsinore series), (2) an extensive body of dacite porphyry (Temescal porphyry), (3) a set of plutonic intrusives of the same general age as the porphyry, but widely intruding it and with an established internal sequence from gabbro to quartz monzonite with quartz diorites predominating, (4) relatively minor sedimentary formations of (a) Eocene age (Alberhill clays) and (b) Pliocene-Pleistocene age San Jacinto series. The evidence suggests that the Temescal dacite porphyry represents the shallow, perhaps surficial expression of the quartz diorite magma, and that some of the plutonic rocks solidified not far below the earth's surface.

Engel[2] in a paper covering part of the Perris Block and a portion of the Santa Ana Mountains (to be discussed next), makes the following statements:

> The area investigated covers about 250 square miles with Lake Elsinore for approximate center. It includes parts of the southwest margin of the Perris block, the Elsinore trough, the southeastern extremity of the Santa Ana Mountains, and the Elsinore mountains.
>
> The oldest rocks consist of an assemblage of metamorphics of igneous effusive and sedimentary origin, probably, for the most part of Triassic age. They are intruded by diorite and various hypabyssal rocks, then in turn by the granite rocks, which occupy a large portion of the area. Following this last igneous activity of probably Upper Jurrasic age, an extended period of sedimentation started with the deposition of the Upper Cretaceous and continued during the Lower Eocene under alternating

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1. Dudley, P.H., The Geology of a portion of the Perris Block, southern California; (Abstract), Cordilleran Section, 30th Ann. Meeting, Geol. Soc. America, p. 3, 1931.
2. Engel, Rene, Geology of the southwest quarter of the Elsinore Quadrangle: (Abstract), Cordilleran Section, Geol.Soc.America, 30th Ann. Meeting, p. 6, 1931.

marine and continental conditions on the margins of the blocks. A marine regression towards the north, during the Neocene, accounts for the absence of younger Tertiary strata in the region under consideration.

A series of reconnaissance trips covering the northwestern half of the Perris Block proved that by far the largest portion is underlain by quartz diorite and granodiorite. In this region, granites carrying conspicuous amounts of flesh colored orthoclase are rare. An interesting feature of the country rock is the surprising number of autoliths[1] or zenoliths contained in it. These probable autoliths are found everywhere in the Perris Block where extensive outcrops of quartz diorite and granodiorite occur. They consist of small blebs to large masses, darker and finer grained than the country rock. They are of a general ellipsoidal shape with their respective dimensions essentially parallel. They are more resistant to erosion than the rock which contains them and protrude from weathered exposures. The minerals in these autoliths, as determined megascopically are: a small amount of quartz, light-gray plagioclase feldspar, green hornblende, and brownish-black biotite. Judging from their color the autoliths contain a larger percentage of the ferromagnesian minerals than the quartz diorite.

Between Corona and Elsinore, the hills and low mountains east of Temescal wash contain large amounts of effusive rocks and porphyry. A good part of these, no doubt, correspond to the Temescal dacite porphyry of Dudley. These rocks vary in color from very light to dark gray. Occasionally they exhibit a pinkish cast, as at the road cut one mile east of Corona, on the road to Riverside. The porphyries contain quartz and plagioclase feldspar phenocrysts, up to 1/8 inch in diameter.

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1. Pabst, Adolf, Observations on inclusions in the granitic rocks of the Sierra Nevada: Univ. Calif. Publ. Dept. Geol. Sci., vol. 17, no. 10, 1928.

Three miles southeast of Corona on the west bank of the Temescal wash, large clustering aggregates of nearly black tourmaline may be found scattered through the granodiorite. These aggregates form masses two or three inches thick.

Three miles northeast of Elsinore Junction there is an outcrop of metamorphosed sediment. It consists of siliceous slate and impure quartzite, showing evidence of rock cleavage. The formation varies from dark red to nearly black.

An area very interesting in its bearing on this investigation is that adjacent to Riverside. The Jurupa Mountains are located four miles northwest of the city. They constitute a group of hills about six miles long and two miles wide. They project from 750 to 1,000 feet above the general level of the valley. At the western end of these hills occurs a series of metamorphosed sediments consisting of mica schist, various types of highly metamorphosed clastics, and crystalline limestone or granular marble. Farther east one encounters the familiar types of igneous rocks: quartz diorite, granodiorite, quartz monzonite. This general area is mineralized, and Daly[1] has written concerning the district, describing its general geology and mineral deposits.

The metamorphosed sediments were designated by him: the Chino limestone body, Chino quartzite, Sky Blue limestone body and Jensen limestone.

The igneous types were classified as: Hypersthene quartz diorite, granodiorite, quartz monzonite porphyry, granite porphyry, pegmatite dikes, garnet contact rock, vesuvianite contact rock, quartz garnet contact rock. The more common types and their constituent minerals as

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1. Daly, J.W., The geology and mineralogy of the limestone deposits at Crestmore, Riverside County, California, Unpublished thesis, Calif. Inst. Tech., Dept. Geol., 1931.

described by Daly may be tabulated as follows:

Hypersthene quartz diorite: (East end of Jurupa Mtns.) Feldspar basic andesine, quartz, hypersthene (a large part of the hornblende was derived from alteration of the hypersthene), biotite, apatite, pyrite.

Granodiorite: (Greatest bulk of intrusive rock) Oligoclase-sometimes andesine or labradorite, quartz, orthoclase, hornblende, biotite, magnetite, pyrite.

Quartz monzonite porphyry: (From Commercial Quarry.) Orthoclase and oligoclase phenocrysts and groundmass, quartz abundant, pale green augite, titanite, apatite and pyrite. (The rock is fresh ash-gray color, slight mottling of dark minerals fine grained to almost felsitic in texture, weathers pale buff. Resistant to erosion. Rock stands above the surrounding ones at outcrop.)

Granite porphyry: Microcline and quartz, a little oligoclase, biotite, rutile, magnetite and apatite.

Pegmatite: quartz and albite.

He states:[1]

> The pegmatite dikes form the most conspicuous feature of the country side. They weather to a white color and form ribs which protrude above the country rock and can, in some cases, be traced for miles. They are so numerous and variable in size and extent that to map them all would be an almost hopeless task.
>
> ***The width of the dikes varies from one inch or less to as much as 25 feet.

Mr. Rene Engel first called the writer's attention to the fact that the white, quartz-albite pegmatites and aplites may be traced for miles toward the southeast, from the above described locality in the Jurupa Mountains and Crestmore district. In the description of the formations occupying the eastern half of the San Gabriel Mountains it was indicated that white quartz-albite aplite and pegmatite pebbles and boulders were brought down by the San Gabriel and San Antonio Rivers from areas drained by them. A northwest extension of the occurrence

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1. Daly, Op. cit. p. 36.

in the Jurupa Mountains would trend into the approximate area containing the same rocks in the San Gabriel Range.

These white aplites and pegmatites are found in abundance in some of the Pliocene and lower Pleistocene conglomerates of the Los Angeles Basin. No outcrops of these rocks, other than the ones already described, were found in the entire area investigated.

SANTA ANA MOUNTAINS: The eastern limit of the Los Angeles Basin is formed by the Santa Ana Mountains. They comprise a range which (combined with the Elsinore Mountains) extends toward the southeast from Santa Ana Canyon for a distance of 30 miles or more, with an average width of 10 miles. Farther south these mountains join with the Peninsular Ranges which continue into Baja California.

The northeast side of the Santa Ana Mountains is bounded by the Chino-Elsinore fault zone, beyond which lies the Perris Block. This side consists of a fault scarp which rises in places from 2,000 to 3,000 feet above the level of the Elsinore trough. The slopes on the southwest side of the mountains are more gradual. The highest point of the range is Santiago Peak, which has an altitude of 5,691 feet.

Structurally the Santa Ana Mountains are a fault block, elevated along the northeast margin and tilted toward the southwest.

Along the escarpment on the northeast side, intrusive plutonic rocks have been exposed by erosion. The central part of the mountains contains these plutonics, also patches of schist, and large areas of effusive and porphyritic rocks. In general progression toward the southwest occur Triassic formations, somewhat metamorphosed, Cretaceous conglomerates and sandstones, Eocene sandstones with conglomerate layers, and Miocene sandstones, conglomerates and shale.

Woodford[1] has given a concise description of portions of the Santa Ana Mountains and adjacent areas, including details concerning some of the formations more commonly encountered. Parts of his description are quoted here:

> The plutonic and metamorphic complex, perhaps entirely of Mesozoic age, which bounds the narrow coastal strip of sediments on the east, will in this paper be called the Eastern Bedrock Complex. There is a great mass of granitic rocks spotted with small schist areas and, intruding at the northwest, in the Santa Ana Mountains, an extensive belt of slightly metamorphosed sediments of Triassic age. The Complex is unconformably overlaid by unaltered Cretaceous sediments.
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> Granitic rocks.: The area of granitic rocks is 50 miles wide and of much greater length parallel with the coast. The principal type is quartz-biotite diorite, with the soda-lime feldspar usually zoned and averaging oligoclase or andesine. There is commonly a very little orthoclase, perthite, or albite, and sometimes a small percentage of hornblende with moderate pleochroism from green to yellow. Titanite is common in large crystals. The other accessories are magnetite, numerous small zircons, and a lesser number of apatites. Epidote and pennine may be present.
>
> Within the quartz diorite there are occasional small darker masses of gabbro, norite, and diorite. Near the western margin there were observed quartz-hornblende gabbro (feldspar labradorite), gabbro with hornblende and hypersthene (feldspar labradorite), etc. Such rocks may contain several percent of magnetite or pyrite.***
>
> The granitic rocks are cut by numerous pegmatites and rarer aplites, composed essentially of quartz and orthoclase.*** Black tourmaline, muscovite, and garnet are rather common in the pegmatites, and many other minerals (such as lepidolite,rubellite, and molybdenite) are more rarely found.
>
> The Triassic slates and associated volcanics.- The central rocks of the north end of the Santa Ana Mountains are interbedded slates and hard sandstones, with a little conglomerate and limestone, and locally an abundance of intrusive and extrusive, acid to intermediate, volcanic rocks. The slates and agglomeratic extrusives show the beginnings of recrystallization, but slatey cleavage is ordinarily imperfect. The sandstones are composed of angular grains and are usually high in quartz, more rarely arkosic or with abundant fine rock fragments. They are hard rocks, and the ferruginous, calcareous or micaceous cement sometimes seems to have been recrystallized by metamorphism; however, the clastic texture is well-preserved and clearly dominant. The conglomerates contain abundant well-rounded to angular sandstone and limestone fragments up to 8 inches in diameter and some smaller well-worn pebbles of feldspathic porphyries, quartz, gray chert, quartzite,

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1. Woodford, A.O., The San Onofre breccia: Univ. Calif. Publ., Dept. Geol. Sci., vol. 15, no. 7, pp. 170-172, May 20, 1925.

> muscovite schist, and in one case a granitic rock. The clastic grains in the matrices of the conglomerates resemble those of the arkosic sandstones in that they are chiefly quartz and acid plagioclase.***
>
> Schists.-Near the quartz diorite the Triassic series becomes more metamorphosed,*** These are almost entirely biotite and muscovite schists and quartzites.

In addition to the "acid to intermediate, volcanic rocks" mentioned above, there are also large areas of more basic lavas, tuffs, and porphyries. These have the composition of andesite. They are somewhat metamorphosed, and frequently badly crushed. Some of the outcrops are cut by closely spaced intersecting sets of fractures, which cause the rock to break up into small rhombic blocks. These formations may be seen to good advantage in the upper part of the San Juan Capistrano Canyon and elsewhere.

Another igneous rock sometimes encountered is diabase, composed of labradorite, hornblende, magnetite and pyrite.

The Triassic slates, sandstone and quartzite are well exposed in the upper reaches of Silverado and Trabuco Canyons. The slates are bluish-black to black. The sandstone is so hardened and cemented that the term quartzite is properly applicable to some of it. Many of the sandstone layers are red, and they superficially resemble jasper and taconite. The alternation of the slate and sandstone beds is rapid, individual beds averaging from 2 inches to 6 inches thick. The outcrops are cut by intersecting sets of fracture planes, which aid in the break down of the outcrops into relatively small sized rubble, easily handled by the streams.

The stream gravels of these canyons contain quantities of this material somewhat rounded by transportation. During transportation the slate disintegrates rapidly; the sandstone-quartzite pebbles survive. In Trabuco Canyon, near the resort "Trabuco Oaks" (loc. 10, fig. 1), the material in the river gravels, in addition to quantities of sandstone-quartzite and slate, includes also quartz diorite, granite, andesite porphyry and basalt.

Burruel Point, located at the northwestern extremity of the Santa Ana Mountains, and immediately east of the town of Olive, contains Upper Pliocene strata which have progressively overlapped truncated Miocene formations. Therefore, not only the plutonics and the Triassic beds, but the Miocene, Eocene and Cretaceous formations which also make up the Santa Ana Mountains, may be important source material for the Pliocene strata. A short description of these formations will be added to those already presented. Packard[1], Woodford[2], Moore[3], and Dickerson[4], have written detailed descriptions of the formations and their occurrences, and these references may be consulted for additional data not included in this paper.

The Cretaceous formations of the Santa Ana Mountains are the Trabuco and Chico. They consist of conglomerate layers, arkosic to quartzose, sandstone, and shale. The lower conglomerates contain large boulders, as much as 3 feet in diameter. The pebbles and boulders consist largely of andesite, porphyry, slate and quartzite.

A good exposure of the Chico occurs at the northwest end of the Santa Ana Mountains along the south side of Santa Ana Canyon. The

[1] Packard, E.L., Faunal studies in the Cretaceous of the Santa Ana Mountains of southern California: Univ. Calif. Publ., Dept. Geol. Sci., vol. 9, 1916.

[2] Woodford, Op. cit.

[3] Moore, B.N., Geology of the southern Santa Ana Mountains, Orange County, California, Unpublished thesis, Calif. Inst. of Tech., Dept. Geol., 1930.

[4] Dickerson, R.E., The Martinez and Tejon Eocene and associated formations of the Santa Ana Mountains: Univ. Calif. Publ., Dept. Geol. Sci., vol. 8, pp. 257-274A, 3 pls., 1914.

strata are a mottled reddish color due to weathering. Some of the conglomerate beds are very indurated, others soft and crumbly. The general aspect of the conglomerates is that of dark color. This is caused by the prevalence of dark to nearly black pebbles and boulders. The following types of rock were identified as composing nearly all of the conglomerates: abundant andesite, andesite porphyry, dacite, dacite porphyry, white, pink to black quartzite, black siliceous slate; a few representatives of quartz-muscovite schist, quartz-orthoclase granite, quartz diorite, and vescicular basalt.

The Cretaceous formations are about 2,500 feet thick.

The Eocene strata, well exposed in Trabuco and Silverado Canyons, consist of 3,500 feet of sandstone, conglomerate and shale. Pebbles, cobbles and boulders up to 6 inches in diameter comprise the conglomerate beds. They consist of quartzite, chert, felsite, slate, feldspathic porphyry, and angular fragments of the Cretaceous sandstone and shale.

The Miocene formations represented in the district are composed of conglomerates, red and buff sandstone and shale, several thousand feet thick. The lower member, the Vaqueros, contains pebbles and cobbles of quartzite, felsite, feldspathic porphyry, slate, chert. Representatives of the quartz diorite are rare.

These conglomerates are similar to those of the underlying Cretaceous and Eocene in the rock types represented in the pebbles and boulders. However, they appear to contain more of the pinkish to reddish felsite porphyry, more pink to grey tuff and agglomerate. Quartz diorites are numerous in some beds, absent in others.

The middle member, the Temblor or Topanga, contains pebbles and breccia material of glaucophane and allied schists, probably derived from a land mass toward the southwest, as suggested by Woodford[1].

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1. Woodford, Op. cit. p. 236.

The recurrence of the same rock types, (many of which are confined to the Santa Ana Mountains) in the successively younger conglomerates forces the conclusion that they are all genetically related. It appears probable that the Cretaceous sea received as debris the surficial and hypabyssal material stripped off from a large area to the east and northeast, perhaps from the present Perris Block and San Jacinto regions; that subsequently this conglomeratic material underwent repeated cycles of erosion, transportation and deposition, to form the successively younger conglomerates. The Temblor formation with its glaucophane schist content is the lone exception to the foregoing.

The preceding paragraphs describe the formations, igneous, sedimentary and metamorphic, which crop out at the present time in the various provinces surrounding the Los Angeles Basin. The science of petrology has brought out facts concerning the relative depth at which certain types of igneous rocks are formed. Granite, diorite, anorthosite, pegmatite, aplite, for example, are known to crystallize out at great depth. Their presence at the surface, therefore, bears witness to the enormous quantity of material removed by erosion between the time of the plutonic invasion and the Present Epoch. The appearance of these deep seated igneous rocks in the successively younger conglomerates should serve as a measure of the time, place, and rate of erosion of the provinces enumerated and discussed.

In this chapter, the formations and their constituent minerals have been described in considerable detail for all of the districts surrounding the Los Angeles Basin. This was done, not only that the pebbles and boulders in the Pliocene conglomerates might be recognized, but also because it would be desirable to have such a summary available for future work with mineral grains.

DESCRIPTION AND ANALYSIS OF THE PLIOCENE CONGLOMERATES

In order to chronicle geologic events successfully, a time reference is necessary. In this paper the evidence of foraminifera is used to indicate the geologic age of the strata. Not only have foraminifera proved their value for correlation purposes in the Los Angeles Basin, but they are often the only time indicators available.

REPETTO HILLS: The best and most complete, exposed section of Pliocene strata in the Los Angeles Basin occurs in the Repetto Hills. Although it contains but very few conglomerate beds, it will be described in detail as a type section for correlation purposes.

The Repetto Hills occupy the central and western portion of the south half of T. 1 S., R. 12 W. This area is approximately 5 miles east of the city of Los Angeles and 1 to 2 miles southwest of Alhambra. The hills are about 4 miles long in an east-west direction and a mile wide.

The general structure is that of a south dipping monocline, with gentle dips along the north side and steep dips along the south. Upper Miocene, lower and upper Pliocene and lower (?) and upper Pleistocene beds are exposed.

The upper Miocene strata crop out in the west half of the hills, west of the Midwick Country Club grounds. The southern limit of the Miocene outcrop is along a line about 1/4 mile south of, and trending approximately parallel to the Pacific Electric Railroad. The contact of the upper Miocene and the lower Pliocene is not well exposed but may be seen 1/2 mile west and a little south of the Midwick Country Clubhouse, along Fremont Avenue 4/10 mile north of its junction with Garvey Avenue. Here the attitudes of the strata of the two formations are parallel. The relationship is that of conformity or at most, disconformity. No conglomerate marks the contact, the sandy to diatomaceous shale apparently yielding to buff colored silt.

A cross section of the Pliocene formations occurring in the Repetto Hills was made, commencing at the intersection of Garvey Avenue with Atlantic Boulevard, and proceeding in a direction approximately S. 20°W. to the high tension transmission line of the Southern California Edison Company. This cross section begins a few hundred feet above the base of the lower Pliocene, since here the contact with the Miocene is concealed. Along the west side of Atlantic Boulevard, by reason of the deep notches cut into the sides of the hills during a period of road construction, good and almost continuous exposures of the strata are afforded for strike and dip observations, and for collecting samples containing foraminifera.. Number 1 on the general map, Figure 1 indicates the locality at which the cross section was made and its relative position to other areas discussed. Figure 3 is a plan view of the traverse from which the cross section is derived. It gives the locations where samples were taken, and observations on the attitude of the strata. A columnar section follows:

	Feet
Light buff silt and sandy silt, with occasional lenses of concretions - - - - - - - - - - - - - - -	400
Conglomeratic sandy layer with calcareous cement. Contains pebbles of granitic rock and silt breccia fragments; also broken shells of pecten, ostrea and turritella - - - - - - - - - - - - - - -	1
Light buff silt and sandy silt with occasional concretions -	575
Conglomeratic sandy layer of buff sand and granitic pebbles -	4½
Light buff colored silt - - - - - - - - - - - - - - -	107
Conglomeratic sandy layer - - - - - - - - - - - - - -	3
Light buff colored silt - - - - - - - - - - - - - - -	40
Conglomeratic sandy layer of buff colored sandstone and granitic pebbles - - - - - - - - - - - - - - - - - -	4½
Light buff colored silt and sandy silt, with occasional concretions. Lower part contains worm borings -	2,380
Total feet	3,515

The measured section gives a total of 3,515 feet. This includes neither the lowermost, unexposed beds north of Garvey Avenue, nor the upper Pliocene beds south of the Southern California Edison power line, the outcrops of which are poor.

Lithologically the whole sequence is a unit. It is composed almost entirely of silt, of a dull, light tan to light buff color. The silt varies in texture from sandy to clayey. The material is poorly consolidated, and if fragments of it are placed in water they will disintegrate almost completely. The upper third contains 4 thin beds and lenses of conglomeratic sand, varying from 1 foot to 4 1/2 feet thick. The strata above and below these layers are parallel and the whole series shows a conformable relationship.

Foraminifera occur thruout the section[1] but not in great abundance. Occasionally stratum layers may be found in which they are common, but the exposures as a whole are not very fossiliferous. The foraminifera show a rather distinctive preservation. They are of a yellowish to buff color, with a dull or unpolished exterior, seldom possessing the translucent, vitreous or hyaline appearance so common in many microfaunas of various other localities. Many of the forms are partially or completely filled with hydrated iron oxide. Globobulimina pacifica Cushman, for example, appears to have a special affinity for limonite. The internal chambers of this species are almost always partially or wholly filled with it, which gives the fossil a characteristic coffee-brown color. Many other foraminifera show the same tendency to a lesser extent.

Concretionary structures are occasionally found. They are post-

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[1] Edwards, Everett C., Foraminifera of the Repetto Hills, unpublished thesis, Calif. Inst. of Tech., Dept. Geol., table 1, pls. 5, figs. 3, June 1, 1932.

like or oval in shape, or they may occur as a series of thin lenses along a single bedding plane. They are more resistant to erosion than the silt; and hence, the rounded surfaces of the hills are often covered with residual rubble of this material. These concretions were formed subsequent to, not contemporaneous with the deposition of the strata, since foraminifera and worm borings are well preserved in them.

The lower third of the horizons exposed at Repetto Hills contains many worm borings. In the upper two-thirds of the section they are not common.

The first change in lithology occurs 2,380 feet above the base of the measured section. It consists of a 4 1/2 foot bed of medium to coarse, light-brown sandstone containing granules and pebbles. Broken fragments of pecten and ostrea furnish evidence of its marine origin, but a mechanical analysis of the sand (sample AL, no. 2, figure 2, page 70,) shows it to be very poorly sorted. The pebbles are rare. Those collected were nearly round to ellipsoidal, maximum size 2 inches in diameter, and consisted of the following types: quartz diorite, dacite porphyry, white quartz-albite aplite, sandstone and siltstone. Forty feet above the first sand layer there is a lense of sand, maximum exposed thickness 3 feet. It contains the same kind of material as the layer just described. One hundred and seven feet above this sand lense another 4 1/2 foot conglomeratic sand bed occurs. It corresponds to the others in texture, color and content. The mechanical analysis of a sample of this sand is given. (Sample AN, no. 3, figure 2.) The analysis shows the sand to be very poorly sorted. A few granules and small pebbles were found and classified as follows: quartz, fine grained quartz diorite, white quartz-albite pegmatite, dacite porphyry, and siltstone.

Near the south end of the hills in a small ravine is a lense of conglomeratic, calcareous sandstone. Its location may be seen in Figure 3, locality bd. The bed is about 1 foot thick, but lenticular, since it cannot be traced for any distance laterally. A few pebbles and small cobbles up to 4 inches maximum diameter are scattered through the layer. They were identified as 3 dacite porphyry, 4 medium to fine grained quartz diorite, 1 white aplite, 1 pink banded chert, several small chips and pebbles of indurated siltstone resembling the Pliocene concretions mentioned above, containing impressions of foraminifera. The matrix resembles physically a mixture of sand and caliche. Fragments of pectens, ostrea and turritella are common.

By means of foraminiferal assemblages the Pliocene sequence of strata cropping out at Repetto Hills may be subdivided into two formations, which will be referred to henceforth in this report as lower and upper Pliocene. The last described bed, the upper conglomeratic sand marks the contact between the two formations.

The equivalent of the lower Pliocene of the Repetto Hills does not occur at the type locality of the Pico formation, described by Kew[1]. It corresponds in age to lower Pliocene foraminiferal beds found in the Ventura Basin and elsewhere, which have a stratigraphic position between the Pico and the upper Miocene. Eaton[2] has referred to strata of similar age as Santa Paula. Geologists in the Los Angeles district have sometimes alluded to these lower Pliocene beds as the "Repetto" formation. In this report they are taken to include the lower 3,115

1. Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U.S. Geol. Survey Bull. 753, p.70, pl. 1, 1924.
2. Eaton, J.E., The by-passing and discontinuous deposition of sedimentary materials: Am. Assoc. Petroleum Geologists Bull., vol. 13, pp. 752-755, fig. 10, 1929. Also in: Ventura field controlled reservoirs: Oil and Gas Jour., p. 72, Nov 11, 1926.

feet described in the section, and in addition the lower silt beds exposed farther west which extend down to the Miocene.

The upper Pliocene includes the upper 400 feet described, and additional overlying beds to the base of the Pleistocene. Table 1 on page 41 gives the foraminiferal assemblages characteristic of the two formations. The foraminifera were collected and identified from the samples taken in Repetto Hills at the stations indicated in Table 1 and in Figure 3.

Between the lower and upper Pliocene of the Repetto Hills there is a hiatus, represented to the west in the basin proper by a thickness of sediments. This hiatus is not indicated by discordance of the strata above and below the break; at least none was observed within the limited area of the exposure. The hiatus represents a diastem, since only a relatively thin sequence of beds is missing.

The strata which occur in the central part of the basin, and which correspond in time to the marginal diastem consist of 600 to 900 feet of sand and brown silty shale in about equal proportions. They are characterized by the following foraminiferal assemblage, according to Mr. Boris Laiming,* micropaleontologist for The Texas Company:

Bolivina cf. robusta Cushman
Uvigerina peregrina latalata Stewart
Bolivina spissa Cushman
Bolivina interjuncta Cushman
Pulvinulinella pacifica Cushman
Cassidulina translucens Cushman and Hughes
Cassidulina laevigata d'Orbigny
Cibicides sp
Eponides tenera Brady

It is astonishing that no strata corresponding in age to the above beds were found cropping out around the perimeter of the basin. Evidently the diastem marking this middle Pliocene interval involves the entire margin of the basin of deposition.

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*Oral communication.

The age of the conglomerates of the Repetto Hills is determined by their position in the section. There are three thin layers in the upper part of the lower Pliocene. A fourth thin conglomeratic bed occurs at the base of the upper Pliocene.

Pebbles contained in these layers could have come from either or both of two source areas: the eastern end of the San Gabriel Mountains, or the Perris Block. The presence of the white quartz-albite aplite and pegmatite pebbles supports this conclusion because these types are only indigenous to those two areas. The quartz diorite and dacite porphyry pebbles are of lesser diagnostic value, since these types may be found in many potential source areas, altho quantitatively, they too are much more characteristic of the eastern areas named than any other.

The pebbles, chips and fragments of siltstone which are found scattered thru the four conglomeratic sand layers and thru many other silt beds, so completely resemble the silts in which they are embedded that they are assigned to the Pliocene as intraformational material. They are believed to indicate small erosion intervals, minor diastems, contemporaneous with the deposition of the series.

Contributions of conglomeratic material from all of the potential source areas adjacent to the Los Angeles Basin have been recognized in respective sediments. These contributions have been found to have characteristic assemblages of pebbles and boulders, distinctive of each of these potential contributory areas. When the evidence from all of the conglomerate outcrops has been presented, the justification for assigning various assemblages to one or another source will be more apparent.

Because the Pliocene epoch has an end as well as a beginning, it

TABLE 1

FORAMINIFERA	COLLECTING STATIONS									
	Up.Plioc.	Low. Plioc.								
	BA	AW	AT	AR	AD	AB	AA1	X	K	B
Uvigerina peregrina Cushman	C									
Uvigerina gallowayi Cushman	C									
Nonion sp	A									
Nodosaria soluta Reuss	R				R	R	R	R		
Uvigerina pygmia d'Orbigny	A		R		R	A				C
Uvigerina peregrina var.parvula Cushman	C		R			C	C			C
Pyrgo sp	R	R		R		R	R			
Cassidulina californica Cushman & Hughes	A			R	C	C		R	R	
Cassidulina translucens Cushman & Hughes	R	A			A	R	R	R		A
Cibicides mckannai Galloway & Wissler	R	C	A	A	A	A	A	A	C	C
Glandulina laevigata d'Orbigny	R	R		R	R	C	C	R	R	
Bolivina marginata Cushman	C	C				C	C	C		R
Globigerina bulloides d'Orbigny	C	A	C	C	C	C	C	C	C	
Globigerina dubia Egger	C	A	C	R	C	C	C	C	C	
Globigerina irregularis	C	A	A	R	C					
Globigerina pachyderma (Ehrenberg)	C	A		C	C	C	C	C	C	
Globigerina quadrilatera Galloway & Wissler	C	A	C	C	C	C	C	C	C	
Bolivina miocenica Cushman		C		A	A	A	C	A	C	C
Orbulina universa d'Orbigny		C		C	R	C	C	R		
Nodosaria elegans Schwager		R		C	R	C	C	C	R	R
Planulina wuellerstorfi (Schwager)		C		C	C	C	C			R
Virgulina schreibersiana Czjzek		R			R	R	C	C		
Robulus cushmani Galloway & Wissler		A						C		C
Globobulimina pacifica Cushman		C	A	C	C	R	C	C		C
Pulvinulinella bradyana Cushman		C			R	C	R			R
Textularia flintii Cushman		R		R	R		R			
Quinquiloculina seminulum (Linnaeus)		A		R						
Frondicularia advena Cushman		R	R	R		R	R	R		
Plectofrondicularia californica Cushman & Stewart		R					R			
Sigmoilinia elliptica Galloway & Wissler		C			R				C	
Lagena sulcata (Walker & Jacob)		R		R		R	R			
Nodosaria sp		R			R	R	C	R		
Bolivina subadvena Cushman var.spissa Cushman		C								
Robulus sp				R						
Clavulina communis d'Orbigny var.pallida Cushman				R				R		
Uvigerina proboscidea Schwager				A	R	C	C	A	C	R
Lagena substriata Williamson				C		R	R	R		
Gyroidina soldanii var.altiformis R.& K.Stewart				A	C	A	A	C	C	R
Bulimina inflata Seguenza					C	A	C	A	C	R
Bolivina beyrichi Reuss var. alata (Seguenza)					R	R	R		C	R
Cibicides cf. lobatulus (Walker & Jacob)					R			R		
Fissurina laevigata Reuss					R	R		R		
Bolivina sinuata Galloway & Wissler					A	A	A	R		A
Bolivina aeneriensis (Costa)					A	A	A	C	C	A
Bulimina marginata Cushman					C	A	R	R		
Bulimina buchiana d'Orbigny						C	C	C		
Lagena williamsoni (Alcock)							R			
Dentalina sp							R			
Angulogerina angulosa Williamson								R		
Discorbis sp								R		
Nonion umbilicatula (Montagu)										R
Valvulinaria sp										R
Ehrenburgina bradyi Cushman										R
Planulina orbicularis d'Orbigny										R

is necessary to mention the character of the Pleistocene beds which overlap the upper Pliocene on the south side of the Repetto Hills.

These Pleistocene deposits consist of red to brown sandy conglomerate. The color is due to ferric oxide. The material is poorly sorted and contains boulders up to 8 inches in diameter. The pebbles and boulders consist of quantities of quartz-orthoclase pegmatites, quartz-orthoclase granite, quartz monzonite, granodiorite, granodiorite gneiss, hornblende schist, biotite schist, and large numbers of the dappled diorite.

This assemblage can be assigned very definitely to the San Gabriel Mountains for its source. It is a typical San Gabriel assemblage. Anorthosite pebbles and boulders, which characterize the debris of all of the streams flowing from the western end of the San Gabriel Mountains, are absent. Therefore, the western extremity of these mountains was not contributory. This conglomerate came from the region of the present drainage area of the Arroyo Seco and, possibly farther east. It differs from the pebble assemblages contained in the underlying Pliocene and indicates an intervening drastic geomorphic change.

From investigations in the area to the east of the one under discussion, the age of this reddish conglomerate is determined to be upper Pleistocene.

LOS ANGELES CITY AREA: Scattered outcrops in the north part of the main business district of Los Angeles at locality number 2, Figure 1, expose a combined thickness of about 1,000 feet of Pliocene strata. These oucrops result from roadcuts and excavations.

Good exposures occur along the northwest side of Hill Street between First and Fourth Streets, also along the southeast side of Flower Street between Second and Fifth Streets, and again along Beaudry

Avenue between Fourth and Sixth Streets.

The base of the Pliocene overlies layers of Miocene laminated diatomaceous shale, of a buff to nearly white color. The contact of these two formations may be seen at the intersection of First and Hill Streets, also at Second and Hope Streets, and immediately southwest of the corner of Fourth Street and Beaudry Avenue. The contact is rather sharp, being marked by the sudden change from diatomaceous laminated shale to poorly consolidated buff silt. No suggestion of unconformity or disconformity is observable other than the change in character of the beds. The fossils likewise indicate a conformable relationship; Miocene types of foraminifera and siliceous organisms mingling with the lower Pliocene forms, then disappearing. Conglomerates are absent at the contact.

Immediately east of the corner of Fourth and Flower Streets there are six thin beds of conglomerate. The lowest occurs approximately 500 feet above the base of the Pliocene. The conglomerate layers vary from 6 inches to 3 feet thick. They are about 10 feet apart.

The material contained in the conglomerates consists of granules, pebbles and cobbles, poorly to well rounded, and of sedimentary breccia fragments so poorly rounded that they may be termed chips, slabs and blocks. These conglomerates apparently contain a combination of material of both short and long transportation, and the more resistant types are the better rounded.

Above these conglomeratic layers are several hundred feet of buff colored silt.

The clastic material in the conglomerates consists so predominantly of limestone that relatively there is very little else. The limestone shows many variations, occurring as rather well rounded pebbles, and chips, blocks and slabs, as large as a foot maximum dimension. Most of the limestone shows a dense texture. Individual pebbles and fragments vary in color from nearly white, light gray to dark buff. A great many of the blocks and slabs are pholas-bored. Several dark reddish-buff limestone pebbles contain diatom impressions.

Driver, Holman and Ferrando[1] note the presence of numerous casts of Valvulinaria cf. californica Cushman, typical of the lower Modelo formation, in one of the limestone pebbles.

In addition to the limestone, the conglomerates contain a few poorly to well rounded pebbles and cobbles of fine grained quartz diorite, basalt, andesite porphyry and chert, a few fragments and pebbles of glaucophane schist, and chips and small blocks of buff to white, laminated, foraminiferal Miocene shale. The matrix consists of calcareous sandstone.

The Pliocene strata thin from east to west. This may be due to a thinning of the individual beds, or it may be due to the presence of diastems at the points in the stratigraphic column marked by the conglomerate layers. No great discordance in attitude between the beds above and below the conglomerates could be observed, but the strata below appeared to have a slightly greater dip than those above.

These conglomerates are of lower Pliocene age. The foraminiferal assemblages contained in the silts interbedded with the conglomerates correspond with those of the Repetto formation.

The origin of the pebbles, cobbles and breccia is believed to be in the Miocene strata of the Santa Monica Mountains. The limestone material is assigned to the limestone layers and lenses of the Modelo

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1. Holman, W.H., Ferrando, A., and Driver, H.L., Pliocene of a part of the City of Los Angeles, Unpublished Report, May 7, 1931.

formation; the well rounded pebbles and cobbles of igneous rock to the Miocene conglomerates; the diatomaceous shale fragments to the upper Modelo. The glaucophane schist pebbles can be related originally to a former land mass west or southwest of the present shoreline. They were no doubt washed along by shore or near-shore currents to their place of interment. Their source in the Pliocene Epoch was probably an outcrop of San Onofre conglomerate. The origin of the andesite and basalt pebbles presents difficulties, since these types of rock are common in many of the potential source areas. However, in view of the probable origin of the balance of the material in the Santa Monica Mountains, they may correspond to the Miocene intrusives of that character in the same district.

Reasons for postulating the Santa Monica Mountains as the source of the Los Angeles city conglomerates are many. The glaucophane schist pebbles give evidence for eastward moving currents. No pebbles or boulders were found which could be definitely linked to the San Gabriel Range. The limestone pebbles and breccia, in texture, color and faunal content are similar to limestone layers in the Modelo of the Santa Monica Mountains. The same comparison may be made for the diatomaceous shale of the two areas. The absence of rounding of the limestone fragments indicates short transportation. Thinning of the strata toward the northwest may indicate shore in that direction.

<u>POTRERO CANYON:</u> One half mile northwest of Rustic Canyon, which marks the west boundary of the city of Santa Monica, is Potrero Canyon. On the north side of the Coast Boulevard and within the mouth of the canyon occurs a small area of Pliocene sediments, preserved as a down faulted block. The location is represented by number 3, Figure 1.

Not over 1,000 feet of strata are exposed. They consist of gray clay shale beds, some of which are sandy. There are occasional thin beds and lenses of brown to gray limestone, and breccia beds composed of angular fragments of limestone. Hoots[1] considers that the breccia material was derived from the underlying Miocene formations. Both lower and upper Pliocene are represented in the strata cropping out at the locality.

SAN PEDRO HILLS: On the north side of the San Pedro Hills, about 400 feet of Pliocene beds crop out. (See loc. 4, figure 1.) They are of a light-brown color, and consist of silt and clay shale. The foraminiferal assemblage obtained from these strata is characterized by an abundance of Plectofrondicularia californica Cushman and Stewart, among others, indicating lower Pliocene age.

From a road cut on the northeast side of Western Avenue, a short distance within the San Pedro Hills, several small subangular pebbles of glaucophane schist were recovered. The source of these pebbles is no doubt an old land mass which existed somewhere to the west or south, and they arrived at their present site by one or more cycles of erosion and deposition.

Lomita Quarry also contains lower Pliocene strata, but no pebbles were found in them.

GARFIELD AVENUE: Slightly less than 3/4 mile east of Atlantic Avenue and the Repetto section previously described, another pass occurs through the eastern end of the Repetto Hills. (See loc. 5, figure 1.) Garfield Avenue traverses this pass, and in the excavations along the sides of the avenue are exposures of lower and upper Pliocene and lower Pleistocene rocks.

Three quarters of a mile south of the north entrance of the pass,

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[1] Hoots, Op. cit., p. 116.

on the west side of the avenue is a Southern California Edison Company power house. The strata outcropping north of this point are classified as lower and upper Pliocene; the beds to the south as lower Pleistocene. At the north edge of the hills the strata have a gentle dip of 10° - 20° south. The dips steepen toward the south averaging 55° south at the lower end of the pass. In the northern three-fourths of this district the outcrops are scattered and the bedding planes obscure; therefore, a cross section was not attempted. South of the power house the exposures are continuous.

Lower Pliocene beds crop out only at the northern end of the pass, occurring as far as 1/8 mile south of the divide. Between here and the power house the beds are upper Pliocene. These age determinations are made on the basis of foraminifera.

The Pliocene formations, lower and upper, are composed of light buff silt, occasionally sandy. Conglomerate layers were not found, nor were pebbles or boulders observed in the soil mantle of the adjacent hills. The presence of foraminifera indicates that the formations are marine.

South of the power station, road excavations left a curb about 15 feet high on the west side along which a continuous outcrop of the strata may be observed. A cross section of this exposure gives the following section, described from top to bottom:

		Thickness
A	Mixed sand and silt, dark buff color.	200 feet.
B	Irregular stringers of gravel, sand with siltstone pebbles and fragments. (Mechanical analysis of sand sample GO, figure 2 , p. 70.)	3 "
C	Sandy silt beds of buff color above, more sandy below. 3 impressions of *Globigerina*(?) and two of *Globobulimina pacifica* Cushman (?) in two stratum layers.	144 "

			feet.
D	Coarse quartzose sandstone containing some weathered feldspars.	20	"
E	Subangular to well rounded pebbles in sandy matrix.	36	"
F	Interbedded silt and sand, buff.	12	"
G	Coarse to fine grained sandstone and conglomerate containing granules, pebbles and cobbles, (see pebble counts,) chips and small blocks of siltstone and white diatomaceous shale.	228	"
H	Breccia of silty sandstone with coarse sand matrix.	2	"
I	Sand and silt filled with sandstone and siltstone fragments and blocks, and poorly to well rounded pebbles of igneous types.	12	"
J	Hard well indurated conglomerate, pebbles and cobbles up to 3" of same types as in beds G and I above.	2	"
K	Buff sandstone containing sandstone fragments.	2	"
L	Buff silt.	6	"
M	Buff silt containing lens of gravel at top. Gravel consists of nearly flat to ellipsoidal pebbles and granules.	2	"
N	Fine grained buff sandstone.	3	"
O	Cross bedded layer of sand and gravel, topset beds removed.	6-10	"
	Well and poorly banded, buff silts of upper Pliocene, thickness not known.		
	Total thickness	682	"

Pebble counts were made from two of the more purely conglomeratic layers contained in part G of the above described section. They indicate a very unusual assemblage of rocks, since 60 percent of the conglomerate is composed of white quartz-albite aplite and pegmatite. The results of the pebble counts are given below.

Pebble Count No. 1. (230 pebbles)

Rock types.	Percent.
White albite-quartz pegmatite	35
White albite-quartz aplite	24
Quartz diorite	7
Quartz diorite gneiss	6
Dacite porphyry	9
Dacite porphyry gneiss	4
Biotite schist	1
Quartz	4
Banded impure quartzite	2
Epidote altered plagioclase-quartz gneiss	2
White diatomaceous (Puente) shale	2
Dappled diorite	1
Felsite porphyry	3
	100

Pebble Count No. 2. (100 pebbles)

Rock types.	Percent.
White albite-quartz pegmatite (1 graphic)	38
White albite-quartz aplite	25
Quartz diorite	9
Quartz diorite gneiss	3
Dacite porphyry	14
Basalt	2
Felsite porphyry	4
Quartz	2
Hornblende diorite gneiss	1
Epidote altered quartz-plagioclase gneiss	1
Granite	1
	100

In addition to the types enumerated in the above counts, a rapid classification of hundreds of additional pebbles disclosed three dappled diorites and two pink orthoclase granites.

The preponderence of pebbles of white pegmatite and aplite, gray quartz diorite and dacite porphyry, and the absence of pebbles diagnostic of other areas shows very clearly that nearly all of the material came from the east from the Perris Block. It is the only potential source area which contains the white pegmatite-aplite in abundance. That the San Gabriel area contributed very little to the sediments is indicated by the paucity, almost total lack of typical San Gabriel material such as: orthoclase granite, orthoclase pegmatite and aplite, dappled diorite.

From the Repetto Hills eastward to the eastern end of the Puente Hills the Pliocene and lower Pleistocene conglomerates contain practically no San Gabriel material. This fact cannot be explained by differential erosion. Examination of the debris issuing from the San Gabriel Canyon, and again at points 10 and 20 miles downstream from the mouth of the canyon, shows clearly that the pink pegmatites and aplites are as resistant to corrasion and corrosion as the white; that the pink granite and the dappled diorite, altho less hardy types than the pegmatite and aplite, compare favorably with the quartz diorite of the Perris Block in these respects. The only conclusion permissible is that this conglomerate material came from the east, from the Perris Block.

The extremely high percentage of white pegmatite and aplite pebbles and cobbles in the conglomerate at the Garfield Avenue locality is explained by the selective action of weathering and transportation. These rocks make up much less than 5 percent of the mass of the Perris Block and yet comprise 60 percent of the conglomerates derived therefrom.

The effects of differential erosion were mentioned in the introduction. The selective action of weathering commences as soon as the rocks come within the surficial zone of oxidation, hydration and carbonation. Some rocks resist the attacks of these chemical agents much better than others because of their chemical and mineralogical composition, their texture and structure. Likewise some rocks survive the abrasive action of transportation better than others due to superior toughness. Many rocks, however, are represented in conglomerates, not because of their resistance to chemical action or their toughness, but because of their inherent structure. The effect of structure in the manufacture of rubble has been aptly described by Barrell[1].

> For many kinds of rock the inherent structure is of fundamental importance in determining the size of the debris. A closely jointed or fissile rock will supply many fragments capable of being handled by the agencies of erosion. A massive rock, on the other hand, yielding fragments to be directly handled, may require assistance, through the friction of pebbles and sand. Such wear as Daubree[2] has shown, tends to produce mud and very fine sand until the fragments have been reduced to a size which the erosive agency can move. His experiments also showed that, even in the presence of violent shocks comparable to those given by the most rapid waves, fragments of granite did not break up into smaller ones, but, on the contrary, were pulverized. Consequently, an inherent structure which permits a rock to break into numerous small but resistant fragments is highly favorable for the production of gravel.

The white pegmatites and aplites occur as narrow dikes, cut by numerous fractures. This causes the rock to break up into small blocks easily carried away by the streams, in accordance with Barrell's description of the process. They are resistant to the destructive action of weathering and transportation, which property likewise aids in their survival as pebbles and cobbles.

The contrary is true of the quartz diorite which makes up possibly 80 percent of the mass of the Perris Block. It disintegrates and decomposes rapidly. The material so formed is carried away as sand, silt and clay. When blocks of the quartz diorite break off and slide or roll into the stream channels, they are usually of such dimensions that most of their bulk must be worn away by abrasion before they become small enough for the stream to handle. This is confirmed by the types of heavy residual minerals abundant in the finer grained sediments.

[1] Barrell, Joseph, Marine and terrestrial conglomerates: Geol.Soc. America Bull., vol. 36, p. 287, 1925.

[2] Daubree, G.A.: Geologie experimentale, vol. 1, pp. 250-253, 1879.

They are green hornblende and biotite, with lesser amounts of titanite, zircon, epidote and garnet. The flood minerals, green hornblende and biotite are especially characteristic of the granodiorite masses.

By these processes, it is believed, the discrepancy between the relative percentages of the pegmatite-aplite and the quartz diorite in the source area and in the end product conglomerates, may be explained. Each cycle of erosion, transportation and deposition suffered by the pebbles in their journey to their present location would tend to enlarge this discrepancy. The pebbles in the conglomerate at Garfield Avenue show such a degree of selectivity that they may have gone thru more than one erosion cycle.

The histogram of the sand sample GO in Figure 2 clearly indicates that it is poorly sorted. Altho much time has been devoted by sedimentary petrologists to the problem of mechanical analysis of clastic sediments since Udden's[1] paper, nevertheless it is still hazardous to assert a definite origin for a sand from its histogram. The poor sorting of the grains in sample GO is hardly in keeping with our knowledge of marine sandstones, but it is better sorted than samples AL and AN which contain fragments of marine invertebrate shells.

Repeated search failed to disclose any fossils in the beds cropping out south of the power station, with the exception of the few doubtful casts of Globigerina and Globobulimina mentioned in the description of the Garfield Avenue section.

The rapid alternation of the sands, silts and conglomerates, the channel like appearance of many of the gravels, the poor sorting of the sands, and finally, the essential absence of fossils makes it probable that these strata are non-marine. They may be entirely non-marine or

1. Udden, J.A., Mechanical composition of clastic sediments: Bull. Geol. Soc. Am., vol. 25, pp. 655-690, 730-744, 1914.

they may represent an area repeatedly traversed by a migrating strand line.

These beds are either lower Pleistocene or uppermost Pliocene. Because of their apparent non-marine character, and their superposition over the marine upper Pliocene, their lower Pleistocene age is assumed.

About 1/4 mile south of the Southern California Edison power station, there is a low line of hills trending east and west along the south side of the Repetto Hills. These are composed of reddish sand and conglomerate. The conglomerate consists of San Gabriel material, being high in dappled diorite, pink granite, pink aplite and pegmatite pebbles and boulders. This formation unconformably overlies the Pliocene and lower Pleistocene of the Garfield Avenue section. It may be traced into similar material previously described as occurring at the south end of the Atlantic Avenue pass. It is placed in the upper Pleistocene.

PUENTE HILLS: In the northeastern part of the Los Angeles Basin the Puente Hills form a conspicuous topographic feature. They have a trend slightly south of east, and extend from the San Gabriel River near the town of Whittier eastward to the Santa Ana Canyon and Chino Creek. Their altitude averages somewhat over 1,000 feet, the highest prominence being San Juan Hill with an elevation of 1,780 feet near the eastern end. The hills are 23 miles long. The western half averages about 4 miles wide. The eastern half is of triangular shape with a maximum width of 10 miles. The point of the triangle occurs near the city of Pomona, a short distance southeast of the San Jose Hills.

The southern side of the hills has a nearly straight trend, determined by the Whittier Fault. The northeastern side is bounded by the Chino Fault. The Puente Hills have been very complexly faulted and folded.

Formations at Puente Hills: The strata represented in and near Puente Hills consist of Miocene, lower and upper Pliocene, and lower and upper Pleistocene. English[1] has described them in detail. He does not differentiate the lower and upper Pliocene and the lower Pleistocene, describing them all under the heading of "Fernando", Pliocene.

Physical conditions immediately preceding the Pliocene are reflected in the character of the Puente formation, Miocene. It consists of white to buff colored diatomaceous shale, sandy shale, sandstone and some conglomerate. Most of the clastic material is fine grained. It was carried in and dropped at so slow a rate that the large numbers of diatom tests settling out in the same sea were well represented in the deposits formed. These beds testify to surrounding land masses of low relief.

Above the Puente diatomaceous shale there suddenly appears a series of coarse conglomerates, sandstone and siltstone, over 5,000 feet thick. This conglomerate-sandstone-siltstone series is well exposed near the summit of Workman Hill north of Whittier, also along the northwest end of the Puente Hills where English[2] measured and described a section consisting of 5,350 feet of this material. Approximately one-third of this section consists of conglomerate; the remainder of sandstone and siltstone. This series is also well exposed along the entire south side of the Puente Hills, south of the Whittier Fault. A cross section just east of the town of Whittier, (loc. 7, fig. 1,) indicates a thickness of 5,700 feet of strata for the lower and upper Pliocene. The formations are composed of alternating beds of sandstone, siltstone and conglomerate.

1. English, W.A., Geology and oil resources of the Puente Hills region, southern California: U.S. Geol. Survey Bull. 768, pp. 109, pls. XIV, 1926.

2. English, idem., p. 40.

In the low hills immediately east and west of the main headquarters of the Murphy Ranch the lower Pleistocene beds crop out. Approximately 1,000 feet of strata are exposed.

Many of the conglomerate beds are well indurated. They show a wide variation in size of material, ranging from granules to large boulders 2 feet in diameter. Likewise the degree of rounding is variable, some of the pebbles being very well rounded, others occasionally exhibiting the original flat sides, with only the corners rounded.

A count of 300 pebbles and boulders taken 1/2 mile south of the summit of Workman Hill, on the side of the road in Turnbull Canyon indicates the following types of rock as composing the conglomerate. (See loc. 6, fig. 1.)

Rock Type.	Percent.
White albite-quartz pegmatite	26
White albite-quartz aplite	19
Dacite porphyry	10
Quartz diorite	9
Felsite porphyry	6
Andesite porphyry	4
Vein quartz	4
Fine grained quartz diorite	4
Felsite	3
Dappled diorite	2
Fine grained gneissic diorite	2
Biotite schist	2
Quartzite	2
White diatomaceous shale	1
Sandstone	1
Unknown	3
Hornblende schist	1
Total	100

In addition to the above, examples of other types not encountered in the pebble count were biotite granite, diabase and gabbro. These types are rare. Only one pebble of orthoclase granite was found.

The assemblage of rock types in the foregoing pebble count is remarkably similar to that of the Garfield Avenue conglomerates. It contains a higher percentage of those igneous and metamorphic types with relatively large amounts of the femic minerals, and a corresponding smaller percentage of the white pegmatite and aplite. At the outcrops pebbles and boulders high in femic mineral content are usually decomposed, and another cycle of erosion would undoubtedly destroy many of them. Because ofthis, it is thought that the lower Pleistocene conglomerates were formed in part at least by the reworking of the Pliocene conglomerates. Since the two formations are conformable at the present outcrops, the Pliocene pebbles furnished to the lower Pleistocene beds must have come from deposits nearer the margin of the basin of deposition.

Examination of the conglomerates in dozens of other localities in the Puente Hills indicates rock type compositions similar to those in the pebble count listed above. This statement applies also to the pebble assemblages found at the west end of West Coyote Hills and the east end of East Coyote Hills, and to the upper Miocene Puente conglomerates, (loc. 8, fig. 1,) in the San Jose Hills between Pomona and Covina. They all show a high content of white quartz-albite aplite and pegmatite.

Origin: All of these conglomerates represent a unit assemblage from a single source area. They originated in the northwestern part of the Perris Block area. Among the thousands of pebbles and boulders examined, 3 dappled diorites from the San Gabriel Mountains and two pink granites which may have come from that range were seen. This illustrates the negligible part played by the San Gabriel Mountains as a contributor to this series. From the upper Miocene to the end of the lower Pleistocene, the Perris Block area was contributing clastic sediments to the basin of deposition, most of the material finding lodgement in the northeastern portion of the basin.

Age: The relationship of the conglomerate series to the underlying white to buff diatomaceous Puente formation is not entirely clear. Occasionally the two are locally nonconformable. Over most of the area, however, they appear conformable and frequently gradational. They are gradational in the sense that lenses of the diatomaceous shale are sometimes interbedded with lower sandstone and conglomerate. Upper Miocene foraminifera have been found in the lower part of the conglomerate and sandstone series. These diatomaceous shale lenses and the Miocene foraminifera may represent material obtained from areas of exposed unconsolidated Puente clays, transported and recomposed in lower Pliocene playas. Miocene material can have been reworked into Pliocene sediments but the reverse is impossible. The exact contact between the Miocene and Pliocene must be left in doubt. It may be sufficient to say that at or near the end of the Miocene there occurred an elevation of the surrounding land masses which caused a sudden and radical change in type of deposition.

Roscoe E. and Katherine C. Stewart[1] report lower Pliocene foraminifera from the conglomerate series near the eastern end of the Puente Hills. Upper and uppermost Pliocene foraminifera are found in the outcrops along the south side of the hills. Conformably overlying the strata containing the uppermost Pliocene foraminifera and occupying the outermost fringe of the outcrops along the south side of the Puente Hills, are a group of beds of continental aspect. They resemble the conglomeratic strata exposed at Garfield Avenue and contain a similar assemblage of Perris Block pebbles. Likewise they contain many chips

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1. Stewart, R.E. and K.C., "Lower Pliocene" in eastern end of Puente Hills, San Bernardino County, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 14, no. 11, pp. 1445-1450, 1 fig., November, 1930.

of Puente shale.

These beds are non-fossiliferous and it is difficult to assign an age to them which would not be subject to question. However, they have a place in the stratigraphic column, which in the San Pedro Hills is occupied by marine lower Pleistocene. They conformably overlie the uppermost Pliocene beds and unconformably underlie the upper Pleistocene strata. For these reasons they are believed to represent continental beds equivalent in age to the marine lower Pleistocene in other parts of the basin.

The Puente Hills 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 conglomerates.

Upper Pleistocene: Around the margins of the Puente Hills the upper Pleistocene overlies the earlier formations unconformably. At the west end of the hills the upper Pleistocene contains San Gabriel material, as it did along the south side of the Repetto Hills. The most common rock types comprising the pebbles and boulders are pink granite, pink aplite and pegmatite, and dappled diorite.

In the vicinity of the eastern end of the Puente Hills, Santa Ana Canyon and Burruel Point, the upper Pleistocene consists mainly of material from the San Bernardino Mountains, containing quantities of pink granite, pink pegmatite and aplite, gneisses, feldspathic porphyries and quartzite.

The upper Pleistocene and recent alluvium underlying the La Habra terrace, along the south side of the Puente Hills near La Habra and Yorba Linda, (loc. 9, figure 1,) consist of Perris Block material furnished by the Pliocene conglomerates of the Puente Hills themselves, reworked and deposited as alluvial outwash.

BURRUEL POINT: The lower Pliocene is missing at Burruel Point. Upper Pliocene strata have progressively overlapped the underlying truncated Miocene measures. The upper Pliocene and lower Pleistocene beds contain pebbles and cobbles furnished by the Santa Ana Mountains, mainly by the reworking and redeposition of earlier conglomerates. The pebble assemblage contains large numbers of feldspathic porphyries, light, dark and reddish tuff and agglomerate, quartzite, siliceous slate, Triassic sandstone and quartzite, a little muscovite schist, quartz diorite and chert.

COYOTE HILLS: The East and West Coyote Hills are located a short distance west of Burruel Point. They lie to the south of the Puente Hills and are within the Los Angeles Basin proper. Lower Pliocene strata are absent at Burruel Point but underlie the Coyote Hills.

The Standard Oil Company of California drilled a well in the West Coyote Oil field which was called the Bastanchury No. 1. At a depth of 5522 feet small pebbles and chips of glaucophane schist were cored. As indicated by associated foraminifera, the strata from which these pebbles were derived are of lower Pliocene age.

The nearest source of this glaucophane schist is the San Onofre facies of the Temblor formation, which occurs along the southwest side of the Santa Ana Mountains. During the lower Pliocene Burruel Point and the Santa Ana Mountains were emergent, and it is, therefore, highly probable that the glaucophane schist fragments came from this source.

SAN JOAQUIN HILLS: At the southeastern end of the Los Angeles Basin, adjacent to the Pacific Ocean, the San Joaquin Hills are located. At the western end of the hills, about a mile north of the coast resorts of Newport and Balboa, are good exposures of both Miocene and Pliocene rocks. They crop out on both banks of the Newport Sloughs. (See loc. 11, fig. 1.)

The lowest beds exposed are composed of white siliceous diatomaceous shale overlain by gray, "punky", carbonaceous, diatomaceous shale of Puente or Monterey, Miocene age. Above these beds are three layers of sedimentary breccia, 5 to 15 feet apart, and 2 to 6 feet thick. They mark a slight angular unconformity between the beds above and below. They are overlain by a thin deposit of brown shale, then by lower and upper Pliocene silt and sand.

These breccias contain chips and blocks of pholas-bored sandstone (highly indurated), and white diatomaceous shale. They also contain pebbles of quartz diorite, andesite porphyry, dark quartzite, vein quartz, muscovite schist and glaucophane schist, whale bone and whale teeth fragments and fossil wood. These breccias and conglomerates contain a mixture of Santa Ana Mountains and San Onofre material.

The age of these beds is in doubt but they are either uppermost Miocene or basal Pliocene.

SUMMARY OF SOURCE AREAS AND DERIVED CONGLOMERATES

All source areas contain a large variety of formations, not all of which survive to be represented in the conglomerates derived from those sources. There remain, however, so many different rock types in each of the conglomerates that an enumeration of all of them leads to cunfusion rather than to clarity. For each conglomerate and for each source area there are dominant characteristic groups of rocks, and these are listed below. Some types are present in more than one group. The important principle in such cases is that the whole assemblage must be used in order that it have diagnostic value.

Santa Monica Mountains: Sedimentary breccia material composed of limestone fragments, often pholas-bored; pebbles of igneous rock such as quartz diorite, granodiorite, feldspathic porphyry and basalt.

San Gabriel Mountains: Pink orthoclase-quartz granite, pink orthoclase-quartz pegmatite and aplite, white dappled albiclase diorite, lesser amounts of hornblendite and gneisses. Conglomerates derived from the western end of the mountains contain anorthosite,- not present in the conglomerates of the Los Angeles Basin.

San Bernardino Mountains: Pink orthoclase-quartz granite, pink orthoclase-quartz pegmatite and aplite, lesser amounts of quartzite, felspathic porphyry and gneiss.

Perris Block: White albite-quartz pegmatite and aplite, lesser amounts of light and dark-gray feldspathic porphyry, gray quartz diorite.

Santa Ana Mountains: Dark and light-gray and pink feldspathic porphyries ranging in composition from andesite to latite, various colored quartzites from black to white, Triassic sandstone and black siliceous slate, lesser amounts of gray quartz diorite, schists and gneisses. Glaucophane schist chips from the San Onofre facies of the Temblor formation. (See pl. VI.)

PLIOCENE AND LOWER PLEISTOCENE PALEOGEOGRAPHY

In many descriptive geologic reports it is customary to emphasize the differences between formations. The purpose underlying this, perhaps, is a desire to aid field workers in distinguishing the various formations. When the same group of strata are studied, however, from the point of view of their lithogenesis and the implied paleogeography, one is frequently impressed more by their similarities than by their differences; by the continuity of geologic processes rather than by the interruptions.

Observations concerning the relationship of formations, which are confined to outcrops only, may result in the placing of nonconformities or disconformities in the stratigraphic column and the perpetuation of partial truths in the literature. A short distance from the observed outcrops the formations may be entirely conformable, the contact being obscured by overlying beds. Difficulties of this kind are encountered more often around basins of deposition and geosynclines than elsewhere, because shore areas and neritic depositional areas frequently maintain their approximate relative positions through many geologic epochs. Changes of elevation cause diastems, disconformities and even nonconformities in the province of the migrating strand line, whereas but a change of lithology may develope in the province of continuous deposition. When uplift and erosion of the beds finally occurs, it is usually the marginal facies which are exposed for observation, where unconformable relationships are most common.

Companies engaged in prospecting for petroleum often drill numerous tests, the locations of which are scattered over entire basins of deposition. Sample cores of the formations encountered during the drilling are obtained and brought to the surface. With the aid of these cores geologists have been given a three dimensional perspective of the relationships existing between groups of strata. Contacts marked by unconformities at outcrops in the marginal areas are often contemporaneous with "transition zone" deposits in the subsurface, basin areas. When this is the case diastems, disconformities and nonconformities at the outcrop lose much of their significance.

The Los Angeles Basin exemplifies all of the foregoing. The

Tertiary and Quaternary sediments which fill the basin have many characteristics in common. All are composed almost entirely of clastic material, ranging in texture from coarse to fine. Organic or chemical limestone and dolomite are essentially absent. The conglomerates are usually lenticular and change rapidly laterally into finer clastic material. The pebbles and boulders composing the conglomerates have a local source from adjacent land masses, (altho the rate of shedding of sediments from the various adjacent land sectors is not uniform through the successive epochs). There are frequent examples of transition from continental to marine types of deposits. The Modelo-Puente formation, being of a rather unique composition, may represent an exception to the above described conditions.

Regarding relationships between formations, there are examples of nonconformities, disconformities and diastems in the marginal outcrops of the Los Angeles district, which die out basinward, and are replaced in the central portion of the basin by transition zone material representing continuous deposition.

Pre-Pliocene Events: Rocks antedating the Jurassic granodiorite intrusion have suffered metamorphism to a greater or lesser degree. These rocks formed a mantle over the plutonic granodiorite and attendant deep seated types, such as anorthosite and pegmatite. Before the latter types could be exposed to erosion the former must first have been removed.

The Cretaceous formations of the Santa Ana Mountains contain a few boulders of quartz diorite. This indicates that the source area from which the Cretaceous beds were derived had been unroofed to the extent of exposing the granodiorite batholith during the Cretaceous. The source area was probably what is now known as the Perris Block and the San Jacinto Mountains. Miocene conglomerates, certain to have come from the Perris Block area, contain plutonic types, so the stripping of the surface and near surface rocks from the Perris Block was prior to Miocene times.

The San Gabriel Mountains likewise had been eroded to the point of exposing deep seated igneous rocks, before the Miocene Epoch. The thick series of Miocene conglomerates exposed in the hills surrounding Occidental College near Eagle Rock contain substantial amounts of granite and granodiorite. The Mint Canyon (Miocene) formation of San Fernando Valley contains boulders of anorthosite, derived from the western end of the San Gabriel Range. These facts are interesting, as they indicate the antiquity of the positive elements as such, which were to supply clastic material to the Los Angeles Pliocene basin. They point to the position of the Perris Block as a positive element in the earlier epochs, whereas it is now negative.

The areal arrangement of the Modelo outcrops in the Santa Monica Mountains indicates that these mountains were covered by that formation at the end of the Miocene.

Evidences of the pre-Pliocene history of southern California are rather fragmentary, but much could be learned by detailed study.

Late Miocene: Near the close of the Miocene, during Modelo-Puente time, the sea was more widespread than at any subsequent time. Miocene outcrops occur outside of the area underlain by the Pliocene and later strata, and many of these do not indicate near-shore conditions of deposition. Aside from sporadic occurrences of conglomerate lenses in the Modelo-Puente formation, it gives the appearance of a truly marine, fine grained, shaley, clastic deposit.

The Ventura Basin was connected with the Los Angeles Basin. The

Miocene sea overlapped the Santa Ana Mountains and the San Gabriel Mountains farther than any subsequent sea has done.

The very fine-grained clastic material which the Modelo-Puente contains, and the large amounts of diatomaceous material, unobscured by terrestrial deposits, testifies to surrounding land areas of low or moderate relief.

At or near the end of the Miocene, uplift took place. The Miocene sea withdrew partially but not wholly from the Los Angeles Basin. The effect of this partial withdrawal was that deposition continued in and near the center of the basin, while an unconformity developed around the margin. The type of deposit changed from diatomaceous shale to non-diatomaceous sand, silt and conglomerate.

The Santa Monica Mountains became high land.

The Santa Ana Mountains district and the Perris Block area became mountainous. Burruel Point was emergent. The San Gabriel area was above the sea but had not sufficient relief to be an important source for clastic material.

The Los Angeles Basin was separated from the Ventura Basin and the San Fernando Valley area by the Santa Monica Mountains, from the Imperial Valley area by the mountains on the Perris Block, and from the Mohave Desert by the San Gabriel Hills.

Lower Pliocene: When the Santa Monica Mountains became high land, the Modelo formation which blanketed them was exposed to erosion. The more resistant limestone members which it contained were broken up into breccia rubble. These fragments were washed about by the waves and currents, attacked by Pholads and other burrowing invertebrates which infested the littoral zone, until they were finally buried in the Pliocene sediments. The pebbles and boulders in the conglomerate beds of the Miocene formations were subjected to another cycle of erosion, transportation and deposition, to find lodgement finally in the Pliocene sea. These conglomerates and breccia beds may now be seen in the exposures at the Los Angeles city section and Potrero Canyon. They are also believed to exist unexposed, south of the Santa Monica Mountains.

Exposures of San Onofre beds somewhere to the west or southwest contributed glaucophane schist pebbles and chips to the Pliocene deposits. Some of them were carried along the shore eastward as far as the Los Angeles city section. Others were deposited on the north side of the present Palos Verdes Hills, which may have been a submerged high area in the Pliocene basin.

The eastern side of the Los Angeles Basin was bounded by mountains. The region of the present Santa Ana Mountains was then a high range, with its northwestern terminus, Burruel Point, extending out as a promontory into the lower Pliocene sea. Between Burruel Point and the vicinity of the present San Gabriel Mountains was a wide embayment touching upon the western edge of the present Perris Block. It was the site of a master drainage system which brought in enormous amounts of boulders, pebbles, sand and silt from the mountains in the northern part of the Perris Block, depositing the load in the region of the present Puente Hills. Here the debris was reworked by the waves and currents, and spread along the strand line. In times of flood and strong oceanic storms it was carried into deeper water. The coarser terrestrial material from the Perris Block was carried westward as far as the Repetto Hills, and the finer, no doubt, was much more widely distributed over the bottom of the lower Pliocene sea floor.

The northwestern portion of the Santa Ana Mountains, being topographically a projection into the sea, did not develope large drainage patterns, but was cut away by short streams and by wave action. It was surrounded by a fringe of indigenous conglomerate, sand and silt.

During the time of the deposition of the breccia and conglomerate beds along the western side of the San Joaquin Hills, described on page 59, those hills may have been emergent. If so, they were subjected to erosion to a depth sufficient to uncover the Temblor and its glaucophane schist content. However, since the coarser material may have come equally well from the Santa Ana Mountains, the emergence of the San Joaquin Hills at that time is open to question. As previously mentioned these breccia beds may be of lowermost Pliocene or uppermost Miocene age. Strata which are of definitely identified lower Pliocene age consist of non-conglomeratic silt of marine origin. The foraminifera have a more or less dwarfed aspect, characteristic of near shore conditions. For these reasons it is thought that the site of the present San Joaquin Hills was a submerged shallow water area during most of the Pliocene, and that a relatively thin veneer of marine Pliocene beds were laid down over it. (See pl. I.)

Middle Pliocene: Subsidence kept pace approximately with deposition, but for an interval during the middle Pliocene, grade was apparently attained between the land and sea. While this condition obtained, the clastic material brought in by the contributing rivers by-passed the edges of the basin, and was deposited in the deeper water of the central portion. (See pl. II.) This interval is marked by marginal diastems.

Upper Pliocene: At the beginning of the upper Pliocene, subsidence of the basin and uplift of the adjacent land areas inaugurated another period of widespread deposition. Thruout most of the district, the relations between land and sea were similar to those during the lower

Pliocene. The Santa Ana Mountains, however, did not share as a whole in the general uplift. The western end including Burruel Point, which had suffered much denudation during the lower Pliocene, was gradually overlapped and inundated by the upper Pliocene sea. Strata were deposited over this area, composed mainly of material derived from earlier formations comprising the Santa Ana mountains. (See pl. III.)

Lower Pleistocene: The close of the Pliocene Epoch was marked by no striking physiographic changes. The major cycle of erosion and deposition from one important uplift to the next had not been completed. At the beginning of the lower Pleistocene, a partial withdrawal of the sea took place. Source areas were thereby rejuvenated, and terrestrial material containing assemblages of pebbles similar to those in the Pliocene strata were brought into the basin of deposition and dropped. Due to the partial withdrawal of the sea, marginal areas which were formerly the sites of marine and sub-aerial deposition, received continental deposits. They may now be seen along the south side of the Puente Hills. As in most cases of marine retreat the exposed portions of the strata previously laid down were subject to erosion, reworking and redeposition.

By the end of the lower Pleistocene, the adjacent land masses had been reduced to low or moderate relief. (See pl. IV.)

Middle and Upper Pleistocene: In middle Pleistocene a diastrophic revolution occurred[1], and the modern physiographic features of southern California developed. (See pl. V.) The Santa Monica, San Gabriel, San Bernardino, San Jacinto and Santa Ana Mountains were elevated, thrust upward along fault planes. The Puente, Repetto and Los Angeles City

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1. Grant, U.S. IV, and Gale, H.R., Pliocene and Pleistocene Mollusca of Calif.: Memoirs San Diego Soc. of Natural History, vol. 1, pp. 62, 63, November 3, 1931.

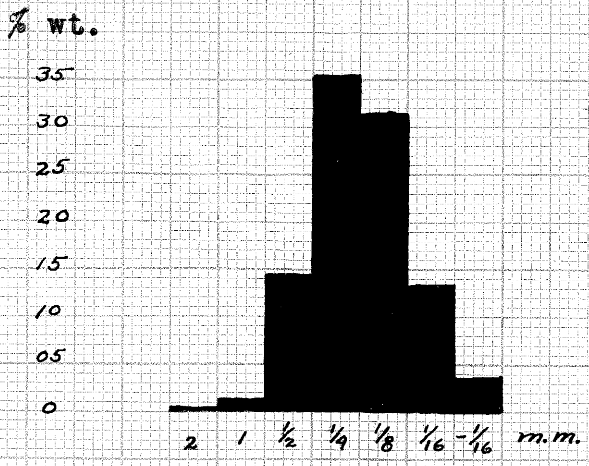
Hills became elevated. The Perris Block, however, long a positive and prominent physiographic element, became depressed, overridden perhaps by the eastern end of the San Gabriel Mountains.

The Santa Ana River succeeded in maintaining its course, became an antecedent stream, and grew headward into the San Bernardino Mountains, tapping them for the first time.

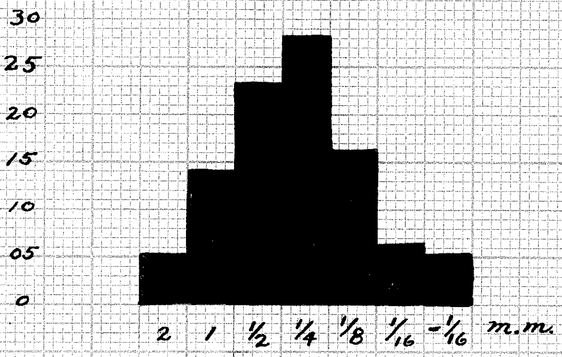
A flood of coarse clastic material descended from the rejuvenated ranges, enormous quantities being furnished to the Los Angeles Basin by the San Gabriel, Santa Monica, San Bernardino and Santa Ana Mountains. The Perris Block was at or below grade and contributed none. Alluvial fanglomerates began to build themselves outward from the mountain fronts, and are still accumulating.

HISTOGRAM, SAND SAMPLES

Sample GO



Sample AL



Sample AN

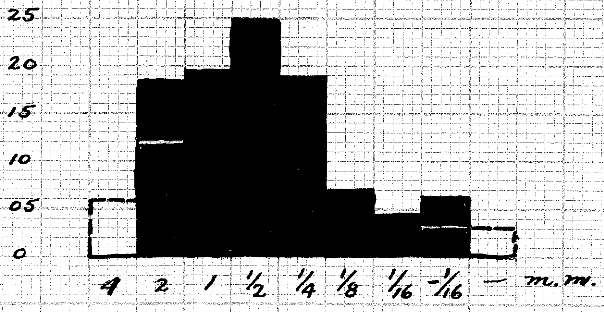


Figure 2.

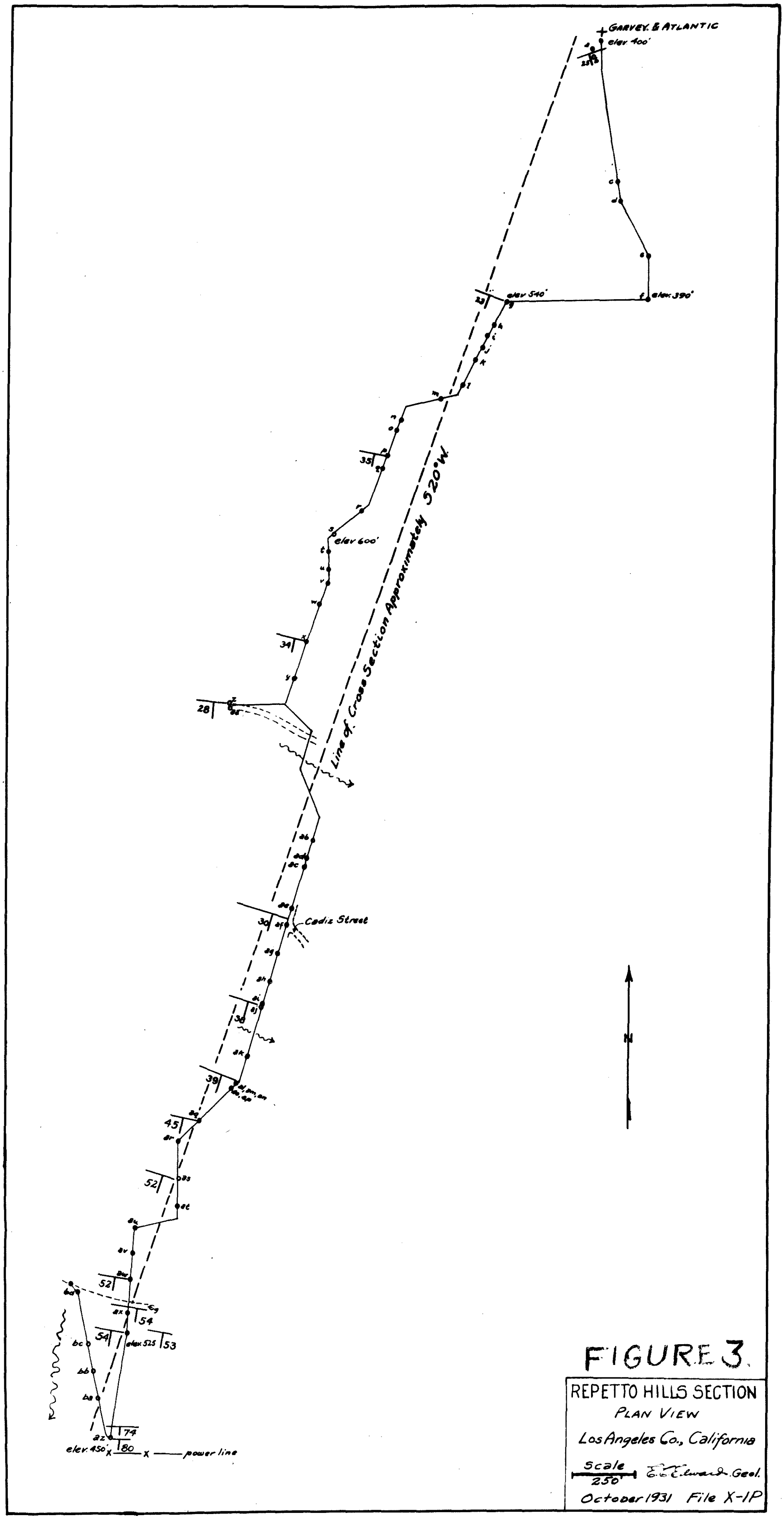
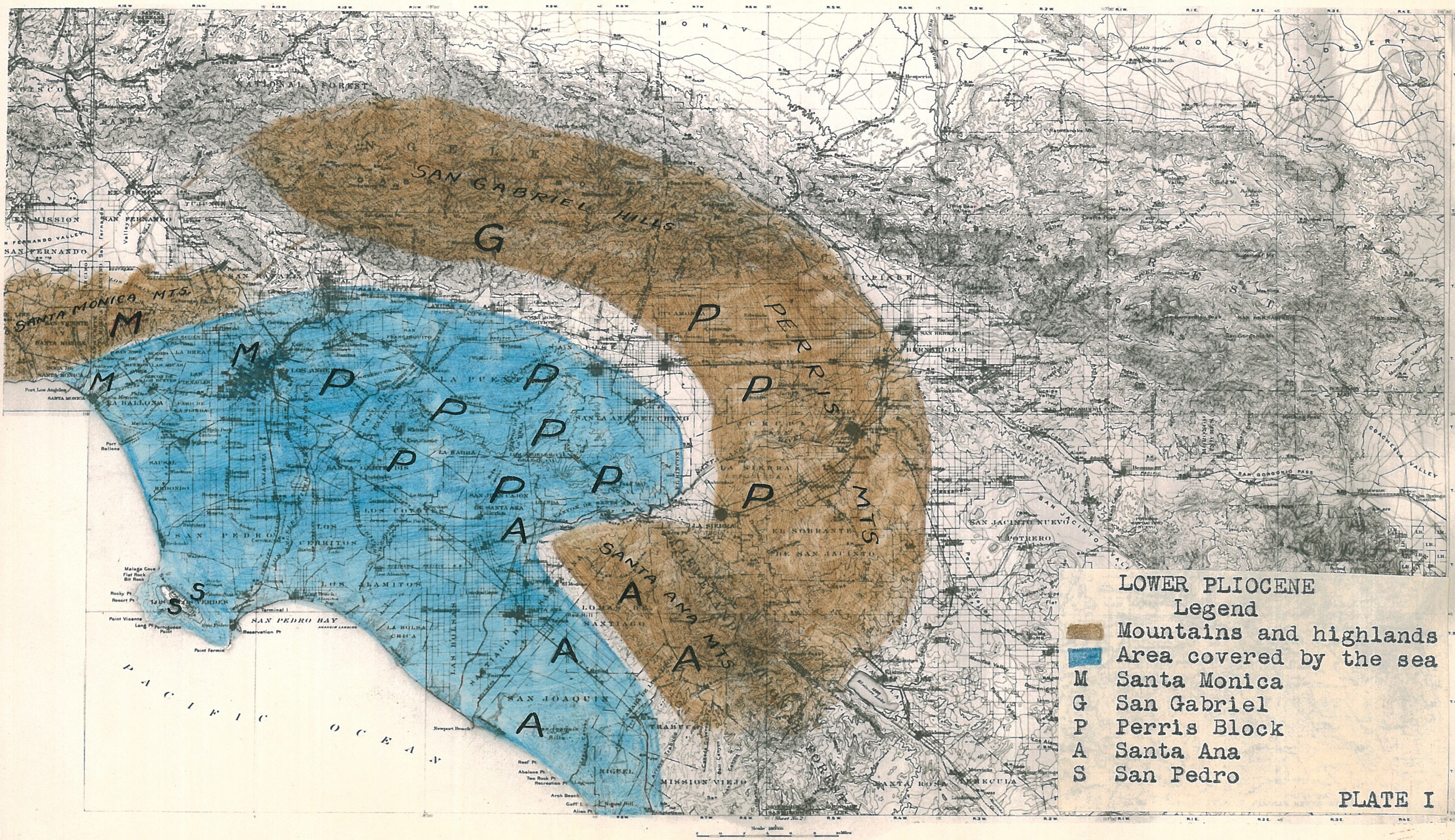


FIGURE 3.

REPETTO HILLS SECTION
PLAN VIEW
Los Angeles Co., California
Scale 250'
E. E. Edwards Geol.
October 1931 File X-1P

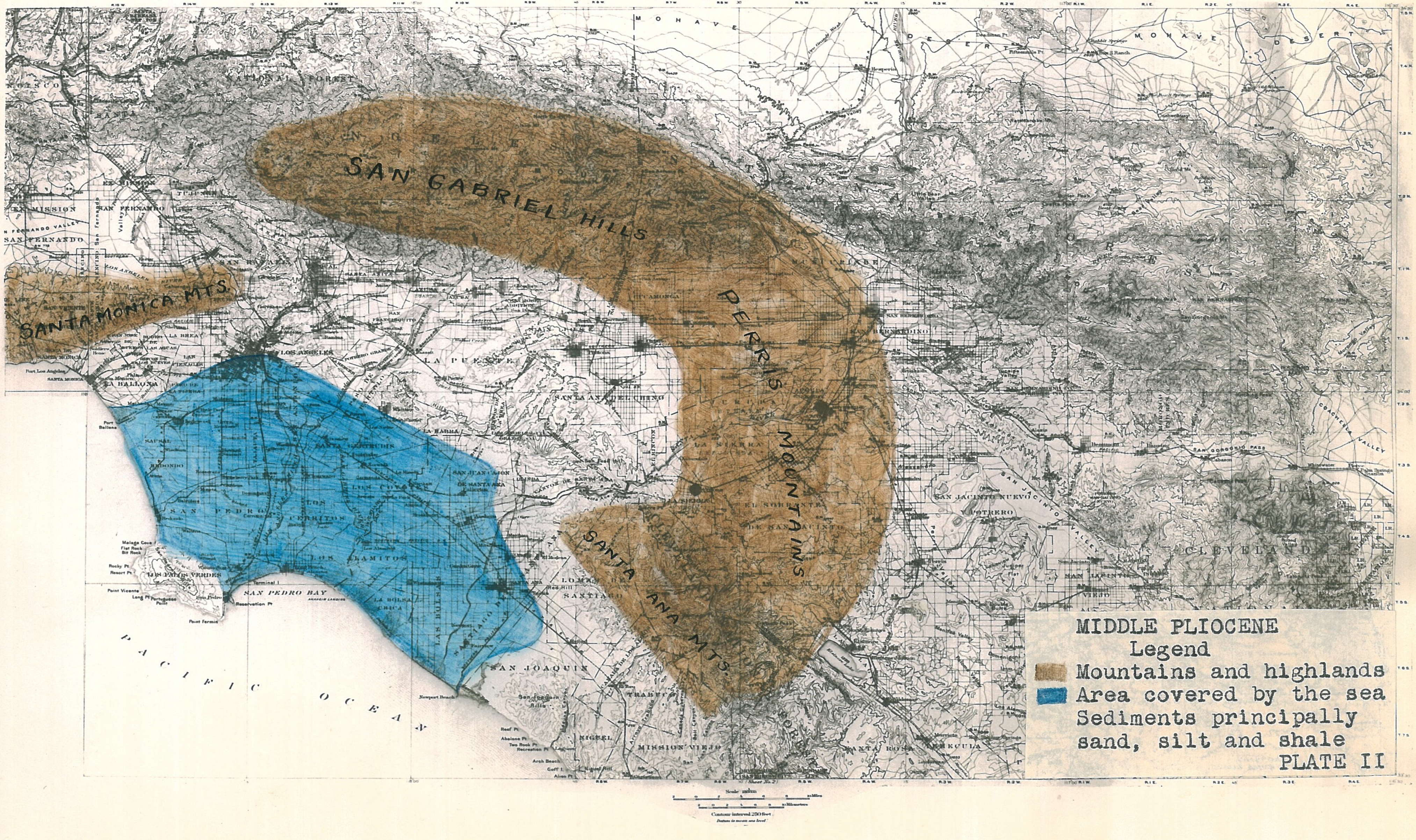


LOWER PLIOCENE

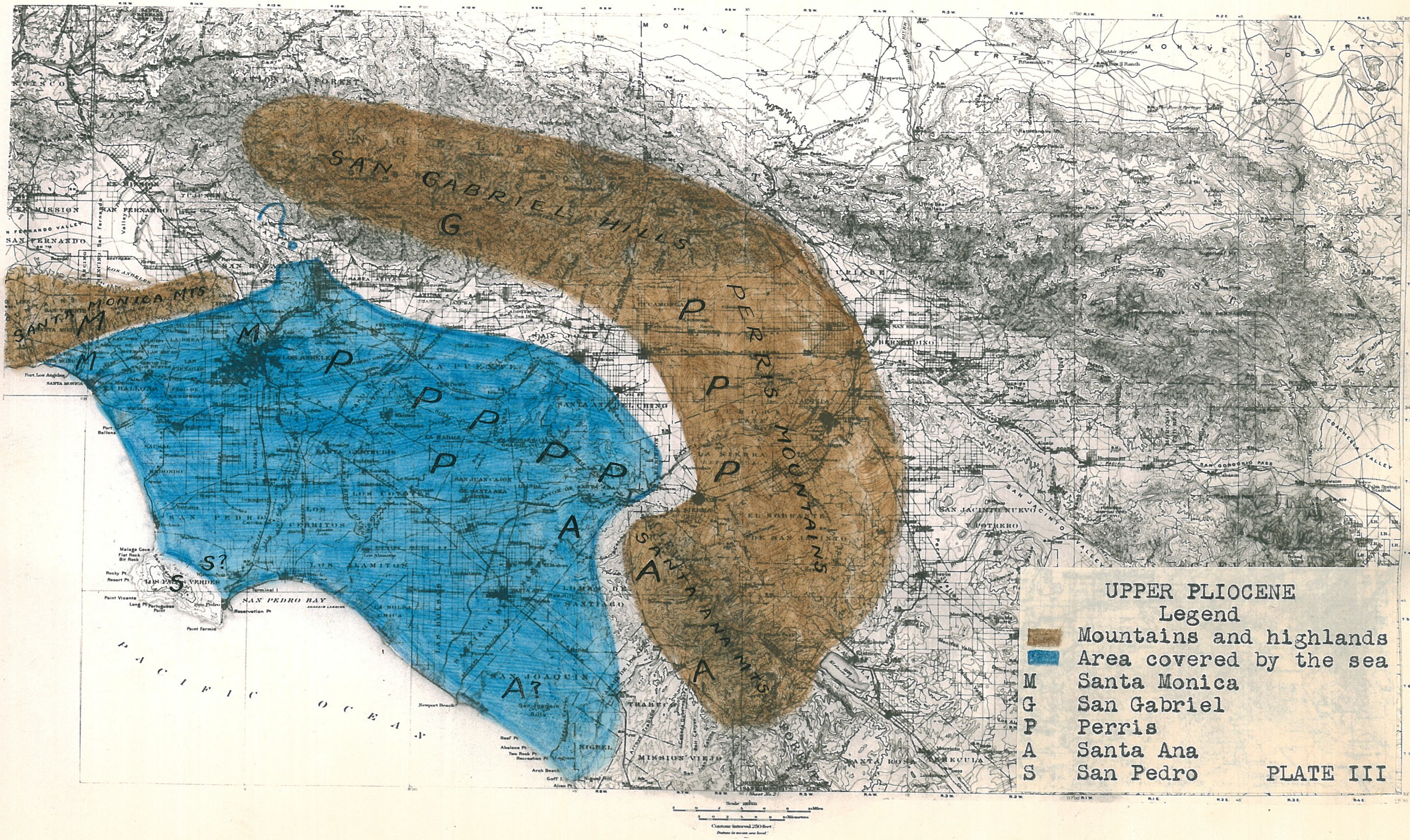
Legend

🟫	Mountains and highlands
🟦	Area covered by the sea
M	Santa Monica
G	San Gabriel
P	Perris Block
A	Santa Ana
S	San Pedro

PLATE I



MIDDLE PLIOCENE
Legend
🟫 Mountains and highlands
🟦 Area covered by the sea
Sediments principally
sand, silt and shale
PLATE II



UPPER PLIOCENE

PLATE III

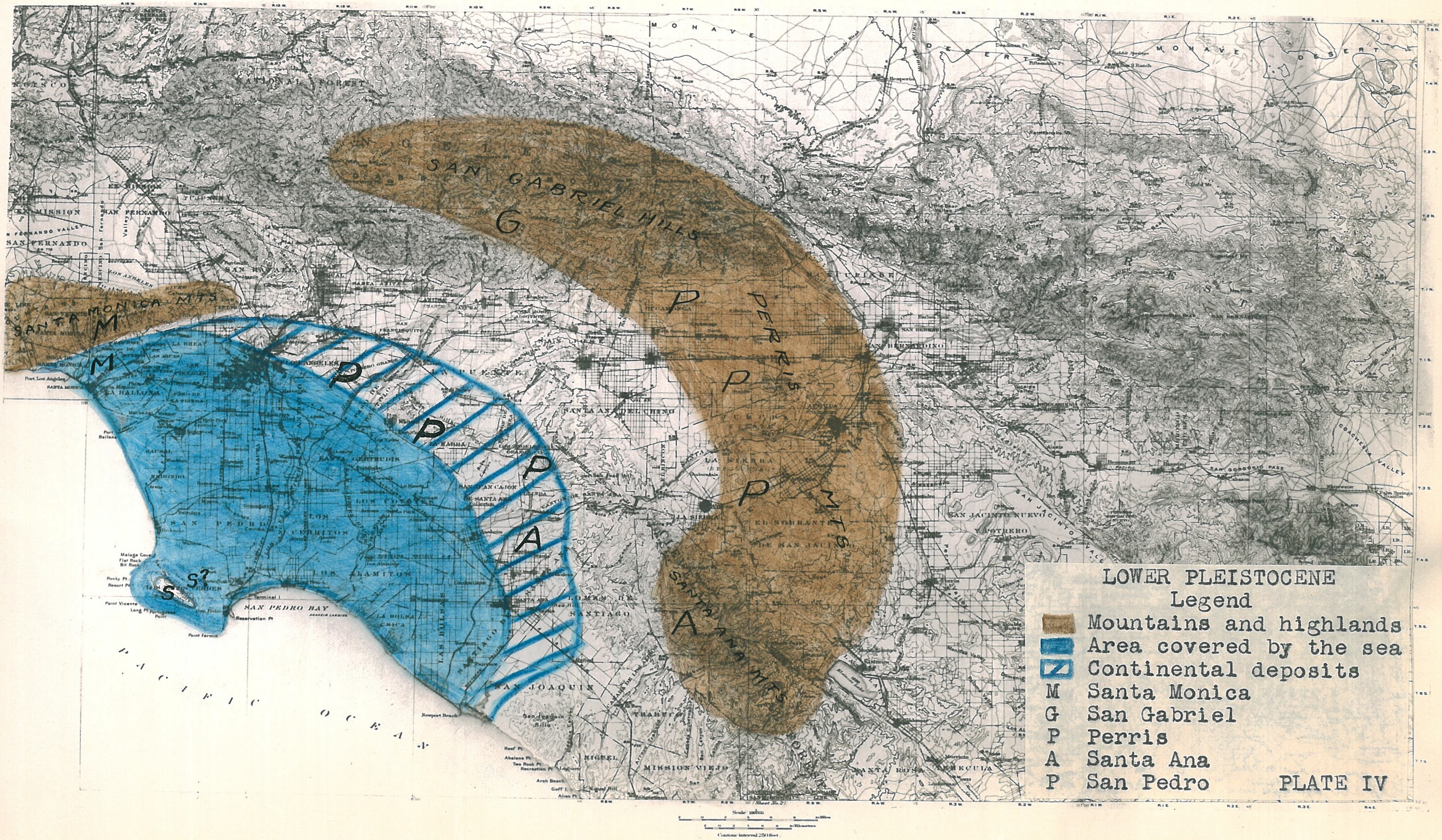
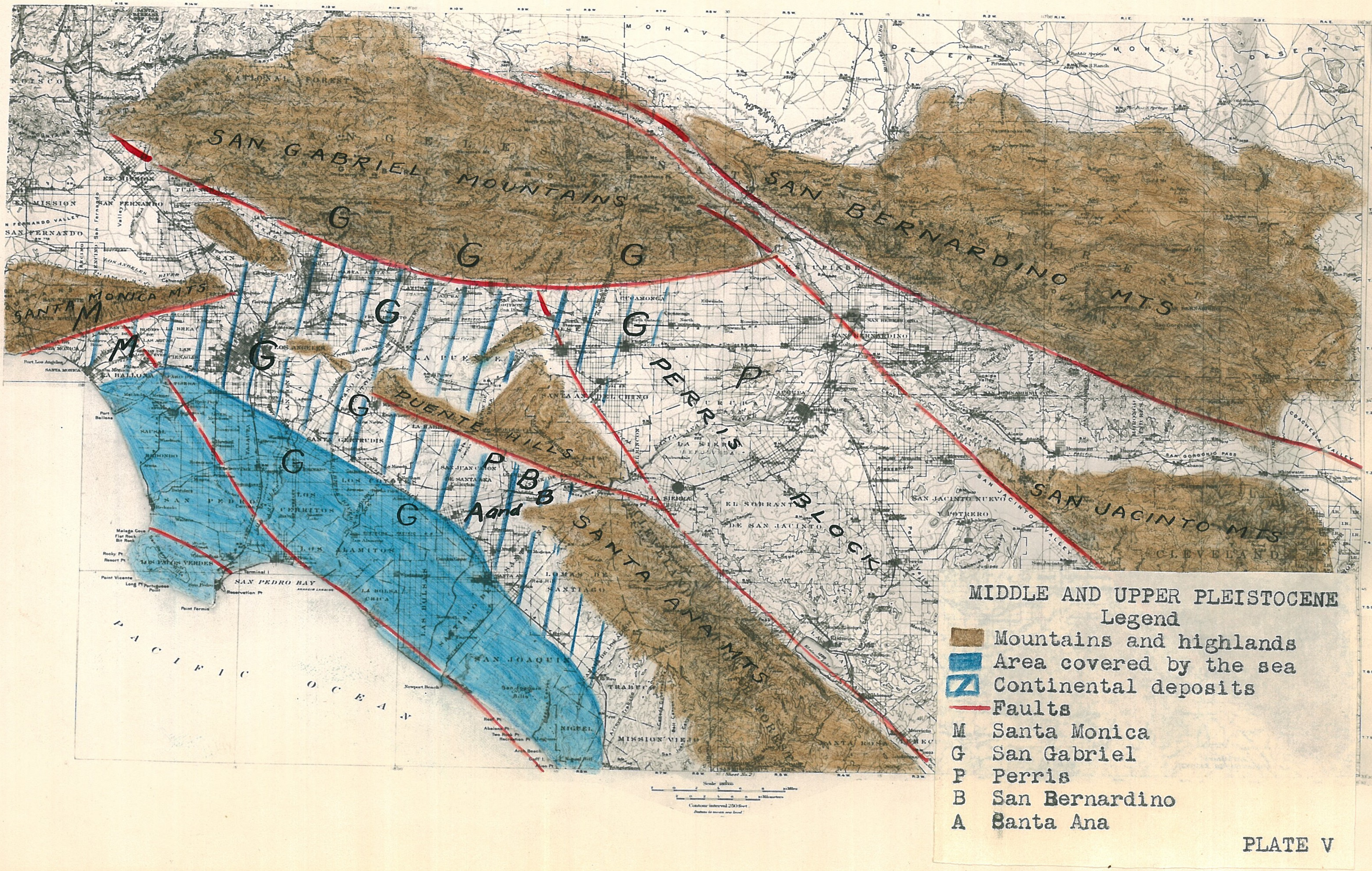

LOWER PLEISTOCENE
Legend
▨ Mountains and highlands
▨ Area covered by the sea
▨ Continental deposits
M Santa Monica
G San Gabriel
P Perris
A Santa Ana
P San Pedro
SAN GABRIEL HILLS
G
PERRIS MTS
P
SANTA ANA MTS
A
SANTA MONICA MTS
M
S
S?
PACIFIC OCEAN
MOHAVE DESERT
SAN PEDRO BAY

PLATE IV

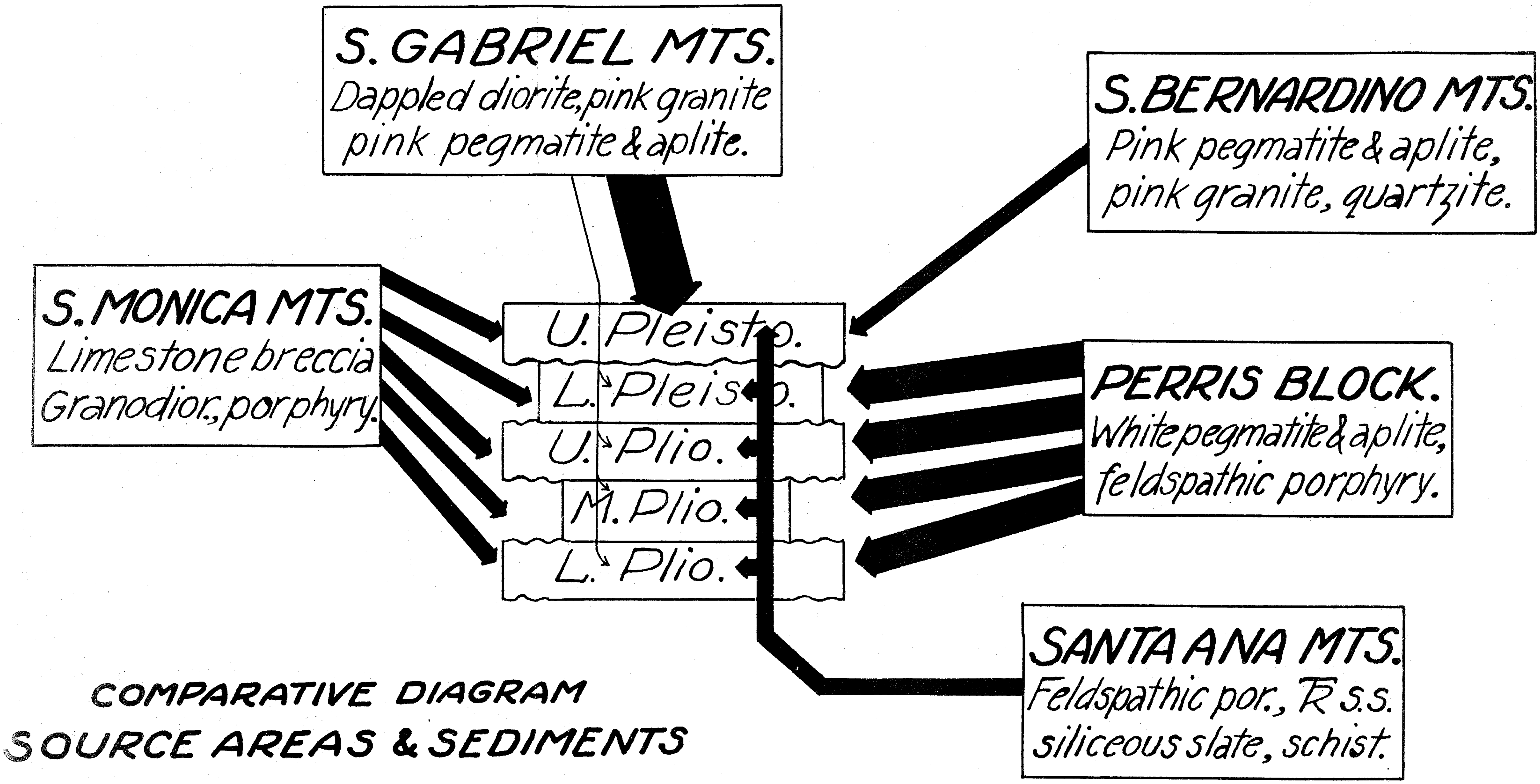


MIDDLE AND UPPER PLEISTOCENE

Legend

▨	Mountains and highlands
🟦	Area covered by the sea
▨	Continental deposits
—	Faults
M	Santa Monica
G	San Gabriel
P	Perris
B	San Bernardino
A	Santa Ana

PLATE V



COMPARATIVE DIAGRAM

SOURCE AREAS & SEDIMENTS

Note: Width of arrows indicates relative quantity of material furnished by each area.

PLATE VI

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