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Preface.

In the last twenty years Los Angeles has become one of the large cities of the world. Its setting is so well defined topographically that it invites regional analysis. As a basis for such study there must be a comprehensive description of the physical geography, and the main work of this thesis has been devoted to such a study. In this respect it is a pioneer work. In spite of the importance of the region and the activity in scientific investigation within its borders, a geographer finds here an almost unexplored field.

The field work was carried on during two years in which I was an Instructor in geography at the University of California at Los Angeles. The study began with an investigation of the soils. The correlation of land surfaces through the similarity in soils was found to be of great aid in the physiographic analysis of the great plains of alluvial deposition. The enormous size of the land forms developed on these plains and the complications caused throughout the region by tectonic movements have made physiographic study very difficult. The discovery of evidence of horizontal displacement, the use of soil studies, and the publication of detailed topographic maps for Los Angeles County, opened up a new opportunity for study and the explanation of
the topography as given in this thesis is almost entirely new work.
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PART I.

PHYSICAL GEOGRAPHY.
A Geographical Study of the
Los Angeles Region
of
California.

The topography of the State of California is dominated by great mountain ranges. The earth's crust has here been broken like ice in an ice jam. The only considerable stretches of level land in the State are the areas of alluvial deposition between mountain blocks. For want of a better name, these inter-mountain plains are called "valleys", though in many ways they are the antitheses of the stream-worn valleys of other lands.

Human occupation is almost entirely restricted to the valley lands and these are comparatively small in extent. Of the 100,000 square miles on the western slope of California there are fewer than 30,000 square miles of valley floor.

In the northern and central parts of the State the mountain ranges and the valleys between them trend NNW. Here the steep slope of the Sierra Nevada faces eastward toward the Great Basin, and drains most of its water and rock waste westward into the Great Valley of California. West of the Great Valley rise the Coast Ranges. These also have a NNW trend and strike the coast in echelon. Between these ranges are narrow, filled valleys, the two largest
being the one partly occupied by San Francisco Bay, and the other the Salinas Valley.

The Salinas Valley and its enclosing ranges extend about as far south as the Great Valley and the Sierra Nevada, that is, to about 35° North latitude. South of this the ranges no longer have a NNW axis, their direction tending, rather, to become east-west. The coast turns with these ranges and runs nearly eastward for 150 miles from Point Conception. Then, another group of NNW trending ranges is encountered and the coast bends about SSE along the Peninsula of Lower California.

In the angle formed by the meeting of the east-west ranges and the southern group of NNW trending ranges, there is an area of plain. This is the Los Angeles region. It is unique on the whole western coast of North America - a wide lowland open to the sea, united with broad valleys which are backed by high mountains. (Map K).

The Los Angeles region is a well-defined geographical unit. It is not a single structural valley as are most of the topographical regions of California; it is a group of lowlying plains, separated by low ranges with many easy passes, and shut off landward by high rugged mountains. Movement within the region is easy, but from without, the approaches are through narrow defiles between mountains, and, in most cases,
from lands of desert climate.

The relation of the region to its surroundings, and the position of its several subregions, can be best explained with reference to the mountain chains of Southern California. The east-west ranges are well separated at their western ends where they jut out into the Pacific Ocean in three points between well defined lowlands north of Point Conception. Farther east (Map 7) these ranges unite in a single mountainous belt which is somewhat broken by the rift of the Santa Clara Valley. Its southern edge is fairly well marked along the flank of the Santa Inez Mountains, South Mountain, Oak Ridge, the Santa Susana, and finally, the San Gabriel Mountains.

The belt narrows toward the east and the San Gabriels are a single Range considerably higher than the other parts of the east-west ranges. Also, in this part, the east-west chain has extended east of the end of the Sierra Nevada, and the San Gabriels become the bounding Range of the Great Basin.

Cajon Pass marks the eastern end of the San Gabriels. Beyond lie the San Bernardino Mountains. The axis of this Range is somewhat parallel to that of the San Gabriels, but the flank of the Range along the San Andreas fault, strikes definitely south-east and is continued in an escarpment which bends still more southward as it becomes the eastern boundary of
the great trough in which is the Gulf of California.

Thus there is a great mountain wall extending eastward from Point Conception to Cajon Pass, and then SSE into Mexico. This is the background of what is most properly Southern California. The Los Angeles region lies in front of the San Gabriel and San Bernardino Mountains. The whole chain is called the "Sierra Madre".¹

Rising on the outside of well marked troughs in front of the Sierra Madre, are two straight lined ranges running parallel to the two sides of its angle. The east-west Range starts in the west as the Santa Barbara Channel Islands, and continues as the Santa Monica Range, until it almost touches the San Gabriels at the Los Angeles River. The NNW-SSE Range which is called the "Peninsular Range", starts in the south as the dorsal range of the Peninsula of Lower California, and continues through the Santa Ana Mountains and Puente Hills, until it almost touches the San Gabriel Mountains near the San Gabriel River. Between the ends of the Puente Hills and the Santa Monica Mountains is the low arc of the Repetto Hills which is cut by many gaps, but, nevertheless, joins the two ranges. The chain thus formed will be called the "Santa Monica-Santa Ana Range" in this thesis.

The Santa Monica-Santa Ana Range is to such a great extent an offshore Range that one is reminded that California was once thought to be an island.

¹ For discussion of names see Supplement, p. 78
However, there is no continuous trough between this Range and the Sierra Madre. There are, rather, two troughs connected by the San Gabriel Valley, and each trough is interrupted by a crustal block some twenty miles from the inner end. In the spaces between these crustal blocks are the three valleys of the Los Angeles region — the San Fernando Valley in the trough between the Santa Monica and San Gabriel Mountains, cut off on the west by the Simi Hills block; the San Bernardino Valley in the trough between the Puente Hills and the San Bernardino Mountains, cut off on the south-east by the Perris-San Jacinto block; and the San Gabriel Valley which is not enclosed by trough-like walls, but lies in front of the San Gabriel Mountains and behind the Repetto Hills in the shape of a half moon. (Map 7, p. 12)

It is noteworthy that whereas the Sierra Madre is highest behind the Los Angeles region, the Santa Monica-Santa Ana Range is very low in the section that crosses the region. It is this peculiar circumstance which has been in a large part responsible for the building of the region, and for its favorable conditions for human occupation.

The low range in front has allowed the sea breeze to penetrate to some extent into the valleys, and the storms to break against the Sierra Madre in the rear. The height of the Sierra Madre has enabled
it to gather a large proportion of the moisture from the storm clouds, and the rock waste that this water has washed down has filled in the valley basins. The comparatively easy drainage through the Santa Monica-Santa Ana Range has resulted in sufficient outwash to keep the elevation of the valley floors largely between 500 and 1500 feet above sea level. The outwash has built up a great area of plain outside of the Santa Monica-Santa Ana Range.

In recent geological times the material from the Sierra Madre has been carried through the Santa Monica-Santa Ana Range by the three rivers - the Los Angeles, San Gabriel and the Santa Ana. These rivers have carried out enormous quantities of alluvium, though this alone might not have resulted in the building of any great area of delta plain had there not been a line of low hills in front to act as a retaining wall.

The line of hills here referred to is called "Dominguez Range". It extends in a flat arc between the Santa Monica Mountains at a point about fifteen miles west of their eastern extremity, to the Peninsular Range at a point some thirty miles southeast of the end of the Puente Hills. The Dominguez Range is for most of the distance inconspicuous on the landscape, and it is much broken by gaps, but its effect in damming back the underground water shows that it is nearly continuous, while the oil wells it has produced
prove it to be a deep-seated anticline.

In some ways the Dominguez Range seems to be akin to the Repetto Hills. The two ranges are nearly parallel; they are both broken by gaps, and they are both geologically younger than the two ranges which they connect. However, the Dominguez Range is much the younger of the two. Its surface is composed of deposits not very much older than the alluvium which it retains, and its slopes in places show only the first stages of the work of erosion.

The plain to the northeast of Dominguez Range has never been named, though, together with the terraces at the foot of the Santa Monica-Santa Ana Range, it forms a well marked unit. This is the subregion most closely identified with the City of Los Angeles and it might be called the "Vega", a term in Spanish which means plain.

In so far as it has been described, the Los Angeles region shows a remarkable symmetry of form. There are two trough valleys on the wings, a central valley behind a short arc of hills, and in front of that, a long plain behind a parallel arc of hills.

There is one further lowland region to describe. It lies west and south-west of Dominguez Range and thus spoils the symmetry of the region, but this only emphasises the regularity of the mountain framework, for this lowland is not a mountain-enclosed basin;
it is an accumulation of coastal material between Dominguez Range and the San Pedro Hills which were formerly an island. This built-in land has been raised and subjected to some distortion, but it still shows the old causeway beaches leading along the shores to the San Pedro Hills. Between these beach lines is an old lagoon floor lying as a plain at the foot of Dominguez Range. This area might appropriately be called the "Orilla", which means shore lands.

The San Pedro Hills are a short high ridge standing out boldly against the sea. Behind them are the sickle-shaped beach coasts of the Orilla, and the very open bays of Santa Monica to the west, and San Pedro to the southeast. The San Pedro Hills are the seaward extremity of the Los Angeles region.

The boundary of the region presents no difficulty except where it must cross the Santa Monica Mountains. The most natural division here seems to be from Santa Monica Bay, through Topanga Canyon (see Map A in folio), to the southwestern corner of the San Fernando Valley. From this point the boundary runs around the western end of the Valley, along the foot of the San Gabriels and San Bernardinos to the Perris-San Jacinto block, along the northwestern face of this, through the Santa Ana Canyon and along the flank of the Santa Ana Mountains and San Joaquin Hills to the ocean at Balboa. As thus outlined, the region has an area of 2000 square miles.
Roads into the Los Angeles Region

[Map Reference]
The Los Angeles region, as a geographical unit, stands out from its surroundings in a way that can hardly be appreciated by people living in lands of less pronounced topography. Nothing can be more striking than the change from the steep, eroded slopes of the mountains to the flat, smooth, alluvial floors of the filled valleys. There are, in reality, no foothills in the sense that the word is used east of the Rocky Mountains. One steps from plain to mountain. "Foothill" in California is generally used in the singular and means literally the base of the slope.

The small number of roads leading out of the Los Angeles region clearly shows how completely it is bounded by mountains. (Map 3) There are, at either end of the region, two routes along the edges of the valley troughs. Toward the west, the Simi Hills block lies between the Santa Monica Mountains and the Sierra Madre, but on either side of this block there are passways - the Simi Valley along the north, and the Calabasas-Conejo along the south. These routes both lead to the delta plain which the Santa Clara River has built in the end of the Santa Barbara Channel.

At the other end of the region, the Perris-San Jacinto block fills the trough between the Peninsular Range and the Sierra Madre, but again there are trough-edge passes - the San Gorgonio along
the base of the Sierra Madre, the Temescal-San Felipe along the Peninsular Range. These routes both lead to the Imperial Valley. This Valley lies below sea level and is a part of the floor of the Gulf of California, which has been cut off by the Delta of the Colorado River, and dried in the desert atmosphere.

These two pairs of routes, at either end of the region, have a curious similarity. In each case, the pass along the flank of the Sierra Madre is straight and smooth. A high narrow ridge of sandstone cuts across the Simi Valley route at Santa Susana Pass, but otherwise it is comparable to the San Gorgonio Pass. The passes along the flanks of the Santa Monica-Santa Ana Range, on the other hand, are both cross-drained through that Range to the ocean, and neither is a straight-lined passway. The San Felipe region in particular, is greatly affected by faulting, but the various rifts give one general route.

Even the Simi Hills and Perris-San Jacinto blocks, though differing greatly in size, are in some respects similar. In each case the western end is low and is partly occupied by plains which carry cross-roads, while the eastern ends are more mountainous and have only lateral passes. Thus, the high end of the Simi Hills block faces the San Fernando Valley, and only two routes lead out along the block edges, while the low end of the Perris-San Jacinto block faces the region and several roads ascend the face of the block and run across the high plains. All roads that lead
southeastward, however, must enter either the San Gorgonio or San Felipe Passes to get through to the Imperial Valley.

There is one other road at each end of the region on the seaward flank of the Santa Monica-Santa Ana Range. The route to the west, along the foot of the Santa Monicas, is difficult. It was never used by the Spaniards, and so the right of way had to be purchased, and the road was only finished in 1929. The route to the southeast leads along raised beach terraces, and was the old mission road to San Diego. These roads complete the set at each end of the region along the mountain flanks.

Toward the north, the roads must traverse the chain of the Sierra Madres. Directly to the north of the Los Angeles region it cannot be crossed, but in the northeast where it is highest, with a crest of 6000 feet and peaks above 10,000 feet, it is completely traversed by Cajon Pass, along the line of the San Andreas fault between the San Gabriels and San Bernar-
dinos. The road through this Pass does not cross a crestline, but follows a stream up to the 4000 foot level of the floor of the Mojave Desert which is part of the Great Basin.

In their western extension, north of the San Fernando Valley, the San Gabriel Mountains are much lower, about 3500 feet, and a road cuts through in a pass at about 1500 feet, now slightly reduced by a
tunnel which leads to the Santa Clara Valley. Up this Valley one road goes northeast to the Mojave Desert, and one goes down the Valley to Ventura. A third cuts across the mountains directly to the Great Valley of California.

There is a simplicity in the arrangement of the passways that connect the Los Angeles region to the outside world; at the western end of the region three routes lead west and one north; at the eastern end of the region three routes lead southeast and one north.

The Los Angeles region in area is only a little over one per cent of the State of California, but its importance may be judged by the fact that it contains 2,500,000 people, or nearly half of the population of the State. In fact, this tiny area contains one-quarter of all the people in the million square miles of the United States west of the Great Plains.
Part of Southern California
Los Angeles Lowlands
Scale 1:1,000,000
Rainfall and Temperature
Los Angeles
Fig. 1.

Water Temperatures
Off Point Conception

Water Temperatures
Off San Diego

--- Normal Temperature Curve
--- Observed " "

Fig. 2.
Climate.

Los Angeles has a well marked Mediterranean climate. In North America this type of climate is limited to California, and of its many variations in the State, that which is characteristic of Southern California extends only from Point Conception to San Diego in a narrow coastal belt. This is the climate of the City of Los Angeles, and though the station of the United States weather bureau in the heart of the City is 14 miles inland, it is well exposed to the influences of the ocean. Not all the Los Angeles region is so well situated.

The chief characteristics of this climate are the warm, sunny winters with occasional rains, and the rainless summers cooled to some extent by the sea breezes.

The coastal waters are here very cold for their latitude. According to McEwen (1912, p.241) their low temperature is due to the northerly winds off the Californian coast producing a southward drift which is deflected westward by the earth's rotation and thus causes an upwelling of cold bottom waters along the coast. The inshore waters are not as abnormally cold at Los Angeles as they are north of Point Conception, but they vary, from less than one degree in winter to four degrees in summer, below the normal ocean temperatures for the latitude. (See chart for San Diego and Point Conception, the closest stations, Figure 2.). The winter ocean temperature is about
Mean Maximum and Minimum Temperatures

San Bernardino 22 yr record
Los Angeles 42 yr record
Santa Monica 34 yr record

(Los Angeles maximum figure heightened by position on city building)

Fig. 3
58°F., the summer temperature about 63°F.

During the summer the influence of the cold ocean is marked in the Los Angeles region. At 34° N. Lat. on the west coast of the continent the region is at this season unaffected by the storms of the prevailing Westerlies. Only the sea breeze stirs the air and this is strengthened by the low ocean temperatures. In summer, as the heat of the day rises, the sea breeze blows in from the west. It may reach velocities up to twenty miles an hour along the coast of Santa Monica Bay, but its force decreases rapidly inland. Only where mountains face the coast is there a noticeable reversal of the air in a land breeze, and at Los Angeles the nights are calm.

In May and June the sea breeze brings in fog which hangs over the land as a "velo" (Spanish for veil). The velo is due to the condensation of moisture from the saturated air of the open ocean as it passes over the colder belt of water near the coast. It is not a true fog, for the lower few hundred feet of it are evaporated by the heat of the land, but it hangs above the country as a heavy haze. In the early summer the velo is carried far inland and may last all day. As the season advances it is dissipated by the afternoon sun, and by midsummer it is almost entirely absent.

The velo screens the sun at its height and makes a noticeable irregularity in the temperature
curve, even as far inland as San Bernardino (Figure 3).

It is not until July that all the region except the immediate coast becomes uncomfortably hot.

It is during the hot season that the direct effect of the sea breeze has the greatest influence on temperatures. The mean maximum temperatures for August (Map.8.) show wide variation between the coast and inland cities. At Santa Monica the highest day temperature reaches only 68°F. as an average for the month. The sea breeze enters here and invariably blows from the west at Los Angeles. At the latter station the mean maximum August temperature is 82°F, an increase of one degree per mile from the ocean. To the east of Los Angeles the temperature no doubt rises even in the Vega, but there are no stations except Tustin at the southeastern end of the Vega, ten miles inland, which has a mean maximum August temperature of 83°F.

None of the above temperatures is exceedingly high, and Los Angeles, in latitude eight degrees south of Chicago or New York, has lower average summer temperatures than either. In fact, the California Coast is remarkable in the whole northern hemisphere for the coolness of its summers.

Behind the Santa Monica-Santa Ana Range the temperatures are much higher. In the San Gabriel Valley to the south of which the above Range is low and broken, the stations that have elevations higher
than the intervening hills do not show a particularly rapid rise, but distance from the sea much more than offsets their higher positions; Pasadena - 227 feet high has a mean maximum August temperature of 86°; Sierra Madre - 1400 feet - 86°. On the other hand, Azusa which is low - 540 feet - shows the full effect of its inland situation and has a temperature of 92°.

In the San Bernardino Valley the mean maxima of all the stations are 90° or above, but even in the valley, temperatures continue to rise with distance from the ocean. On an average, the San Bernardino Valley temperatures are ten degrees higher than those of Los Angeles and Tustin, and twenty-five degrees higher than Santa Monica.

Beyond the mountains the desert temperatures rise to well over a hundred degrees; Bagdad to the northeast and Indio to the east, are both 106° for their average maxima in July.

No mention has been made of the San Fernando Valley for it is without a weather station. The Santa Monica Range to the south of it is fairly high and is unbroken, so that there are temperature differences on opposite sides of this Range, especially where it approaches the ocean.

Remarkable as are the above differences in the mean maximum temperatures for August, it is probably even more surprising that the temperatures all sink to about the same level at night; the daily range is
in almost exact proportion to the height of the day temperatures. All of the average minimum temperatures are within 2.5 ° of 56.5 F., except that of the Los Angeles station which is abnormally high because of its position on top of a building in the business district of the City. Nocturnal maxima at Santa Monica (54.3 Aug. mean) are only slightly lower than at San Bernardino (56°) and the stations all have such low average minima that cool nights are everywhere a pleasant feature of the climate of Southern California.

It is also true that low relative humidity ameliorates high temperatures in this region. At first glance this statement may appear erroneous, for the average relative humidity is fairly high (Los Angeles 63%). However, at Los Angeles, the moisture is acquired only from the cool ocean, and so the absolute humidity remains almost constant, and relative humidity decreases regularly and rapidly with the rise in temperature. As a result, hot, muggy days are very rare in Southern California. To counterbalance this there are never any storm clouds, nor cooling showers, and the uninterrupted sunshine greatly increases temperatures in the open. Because of the velo, May with 62% of the possible sunshine hours has the lowest average of sunshine for the year, but as the velo diminishes the percentage rises to a maximum of 79° in August. Also it must be remembered
that the sun is high, passing within 11 of the zenith at its highest and being more nearly overhead at Los Angeles than at the equator from nearly June to mid-July.

Late in the summer the sun is merciless. At eight o'clock it is already a "ball of fire", and a morning newspaper thrown onto a lawn (the regular method of delivery) is, by evening, discolored in the parts exposed to the sun.

It cannot be said that the sun is harmful; none of the bad effects it has in the eastern hemisphere tropics is noticed here. Children play bareheaded and the sun only fades their hair; bathers, even on a cool beach, may get a painful sunburn, but it turns harmlessly to some shade of tan. Livestock thrives without shade and most plants that are given water do exceedingly well.

The hottest month for nearly all of the region is August, but the temperatures do not decrease rapidly and it is somewhat surprising to find that September has by far the worst record for very hot days in the City of Los Angeles. Of the 51 days above 100° which have occurred in 47 years, 22 were in September, August having only 9. This appears to be due to cyclonic interference with the sea breeze during hot weather, for Santa Monica has its highest record of 104° in September, while its highest record in any other month is 95°. The highest records in the
Valleys are all in the month of June with temperatures above 115, and for Los Angeles, July with 109.

After September, the day temperatures decrease rapidly in the Valleys but only slowly on the coast. October is often warmer than June at Los Angeles.

By January, which is the coldest month, all the stations are nearly the same with monthly mean maxima varying from 58 at Santa Monica to 66 at San Bernardino. Thus, even in winter, the coast is comparatively cool (the prevailing wind is then off-shore) and the sea can never be considered as a warming agent except that it makes slightly warmer winter nights close to the coast. (January mean minima - Santa Monica 42; San Bernardino 36.8). In general the marine influence, aside from increasing absolute humidity and producing the sea breeze, can be said to be restricted to the cooling effects of the sea breeze on summer days. The nights throughout the year and the days in winter are very nearly the same in temperature for the whole region.

The lag in season is distinctive of marine influence and may be used in estimating it. The summer days are all at their maximum in August except at two stations in the San Bernardino Valley which are slightly warmer in July. The summer nights, on the other hand, show a strong tendency to reach their highest temperatures in July. Los Angeles and Sierra Madre do not reach their maxima until August. In the case
of Los Angeles the day temperatures are partly retained during the night by the neighboring buildings.

Sierra Madre is on a terrace at the foot of a mountain slope and in such positions where there is excellent air drainage, night temperatures tend to approach day temperatures. The winter days are at their minimum in January while the nights are coldest in December. (Los Angeles, Sierra Madre, and Santa Monica excepted).

The comparison of the seasonal lag at the Los Angeles station with that in other parts of the State shows the relative influence of the sea here. The number of days lag after the summer solstice of the highest daily mean temperature (using the middle day of the group having the highest temperatures) is, for Great Valley stations about 35 days, San Francisco - 100 days, San Diego - 55 days, and Los Angeles - 48 days.

The region is well warmed by winter sunshine. At this season there is no advantage in being near the coast, rather otherwise, and the valleys are then the favorite resorts. The temperatures are high. An extreme maximum above 85 and a mean maximum above 60 is reported every month for every long-record station in the region. Moreover, the sun shines over three-quarters of the possible hours until the first of the year and over two-thirds for the remainder of the winter.

*Data in letter from Dr. Varney, meteorologist, University of California at Los Angeles.*
There are never any cold north winds at Los Angeles, for in that direction lie the high Great Basin deserts warmed by a strong sun, and the air from them, in coming down the mountain slopes to the Los Angeles region, is raised in temperature by adiabatic heating. When there is a well developed high pressure area to the north, especially if accompanied by a low pressure area to the south, a strong wind blows down from the mountains. It is warm and often exceedingly dry (relative humidity as low as 4%). This wind is called the "Santa Ana" and in the eastern part of the region it is sometimes violent, whipping sand along, blasting the paint from automobiles and blighting trees. At Los Angeles the air will be full of fine grit, and vessels off the coast to the south report their decks dusty with the fall from these dry desert winds. Santa Anas are not common - only one or two a year are strong enough to be noticed at Los Angeles.

In the winter season, however, there is some complaint of the cold, for though relative humidity is low during the winter months, the rainy days are often cold and the damp air chilling. Fires are usually necessary in the evenings and frequently during the day, for most of the houses are thinly built and have overhanging eaves for sun protection.
Frost in the valleys and plains is not infrequent, but moderate slopes with good air drainage are little subject to killing temperatures for any but the most delicate plants. There is, however, great local variation in the frost hazard, due to topography, and in low pockets where cold air accumulates freezing usually occurs several times each winter.

For native plants the controlling factor is not frost, but rainfall. The summer has the dryness of a desert, alleviated somewhat on the coast by high humidity. The winter is a "rainy season" by comparison though it rains no more than in New England in the summer, and there are on an average only ten days without sunshine and forty days with any rain at all.

The rains come only between October and May, and even then with great irregularity. The usual storm tracks are so far to the north that only an occasional depression touches the Los Angeles region, (Figure 4) and between the storms the bright days and untroubled skies of summer return. Only a few score miles farther south in the Peninsula of Lower California the nearly rainless horse-latitude calms rule supreme the year around. The cyclonic storms generally bring Los Angeles several successive days of rain as is illustrated by the following chart of the daily rainfall for a fairly typical season.
Fig. 6.
Heavy rains are not uncommon, and five inches in twenty-four hours was once recorded at Los Angeles, a station with relatively low average rainfall. Sometimes the winter rains are accompanied with thunder, but summer thundershowers are practically unknown except on the high mountains and the lightning display in the winter storms is comparatively weak.

The outstanding characteristic of the rainfall is its great variability, not only from season to season, but also as regards its intensity per rainy day, and its time of occurrence within the "rainy season". The extremes in fifty-two years of records are 38.18 inches in 1833-34 and 5.59 inches in 1898-99.
The wide variation by months is shown in Figure 6, and in Figure 7 it is further illustrated by arranging in order of magnitude the contributions of each month during the last fifty-two years. It will be noticed in the latter Figure that the arithmetical average for any month cannot be expected to be attained in half of the years; that is to say, the median is lower than the average. This is not unusual for the average deficiencies are normally less than the average excesses. Also, the division into months tends to bring in many low figures. Thus, if the rainfall were subdivided into contributions by days, the median rainfall for any day of the year would almost certainly be zero.

The real interest lies in the accumulation of rainfall during any season. Where rain is so all-important as in Los Angeles, the daily newspapers announce every rain with the accumulation for the season and the average accumulation to the same date which is called the "normal". If, for comparison, the accumulations to the end of each month for all of the seasons are arranged in order of magnitude as in Figure 9, it will be seen that the accumulated average will not be reached in half of the years. The greatest disparity between the median and the average being at the beginning of the season, and three years out of four, there is a deficiency announced at the
### Contributions of each Month to Rainfall of 52 Years at Los Angeles.

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<th>Sep</th>
<th>Oct</th>
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**Average Rainfall:** 0.16

**Figure 7**
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<tr>
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<td>12.9</td>
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Seasonal Rainfall Accumulation in Inches & Hundredths to the End of Each Month, Los Angeles 1977-1980

Fig. 9
end of October and two years out of three, at the end of November. (Figure 7). This is very depressing in a country where every natural living thing is waiting for the rain and the whole economy is regulated by the amount that falls. Moreover, over a period of years such figures cannot fail to leave the impression that the country is becoming drier, or at least, the rains are coming constantly later. No figures are of much use in predicting the rainfall, but the median would seem to have advantages over the average.

The relation between precipitation at the different stations from year to year is not constant. The records of four lowland and three mountain stations (Figure 10) show a general similarity, but also erratic changes in the relative amounts of even closely grouped stations. Mt. Lowe and Mt. Wilson have a difference of 2400 feet in elevation, but they are only five miles apart and are both exposed to the south winds, yet there are remarkable differences in their rainfall from year to year. It would appear that nearby irregularities of topography produce erratic local variations. Thus, Claremont which is situated on a broad alluvial fan, gives the best indication of general trend of the rainfall for the entire district, for the seasonal totals in the fifteen years. (Figure 11). In 1906-7 the Los Angeles station record stood low in comparison with the other stations and
Rainfall in the Los Angeles Region

Average of 8 Stations

Fig. 411.
in 1912-13 which was for the district a very dry season, the Los Angeles station total was nearly up to its fifty year average.

In general it can be said that the plains have from 12 to 20 inches, the foothill slopes, between 15 and 25 inches, and the mountains, up to 40 inches as an average rainfall.

There is a very small accumulation of water in the mountains for there is only a shallow permeable layer of disintegrated rock, so that rainfall data is of little use in predicting future run-off. Stream measures are satisfactory in determining the amount of water which enters the gravel beds in the basins. The extraordinary variability in stream flow shows the fundamental part played by the gravel reservoirs of the plain in making possible a steady water supply. In 1929 the State of California organised a water resource department, and it is now proposed greatly to expand the program of careful measurements of the winter rainfall and snowfall on the mountains in order to be able to predict the amount of water that will be available during the following summer. This information is sought after for the intelligent regulation of artificial reservoirs which generally combine hydroelectric power plants with the storage of water for irrigation or city water supply. At present little can be said of the mountain snowfall on the basis of
## Stream Flow in the Los Angeles Region
from U.S.G.S. Water Supply Papers 1920-25

<table>
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<td>1210</td>
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Fig. 12.
measurements. It usually whitens the higher peaks until the end of April, but there are no permanent snow-caps in Southern California.

In conclusion, the climate of Los Angeles may be said to be that of a cool coast, sub-tropical desert, invaded in the winter by occasional mid-latitude storms whose southerly winds are robbed of their moisture, and northerly winds of their cold, by the protecting mountains.
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Natural Vegetation.

The most characteristic plant association and the only native growth that is still to be widely seen in the Los Angeles region is the bush covering of the mountains, called "chaparral". This word is from the Spanish, and is derived from choparre, the scrub oak. It is widely applied to any kind of brush in the old Spanish part of the United States. Some botanists apply the word as broadly as the Spaniards did, in which case the Southern California type is called "coastal chaparral". (Clements, 1920, p.177).

The chaparral, with some variation in species, covers all of the steep mountain slopes near the Los Angeles region, and only gives way to coniferous trees near the peaks of the Sierra Madre. The latter need hardly be considered in this study, for though there are some large pines which were formerly cut for timber, the trees are now valued solely for protecting the mountain slopes and beautifying pleasure resorts. Much of the mountain area is in National Forests, but that term is misleading if it is thought of as meaning only timber reserves. In Southern California these lands were set aside and protected against homesteading in order to save the plant cover on steep slopes. Near Los Angeles the National Forests are almost entirely chaparral areas.
The chaparral has been made the subject of an ecological study by Cooper. (1922). He says, (p. 7)

"The chaparral may be defined as a scrub community, dominated by many species belonging to genera unrelated taxonomically, but of a single constant ecological type, the most important features of which are the root systems, extensive in proportion to the size of the leaf which is small, thick, heavily cutinized and evergreen. This definition might be applied with equal accuracy to the macchie of the Mediterranean regions; chaparral is characteristic, almost exclusively, of California west of the Sierra crest and the deserts; in other words, of the region of California climate."
The center of distribution of this growth he places in Southern California where there is the greatest number of species (47) common in the association, 13 of which are confined to that area. The dominant species near Los Angeles is generally the chamise (Adenostoma fasciculatum) and the scrub oak (Quercus cumosa). Several other oaks and several species of Ceanothus are also important, while at high elevations the manzanita (Arctostaphylos) becomes abundant. Of the two last mentioned genera there are ten to twenty species and numerous varieties.

The appearance of the chaparral is that of a light green covering which is generally dense enough to soften the sculpturing of the mountains, though very often on the drier slopes, the light coloured ground shows through. It is difficult to get any impression of the height of the bushes without walking among them, for though there are generally many species, they all grow to about the same size in any situation and show as an even covering. In general, the height runs from three to six feet.

On the northern slopes of the Santa Monica Mountains, Verdugo Mountains, and the Puente Hills, steep shady exposures afford good protection from the drying sunshine, and possibly to some extent, the
protection from the sea breeze is also a help, so that in these situations the growth is much denser and tends to become dominated by some of the chaparral oaks, especially *Quercus chrysolepis*, which develop into small trees and then give way to the larger tree-oaks on the lower slopes.

The characteristic growth of all the species in the chaparral is a bush with several branches rising from a crown. This type of growth is especially suitable for withstanding fires, or in many cases, it may be the result of fires. There is probably none of the chaparral that has not been burned over during the existence of most of the present bushes. Fires are a regular event, especially in years with late rainfall. The mountains are criss-crossed with fire-breaks, spaces thirty to forty feet in width along ridges cleared of vegetation, but once a fire is started in the tinder-dry chaparral of late summer, it burns with excessive heat and quickly runs over a mountainside.

In December of 1929, before any rains came, 3000 men and all of the fire-fighting apparatus that could be spared in Southern California tried to control a chaparral fire in the Santa Monica Mountains only a few miles from the heart of Los Angeles. Even so, it was only a fortunate change in the direction of the wind that saved valuable residences, and the City Zoological
Gardens. The mountain areas are in the control of the United States Forest Service, with patrols and lookout stations, and strictly enforced regulations for the purpose of preventing accidental fires. The appearance of the chaparral which is often rather sparse, belies the fierceness with which it will burn, and great volumes of smoke by day, and a line of licking flames by night frequently mark the course of a fire through the mountains.

BE CAREFUL WITH FIRE

Fires are particularly severe and disastrous in the Angeles National Forest, because of the dense and inflammable nature of the brush cover which clothes the mountain slopes.
Fires in the chaparral are not, however, the stark, black tragedy that they are in coniferous forests. The majority of the bushes spring up again from their untouched crown; and in four or five years the scars in the mountain cover are healed. Chaparral is in a way benefited by fires, for it has certainly advanced upward against the coniferous forests by the aid of fires.

The stems of the chaparral which grow up from the ground in bush clusters are extraordinarily stiff and rigid. Even the tiny twigs are in some species so strong and unbending that they act as thorns. In many species the stems are very crooked and twisted.

The leaves are the really distinctive feature of the association as a whole. They are

"at most, of moderate size, about as large as the leaves of laurel or oleander, usually smaller, or even very small; they are scarcely ever compound, as a rule narrow, lanceolate or linear to acicular. Their margins are usually entire. The leaves are not generally placed with their flat surfaces perpendicular to the strongest light, but usually avoid it by assuming an oblique or parallel position ..... Glandular hairs are not uncommon on both leaf surfaces..... the leaves, comparatively speaking, are seldom shiny, but more frequently, even if smooth on the surface,
are dull, perhaps owing to exudations of resin, and often bluish. Histologically, the foliage is characterised by the thickness of the walls of all the cells ....... by abundance of sclerenchyma, by the strong development of cuticle, and by the diminution of intercellular spaces; these qualities in the aggregate give the leaf its characteristic stiff, leathery consistence."

The above quotation is from Schimper, (1903, p.510) and applies to what is termed "broad sclerophyll" vegetation. The fact that his description applies to the vegetation of the Mediterranean shores, Cape Town, most of southern Australia, and central Chile, as well as California, shows the ecological character of the growth. Cooper uses the above quotation as a satisfactory text for his description of California broad sclerophyll leaves.

Probably the most striking feature of sclerophyll leaves is that they are evergreen. On young oaks, leaves may remain for four years, but in general the leaves remain only a little over a year. The new leaves come with the first rains and the old and new leaves both function during the winter growing season; in May and June the old leaves fall. There are a few
deciduous species, but the formation as a whole never gives any indication of becoming bare.

The leaf habit is distinctly adapted to climate. "The prominent cuticle and the other features that are effective in limiting water-loss enable the plant to exist through the critical period of late summer and autumn. The evergreen habit permits it to make use of the spring period when growth conditions average best - a time when an ordinary summer green plant would be putting all its energies into the building of a new photosynthetic apparatus - as well as the rather frequent periods during the winter months when the temperature is high enough for effective photosynthesis. This explanation has been advanced by Guttenberg for the broad sclerophylls of the Mediterranean region, and by Schimper for the type in general. It seems entirely adequate for the California species. It might be added, however, that possibly in Aesculus californica we have a still more effective and economical way - the quick production of thin, deciduous leaves for use during the favorable period, and their gradual elimination as unfavorable moisture conditions render them dangerous rather than useful."}

Many of the bushes have rather prominent flowers. Some of them bloom at the beginning of the growing season before new leaves are put forth, others toward
the end - the California lilac (Ceonanthus) in April and the Andenostoma in June. The tollon bush bears conspicuous bunches of red berries which ripen about Christmas time and are called "California Holly". Among the chaparral, poppies are sometimes found, but in general very little herbaceous growth. On the lower slopes, in early spring, the yucca sends up its tall flower stalk, bearing a cluster of waxy white blossoms which can be seen for miles.

A less welcome member of the chaparral flora is the poison oak (Phus diversiloba) which is not an oak at all, but a tri-leaved cousin of the poison ivy of the Eastern United States. This plant is extraordinarily dangerous to some people, and poisonings are said to have resulted from the breezes which have blown over, or from the smoke of a camp fire in which the plant was burning.

The natural distribution of chaparral in the Los Angeles region is a matter of doubt. Clements (1920, p.150) thinks that much of the present chaparral exists in places where bunch grass is the natural dominant. Cooper, (1922, p.76) on the other hand, thinks that chaparral once occupied much of the area which is now considered natural grassland. He is most certain of this in the "foothills and low mountains of Southern California" and "the Los Angeles and San Bernardino Valleys".
It is not clear how much he intends to include under the latter phrase. No one seems to have made a study that refers primarily to the Los Angeles region.

Shreve in the study of the vegetation of the Santa Lucia Range (coastal mountains between the Salinas Valley and the ocean) observes that grass requires soil at least one or two feet thick, while below 1500 feet grass grows, to the exclusion of bushes, on soils with a depth of 20 feet. On the ocean side of the mountains, the sea breeze tends to favor grass on exposed terraces.

This last study furnishes the most useful basis for picturing the natural vegetation of the Los Angeles region. It is a study of present conditions, but in an area little cultivated, so that it might be considered almost as the Spaniards left it. Whether the Spaniards did more than bring in annual Mediterranean grasses, and whether the Indians before them had much influence on the natural vegetation, is open to speculation.

Shreve's controls satisfactorily apply to the Los Angeles region as far as can be judged by present conditions. The steep slopes of the Santa Monica, Verdugo, and Sierra Madre Mountains and the Puente Hills are covered with chaparral. The more gentle soil-covered slopes that have developed on the low
shaley hills northeast of Los Angeles and along the Dominguez Range are now occupied by grass — mainly wild oats (Avena fatua). In the San Pedro Hills the steepest slopes produce brush, while the terraces and gentler slopes where soil accumulates are grass-covered or cultivated. This region was for a century used as a pasture land, but even if there was effort made to extend the area of the grasses, the present distribution of chaparral shows where it is naturally the most dominant.

The lowlands are so completely cultivated that the question of their natural vegetation can be answered only by early descriptions which are neither numerous nor very satisfactory. The best that can be done here is to use the general studies that have touched this region, and to apply the results of detailed studies of somewhat similar areas.

The lowlands must have been mainly grasslands. The rapid success of the pastoral Spanish indicates this, though Cooper (1922, p.85) found enough scattered chaparral to suggest a natural dominance of that growth.

There are, however, some natural trees on the lowlands. The principal one is the coast live oak (Quercus agrifolia) which has the same type of foliage
as the chaparral. In fact, this tree is the most impressive plant of the broad sclerophyll vegetation, for being of a well known family, and often standing alone in grass lands, it can not be dismissed as a part of the strange growth on the hills.

At first glance, the name "oak" seems as far-fetched for this tree, as it does for the poison oak. It is only by the smell of the crushed leaf, or the quantities of acorns, that one recognises it as an oak. In open locations the trunk is short—sometimes it will be four feet in thickness and a few feet above the ground will divide into massive sprawling branches, some of which twist their way out horizontally, or rest on the ground. The spread in such cases may be 150 feet in diameter, and the height not over forty or fifty feet. The leaves are about the size and outline of the first joint of a man's thumb, and they are stiff and leathery, with slight prickers on the edges. They remain green throughout the year.

Vancouver (1798, Vol. 3, p. 7) called this "the holly-leaved oak", and the specific name agrifolia is one of the forms of the Latin name of holly.

Nothing could differ more in appearance from the common oak of the eastern states, and yet this western oak has simply adapted itself to a certain
type of growing condition in California. It grows only near the coast on the lowlands, or on the protected moist lower mountain slopes. It requires, according to Shreve, a moist surface soil; according to Cooper, a water-table from ten to twenty feet below the surface. Probably either of these conditions will satisfy the tree; the former promoting the growth of this oak on the protected northern slope of the Santa Monica-Santa Ana Range and Verdugo Mountains, the latter on alluvial fan terraces, especially in the San Gabriel Valley. It seems, in any case, to prefer heavy, well-drained soils. Its form makes it well able to withstand winds which it often encounters in situations along the coast.

It is doubtful whether or not there were ever many coast live oaks on the Vega or the Orilla. In a few places there, the water-table might be favorable, but in such places the soils are recently deposited river sediment. On the other hand, if there were any oaks, they might have been cut down, for this is a favorite tree for fuel.

The San Gabriel Valley must have been the best location for the live oak. There are still large groves that are practically forest, and in which the
trees grow tall and fairly straight. In other places they are more scattered and gnarled, but they are generally common, especially over the western part of the Valley. The San Bernardino and, to a lesser degree, the San Fernando Valley must have been too dry and hot.

The other common lowland oak is called the "Valley oak" (Quercus lobata). It is more normal in appearance, being tall, with lobed leaves much like a very small leaf of the white oak of eastern United States. The valley oak drops its leaves for a few weeks in the winter, and for that reason, probably, has an advantage over the live oak in colder places, and also because of a tap root in places with a lower water-table. Often it is mixed with the live oak, but its range in the Los Angeles region is almost restricted to the San Fernando Valley, with a few trees in the San Gabriel Valley.

In the mountain canyons, along the more permanent streams, the willows (Salix lasiolepsis), sycamores (Platanus racemosa), and black walnuts (Juglans californica) are still largely untouched. These are all deciduous, but they are hidden in canyons and can never have counted for much in the general scene. The same trees must once have formed dense thickets in the gaps by which the Santa Ana, San Gabriel, and Los Angeles Rivers pass through the Santa Monica-Santa Ana Range, and probably once made these difficult as routes.
On the plains, along stream ways, it seems likely that there would have been a line of brush and trees - mostly willow (Salix × lasiocarpa). McKenney gives this description for Orange County, probably referring to the Santa Ana River on the Vega.

The prickly pear cactus (Opuntia), which has done so well in many lands of Mediterranean climate, is not prominent in the Los Angeles region, being generally restricted to gravel terraces and weakly consolidated conglomerate outcrops. There is one steep ocean-facing slope on the San Pedro Hills that is covered with it, and isolated individuals, or groups are not rare. It may have been cleared in some places, but it seems never to have overrun this region. In the main, the lowlands must have been grass-covered, with coastal sagebrush coming in toward the eastern part of the San Bernardino Valley, and probably on the drier upper parts of the alluvial fans in the San Fernando Valley.

Oddly enough, the native grasses were perennial bunch grasses with Stipa sitigera or Stipa eminens dominant. This genus is also dominant in the prairie of the Middle West and grasslands as "a single great climax formation" ...range from central Saskatchewan and Alberta in the north, to the highlands of central Mexico on the south, and its subclimax form, at least from Illinois on the east to California on the west.
The three most important dominants, Stipa, Agraphrum, and Bouteloua, extend over most of the area and one or the other is present in practically every association in it". (Clements, 1920, p.114). The differentiation that makes the western coast winter rain region stand out is the bunch type of growth - a growth habit that is also typical of the Nebraska sand hills, while California differs from the northern bunch grass area only in the species of the dominants.

The extension of the grasses of California through such a wide range of climate, brings out the fact that climates which differ greatly from a human point of view, may be much alike for plants. The weather of the growing season would seem to be the important part of the climate as far as these grasses are concerned. The dominance of perennial grasses in this land of desert summers is surprising, annuals appear to be so much better adapted.

Wild oats (Avena fatua) were introduced by the Spaniards and have become the dominant wild grass in Southern California. Clements (p.304) ascribes this to over-grazing, but it would seem quite possible that they are actually better adapted to the climate. Cooper, as quoted on page 35 points out that an effective
thin leaf, formed for the favorable season and dropped during the summer, might be considered the most desirable adaptation in chaparral, and this would be even more true of the grasses. The bunch grasses, though they must be nearly as dormant as seeds during the summer, require a wide space for collecting moisture. Wild oats, on the other hand, grow thickly in the winter and die down completely in the summer. They are not weeds here in the sense that they come in only as by-products aided by cultivation, for they occupy soil that has never been cultivated, and persist year after year on vacant places where there is neither cultivation nor grazing. It would seem that the introduced coarse grain grasses of the Mediterranean are more characteristically adapted to the climate of California than the native grasses.

Their adaptation is not strikingly apparent for they have been vulgarised by wide cultivation, but their requirements are peculiar, and are only naturally met in something equivalent to Mediterranean climate. Under such conditions the ground is rich from lack of leaching, and it is naturally aerated by the drying and cracking of the summer season. The cracking also aids in covering the large seeds, and these in turn give a strong, quick growth as soon as moisture is available. Such native grasses around
the Mediterranean provided primitive man with a basis for civilization. The summer of northern Europe and of the eastern United States provides a growing season not essentially different from a plant standpoint, from the winter Mediterranean regions. By cutting the forest, subduing the native grasses, cultivating, and sometimes liming and manuring, the soil requirements can be met, and Mediterranean wheat has traveled with Mediterranean civilization. It is, however, in regions of Mediterranean climate that the natural conditions favor these plants. In California a volunteer crop of wheat will sometimes give a good yield.

The broad sclerophyll perennials and the coarse grain grass annuals can be looked upon as the characteristic vegetation of the Los Angeles region.
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The Soils of the Los Angeles Region.

The soils of the Los Angeles region have all been mapped, and information regarding them is published in bulletins issued by the United States Department of Agriculture in conjunction with the California State Experiment station.

Because of the general lack of appreciation of these bulletins, it might be well to mention that they are the nearest approach to regional studies that are available for California. They include descriptions of topography, climate, water supply, and crops, as well as the more detailed soil studies.

In the bulletins, the soils have been described especially from the standpoint of crop production. The chief effort has been to show differences between specific pieces of land, and the broad relationships of the many divisions are but slightly mentioned.
As a result, there is extreme differentiation. About fifty types, grouped into nineteen soil series, are described in mapping the Los Angeles region. The series are not given any scientific arrangement in the bulletins and the divisions become incomprehensible in their detail.

Mr. C.F. Shaw has proposed a classification of California soils that has proved very satisfactory for this thesis. He has grouped the soil series into families having the same "parent" material, and has arranged series within the families according to stage in development. Soils weather vertically downward, so that eventually they develop fairly well-defined horizontal layers called "horizons". A vertical section through all of the horizons is called a "profile". It is by studying the stage of the development of the profile that the relative age of a soil can be determined.

Shaw has published the classification for only one family, but other families fit satisfactorily into that outline, and so it will be extended to all of the Los Angeles soils. (Map //, p. 55) In order to obviate the confusion of proper names used in the bulletins, the families and soils will here be referred to by descriptive titles, and their relationship

with the named soils of the bulletins will be explained in an appendix. (Page 87)

The family outlined by Shaw will be called the "granitic alluvium family". It contains those soils developed on transported material, derived from granite rocks. The exposures of granite are shown approximately on the accompanying geological map. (Map 57)

As it is deposited by the mountain streams, the granitic alluvium shows every degree of pulverisation. Near the mountains the tops of the alluvial fans often consist largely of boulders, quickly changing to gravels and sands farther down the slope, and then more slowly, into finer sediments, but everywhere having much the same minerological content.

The original color of this material is commonly a light grey which, on the accumulation of plant remains, darkens to a yellowish brown through the first few feet, but does not at first separate into distinct horizons. The soils, up to the brown horizonless stage, will be mapped as "young".

The effect of weathering on this youthful soil is to break down complex mineral particles and to filter the very fine material, called "clay", through the surface eight or ten inches to a layer of accumulation. The surface layer which is losing material, is called the "A" horizon; the layer where the clay and, often also, organic colloids are accumulating, is called the "B" horizon. The A and B horizons
Soil profile showing well developed B horizon.
correspond somewhat to soil and subsoil, but they are much more exact and are the accepted terms of international soil science.

If the soil surface remains practically stable for a sufficient length of time, the B horizon becomes a brown, compact, clayish layer, so much firmer than the soil above or below it, that it weathers out as a distinct band.

Soils with a well developed B horizon are common in the Los Angeles region. They will be mapped as "old soils". They are remarkably different from the young soils, and several intermediate stages are recognised by Shaw in other parts of California. Physiographically, the difference between young and old soils in the Los Angeles region is the difference between modern alluvial fans which are in many cases still forming, and older fan terraces. Very probably this break can be traced to tectonic disturbances of a former fairly well graded surface. Such a former surface has been recognised by geologists though it has not been related to the soils.

Two further stages are recognised by Shaw. They will here be grouped as "very old" soils. These have a very compact B horizon, almost a hardpan, and are generally red in color. They are best developed in the eastern part of the San Bernardino Valley on which the Los Angeles Surface writer's name is not legible:

much dissected old fan terraces. There is some question whether these soils are a normal development from the soils called "old", but there is little doubt about the difference in age, so that this classification seems satisfactory.

There is one subfamily of the granitic alluvium family which is widespread and of considerable physiographic interest. To it belong the soils developed on wind-blown sand. The greatest area of such soils is on the beach dunes, and an objection might be raised to classifying such soils as belonging to the alluvium granitic family. However, the beach sand in this region is composed largely of fresh granitic material and, since the old soils developed on this material are grouped in the bulletins with the old soils of the granitic alluvial fans, it avoids altering the official maps to treat this wind-blown soil group as a subfamily.

The second family of alluvial soils includes those developed on parent material derived from sedimentary deposits. The sedimentary rocks are largely of the Tertiary age and for the most part are rather poorly consolidated conglomerate, sandstone, and shale, with practically no limestone. The soils developed on the parent material derived from these rocks will be known as the sedimentary alluvium family, with the stages - young, old, and very old.
In the young stage this family shows much higher clay content than the granitic alluvium family. In the old stage, it more nearly approaches the old granitic alluvium soils, and, in fact, the two families were not differentiated at this stage when the region was mapped. If they had been mapped later, the two soils would have been placed in different series.

On the accompanying map the old sedimentary alluvium soils are shown where they are known to the writer, though some may be included under the tint for old granitic alluvium soil.

The sedentary soils of the hill slopes have not been included on the map made for this thesis. Except on the San Pedro Hills, these soils are on such steep slopes that they are little cultivated, and the small areas mapped in the soil bulletins are difficult to show on a small scaled map.

The position of the soils of the Los Angeles region in a world classification is not decided. The present broad classifications are based mainly on climate. Climate is the active factor in rock weathering, and theoretically, the climate would ultimately determine the soil characteristics. This would be true only for very old soils which are not common in the Los Angeles region where erosion on the one hand, and deposition on the other, are constantly renewing the surface material. There seems to be a fairly
embarrasses plant growth. Where there is poor drain-
age the ground water evaporates and results in an accu-
cumulation of salts which produce a so-called "alkali" soil. This hinders the normal osmotic processes, and in the case of some salts, has also a toxic effect. Large areas in the lower part of the Vega are affected by alkali.

Soil moisture is generally the natural limiting factor of plant growth. When irrigation has made water available, the lack of nitrogen is the limiting factor. Organic fertilizers are in great demand. Barnyard manure, bean straw, and dried fish manure all sell at very high prices for soil dressings. However, most of the nitrogen is shipped into the region in the form of chemical fertilizers.
Structure and Physiography.

The dominant factor in landscape building in the Los Angeles region has been block faulting; vertical, and possibly horizontal displacement of great magnitude along well marked fault lines. Some of these fault lines can be traced far beyond the borders of the region - notably the San Andreas rift which runs through Cajon Pass and is traced to the north beyond San Francisco where it was the seat of the 1906 earthquake. Others are prominent only locally, criss-crossing to mark out large blocks, while within the blocks, many exposures show great distortion and often minute faulting of the strata.

Movements along these faults are known to have started in comparatively recent geological time. Geologists have dated the beginnings of the present mountain system as of the Cretaceous age. Exposures of sediments laid down prior to the orogenic movements are very limited in extent. They are thin deposits that in general have been metamorphosed into slates or marble.

The sediments, since the mountain building, show all of the characteristics of coastal deposits. They are extraordinarily thick - at least 15,000 feet of Tertiary sediments; they are composed of debris varying from granite boulders to fine mud, and beds of
diatom skeletons which are supposed to have thriven in silica-rich coastal waters and to have been, perhaps, the source of the petroleum. The deposits show great variation both vertically and horizontally, as if they had been laid down by torrential rivers.

Throughout the whole thickness of Tertiary and Recent deposits there is nowhere any sharp division nor any index rock, so that although the substrata have been widely explored by drilling for oil, it is not possible to correlate the strata in the different parts of the region. Over much of the region there has been no government geological survey, the area for which bulletins have been issued being delimited on the accompanying map. There are on file with the State of California logs of all the oil wells, but they tell very little as they are only drillers' records, and consist of a monotonous repetition of sand and shale. The only areas where the structure has been mapped to any depth are the individual oil fields, where the water and oil-bearing sands are recognisable.

There is plenty of surface evidence of faulting, not only in the mountains where there is structural evidence, but also on the lowlands, and although there is considerable hesitancy in marking the latter on maps, oil geologists go up in aeroplanes and sight along every surface irregularity to try to trace out faults.
In the work for this thesis the effort has been placed primarily on the study of the physiography. There are so many physiographic anomalies which it seems possible to explain only by structural movements, that it has been necessary to include a whole system of tectonic changes based on the horizontal shifting of crustal blocks. It seems best to introduce this part of the work by pointing out in detail some instances where horizontal movement gives a satisfactory solution to physiographic features that are otherwise extremely difficult to explain, and then to develop the general theory for the greater part of the region.

The first and most striking evidence of horizontal displacement was found between the opposing bluffs along the Los Angeles River just north of the business center of the City.

The right or western bank here is formed by a block of Puente (Miocene) sandstone. (Map B). From the Dayton Avenue Bridge to the Fletcher Avenue Bridge the river face of this block is a very straight and precipitous wall, rising about 400 feet from the river-bed to its crest line which is, in general, less than 1000 feet back from the base of the bluff. The back slope of the block descends more gradually and the lower parts of it are covered by residences.
Much of the high land along the crest is included in Elysian Park and might therefore be called the "Elysian block". In the higher parts, it has the topography of a solid block of sandstone undisturbed by recent tectonic action. The most striking physiographic features of this block are the valleys which completely traverse it at almost right angles to the Los Angeles River. There are six places where one can pass from the river-face, through gaps which definitely breach the crest, and continue on in stream valleys which descend the opposite slope. There is every indication that these passes represent the channels of streams which formerly flowed from the northeast across the block. These streams must have been cut off at the line of the bluff, and drainage reversed in that end of the channel. This reversed drainage, with a steep gradient, has worn deep narrow valleys and has pushed the water-parting to the south of the crest-line.

For lack of names these channels will be numbered - No. I hardly shows on the map, but this is because the contours are drawn on top of a road which has been built across a definite breach in the crest-line. This is the smallest of the six. No. II is a very definite gap. The water parting is 250 feet below the crest-line height. No. III is not so low, but is still well marked, while Nos. IV and V are evidently branches of
one stream which once united behind the little hill on the river-face and passed in a single channel through a low gap. It will be noticed that headward erosion by the reverse streams has here been greater than in the other channels and has probably greatly deepened this gap since the streams were beheaded. No. VI is the deepest channel, cutting down more than 250 feet below the crest. The southern slope of this channel is dammed to form Silver Lake.

Beyond No. VI the topography becomes very complicated, and there are no stream lines leading to the River which definitely connect with any flowing southward. The only through gap - the one occupied by Los Feliz Boulevard - has drainage across, rather than along it, and may be connected with the fault line along the flank of the Santa Monica Mountains. There is no indication of faulting along the other passes.

There, then, in the Elysian block, six streams for which the head waters may be sought on the other side of the Los Angeles River. It is quickly evident that there is no hope of locating the head streams directly opposite. Here the solid wall of the bluff is broken by only one gap. Farther south, however, there are six streams flowing into the Los Angeles River from a high block of Puente sandstone. This will be called the "East Los Angeles block". Like the
Johnson and Warren (1927, p. 95) say that the alluvial sediments north of Pasadena suggest the former flow of the upper part of the Arroyo Seco toward the southeast.

Physiographically then, there is good reason to believe that in reality the eastern half of the Elysian block has been replaced. Geologically, the former connection of the two blocks is inconclusive. They are both Puente sandstone and for the most part correspond in strike and dip. The geological map in Arnold's paper on this area (Map 16) shows an anticline crossing both blocks. When the blocks are replaced so that the streams correspond, the anticline of the eastern block does not quite come into line with the anticline of the western block. There may have been some displacement along the Los Angeles River fault before the streams eroded their channels. It is certainly true that fracturing has antecedent present valley erosion in the hills to the east.

There is no evidence that the Arroyo Seco stream headed in the East Los Angeles block as the other streams do, and so there is a possibility that this stream may have carried telltale gravels into the cross channel of the Elysian block, though considerable search has failed to reveal any gravel beds.

The rocks are very much better exposed now by roadcuts than when Arnold determined the anticline. The writer found it to be as marked on the Elysian block face with double red lines. On the eastern face the anticline pitches so that he could not locate the crest, but it is not south of Arnold's line. Thus the anticlines seem to be more offset in the replaced block than would be indicated by Arnold's map.
The study of the Elysian block gave the first suggestion of a Los Angeles River fault. The tracing out of such a fault has added more evidence of its existence though it has also brought up some difficulties.

Toward the north, the evidence is in support of the faulting. The movement postulated brings the northern shoulder of the bluff to the east of the River, in line with the northern flank of the Santa Monica Mountains, and so brings the granite of the Forest Lawn Cemetery - the only granite on the face of the eastern bluff - against the granite of the north-eastern extremity of the Santa Monica Mountains - the only granite on the western face. South of these two bodies of granite, there is shale and then sandstone on both sides, but as the hills of this section now stand above the alluvium, they can not be brought close together.

Farther north (Map C.) a similar displacement on the eastern side of the fault line will close the gap between the Verdugo and the San Gabriel Mountains. The present corridor of the Tujunga and La Canada canyons is a physiographic abnormality which is thus explained. Miller (1928, p.208) has already in part indicated parallel faults along its edges. (See also, Hill, 1930, p.153) and (Kew, 1924, Plate I).

This movement of the Verdugo Mountains is practically the same as that between the two bluffs of the
Los Angeles River, so that the fault seems to turn eastward here. Therefore, it need not extend farther northwest and, in fact, there is no further evidence of it in that direction. This eastward bend of the fault means that here, at least, the movement of the Verdugo Mountains has been that of pulling away from the San Gabriel Mountains. Even in the case of the movement between the Elysian and East Los Angeles blocks, the same thing seems to be true, though in the latter case the movement is not so oblique to the fault line. The Verdugo Mountains are now separated from the San Gabriels by the Tujunga-La Canada corridor which is a mile in width. That a chasm has been formed along this corridor is suggested by the action of the northern part of the Verdugo Mountains. Miller (1928, p. 212) points out that a block north of La Tuna Canyon has slipped down a thousand feet in relation to the main part of the Verdugos. This may be a landslip block caused by the opening of a chasm. There are isolated rock hills protruding through the alluvium northwest of the Verdugo Mountains which appear to have been left behind in movement. A water-damming sill of some sort extends from these hills eastward across the Tujunga wash, where a chasm would be predicted by the postulated movement. (Nov, 1934)

To the east of La Canada corridor the recent sediments of the San Gabriel Valley bury most of the
rock structure, but there is some evidence of the same movement which will be discussed later. (Page 79.)

In endeavoring to trace the Los Angeles River fault toward the southeast from the Elysian block, it will be noticed that there is no evidence of continuation of the fault line southeast of the East Los Angeles block. (Map B.) There is an opening to the south along the line of the Los Angeles River. If the fault line bends here, the movement should produce a chasm some two miles in width. The present river bottom is only about a mile wide, but the high land to the east of the River is largely old alluvium. There are isolated shale knobs here that present a difficulty in interpreting this opening as a chasm, but they are also difficult to explain by any other cause. Ignoring the shale knobs, there is an opening to the south such as would be formed by the postulated horizontal shifting. The deposit of old gravels in this part dates the movement as prior to the laying down of the surfaces on which old soils have developed. This accords with the fact that the Arroyo Seco runs through a gap in the Repetto Hills in a narrow trench cut in a wide deposit of old sediment. The location of old gravels on the shoulder of the Elysian Hills, just above the Plaza (Map B), is evidence of the former extension of the old sediments across the present Los Angeles River channel.
Farther to the south the recent alluvial deposits of the Vega cover all the rock structure. Directly in line, however, on the south side of the Vega, there is a chasm through the Dominguez Range which can be explained by a horizontal shift nearly equivalent to that of the Elysian-East Los Angeles blocks. (Map D).

The recognition of horizontal crustal movements along the Los Angeles River through Dominguez Range to the ocean depends in part on the identification of the lowland between the Dominguez Range and the San Pedro Hills as a coastal deposit between an island and the mainland. This is an unpublished interpretation, but the physiography so strongly suggests that the dune land from Santa Monica to Redondo (Map A) is a raised tombolo, and the Gardena Plain at the foot of Dominguez Range the elevated floor of a lagoon, that the sand ridges behind Wilmington appear to have been the southeastern tombolo enclosing the lagoon. There is a double sand ridge here extending from Bixby Slough to Watson. There is one small outlier just beyond Watson, but in this the tombolo ends at the bed of the Los Angeles River. Beyond the river-bed and about two and one half miles south of Watson, is the truncated end of another tombolo ridge on which the City of Long Beach is located.
If the Long Beach tombolo, and Signal and Cerritos Hills are taken as the surface features of a crustal block east of the River, and this block were moved to bring the Watson and Long Beach tombolos into line, the river-face of Cerritos Hill would fit nicely against the river-face of Dominguez Hill. What is more significant, the oil field of Cerritos Hill would come exactly in line with the oil field of Dominguez Hill. The gap between, where no oil has been found with extensive and deep drilling, is thus explained by this movement. Likewise, the depth of the filled channel along the Los Angeles River is accounted for. Water wells have proved that water seeps through the Dominguez Range in a channel at least 1000 feet in depth. There is serious difficulty in explaining this channel as a river-eroded canyon. Such an explanation would require enormous changes in elevation that can hardly be admitted in the face of the youthful topography of Dominguez Range. Slight traces of oil sand have been found under the river bottom, but they would be expected in the down-slipped blocks of a chasm fault zone.

The coastal erosion of the bluff at Long Beach and the building of Terminal Island would be the natural result of the movement postulated. There is no
evidence of the fault in the ocean bottom, but San Pedro Bay receives quantities of sediment from the three rivers of the region, and any breaks in the surface might soon be smoothed over.

Assuming that there is a chasm fault here, there is some difficulty in connecting it with the one between the Elysian and East Los Angeles blocks. The distance of the movement is nearly the same, but the direction is slightly different, being more nearly north and south between Dominguez and Gerritos Hills. Another difficulty lies in the evidence of the date at which the movements took place. In the case of the Elysian-East Los Angeles rift, this is certainly before the deposition of the alluvium on which old soils have developed. In the case of the Dominguez-Gerritos rift, it seems that the movement has occurred after this old soil surface was deposited; certainly it was after the formation of the Long Beach-Wilmington tombolo which has a surface of old soil. However, soil stages are so indefinitely related to time, and are as yet so crudely determined, that it can hardly be said that this is any proof of difference in time.

A further evidence of chasm faulting along this line is contained in a reference to gravity anomalies in this region mentioned by Bowie (1927, p.99). He says of the gravity tests shown in Figure 15.

"The anomaly at Compton, California is 0.050
Fig 15
dyne, while at Long Beach, only eight miles distant, the anomaly is 0.022 dyne. The difference is 0.028 dyne. Here again, the cause of the anomalies is local and high in the crust, for the elevations of the stations are less than 70 feet, and no distribution of the compensation of so small an amount of topography close to the stations could affect the anomalies materially."

The station at Compton must be very close to, or on, the predicted fault chasm. The station at Long Beach is over a mile to the east of the fault zone. These two stations do not prove anything in themselves, for the Compton anomaly might be due to a deep syncline parallel to Dominguez Range. A few further gravity tests would settle this, and if it happens that chasms can be found by these tests, there is much hope for tracing the lines under the alluvium.

At present it can only be said that there is some evidence that the earth's crust, east of the Los Angeles River and south of La Canada Canyon, has moved southeast about two and a half miles in relation to the crust west and north of those lines. It might be noted that there is no evidence of vertical displacement along this fault line. The similarity of height in the two parts of the tombolo admits of a vertical displacement of only a few feet.
There are several other places in the Los Angeles region where chasm faulting might be used to explain the physiography. Only the Paso de Bartolo need be mentioned here. (Map E) The study of the depth of this waterway throws some light on the subsurface condition which may be expected in what are called "chasm faults" in this thesis. The Paso de Bartolo is the gap by which the San Gabriel River and Rio Hondo leave the San Gabriel Valley. The surface of the alluvium here is about 200 feet above sea level. The shale hills on either side stand about 400 feet higher. The depth of the alluvium in the Paso de Bartolo, or Whittier Narrows, is referred to by Johnson and Warren as follows: (Conklin, 1927. p. 94)

"The study of the logs of oil wells drilled in the Narrows at the east end of the Montebello Field, shows them very conflicting and of little real value, as oil well logs are more concerned with the earlier sedimentary formations than with surface material. The Keeler and Taussig well No. 1, (Map 18) located near the junction of Durfee Road and San Gabriel Boulevard, is the most detailed log on file in this office. This shows the first hard sand at 246 feet, followed by clays and gravels, then hard sands again at 489 feet, again with clays and conglomerates below, with the first sticky shale struck at 904 feet, below which the log shows hard formations to predominate."
sides of the chasm. To explain the deep, filled gap as a river-eroded channel is almost impossible. English (1926, p. 61) has postulated a syncline here; Johnson and Warren (1927, p. 97) a fault.

The evidence of horizontal crustal movements in the Los Angeles region lends interest to the theories of continental displacement in which the region has been mentioned. The first of these was Wegener's (1924, p. 184). He notes that there is a notch in the mainland coast which would be filled if the Peninsula of Lower California were moved slightly southeastward. He accounts for this by a movement of the North American Continent away from the Peninsular Range.

Hans Cloos (1928, p. 281) deals more definitely with the California Mountains. His theory of continental drift is different from that of Wegener, so that he makes the coastal mountains move northward, rather than the Continent move southward, but since the movement that can be measured is purely relative, this difference in direction makes no difference in the results. In describing the Los Angeles region it is easier to speak of the eastern blocks as moving southward. Cloos does not enlarge on the Los Angeles region in the text of his article, but from his figure (Figure 16) the position is fairly clear. The San Andreas fault is a line of major movement and the crust to the northeast of the fault has moved southeastward. Cloos does not include the Gulf of California.
Sketch of the Structure of the Pacific Ranges of North America showing the Western and North Western Movement of the Coast Ranges and the R.W. H. and its escarpments.

Fig 16
in his figure, but the movement he postulates would account for it in somewhat the same way that Wegener did.

In the Los Angeles region Cloos's figure indicates that the Perris-San Jacinto block has pulled away from the San Gabriels, forming the San Bernardino Valley, while the end of the Peninsular Range (the Puente Hills) in pulling away from the San Gabriels, has formed the San Gabriel Valley. The figure does not include San Fernando Valley. Little detail is given concerning the Los Angeles area, and so the above may be reading more into Cloos's figure than he intended, but certainly there is a suggestion of such valley formation. The above theory provides a basis of rock structure which seems to be an adequate explanation of the topography.

The theory might be stated a little more comprehensively as follows; the continental mass to the northeast of the San Andreas fault tends to move southward in relation to the continental edge which lies to the southwest of the fault. Where the great east-west chain of mountains faces the ocean from Point Conception to Cajon Pass, it has resisted the southward drift, but the movement along the San Andreas fault has involved successively, blocks lying in front of the San Gabriel Mountains, and as these have
been pulled away from the San Gabriels, they have left chasms which have been filled to form the San Bernardino and San Gabriel Valleys. The movement of the blocks has not always been parallel to the edge faults; therefore, in some cases, edge chasms have been formed and in others, pressure ridges.

It is essential for detailed physiographic description to have some comprehensive theory of the surface modelling, and this theory correlates so many topographical features that it forms a working basis for a discussion of the physiography.

The San Bernardino and San Gabriel Valleys.

According to the horizontal shift theory, the San Bernardino Mountains have moved a considerable distance toward the southeast. There is no need here to estimate that distance, but at least, the movement is great enough to mean that the San Bernardino Mountains have moved out from behind the San Gabriels (Map F). This may, to some extent, explain the difference in the stage of erosion of the two Ranges. The San Gabriels are maturely eroded with practically no level areas. The San Bernardininos, on the other hand, are a high plateau in the youthful stage of erosion, with wide "flats" and narrow canyon streamways. The lakes now shown on the maps are artificially dammed, but there are no similar sites in the San Gabriels. If the San Bernardininos were once behind the San Gabriels, and
to a certain extent protected from rainfall, they should show less erosion, but the contrast is so great and the evidence of youth so strong, that it seems necessary to postulate recent elevation for the San Bernardino Mountains.

The escarpment of these mountains facing the San Bernardino Basin is the most abrupt mountain slope in the region. The foot of the slope forms a straight line along which the San Andreas fault has been traced. The elevation at the base of the Mountains is only 1500 to 2000 feet, but the slope rises at an average rate of as much as 1200 feet per mile to the plateau height of 5000 to 6000 feet. The edge of the plateau is very well defined and so nearly straight that it can have been but little eroded by streams. However, the slopes which in few cases make an angle of more than thirty degrees with the horizontal, can hardly be taken as exposed fault planes on the face of a crustal block, unless there have been landslip blocks.

The San Bernardino Basin has been little explored by the writer, but it may be looked upon as a filled chasm formed by the southeastward movement of the Grafton Hills area and possibly, to some extent, by the movement of the Perris-San Jacinto block in a direction more southerly than that of the San Andreas fault line. The Basin is about twenty
miles in length along the foot of the San Bernardinos. It is about seven miles in width. Its elevation (1000 to 2000 feet) is low, so that it is, to some extent, enclosed on the west by the high alluvial apron lying in front of the San Gabriels. The absence of any alluvial cones at the mouths of even the small mountain canyons of the San Bernardinos may be the result of horizontal movement of that Range.

The Perris-San Jacinto block is the first well defined crustal mass to the southwest of the San Andreas fault. It appears to have moved about fifteen miles away from the San Gabriel Range. It thus opened a chasm which has been filled to form the San Bernardino Valley. The end of the block has dragged off and stands as an arc of hills running from one corner of the block to the other and bowing out in the center. This might be called the "Jurupa Arc". Between the Jurupa Arc and the end of the block is the alluvial-filled Riverside Basin which is dotted with isolated rock knobs.

Outside of the Jurupa Arc is the main part of the San Bernardino Valley. For the most part, this is occupied by an enormous alluvial apron in front of the San Gabriels, called the "Cucamonga Plains". The surface of this apron is formed by the coalescing fans of the short streams entering the valley between Lytle Creek on the east and San Antonio Creek on the west. (Map 20)

1. See p. 183.
Fig. 18

Diagramatic Section Through Red Hills. a. Granitic Rocks. b and c. Earlier and later alluvium and hypothetical boundary between them.

Traced from Mendenhall.
The Cucamonga Plains are higher than the alluvium on either side of them. Their height may be due in part to buried landslip blocks.

The Red Hills and Indian Hill are areas with an old soil cover which protrudes through the newer alluvium. These areas have a steep south-facing escarpment but their surfaces slope gently toward the north. In cross section, Mendenhall (1905, W.S.P.219) shows the Red Hills north of Ontario as in the accompanying tracing. (Figure 18) He considers these hills as erosional remnants. On the other hand, they may be explained as the outer edge of landslip blocks. Lack of frontal support along the San Gabriels, due to the movement of the Perris-San Jacinto block, might well cause such slips. The northward slope of the surface of Red Hills is explained as being due to the reverse rotation to be expected in landslip blocks. This explanation is illustrated in cross section by Figure 19.

The Indian and Red Hills apparently mark the edge of a landslip block which fills the northwest corner of the San Bernardino Valley where the San Jacinto block has broken away along a line at right angles to the line of movement. The flank of the San Gabriels is slightly oblique to that line.

The Puente Hills form the main part of the southwestern wall of the San Bernardino Valley. They
are a block of Tertiary rocks much faulted and folded and with an overthrust fault along their southern edge as is shown by the geological study made by English. From a physiographic point of view they are interesting chiefly because of the passes that completely traverse them. The drainage of the Hills is mainly toward the Vega, but the water-parting, in many cases, is simply the highest point in a deep, narrow valley which leads directly from the San Bernardino Valley to the Vega. The channels point to former drainage across these Hills. The Puente Hills can be thought of as the lower portion of a long southwest facing slope, the upper part having been the Perris-San Jacinto block in its former position.

The Puente Hills are the northwestern end of the Peninsular chain, but they are cut off from the Santa Ana Mountains of that chain by the Lower Santa Ana Canyon. This Canyon now carries off the drainage of the San Bernardino Valley.

The Puente Hills are more than the bounding wall of the San Bernardino Valley; they are a crustal block which, like the other blocks, has moved toward the southeast. The movement in this case appears to have been only about four miles, but this has resulted in the formation of the San Gabriel Valley. This Valley is structurally the most interesting in the region. It is mapped on a large scale map, and has been the subject of much investigation.
Fig. 20.
Cross Section of San Gabriel Valley
Thus, while the San Gabriel Valley can not have been formed by a block slipping between parallel faults, as has been postulated for the San Bernardino Valley, the replacement of the various blocks in what seems to have been their former position shows that the southern part of the Valley can be accounted for as a crustal chasm. The northwestern quarter of the Valley, which cannot be thus accounted for, is the very part which shows evidence of dislocated crustal blocks near the surface.

These subsurface rocks are best exposed along the Arroyo Seco on the western side of the Valley. This streamway is one of the most remarkable in the region. It is a trench, with almost vertical sides, cutting through the undisturbed old-alluvium surface of the Valley. At the northeastern point of the San Rafael Hills the Arroyo Seco crosses a granite sill in a gorge 800 feet long, 80 feet deep and less than 100 feet wide. This is called the "Devil's Gate". The sill is part of an underground ridge that has been traced by water table contours (Map 30, 31) to Monk Hill in Pasadena. The ridge is known as "Monk Hill Dike". It is shown in a cross-section from the San Gabriel Investigation. (Figure 20) Its form has been explained by Miller (1927, p. 248) as is shown in the accompanying tracing (Figure 22). He considers the terrace near the mouth of the Arroyo Seco to be the northern
Diagrammatic section across San Gabriel Valley.  

a. Granite Rock  
b. Alluvium  
c. Sandstone and Shale  

Traced from Handotnli.

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Fig. 21

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A = Terrace near mouth of Arrayo Seco.  
M = Monk Hill.

Newer Alluvium  
Older Alluvium

Traced from Miller.

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Fig. 22

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Fig. 23
edge of a rift of which Monk Hill Dike is the southern edge. The cross-section seems to be better explained by considering the terrace at the mouth of the Arroyo Seco and Monk Hill Dike as the outer edge of landslip blocks. (Figure 23).

There are two other places where the Arroyo Seco crosses sills that do not show on the surface, and then just before it turns westward through the Repetto Hills, it crosses Raymond Hill Dike. This again may be the edge of a landslip block which has been subjected to a great deal of reverse rotation. Raymond Hill Dike at its western end is a sandstone ridge damming back the alluvium on the north and facing the south in an escarpment 100 feet in height. The Dike does not appear on the surface for its full length, but it is evident in the water-table contours, and can be traced through the knolls which dam back the alluvium of the Sierra Madre Terrace. Miller (1928, p.206) has suggested that there is a fault line along the southern edge of Raymond Hill Dike which continues into Sawpit Canyon. (Map p.81). If this can be traced, it throws a difficulty in the way of interpreting the Raymond Hill Dike as the outer raised edge of a landslip block, for such a slip would be accompanied with southward movement which should throw faults out of line at the edge of the Valley.
Fault lines of the Southwestern Part of the San Gabriel Mountains. After Miller.
The faults curving up Sawpit, San Gabriel, Big Dalton and other canyons (Map 22) which are pointed out by Miller (1928, p.206) as remarkable can be regarded as tensional faults at right angles to the direction of movement of the Puente Hills. These faults run only a short distance into the mountains.

The Repetto Hills, to the southwest of the San Gabriel Valley, have already been mentioned in connection with the Los Angeles River fault and the Paso de Bartolo. The wide gaps which separate the several hills of the Repettos are notable. The hilltops are fairly flat, though the rocks are in the main highly contorted Tertiary shales and sandstones. The skyline height rises very gradually from 600 feet in the Merced Hills overlooking Paso de Bartolo to 900 feet in the hills overlooking Eagle Rock Valley. The gaps which cut across the line of hills are 200 to 300 feet in depth, and have straight sided walls which are smooth, uneroded, and grass-covered.

Most of these gaps are floored with gravels carrying an old soil cover which is a continuation of the old soil surface within the San Gabriel Valley. Along the southern edge of the hills is a fault, to the south of which the old alluvium lies at a level 140 feet lower than the gravels in the gaps. Some of this difference in height has been due to elevation to the north of the fault, for the old gravel surfaces show a slight rise toward the south. (Figure 24.)
Section Through Gravel Terraces along Bird Egg Creek

Right bank

Left bank

San Gabriel Valley

Fig. 24.
There are two of the gaps which do not carry any old gravel floors. One of these is the Paso de Bartolo, and in this case the gravels may have been completely eroded away; the other is Coyote Pass. The absence of gravel in Coyote Pass is an astounding circumstance. There is no drainage which could have eroded the gravels through this gap from the San Gabriel Valley. The Pass is only 415 feet in elevation, which is fifty feet lower than the gravel surface in Bird Egg Gap to the west of it, and only 15 feet higher than the gravel in Atlantic Avenue gap to the east. The difference in elevation between Atlantic Avenue and Coyote Pass gaps can hardly be used to explain the lack of gravel in the latter, for with no through drainage it seems certain that the high, steep sides must have contributed some sediment to the floor of the narrow Coyote Pass, but in any case, the lower end of the Pass, with no sediments at all, is much lower than the gravels in both Bird Egg and Atlantic Avenue gaps. It seems, therefore, that this gap must be a recently formed chasm fault, and it is possible that the other gaps are earlier examples of the same character. This would mean that in shifting southeastward the long narrow ridge of the Repetto Hills has broken into blocks.

The Merced Hills are an anticline on which an oil field has been developed. On the north of these
Hills is a low pass which continues across the old alluvium to the south of the Repetto Hills. The Pass carries a surface of gravel which extends as far as the fault line marked $x - y$ (Map E). If the Pass represents a syncline, formed since the deposition of the old alluvium, and the Merced Hills are a recently elevated anticline, they must have been formed by compression, and their position among what has been interpreted as tensional fault gaps in the Repetto Hills seems to be anomalous. However, the direction of the axes of the Merced Hills and the Pass are nearly east-west, and it may be that the southward component of the southeastward movement of the crustal blocks has met with resistance. This would also account for the thrust fault on the south of the Puente Hills and the east-west line of anticlines to the south of these Hills. The fault line on the south of the Repetto Hills may also be a thrust fault. It has already been noted that the terrace gravels indicate an uplift to the north, and an overthrust may have depressed the south side of the fault.

The areas of old soil in the San Gabriel Valley make it possible to reconstruct the former surface. (Soil Map, /P. 55). The alluvium coming from the San Gabriel Mountains flooded southward, was dammed back by the Raymond Hill Dike to form the Pasadena and

*The fault $x - y$ is not shown on any geological map but it is traceable in the soils and is easily followed along a noticeable break in the surface.*
Sierra Madre Terraces, beyond which it sloped more gradually toward the south. This alluvial apron washed against the San Jose and Puente Hills where there are still remnants of it in terraces, while the Repetto Hills only partially dammed it back and it washed through the gaps and built a great apron to the south.

The present topography of the San Gabriel Valley can be described as the result of erosion and deposition on the old valley floor. At the foot of the Mountains recent fans cover the old surface, but the greatest effect has been caused by the displacement along the fault to the south of the Repetto Hills. This has given a new local base level to the streams leaving the Valley. The Arroyo Seco has eroded its trench; the streams in Bird Egg and Atlantic Avenue gaps have eroded through a hundred feet of old gravel and into shale; and the San Gabriel River and its tributaries have eroded into the old soil surface through the center of the Valley and are now building up their beds again.

The San Fernando Valley.

The San Fernando Valley (Map G) can not be accounted for by the crustal movements which have apparently produced the San Bernardino and San Gabriel Valleys. As has already been pointed out, there is a similarity in the forms of the San Bernardino and the
San Fernando Valleys (page 10), but if block movements have produced a crustal chasm here, they must have been in a different direction from those already described, and no evidences of such movement have been observed. Kew (1924, Plate I) has shown the Valley in cross-section as underlaid by the down-tilted northern part of the block of the Santa Monica Mountains, faulted against the San Gabriel Mountains on the north, and carrying a thin covering of alluvium. He gives no references to any evidence of the underlying rock in the center of the Valley and, as will be shown later, there is some doubt as to whether the rock under the Valley floor is integral with the Santa Monica Mountains. For physiographic description the area may be treated as an alluvial deposit in a basin of unknown depth.

The San Fernando Valley is almost a rectangle. On the south is the straight wall of the Santa Monica Mountains running almost east and west. On the north is the parallel wall of the San Gabriel Range which also has a straight-lined flank, except for a square alcove of lowland which cuts into the Range. Toward the west, the Simi Hills present a steep escarpment of massive sandstone rock which runs at right angles to the northern and southern ranges. On the east the Verdugo Mountains lie at an angle across the end of the Valley. Horizontal movement has opened up
passways toward the east, La Canada corridor to the north of the Verdugos, and the Los Angeles River gap around the end of the Santa Monica Mountains.

The Valley floor is an alluvial apron in front of the northern mountains. The Santa Monica Mountains and Simi Hills have hardly contributed any material to this apron. The smooth surface of the alluvium is broken only by a few rock knobs in the northeast, and a line of low old-alluvium covered hills extending SSE from the northwestern corner of the Valley.

The alluvium lies within the Valley in a gentle southward slope, decreasing in height from 1500 feet at the base of the northern mountains to from 500 to 700 feet at the Los Angeles River. Over much of the area the slope is about 40 feet per mile, which increases to 200 feet per mile near the apex of the smaller fans. This flood of mountain waste has spread out like the waters of a lake against the rugged mountains which rise sharply from it at the rate of 800 to 1500 feet per mile.

Over the main part of the Valley the soils are young; the mountain streams are still depositing alluvium and none has eroded a channel. Only during floods does water run over the surface of the Valley floor. Normally the streams sink into gravel washes at the canyon mouths, and reappear in the seepage
water which gives rise to the Los Angeles River along the southern edge of the Valley. On the whole, it would be hard to find a better example of a structural basin in the youth of its physiographic cycle, being filled by deposition.

The Santa Monica Mountains.

The Santa Monica Mountains (Map A) have not been involved in the horizontal movements observed in other parts of the region. The Range as a whole extends from the Islands south of Santa Barbara almost straight eastward to the Los Angeles River. Only that part of the Range east of Topanga Canyon has been included in the Los Angeles region.

No detailed geological study of the Range has been published. Kew (1924, p.1) included the northwestern part in a bulletin on geology of oil resources. In this he shows the Range dipping to the north under the alluvium of the San Fernando Valley. English (1926, p.60) makes the more definite statement that the Range appears to be the upper end of a block which rises from the fault to the south, and has been tilted northward.

Physiographically the Santa Monica Mountains have decidedly the aspect of a maturely eroded horst. The eastern end of the block is narrow and highly
eroded. As far west as Coldwater Canyon the physiography has been complicated by the presence of volcanic intrusions and areas of granite, but between Coldwater Canyon and Topanga Canyon the Range has almost the perfection of a schematic diagram showing the results of erosion on a steep-sided, flat-topped mountain block.

In this part the parallel streams flowing southward have eroded deep canyons which are graded back to a crest line running along the northern edge of the block. This crest line is extraordinarily straight and narrow. It is about 1200 feet above sea level at the head of Coldwater Canyon, and gradually rises without a notable break for nine miles where, having attained a height of 1900 feet, it is bent northward and lowered by the increased strength of erosion of Topanga Creek, which is the first stream to flow directly to the ocean. Beyond the Los Angeles region the Santa Monica Range is breached several times by cross streams.

At Coldwater Canyon the Range is about four miles in width. Toward the west, as the height increases, the Range widens and at Topanga Canyon it is about nine miles in width. Some of this increase in
width is due to the greater exposure of a block which has steep, but not perpendicular, sides. The width of the Range increases faster than can be accounted for by increase in elevation, so that the block edges must taper toward the east.

The vastly greater effect of erosion on the southern slope of this Mountain block presents a physiographic problem. Even if it is assumed that all the rain-bearing winds come from the south, it must be remembered that the Range is under 2000 feet in height, so that if it rose roof-like to a gable ridge, the heaviest precipitation would be to the north of the crest. On a flat-topped block, and for the wind, these mountains may still have that shape. The rainfall may increase on the steep southern face and just behind it, and decrease on the northern slope.

There are some additional factors which would increase erosion on the southern slope. The ecological effects of the hot sun and possibly also, of the sea breeze, make the plant cover noticeably less dense, and the mechanical action of the sun's heat may disintegrate the rocks faster on that side. The northern dip of the rocks here may also have aided southward erosion. If all these factors prove too small to account for the difference between the northern and
Place names of the Vega and Orilla
southern slopes, then a tilting of the horst block toward the south would seem to be indicated.

The flanks of the Range may be taken as fault lines, or more properly, the block faces may be regarded as fault planes. On the north, the alluvium lies against the mountain face at heights increasing from 500 feet at the eastern end to 900 feet at Topanga Canyon. Toward the west there has been a rise in the local base level due to sedimentation in the Valley, and the streams have built "fan bays" in the lower ends of their canyons. (See canyon south of the town of Girard in the southwest corner of the San Fernando Valley. Map C.)

To the south of the Santa Monica Mountains there are two adjacent heights; the Elysian block at the eastern end of the Range, separated from it by a fault line pass; and the northern end of Dominguez Range which abuts on the Santa Monicas just west of the City of Beverly Hills.

The Vega.

The Vega subregion (Maps A.E.F.H.) is not a physiographic unit, but consists of two well defined, though closely united, parts. The great plain which runs from Culver City in the west to Santa Ana in the east, is formed by the coalescing fans of the Los Angeles, San Gabriel, and Santa Ana Rivers. This plain is practically all under 250 feet in elevation. It is
separated from the Santa Monica-Santa Ana Range by a piedmont slope which is cut into several terraces by the river courses. The junction of the alluvium of the terraces and the eroded slopes of the Santa Monica-Santa Ana Range is almost exactly 500 feet above sea level for the full length of the Vega, except in front of the Repetto Hills where the hill slopes descend to about 300 feet in elevation.

The structure of the Vega has been a matter of great concern to the oil geologists, for it is within the proved oil bearing area, but in spite of a great amount of drilling there is little information available, because of the thickness of the Recent and Tertiary sediments which are without index strata. Drilling records show that the recent alluvium of the Vega plain merges with Pliocene deposits in which wells more than 4500 feet in depth have ended. English (1926, p.61) looks on the area of the plain as a depressed block. The fact that Dominguez Range, at least toward the west, is covered with old granitic alluvium soils that appear much the same as the old soils of the San Gabriel Valley, is evidence that the depression is recent and that there was once a continuous slope from the San Gabriel Mountains across the area now elevated to form Dominguez Range.
The Piedmont plains along the northern side of the Vega call for separate description. The most important in its relation to the City of Los Angeles is what might be called the "Hollywood Piedmont", lying along the foot of the Santa Monica Mountains between the Elysian block and the northwestern end of Dominguez Range.

The southern edge of this area is marked by the line of erosion and deposition of the Los Angeles River, at a time when that River turned westward around the end of the Elysian Hills and flowed through the Ballona Creek gap in the Dominguez Range to Santa Monica Bay.

The surface of the Hollywood Piedmont is occupied by two alluvial fans of very unequal size which are built out from the Santa Monica Mountains. In the eastern part of the Piedmont is the large fan sloping southwest. Toward the east this fan is banked up against the Elysian Hills and has flooded over their lower slopes, so that some former hillocks now protrude above the fan slope as isolated knobs. A stream has trenches the fan along the flank of the Elysian Hills, but otherwise the old alluvial surface is little eroded. Toward the west, the fan sinks down to a swale which extends from Ballona Creek to the Santa Monica Mountains. Beyond this low swale is the
small, and young, alluvial fan on which the City of Beverly Hills is located. Parts of this fan are not yet built upon, and the smooth slopes are still sufficiently visible to show the outlines of the cone.

To the south of the Repetto Hills is another area higher than the plain of the Vega, standing as a terrace between the Los Angeles and San Gabriel Rivers. This terrace is built of materials that passed through the gaps of the Repetto Hills, but owing to faulting, the surface now lies over 100 feet below the gravel terraces in the gaps. However, in the western end, the terrace is still so high that it is being dissected by erosion. Near the center, the pass which lies north of the Merced Hills extends across this terrace, and here the surface is low. South of the Merced Hills, the terrace is again well marked, but narrow. The southern edge of this terrace sinks under the recent deposits of the Los Angeles and San Gabriel Rivers without any marked topographic break.

There is an example at Laguna of the effect of the rapidly accumulating deposits of the Los Angeles River damming a small tributary stream. The lake thus formed was called a "laguna" by the Spaniards and was distinguished from the lakes of rising water called "cienegas". There are several other lagunas on the Vega.

East of the San Gabriel River, extending as far as Santa Ana Canyon, is another terrace of more
pronounced character called the "La Habra" terrace (Map F). A line of hills here lies south of the flank of the Puente, starting in the very low knoll of Santa Fe Springs and running eastward. The center hills - West Coyote, 610 feet, and East Coyote, 513 feet - are the highest, and beyond them the line again sinks to very low hills that are buried under the alluvium and are only evident because their flank shows as an escarpment, but however slight the surface indication, drilling has proved this line to be a series of oil-bearing anticlines.

English (1926, p.66) discusses this Terrace at length:

"During the formation of the La Habra Terrace these hills acted as dams and caused the streams flowing southward from the Puente Hills to build up an alluvial apron on La Habra Valley. As the alluvial slope was built up, it extended tongues between the gaps in the hills and may even have buried some of the hills completely. Recently, the La Habra Terrace has been dissected by the principal streams to a maximum depth of 100 feet."

The anticlines here might be connected with the horizontal movements already described. The direction of the postulated movement of the Puente Hills has been more southerly than the fault line along their southwestern edge, and this has produced pressure which has raised the anticlines of the hills.
A few further observations might be made on the Santa Fé Springs district. The site of the Santa Fé Springs Oil Field is always pointed out as a very low hill, for it rises but a few feet above the surrounding plain. A study of the soils shows that in reality the Oil Field is located on a dome covered with old alluvium, around which younger alluvium has been deposited. Little Lake, to the west of Santa Fé Springs, is a characteristic laguna formed by the damming of a creek by the fan of the much stronger San Gabriel River. Both Little Lake and Whittier Creeks show swamps along their full length, which may be taken as an indication that once much stronger streams flowed along their beds. In the case of Little Lake stream, English (1926, p. 68) suggests that it may have been at one time the bed of the San Gabriel River.

The piedmonts of the Santa Ana Mountains and San Joaquin Hills nearly fill the point of the Vega lying beyond the Santa Ana River. The Santa Ana River is now near the left edge of its fan as far as the City of Santa Ana. To the south of that, the Santa Ana fan extends east of the present channel. There is hardly any drainage into the Vega beyond the Santa Ana River fan, for the streams on the southern slope of the Santa Ana Mountains are all carried northwest by Santiago Creek.
GENERALIZED TOPOGRAPHIC MAP OF NORTHERN PART OF SANTA ANA PLAIN, CALIFORNIA

Prepared by W. A. English

The contours are generalized from the Geological Survey topographic maps so as to bring out the characteristic features of the land forms. The outlines of the oil fields within the plains are shown in order to illustrate the relation between topography and structure.

Contour interval 25 feet

1 2 3 4 5 Miles
The alluvial plain of the Vega is covered by the recent deposits of the three principal rivers of the Los Angeles region. Of these, only the Santa Ana River has built a distinct fan. (Map 24). The axis of this fan runs from the Canyon mouth to Alamitos Bay and it is evident that, at times, the River must have run directly westward. The perfect development of this fan shows that the river waters found outlet in any direction, and that probably the fan was built as a delta in a bay behind Dominguez Range. The landforms of Dominguez Range will be shown to substantiate the suggestion that there was a bay here.

At present the western edge of the Santa Ana fan is marked by Coyote Creek. Beyond that are the deposits of the San Gabriel and Los Angeles Rivers. The fans of these two Rivers are united. The deposits of the Vega plain are made up of very fine material and the fans are flat. A seven mile baseline for the Geodetic Survey was measured here. The surface is unbroken by any rock structure.

Dominguez Range.

The structure of Dominguez Range has been disclosed through the drilling of oil wells. The oil fields in most cases correspond to the separate hills of the Range and have an axis slightly nearer east-west than the line of the hills. (Map 25). A fault has been marked along the eastern side of the north-
ernmost hills of the Range, through the center of Baldwin Hills and along the southwestern face of the remainder of the Range.

The Range, for the most part, is covered with alluvium on which old soils have been developed. These gradually dip under the younger soils of the Vega plain. The most satisfactory division here is the line of contact between these soil types. The stage of erosion varies somewhat between the different hills, but there is no question that they are geologically very young. Dominguez Hill may well become a classical example of an anticlinal hill in the infancy of its physiographic cycle.

The Range is crossed by many wide gaps which present a physiographic problem. The first gap from the north is at Bollona Creek. This gap is a mile in width and is filled with an unknown depth of alluvium. To the north of it are hills rising to 270 feet above sea level. On the south is the square end of Baldwin Hills which have a peak elevation of 513 feet. The Ballona Creek gap has the appearance of a chasm fault. Further evidence in support of this interpretation will be mentioned in connection with the Orilla.

The next gap is occupied by the Los Angeles River. This has already been interpreted as a chasm fault.
There are four more wide gaps between the Los Angeles River and Newport. These gaps are now coastal lagoons. They average three miles in width. Seaward they are enclosed by sandspits, landward they are open to the recent deposits of the Vega plain. Dominguez Range, in this part, appears to have been a low plain tilted northward. The gaps have cut this plain into flat topped hills - steep on the sides toward the ocean and the lagoons. Some of the gaps may be fault chasms, but no evidence of this has been observed, while under one of the lagoons an oil field has been discovered, and this, at least, cannot be in a chasm. On the other hand, these very wide gaps can hardly be the channels of antecedent streams. It would seem impossible for a river to maintain such a width through a rising range. The most likely interpretation is that the gaps were tide races between islands that now form the line of hills between the lagoons. This would account for the width of the gaps and the steep side walls. The existence of a bay inside of the Range has already been suggested by the form of the Santa Ana River fan.

The Orilla.

The Orilla lies between Dominguez Range and the San Pedro Hills. It is set off from both of these Ranges by well marked fault zones along which the Ranges have risen in relation to the Orilla. The
underlying rocks have been probed by many oil wells but only one geological structure has been disclosed. This is the anticline of the Torrance Oil Field; a broad low flexure with an axis three miles north of, and parallel to the flank of the San Pedro Hills. This anticline shows on the water contours. (Map 30).

At first glance it seems strange that water contours should rise on an impervious dome. The slow horizontal movement of water through the alluvium is responsible.

There is another crustal irregularity which may be considered as belonging to the Orilla. This is the narrow chasm showing in the submarine contours off Redondo. This chasm has been interpreted as an old river gorge. More likely it is a fault chasm. It can not be said to show in the deposits of the Orilla, but it might possibly be traced by gravity tests.

The surface of the Orilla has the characteristics of an area of coastal deposition. The whole area has recently been elevated, but it still shows the form of a Y tombolo. On the west there is a belt of old dune land which starts at Santa Monica, is cut by Bollona Creek, but continues again beyond to
the base of the San Pedro Hills where it widens out and touches the southeastern tombolo. The latter starts just north of Bixby Slough and runs to Watson where it has been broken by a horizontal displacement which moved the eastern end of this tombolo two and a half miles south—now the site of the City of Long Beach. Between these tombolos, lying along the base of Dominguez Range, the raised lagoon floor forms a flat plain.

The western tombolo is extraordinarily large and even allowing for recent increase in elevation, the dunes are very high. North of Bollona Creek this tombolo has been disarranged by tectonic movements, but from the escarpment rising on the south of Bollona Creek to the San Pedro Hills, there is a well preserved old dune land. The surface is no longer sand, but a fairly well compacted soil. The topography is still that of sand dunes, conical hills, and oval hollows arranged in lines parallel to the coast, and entirely without stream ways. Just south of Bollona Creek there are eight or nine ridge and swale lines between the Baldwin Hills and the coast. The height of the ridges here is about 200 feet. Farther south the dunes lose elevation somewhat and toward the east they appear to have been submerged under the deposits of the lagoon, for some dunes now stand as isolated hillocks on the plain. At the southern end, this
tombolo has been involved in the fault movements along the flank of the San Pedro Hills.

It is, however, at the northern end of the western tombolo that the greatest alteration has taken place. There is little question that the tombolo was once continuous across the gap of Bollona Creek. In fact, it could never have been formed except as a continuous beach. To the north of the Bollona Creek Bottoms there is still an area of sand now occupied by Venice, Ocean Park, and Santa Monica. This area does not display any well formed dunes, but it is nearly as high as the area south of the Creek - 200 feet - and it shows similar ridges. The formation of the Bollona gap must therefore be due either to recent stream erosion, or to chasm faulting. It is true that the Los Angeles River has used this gap as an outlet to the sea, but if it broke over the dune lands, there must have been changes in elevation of nearly 200 feet between the Vega and the Orilla in very recent time. There are no streamways in the dunes to work headward and open the gap. Not only must this area recently have risen if the Los Angeles River cut Bollona Creek gap, but it must subsequently have subsided, for the mud and clay deposits under Ballona Lagoon reach to twenty feet below sea level.

It seems probable that the land to the south
of Bollona Creek has moved southeastward. This would account for the gap, and would explain the recent regression of the coast west of Santa Monica, for such a movement would expose that part to wave erosion. It would also explain the recent trenching of the alluvial apron of the Santa Monica Mountains to the west of Dominguez Range. There is evidence of tectonic movement to the north of Bollona Creek Bottoms where the topography is unexplained by the streamways. An oil field has recently been discovered at Venice so that if there is a chasm under Bollona Creek Bottoms, it will be revealed by drilling.

The accumulation of material behind the groins built out from the shore at Santa Monica shows the rapid movement of beach sand on this shore. The sea breeze here is very constantly from the west, and strong breakers push much beach material east, and then south.

The southeastern tombolo is small and low compared with the western one. The Long Beach section reaches 65 feet in height, and the Bixby-Watson section is under 50 feet. Only one small dune in Bixby Park, Long Beach, is noticeable. The smallness of this tombolo, in comparison with that on the west, is in accordance with the infrequency of southern winds and the usual weakness of the waves. The submarine contours indicate the weakness of the waves on this shore.
<table>
<thead>
<tr>
<th>Depth (ft.)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 125</td>
<td>White sand</td>
</tr>
<tr>
<td>125</td>
<td>142 blue sand</td>
</tr>
<tr>
<td>142</td>
<td>166 gravel cut</td>
</tr>
<tr>
<td>166</td>
<td>247 sea mud</td>
</tr>
<tr>
<td>90</td>
<td>Sea mud</td>
</tr>
</tbody>
</table>

STANDARD OIL COMPANY -- El Segundo, Cal. Well No. 1 (From their log)

97 ft. elevation.

0 to 125' white sand
125' 142' blue sand
142' 156' clay
156' 166' gravel cut
168' 247' sea mud

Water stands 88' from surface
Put 5' gravel in bottom of well

STANDARD OIL CO. - El Segundo, Cal. - Well No. 2 (from their log)

90 ft.

0 to 110' sand
110' 112' clay
112' 123' sand clay
123' 128' blue clay
128' 136' blue sand

136 to 148' blue clay
148' 162' gravel
162' 167' blue clay
167' 171' gravel
171' 249' sea mud

Water stands 84' from surface. Put 5' gravel in bottom of well.

The writer has collected nearly 50 well logs for the Orilla. There is much variation in their exactness as in the above logs where the same layer is called in one case blue sand and in the other clay, but they all show thick layers of uniform texture (water or wind sediments) above thin gravel and clay beds - probably river deposits.
Wilmington Lagoon has been enclosed by the Terminal Island sandspit. If the movement of the Long Beach tombolo is confirmed, it is not necessary to postulate any submergence of the coast to account for this Lagoon. In fact, in this thesis all of the coastal lagoons have been accounted for without submergence.

The old Lagoon floor now stands at an elevation of 25 feet at the southeastern end, and rises to 100 feet at the northwest. It is possible that alluvium was carried over the Dominguez Range at Inglewood and deposited largely at the western end, thus producing this slope. The nearly buried sand dunes at the west indicate considerable sedimentation. There cannot have been much greater rising of the land toward the west, because sea shells were found at 32 feet above sea level, under the southeastern tombolo and beach sand extends deeper toward the west. (See well logs, p. 0131) The Lagoon floor now slopes down to Nigger Slough which has a bed typical of a tidal stream. This stream has been dammed back by the recent deposits laid down by the Los Angeles River. It has, therefore, the form of the Lagunas of the Vega.

The San Pedro Hills.

The San Pedro Hills (Map A.) rise steeply from the Orilla along a well marked fault zone. Former beach deposits of sand have been raised to 400 feet
above sea level and there is also evidence of horizontal movement toward the western end of the fault where the lower parts of two north-flowing streams have been offset 1000 feet toward the east. (These are indicated by arrows on the map). The southern coastline of the Hills is almost parallel to the northern flank and is probably also determined by a fault.

The northeastern corner of the Hills is cut off from the main body by a narrow canyon. This can hardly be a streamworn passway, for though Bixby Slough would now drain in this direction, it is inconceivable that during all of the period of upheaval any stream could have continuously maintained a channel here, rather than along the softer deposits to the east. This block has apparently been pulled away from the rest of the Hills.

In outline the San Pedro Hills are almost a rectangular block. The northern, eastern, and southern faces of the block are concave, the western face, convex. From the massive western part, a high narrow ridge runs southeastward to Point Firmin.

There is no question that the San Pedro Hills were once an island and that they have gradually risen from the sea. On the west there is a remarkable series of well preserved beach terraces - seven in all. Toward the north there are deposits of sand on what was once the protected side of the island. This slope is
now being rapidly eroded by many parallel streams. The ridge behind Point Firmin and the southern slope of the Hills show beach terraces. Above the shallow bay on the southern side the surface soil has slumped down the slope. There are many small mounds here with enclosed basins in the rear. This slumping may have occurred during earthquakes.

The coast of the San Pedro Hills is being eroded. This is true even at the back of the small bays, and the shore is of the type called "crenulated" by D.W. Johnson. (1919, p. 278). There is a sea cliff 100 to 200 feet in height all along the coast. In many places the last beach terrace slopes gently down to the edge of the cliff. This terrace shows only very slight effects of stream erosion.

Types of Topography.

There are several types of topography in the Los Angeles region that are sufficiently distinct to warrant mapping. (Map 26). The highly sculptured slopes of the mountains are very prominent in the scenery. The mountain rocks are chiefly granite with occasional areas of the older sedimentary rocks. The slopes are steep, the ridges are narrow, and the stream pattern is so thoroughly branched that there are no level areas.
There are, however, none of the perpendicular cliffs, nor sound rock exposures common to glaciated mountains. The surface consists of decomposed rock. The disintegration, which is probably to some extent due to shattering by earth movement, extends to a considerable depth, and steam shovels are used to excavate road cuts ten or twenty feet deep in granite undiscoloured by seepage. These maturely eroded mountain slopes are covered with chaparral vegetation.

The hills composed of soft Tertiary sediments display a very different type of topography. The slopes here are steep, but they are ungullied and smooth. The surface material normally contains a large percentage of clay from the sedimentary rocks, and probably solifluction plays a prominent part in the modelling of the hill slopes. These slopes are grass covered. The Repetto Hills are good examples of this type of topography.

The alluvial material is deposited on the plains, with a fairly smooth surface, though there are some boulder-strewn areas near the canyons. (See San Gabriel wash on Map E). The slope of the alluvium varies from grades as high as 500 feet per mile near the apex of small fans, (See La Canada Canyon, Map G) to almost flat areas such as the lower edge of the Vega. (Map F).

The change in slope from the mountains to the plains is generally sharp, so that in profile, the
contact of these slopes forms a noticeable angle. Also, where the alluvium has been eroded, normally, steep sided gullies or arroyos make a sharp break in the surface. This is well illustrated by the Arroyo Seco in the San Gabriel Valley. (Map E). In general, therefore, the scenery is severe. The surface is either very flat or very steep. There are no winding valleys among rolling hills.

The forces by which this landscape has been built are still active. There have been no actual measurements of crustal displacement, and earthquakes are relatively infrequent and weak, but there are many fault scarps and anticlinal hills which are geologically very young. The erosion of the higher slopes and the deposition in the structural basins can be observed today. This is almost entirely the work of water, but the process by which it is accomplished is very different from that of lands of more uniform rainfall. The table of stream-flow (page 27) gives all the streams of any consequence which flow from the mountains to the lowlands. It will be noticed that not only is there extraordinary variability in their yearly volume of flow, but all the streams except three fail to reach the lowlands at all for part of the year. These are the records of the main streams, the small branch streamways which cover the mountain sides carry water only during rains. The transportation of alluvium is therefore intermittent. One strong
flood may carry more sediment from the mountains to the lowlands than the more normal flow of many years.

The alluvium is deposited on the plains in different forms according to the size of the stream. The small streams, on reaching the lowlands, spread out, quickly lose volume and speed, and deposit all of their sediment in steep and relatively very large cones. The large rivers, especially the Santa Ana, San Gabriel and Tujunga - main contributor to the Los Angeles River - have more definite courses in the Valleys which lead to gaps in the Santa Monica-Santa Ana Range and during floods their fine sediment is swept out to the Vega. Near the mountains these rivers build no well formed cones, but only a boulder strewn "wash".

The difference in the disposal of sediment by the small and large streams explains the formation of the great areas of alluvial plains in the Los Angeles mainly region. The floors of the three valleys have been built by the sediment of the smaller streams. This is best illustrated in the San Bernardino Valley where the great area of the Cucamonga plains fills most of the open Valley, and yet the granitic alluvium of these plains does not reach to the channel of the Santa Ana River (See soil map, p 55).

The Vega has been built by the fine material carried off by the three main rivers. The San Fernando Valley does not well illustrate this, but in both the
San Bernardino and San Gabriel Valleys the lowest part of the Valley is occupied by the streams carrying by far the greatest quantity of sediment. This can not be accounted for by erosion, for both the Santa Ana and San Gabriel Rivers are making deposits in the Valleys. It is the result of the strong flood flow of these rivers carrying all the fine sediments to the Vega. The deposit of these rivers in the valleys is composed of stones and boulders with only enough sand to fill the interstices between the larger rocks. Thus, the difference in the size of the deposits of these rivers and of the smaller streams entering the valleys is a measure of the relative amount of large material in the sediment.

This explanation places the main responsibility for cone building on the spreading of the streams in the valleys, rather than on change in slope between the canyons and the plains. There are several places in the Los Angeles region where the canyon delivering the sediment has actually less slope than the cone on which the material is deposited at the canyon mouth. This condition has been noted in most of the canyons of the San Gabriels (Miller, 1928, p.224) though it has not been recognised as normal, and the trenching of these cones has been ascribed to the recent lowering of the grade in the canyons. (Eckis, 1927).
Profile of Lower Part of the Santa Ana River

fig. 20

vertical scale exaggerated 200X
A better example of the influence of spread on cone formation is found in the Santa Ana River. This River enters the San Bernardino Valley from a gorge, leaves by another gorge and maintains a well defined channel across the Valley. It is not depositing much material here, except on its "wash". The single outlet and the channel leading to it keep the current deep and strong in time of flood. In the lower Santa Ana Canyon the current is still more confined but on leaving this canyon, the stream has been able to spread out in any direction on the Vega. As a result, a well formed cone has been built, and this cone has a steeper grade than the canyon. (Figure 27). The difference in grade is not large - as nearly as can be measured on the small scale map available, there is a fall of 15 feet per mile in the canyon and 18 feet per mile on the main part of the cone - but in this case the formation of the cone has definitely been due to the spreading of the river waters and probably, to a slight extent, the loss in volume through percolation into the cone deposits.
PART II.

HUMAN GEOGRAPHY.

The preceding part of this thesis has been a serious attempt at a description of the natural landscape of the Los Angeles region. The following is merely an outline of the place of man within this scene.
Historical Introduction.

A very primitive native culture remained absolutely untouched in the Los Angeles region until one hundred and sixty years ago. Cortez had conquered Mexico in 1521; Cabrillo had sailed along the California coast and probably touched at San Pedro Bay in 1542; later the Manilla galleons crossed the Pacific Ocean from the Philippine Islands and made voyages down the coast during nearly two centuries before the Spaniards succeeded in reaching the present State of California, from Mexico.

In 1769 the Franciscan Missionaries with Spanish soldiers entered Alta California (the Peninsula of Lower or Baja California had long been occupied). Missions were built and the country was organised under a system of medieval church feudalism. From 1776 until 1881 the Spanish Government maintained a frail connection between Alta California and Sonora, Mexico, across the Colorado Desert. During this time livestock and colonists were introduced into the region at government expense. The last group of colonists consisted of forty nondescript peons of Spanish, Mexican, and negro blood, who were destined for the establishment of "El Pueblo de Nuestra Senora la Reina de Los Angeles" (Los Angeles).
The passage of these colonists antagonised the Colorado River Indians at Yuma and thus completely closed this perilous desert route. Thereafter, until the American occupation, California, under Spanish and Mexican rule, had only a very inadequate maritime connection with the western ports of Mexico a thousand miles to the south. A few priests, soldiers, and criminals came into the country, but for the most part it existed as a completely isolated illiterate society.

The local Indians were brought under the control of the missions. Cattle, horses, and sheep were allowed to multiply on the vacant plains. A trivial commerce in hides and tallow attracted an occasional ship and gave some slight value to pasture land which was divided into great ranchos. In 1834 the missions were secularised and their lands taken over by private owners. There was some penetration of outsiders, principally Americans, during the second quarter of the nineteenth century, and in 1848 California became United States Territory. The gold rush to the Sierra Nevadas hardly touched Southern California. There was no great change in the country until 1862-65 when drought and flood and new economic conditions wiped out the cattle industry and made room for settlers.
In 1876 the first transcontinental railway connection was extended down to Los Angeles from San Francisco by the Southern Pacific Railway Company. In 1881 the same Company completed a line from Los Angeles east through San Gorgonio Pass and along the Mexican boundary to El Paso and New Orleans. In 1885 the Santa Fe Railway from Kansas City entered the region by Cajon Pass. A year later the competing lines started a rate war. The fare, which had been about one hundred and twenty-five dollars from Mississippi River points to Los Angeles, was for three months reduced to five dollars. Thousands of settlers poured into the country; a land boom started. In two years twenty-five town sites were laid out on the Santa Fe Railway between San Bernardino and Los Angeles - a distance of about sixty miles. The boom soon subsided, but the influx of newcomers continued. It has grown to a veritable flood which continues to this day. The region is a human maelstrom in 1930.
The Native Indians.

The geography of the native Indian inhabitants of the Los Angeles region is a closed book. It seems probable that it will always remain so. These Indians were some of the most backward of the North American natives. They had no tribes, and the related groups are known only as "Fernandeno" and "Gabrielino" from the San Fernando and San Gabriel Missions to which they became attached. Hemmed in by mountains, there was no chance for the valley Indians to move back from the white men. They were gathered to the missions where they rapidly died off, and when the remnant was turned loose in 1834 they disappeared completely. There is not a single member of these groups left, and the only information concerning them comes, not from the religiously zealous Spaniard, but from the recent study of the neighboring groups of Indians in the mountains. It is surprising how much has thus been accumulated, but the basic facts of the Indians' existence, which would make a geographical study possible, are lacking.

Kroeber in his "Handbook of California Indians" gives an estimate of 5000 as the number of Gabrielino and Fernandino Indians in 1770. This included those on Catalina Island, but excluded some in the San Bernardino basin. This may be taken as a rough figure of the Indian population at that time.
gives an average of more than two people to the square mile, which is a very high figure for people with neither cultivated crops nor domesticated animals. Ratzel gives as an average for that stage of culture about one person to ten square miles. However, conditions in all the California valleys were favorable to primitive man, and the native population was very high. This is a matter of pride to many of the present inhabitants and it is often mentioned as an indication of the country's possibilities for the white man. As a matter of fact, the Indian foods were largely acorns, fish, rodents, and insects, the last two having proved a serious pest to white men. The present prosperity is almost entirely an artificial growth, and has little more relation to primitive conditions than has the dense population on the coal fields of Great Britain.

The accompanying map indicates the Indian village sites as located by Kroeber. It is not thought that all of the sites are given, but the Indians are generally supposed to fall into two groups which are fairly well separated on the map—one along the coast and the other inland.

The coast Indians had as food sources, fish which they caught from canoes, great quantities of winter migratory ducks and geese, and probably hair seals which were very abundant along this coast (translation).

until the American occupation. There are no shell fish except along the San Pedro Hill shores, and even here they are not plentiful. No shell mounds are recorded. The Indians may have used grass seeds, or may have traded for acorns with which to make bread.

The inland groups had the acorn as their chief source of food. The native oaks bear abundantly, even those in the chaparral. However, several varieties are given to bearing only on alternate years. It would probably take five hundred pounds of acorns to supply one Indian for a year, and it would be interesting to measure the yield of the oak groves and the chaparral as an indication of the extent and reliability of that source of food. Roots and grass seeds are also mentioned as food. The latter would ripen in the early summer when the acorn crop of the preceding year would most likely be exhausted. The double harvest season may have been one advantage that led to a large population.

Acorns would supply carbohydrates and oil, but the protein part of the diet seems to have been somewhat of a problem, for the Indians ate insects, slugs, and rodents which are normally considered repulsive. They seem to have had as small prowess as hunters as they had as warriors. The first Spaniards, at one time in desperation for food, organized a bear hunt which not only provided meat,
but begot the friendship of the Indians who were evidently anxious to be rid of the bears, but were unable to kill them. The fact that the Spaniards had to resort to bears would seem to indicate a scarcity of deer or antelope.

The missions were established primarily to convert the Indians. Once the missions were firmly established, the Indians were often moved to them, but it may be assumed that the first missions went to the Indians. The San Gabriel Valley, where the first mission was established, was probably a center of Indian population, an assumption which is well supported by the abundance of oak trees in that district.

There are no native Indians now in the Los Angeles region. Probably some of their blood was fused with that of the Spaniards and remains in the Spanish American, or what forty years ago was called the "Californian" population. To the casual observer their descendants are indistinguishable from the Mexicans of whom there are now over 200,000 in Los Angeles.
The Pastoral Period.

The first penetration of Europeans into the Los Angeles region took place in 1769. Missionaries came up through the Peninsula of Lower California to San Diego, where they were met by boats from Mexico. From San Diego, the Portola Expedition set out for Monterey Bay and passed through the Los Angeles region in September 1769.

Two years later, the San Gabriel Mission was established by the Franciscan fathers at the point of the Merced Hills overlooking Pasa de Bartolo. The Mission remained at this location for five years. There are no available records of this period, but the choice of the location is a matter of some interest. Probably, the padres were attracted by the large permanent flow of water through this Pass. Possibly the Merced Hills were looked upon as a defensible position. From the standpoint of irrigation, the site was not well chosen, for the easily irrigable land nearby is subject to overflow.

After five years the Mission was moved to its present site, five miles south of Pasadena. This was one of the best within the region. Water was available from the Raymond Hill Dike escarpment in permanent streams not subject to flood. The water was at a high enough level to irrigate a large area of smooth land which was probably open grass land. The soil was
heavy enough to be used for adobe brick, and this must have been an important factor in the location of a mission where all of the buildings and walls were constructed of this material. From the standpoint of controlling the Indians, the location within easy reach of their oak groves must have been an advantage, while for the management of herds, the central valley position was much superior to that in the pass.

The San Gabriel Mission introduced not only horses, burros, cattle, sheep, and goats, but brought in the Mediterranean grains—wheat, barley and oats—and also wild oats which have since covered the country. In their gardens, the padres had grapes, oranges, pears, apples, figs, peaches, olives and English walnuts. With the exception of the grapes and figs these were all seedlings, so that none of the varieties have survived, but they served as an experiment and as a source of planting for home gardens.

The San Fernando Mission was established much later (1797), but it was built on practically the same lines as the San Gabriel. The Mission had a water source in a ciénega which gave a good summer flow and was not subject to floods. There was clay soil here from which adobe brick could be made, and the site was out in the open valley where livestock could be easily collected.
Another mission station was started at San Bernardino, but it was not permanent.

In 1781 the pueblo of Los Angeles was founded by government decree. Forty colonists who had come across the Colorado Desert from Mexico were placed on irrigated lands, provided with livestock, and given provisions. The site had been noted as favorable by Father Crespi recorder of the Portola Expedition in 1769, in the following often quoted paragraph:

"... after traveling about a league and a half through the pass between low hills, we entered a very spacious valley, well grown with cottonwoods and elders, among which ran a beautiful river from the north-northwest, and doubling the point of a steep hill, it went on afterwards to the south. Toward the north-northeast there is another river-bed which forms a spacious water-course (the Arroyo Seco) but we found it dry. This bed unites with that of the river, giving a clear indication of great floods in the rainy season, for we saw that it had many trunks of trees on the banks. We halted not very far from the river which we named Porciuncula. Here we felt three consecutive earthquakes in the afternoon and night. This plain where the river runs is very extensive. It has good land for planting all kinds of grain and seeds, and is the most suitable site of all that we have seen for a mission, for it
has all the requisites for a large settlement."

"After crossing the river we entered a large vineyard of wild grapes and an infinity of rose bushes in full bloom. All the soil is black and loamy and is capable of producing every kind of grain and fruit which may be planted. We went west, continually over good land well covered with grass."

This reference may have had some influence in deciding the location of the town, not that the Spaniards who had been in San Gabriel ten years would not know more of the country than the Portola Expedition could learn on a single passage, but because the City was founded by government decree and there would be some inclination to select a site already mentioned. The situation was unique in its advantages, and it is worth while to examine it in a critical way.

The establishment of the pueblo, of which there were three in California, was a government effort to colonise Alta California with Europeans under civil authority, in contrast to the efforts of the missions to organise the country, like Paraguay, as an Indian country governed by the church. The pueblo lands were the first to which a citizen had been granted any legal rights. The purpose of this subsidised colonisation was to provide a population under the control of the government which
would raise grain for the presidios and form a nucleus for the settlement of retired soldiers and immigrants. There were soldiers at all of the missions though there was no distinct presidio in the Los Angeles region.

It was desirable to locate the pueblos some distance from the missions, but at the same time in close touch with them, for the missionary and government efforts were closely bound together. At San Jose, fifty miles from San Francisco, the pueblo was located about three miles from the Santa Clara Mission. At Los Angeles the pueblo was about ten miles from the San Gabriel Mission. This latter would appear to have been about the proper distance — too far for easy visits by walking, but within a little over an hour on horses, with which the Spaniards were well supplied. It is probable that any position on the Santa Ana River would have been too far away and anywhere in the San Gabriel Valley rather too close.

The first necessity for the pueblo was a large and continuous source of water that could be carried by gravity to an area of arable land not subject to floods. The Los Angeles River north of the pueblo was a permanent stream, for it had a large summer flow from the seepage of the San Fernando Valley and the water was forced to the surface in passing through the Santa Monica-Santa Ana Range. Moreover,
just at the southeastern end of the Elysian Hills, the little streams flowing from these hills had built an alluvial apron of good soil which stood higher than the flood waters of the River, but low enough for a canal a mile long to bring the river water to it by gravity.

The Los Angeles River had a further and unique advantage at this place. The Santa Ana and San Gabriel Rivers issued from their passways through the Santa Monica-Santa Ana Range in wide gaps within which the summer flow wandered in shifting channels. Near the southern end of the Los Angeles River gap, on the other hand, the alluvial cone of the Arroyo Seco had built out across the gap. This cone forced the Los Angeles River into a permanent channel along the foot of the Elysian Hills. This was a very important advantage, for it meant that permanent head-gates could be built in the west bank and the water easily diverted.

Water and soil were thus favorable at the Los Angeles site, and the climate was even better than that of the San Gabriel Mission. The situation was in every way suitable for an agricultural colony. Also, as a regional commercial center, this agricultural town site had unusual advantages. The Spaniards kept in touch with Alta California by sea, and the roadstead at the eastern end of the San Pedro Hills was the only natural port. Los Angeles on the west
bank of the Los Angeles River had an easy route to this port without crossing any streamways. No floods could disrupt the communication in that direction. In addition, the routes across the Santa Monica-Santa Ana Range made the pueblo accessible from the interior. The Cahuenga Pass led across the Santa Monica Mountains to the San Fernando Valley and northward. The low passes in the Repetto Hills led to the San Gabriel Valley and from that into the San Bernardino Valley.

After the Pueblo of Los Angeles was established the Spanish Government granted ranchos to individuals. The first was the San Rafael rancho granted in 1784, the name of which is perpetuated in the hills west of Pasadena. (Rancho names have been one of the main sources of place names in Southern California.) Further grants were made by the Spaniards and later by the Mexicans. The missions in 1834 were dispossessed of all of their property, except of walled-in gardens, and the land passed into ranchos. It is not to be supposed that there were any very definite limits placed on the ranchos. The country was an open range, and land had little value. When the United States Government came, it recognised the title of land grants, and the ranchos were fixed definitely on the maps, and are still recorded on the topographical survey sheets. Some idea of the uncertainty of
boundaries may be had from the dispute about the boundaries of the pueblo of Los Angeles. The town land was a royal grant, and had been occupied since 1781. The town had been administered as an organised unit for over half a century, yet before the United States Land Commission there was contradictory evidence as to whether the grant was for four square leagues or four leagues square. The former was finally accepted. If this boundary was haphazardly defined, most of the ranchos must have been very loosely determined areas. In fact, there was great difficulty over titles, and the American pioneers being addicted to "squatting", the whole system of ownership was threatened. This insecurity of title hastened the breaking up of the ranchos and the settlement of the land. A map of the ranchos, as recognised by the United States Government on taking over the administration, is appended. (Map I).

The rancho subdivision had little geographical significance, but it is interesting in view of its later influence on settlement and on names.

The culture and the husbandry of the Spanish Californians was of the most primitive type. It is well depicted by Alexander Forbes who in 1839 published a book on California. This is much more intelligible

1. Alexander Forbes -"California", London, 1839. (There is a copy in the Carnegie Library, Edinburgh.)
than any Spanish account, for he saw the country with
the eyes of an English farmer of 1830. Forbes left
England when farming did not differ greatly from
that of today, and visited a country which was so
backward that he used his observations for making
deductions about the life of the ancient Romans.

The Spaniards came into California with live-
stock from Mexico. They made no effort to care for
it; cattle and horses were simply branded and turned
loose. At first there were restrictions against
killing females, but the stock soon multiplied to
such an extent that this was unnecessary. There were
no diseases, and the few bears and pumas were soon
killed off; only the sheep had to be herded for
protection from coyotes.

No livestock were ever castrated, except those
used as oxen. The common diet was bull meat. There
were no vegetables, milk, cheese nor butter. The
principal grain was maize, which is still one of the
main articles of diet for the Mexicans. Wheat was
raised in considerable quantities at the San Gabriel
Mission, but beans, which are such an all important
food for Mexicans, were not so widely grown. This
was probably because of the excessive quantities of
protein available in the form of meat.
Forbes quotes the records for the year 1831-

Bushels of grain raised

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Maize</th>
<th>Beans</th>
<th>Peas</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Fernando Mission</td>
<td>450</td>
<td>625</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Pueblo de Los Angeles</td>
<td>345</td>
<td>4400</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>San Gabriel Mission</td>
<td>3500</td>
<td>1000</td>
<td>33</td>
<td>62</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4295</strong></td>
<td><strong>6025</strong></td>
<td><strong>583</strong></td>
<td><strong>162</strong></td>
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Livestock herds

<table>
<thead>
<tr>
<th></th>
<th>Cattle</th>
<th>Horses</th>
<th>Mules</th>
<th>Asses</th>
<th>Sheep</th>
<th>Goats</th>
<th>Pigs</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Fernando</td>
<td>6000</td>
<td>300</td>
<td>60</td>
<td>3</td>
<td>3000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Angeles</td>
<td>38624</td>
<td>5280</td>
<td>520</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Gabriel</td>
<td>20500</td>
<td>1700</td>
<td>120</td>
<td>4</td>
<td>13554</td>
<td>76</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>65124</td>
<td>7280</td>
<td>700</td>
<td>7</td>
<td>16554</td>
<td>76</td>
<td>98</td>
</tr>
</tbody>
</table>

Bancroft gives the population at this time as about 1000 Spanish Americans, and 1500 Indians connected with the missions. The food supply must have been sufficient for this number of people. There probably would not have been over a twenty-five per cent increase on cattle and perhaps a thirty-three per cent increase on sheep but, even so, there would have been 1400 pounds of beef (counting carcasses as dressing at 300 pounds) and 100 pounds of mutton (carcasses at 40 pounds) for each person. After allowing for seed, there would have been only
three and a half bushels of grain per person. This accords with the description of the diet as having been bull meat.

Forbes notes that horses were shot off because they destroyed pasture. There were about 17,000 square miles of lowland or approximately 1,000,000 acres. Considerable areas of this were dry, but, since the livestock figure is equivalent to under 50,000 head of cattle, this allowed twenty acres per head. This may have been something like the country's natural carrying capacity. During good years there would probably not have been enough food. The only products shipped were hides and tallow. These were carted by oxen to San Pedro, thrown over the cliff, and there dressed and prepared by the crew of the ship which had bought them by trade.

The occupation of California by the American Government in 1848 did not at first greatly change conditions in Los Angeles, and while the gold rush to the Sierra Nevada Mountains brought people through the region, it did not add many settlers.

The irrigation water rights established before 1860 show the state of agriculture. A group of Germans had come from San Francisco in 1856 and settled in the colony of Anaheim, obtaining water from the Santa Ana River Canyon. There was a farm of about a hundred acres under irrigation, drawing
water from the San Gabriel River at Paso de Bartolo. The Mormons, coming down from Salt Lake City, had rather large irrigated farms around San Bernardino. Other than this there was only the farming at the pueblo; probably a few hundred acres and little patches near the present town of Riverside; some along the lower Santa Ana Canyon and a little near Glendale. There was some grain growing without irrigation, but there is little mention of it. The population of Los Angeles was 4399 in 1860. There were a few hundred more people at Anaheim and in the San Bernardino basin, but it is safe to say that there were fewer than 10,000 people in the region.

The end of the grazing period came about this time. A series of dry years 1855-58 was followed by years of flood. In 1861-62 the rivers rose over their banks, destroyed several old irrigation works, and drowned many cattle. In 1862-63 and 1863-64 there was extremely low rainfall, and the cattle died of starvation. It is estimated that from one-half to three-quarters of the cattle in Los Angeles County perished during this drought. The assessed valuation of property in 1860 was 3,650,000 dollars; in 1865 it was 1,622,370 dollars. No taxes could be collected.

The herds were never re-established. The northern market had gone to better cattle which had been introduced to the northern valleys. The ranchers were forced to sell, and the country was being occupied by American settlers.
The Modern Period.

The present development of the Los Angeles region has been accomplished almost entirely since 1865. The region has undergone a very rapid change; not only have the wild pasture lands been turned into orchards and gardens, but great residential areas have been built, and many industries have been established.

The region is divided between four counties - Los Angeles, Riverside, San Bernardino, and Orange (Map 28) which also include large areas outside of the region. It is therefore impossible to use ordinary statistics of population and production which are listed by counties. An idea of the growth of the population of the region may be gained from the figures for the City of Los Angeles which are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1781</td>
<td>44</td>
</tr>
<tr>
<td>1790</td>
<td>141</td>
</tr>
<tr>
<td>1800</td>
<td>315</td>
</tr>
<tr>
<td>1810</td>
<td>415</td>
</tr>
<tr>
<td>1820</td>
<td>650</td>
</tr>
<tr>
<td>1830</td>
<td>770</td>
</tr>
<tr>
<td>1840</td>
<td>1250</td>
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<td>1850</td>
<td>1610</td>
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<tr>
<td>1860</td>
<td>4399</td>
</tr>
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<td>1870</td>
<td>5614</td>
</tr>
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<td>1880</td>
<td>11,183</td>
</tr>
<tr>
<td>1890</td>
<td>50,000</td>
</tr>
</tbody>
</table>
Population of Los Angeles (continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>102,479</td>
</tr>
<tr>
<td>1920</td>
<td>567,673</td>
</tr>
<tr>
<td>1930</td>
<td>1,231,830</td>
</tr>
</tbody>
</table>

The slow increase of the first century is in striking contrast to the rapidly accelerating increase of the last fifty years. To some extent, recent increases have been due to the enlargement of the City's boundaries which now include 442 square miles, but there has been an equally rapid growth in most of the region. The population of the whole area is about 2,500,000 and it is said that forty per cent of the people who have crossed the Rocky Mountains in the last ten years have come to Los Angeles.

The residential areas may be related to the physiographical features already described. The original site of the City, on the small alluvial apron to the southeast of the Elysian Hills, was badly cramped between the precipitous slopes of these Hills and the wide bed of the Los Angeles River. Expansion was easiest toward the south, on the upper part of the Vega cone of the Los Angeles River. This was the more available because of the position of the River on the eastern edge of its cone. Only the upper part of the cone was desirable for residences, for it soon

City increase 1920-30, 113%
County increase "", 140%
flattens and has poor drainage for surface water, and such poor air drainage that it is much more subject to frost than are more sloping positions. Many common garden plants of the region cannot be grown where frosts are severe, so that the frost hazard is a serious consideration in the selection of a home site.

The most desirable place for residences, adjacent to the business district, lay to the west of the City on the large eastern cone of the Hollywood Piedmont. The Elysian Hills which, at the old Plaza, have slopes 300 feet in height, lose elevation rapidly toward the south, and roads have from early times run out across this fan to Cahuenga Pass and to Santa Monica Bay. The fan has a good slope and a smooth surface. It is on the side of the city which is closest to the Ocean and the beaches, and it faces the unobstructed sea breeze. This area is now almost solidly built up with residences and apartment houses, and the retail business of the City is pushing out in this direction.

On the small western cone of the Hollywood Piedmont the City of Beverly Hills became popular a few years ago, and this area is now occupied by expensive residences. The lowland between these two cones has been occupied by small homes which now cover the greater part of the western end of the Vega Plain.
The San Fernando Valley has profited greatly by being located on the main routes leading northward. Because of this it has excellent connection with the City, and it receives water from the viaduct built by Los Angeles from the eastern slopes of the Sierra Nevada Mountains. Much of the Valley has recently been subdivided into residence lots, but the climate is rather severe, and the central part of the Valley has not become very heavily populated. At the extreme eastern end of the Valley, Glendale lies at the northern end of the Los Angeles River passway, and has grown very rapidly in the last few years. Burbank, just west of Glendale, on the alluvial apron in front of the Verdugo Mountains, has increased in population because its fog-free location has attracted aeroplane landing fields and factories.

A desirable residential district which compares with the Hollywood Piedmont is the Pasadena Terrace in the San Gabriel Valley. Pasadena was early established as a town and is not yet incorporated with Los Angeles, but it is definitely a residential district of the City. Practically the whole Terrace is closely built with dwellings.

East of Pasadena there is a series of towns on the alluvial slopes of the San Gabriel Mountains. These slopes are largely planted in oranges, and the
orange district extends eastward to San Bernardino and Riverside. Orange growing areas are usually subdivided into very small holdings, so that this part of the region is rather densely populated.

The southern part of the San Bernardino Valley is the most sparsely settled lowland in the region. There are large alfalfa and grain fields in this district.

The Vega Terrace to the south of the Repetto Hills is densely populated. There are a great many Mexicans in this quarter. The terraces farther east, and the upper parts of the San Gabriel-Santa Ana cones are in oranges and walnuts, with the usual small holdings and prosperous towns. The oil fields here have added to the size of the towns, though there are comparatively few workers in the developed oil fields.

The Vega Plain is becoming the industrial district of the region. The land is not held at such high prices as in the orchard districts; there is easy connection with the port and the City, and the flat land is cheaply subdivided for workers' homes.

The Orilla beaches are the seaside resorts of the region and in many cases these have grown into large cities. From Santa Monica to the San Pedro Hills, residence lots have been laid out on practically all of the land within half a mile of the beaches, and on much of this there are dwellings.
On San Pedro Bay there is a continuous City from Long Beach to San Pedro. There are large industries at the port, which are bringing dense population to the adjacent areas. The central part of the Orilla is now taken up with small holdings.

The part of the San Pedro Hills to the west of the Town of San Pedro was formerly the Palos Verdes Rancho. It remained undivided until recently, when the 16,000 acres were laid out as a residential district. Roads have been built, and large parks have been planted. There has been more careful town planning here than in any other district of the region. Up to date there have been only a few hundred houses built.

For internal transportation the region is dependent mainly on motor cars and motor lorries. The principal public roads are shown on the map page 10. All of the roads shown are paved, generally with concrete. It is estimated that there is one automobile for every three people. Travel by motor car is the common way of getting about. Daily commuters and people who wish to go to the center of the City where it is difficult to park a car, may use the electric railway system. A map of this is included in the folio. (Map J) The steam railways carry very little passenger traffic within the region, and have now little influence on the growth of the different districts. There is, for example, no
railway in Hollywood, and the western part of the City. The railway communications reaching outside of the region are shown on Map J.

The aeroplane has recently taken a place in transportation. There are over fifty registered landing fields in the region. There are daily mail and passenger services eastward, and daily passenger service to San Francisco and San Diego.

Agriculture.

The present development of agriculture is almost entirely dependent on irrigation, therefore it may be well to start with a review of the water resources. The rainfall comes only between the months of October and April. It is sufficient at that season to provide moisture for winter grains and such perennials as oranges, which grow in winter; it is in summer that irrigation water is needed. In most countries, under these conditions, the summer flow from the mountains is the chief source of supply, but in this respect Southern California is unfortunate. There are no permanent snow fields on the neighboring mountains; there are very few thunder showers. In addition, the San Gabriels are maturely eroded, so that there are no lakes or alluvial deposits. In the San Bernardininos there is a high plateau, and the
streams heading in the valleys of this Range have the strongest summer flow of any in the region. Otherwise the layer of decomposed granite on the surface of the mountains is the only place of high level storage. The mountain mass is highly impermeable and there is nowhere great depth of disintegrated rock, so that high evaporation and a heavy loss through plants greatly reduce any seepage.

There was, however, some summer flow in all of the larger streams, and since it was quickly appropriated by the Americans, it calls for notice. There were few streams from which the summer flow normally ran out onto the lowlands. The two principal ones were the Santa Ana River and Mill Creek, both of which rise in the high San Bernardinos and run into San Bernardino basin. Mill Creek was diverted into a canal by the mission fathers about 1810. This is the only case in which the Spaniards made use of a mountain stream. This work was later abandoned, but was used by the Mormons who came down through Cajon Pass and settled at San Bernardino in 1851. The Santa Ana flow was first used in 1855.

Most mountain streams sink into the boulders and debris of their canyons some distance from the valleys. There are two ways of capturing the water from these streams. It may be diverted where it is a surface flow, but in such cases it is rarely practical to build a canal along the steep
sides of the tortuous canyons. Generally the water is led by pipes to the valley. This is a heavy expense, but in cases where there is a good fall the water can be used for hydroelectric power as well as for irrigation. The other method is to excavate to bed rock across the lower end of the canyon, and put in a submerged dam. The dam brings the flow to the surface and the water can be carried to the valley in canals.

Between 1865 and 1888 practically every mountain stream with summer flow was appropriated. The smaller works were often made by individual irrigators, the larger ones by groups, or often by promoters who sold the land with the water rights.

The other source of surface water is the seepage from the water-holding sediments of the structural basin. All the summer flow of the lowlands is from this source; not even the Santa Ana runs as a continuous stream from the mountains to the sea. At first glance, the distinction between the summer seepage streams of the mountains and the lowlands may not seem to be fundamental, but in reality it is. The great basins are filled with hundreds of feet of sediment. This is not a uniform mass, for it contains lenses of clay and beds of gravel and sand in the most confused fashions. In addition to the confusion of sediments, the irregularities in the
underlying rock interfere with normal percolation, while the Santa Monica-Santa Ana and Dominguez Ranges form nearly continuous dams. Yet, as a whole, the basin sediments are a unit as a water source; the stream-flow from the mountains sinks into the unconsolidated sediments until they are filled with water. It is estimated that on an average the alluvium of the valleys holds fifteen per cent of its volume of recoverable water, and gravel beds as high as thirty-three per cent. The great depths of sediment, therefore, hold almost unlimited supplies of water, though only the upper few hundred feet can be economically used.

Once the water sinks into the sediment, it ceases to have anything of the nature of free flow. There are no underground rivers, though that is a popular misconception. The water, even in the gravels, can be likened rather to moisture in a blotting paper. It slowly seeks the lowest levels but piles up behind small obstructions and moves slowly in any direction. Measurements show that the movement in the gravels is at the rate of only three to four miles a year (Slichter, 1905). Even discontinuous underground dikes have the effect of raising the water table, and on the upper side of obstructions water comes to the surface in cienegas, or is retained under pressure below clay deposits, thus forming an artesian source.
The best sources of seepage water are along the Santa Ana River channel. Most of this water comes from winter floods of the mountain streams, though a considerable percentage of that flow escapes to the sea over unsaturated sediments. The San Bernardino basin is dammed by a cross structure just south of San Bernardino, and the water rises here and flows on the surface in the channel of the Santa Ana River. Such a channel of surface flow at the lower edge of a basin is called a "narrows", for it makes little difference how deep the opening is (in some places there are 1000 feet of sediment in a narrow rift), the slowly percolating waters are brought to the surface by the contraction of the width of the seepage beds. At the narrows south of San Bernardino the waters are diverted for irrigation around Riverside.

There is another water basin around Pomona in the northwestern corner of the San Bernardino Valley, and then at the lowest part of the Valley all the seepage waters are forced to the surface to get through the lower Santa Ana Canyon. The flow here for the year is twice the total of that of the Santa Ana River in the San Bernardino Mountains, and the summer flow has no relation to the contribution of that stream.

In the San Gabriel Valley, the buried rock structures have produced many areas of high water-table,

Approximate original artesian areas
Artesian areas 2001

Scale: 1 inch = 1 mile
Contour interval 250 feet
Datum is mean sea level

Generalized Hydrographic contours
Topographic map by the U.S. Geological Survey
the most notable being that to the north of the Raymond Hill Dike, which, though not a continuous dam, in places raises the water-table 200 feet. The seepage from this whole San Gabriel Valley rises to pass through the Paso de Bartolo narrows, even though this narrows is two miles wide, and there is a gravel fill ing known to be at least 800 feet in depth.

The San Fernando Valley has only unimportant seepage basins within the main valley, but the waters rise to pass through the narrows of the Los Angeles River gap.

In the Vega all of the subsurface waters unite, and along the Dominguez Range there is a continuous area of high water-table.

The subsurface water of the Orilla is only slightly connected with this larger body. A small amount flows through the breaks in Dominguez Range, especially at Inglewood, but the main supply is local and the water-table here is being rapidly lowered by the pumping of industrial plants.

A copy of the ground water contours from Mendenhall's United States Geological Survey report (Map 30) illustrates the situation in 1904, and a more detailed map of the San Gabriel Valley, from Conklin's investigation in 1925, that in that year the contours were almost the same as in 1924.

The Spaniards used, almost exclusively, basin seepage streams for their few irrigation works, and
the Americans quickly made use of all of them. By 1888 rights had been established to all the surface flow of the summer, though much of it was used very wastefully.

Fortunately, in the year 1888 W.H.Hall made a complete survey of the irrigation works. His report is the most comprehensive statement of the irrigation and crops that has been made for any period. It came at an opportune moment, for up to that time there was practically no irrigation from wells.

In 1865 there cannot have been more than two or three thousand acres under irrigation, and most of this was in summer crops of corn, or in grapes. In 1888 Hall gives definite figures for 107,523 acres, and mentions a few areas that are not listed. Beside that, at least 6000 acres that had been put under irrigation were already subdivided for residence lots, while grapes had been planted over a considerable area without the benefit of irrigation.

What use was made of the remainder of the lowland can not be determined from available sources. This was a period of heavy grain production over most of California, and beans have since been grown on unirrigated lowlands. Grain growing and pasturing of cattle were only incidents in the agricultural history. They are practically non-existent today in the Los Angeles region. From Hall's statistics, diagrams
### Irrigated Land in the Los Angeles Region - 1888.
(From Hall's "Irrigation in Southern California")

<table>
<thead>
<tr>
<th>Valley</th>
<th>Total Area</th>
<th>Citrus</th>
<th>Deciduous Fruit</th>
<th>Vine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>San Fernando Valley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. San Fernando</td>
<td>543</td>
<td>234</td>
<td>210</td>
<td>55</td>
</tr>
<tr>
<td>2. Tujunga</td>
<td>310</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Crescenta</td>
<td>530</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Verdugo Canyon</td>
<td>1200</td>
<td>700</td>
<td>300</td>
<td>x</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2583</td>
<td>943</td>
<td>510</td>
<td>55</td>
</tr>
<tr>
<td><strong>San Gabriel Valley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Main Valley</td>
<td>16655</td>
<td>7470</td>
<td>5143</td>
<td>x</td>
</tr>
<tr>
<td>6. San Jose Creek</td>
<td>1340</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Paso de Bartolo</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>19785</td>
<td>7470</td>
<td>5143</td>
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<tr>
<td><strong>San Bernardino Valley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Pomona</td>
<td>5375</td>
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<td>9. Cucamonga Plain</td>
<td>5250</td>
<td>1200</td>
<td>800</td>
<td></td>
</tr>
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<td>10. San Bernardino</td>
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<td>1497</td>
<td>2647</td>
<td>1700</td>
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<td>Basin</td>
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<td>2470</td>
<td>1600</td>
</tr>
<tr>
<td>12. Rincon</td>
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<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>27738</td>
<td>7330</td>
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<td>7800</td>
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<tr>
<td><strong>Vega</strong></td>
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<tr>
<td>13. Los Angeles</td>
<td>14987</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Lower San Gabriel River</td>
<td>15500</td>
<td>80</td>
<td>2000 (walnuts)</td>
<td></td>
</tr>
<tr>
<td>15. Lower Santa Ana River</td>
<td>26180</td>
<td>3650</td>
<td>10000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>56667</td>
<td>3730</td>
<td>2000</td>
<td>10000</td>
</tr>
<tr>
<td><strong>Orilla</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>16. Ballona</td>
<td>1600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Inglewood</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1740</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total for Region</strong></td>
<td>107523</td>
<td>21473</td>
<td>15520</td>
<td>17853</td>
</tr>
</tbody>
</table>

**Note.** The figures are not tabulated in Hall's book and they are somewhat varied in treatment. It is probable that all citrus orchards are mentioned and most of the deciduous area irrigated is an estimate.

x- Vineyards mentioned as unirrigated.
indicating the amount of irrigated land are placed on the map in their approximate positions.

The great area of irrigated land in tree fruits in 1888 is noticeable. The country was already in the commercial orchard business. The percentage of deciduous fruits was much higher than it is now, though citrus fruits were already of great importance. There are two items mentioned by Hall that have not been mapped separately: one is thirty acres of irrigated timber trees, the other is ten acres of pampas grass. These give an interesting sidelight on the development of California. To people coming from the Eastern United States, this was a strange fairy-land, and they were ready to attempt anything. It is actually recorded that orange groves were uprooted to plant eucalyptus trees for timber. Also, it meant that old world methods of cultivating orchards were largely ignored, and this proved a great benefit, for California has developed far superior methods. The most casual observer is impressed with the perfection of the orchards.

The latest available map for irrigated lands is one of small scale, issued in 1920 by the State of California. It is useful for a comparison with Hall's figures. There are 307,094 acres marked as irrigated as compared with 107,523 in 1888. Practically all of the San Gabriel Valley. Conklin's detailed report for 1928 gives 60,000.
this development has been through wells tapping the underground water. In addition, the City brings in water from the eastern slope of the Sierra Nevadas. The aqueduct was completed in 1914, and is considered capable of supplying 2,000,000 people. At present a large surplus is used to irrigate land in the San Fernando Valley, and in this way the underground water supply is probably increased from percolation and drainage.

The real expansion has come through the intelligent use of the gravel beds as storage reservoirs, and the economical use of the water on crops. The Conklin report on the San Gabriel water supply is most illuminating on this point. He points out that the lowering of the water-table in the dry years is necessary for the complete storage of the water in wet years. The development of pumps, and especially of deep well pumps that can be lowered several hundred feet into a drilled well, has made this possible. Seventy-five per cent of the water now comes from wells. At the mouths of most of the mountain canyons there are spreading-works to get the water underground, and a big dam is being built in the San Gabriel Canyon, not to store water for irrigation, but to hold it back temporarily, so that it can be released slowly enough to be completely absorbed by the gravel beds. A similar dam is planned for the lower Santa Ana Canyon. The necessity for cyclic storage is
Livestock.

This grazing country of the Spaniards has become a region where there are practically no grazing animals. In a day’s drive not a single pasture will be seen. There are still a few ranches on the hills, where riding horses are kept for hire, and where a few sheep are herded. There are many large dairies where feed is hauled to the cows, but otherwise, there is almost no livestock. Cultivation is done largely by tractor; hauling is all done by motor lorries. The number of horses in California has decreased 34% since 1900. Orange County, with an area of 795 square miles, about half of which is within the region, may be used to give an idea of the livestock. In 1928 there were in that County -

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>all cattle and calves</td>
<td>19,000</td>
</tr>
<tr>
<td>milk cows over two years</td>
<td>9,500</td>
</tr>
<tr>
<td>sheep and lambs</td>
<td>3,000</td>
</tr>
<tr>
<td>horses</td>
<td>3,700</td>
</tr>
<tr>
<td>mules</td>
<td>2,150</td>
</tr>
<tr>
<td>hogs</td>
<td>3,000</td>
</tr>
</tbody>
</table>

There are no figures for poultry, though much is raised on imported feed. This region is the only one in the United States where many rabbits are bred for food and skins.
Citrus Fruits.

Citrus culture is the basis of agricultural prosperity in the Los Angeles region. Citrus fruit is a high priced export crop. It often pays enormous returns, and it does not take a great amount of irrigation water.

The citrus area covered 188,854 acres in the four counties in 1928. Probably about 170,000 acres of this were within the region. Of this total 82% were oranges, 15% lemons, and 3% grapefruit. The area in citrus crops is over three times that of all the other fruit and nut crops listed.

The lemons bear during the whole year. The trees are dwarf sized, rarely over fifteen feet in height, and some fruit is picked every month. Rings are used to measure the size, and no attention is paid to color. Some idea of the nicety in the handling of citrus fruits in California may be gathered from the fact that lemons are allowed to grow to a diameter of four and four-sixteenths inches in the summer, and four and five-sixteenths in the winter. Small fruit which yellows before reaching these sizes is picked once a year.

All but 3% of the oranges of the State belong to two varieties - "Washington Navel" and "Valencia". These are both semi-dwarf varieties, the trees being generally about twenty feet in height. The main reason for having two varieties is to keep the market
supplied during the whole year. Oranges are fairly regular in season, although there are always a few off-season blossoms on every tree. The trees bloom in April or May, and the Navel orange comes onto the market from November to April, while the Valencia hangs on the tree from fourteen to sixteen months and is not picked until the June to October season of the following year. The Los Angeles region does not quite bridge the year with its fruit. The orchards in the Great Valley, to the north, but with higher inland temperatures, supply the early crop of each variety.

Orange production in California is one of the most commercialised and systematised of agricultural undertakings. In the Los Angeles region the greater part of the production is from small holdings of from five to twenty acres. Very often they are places of retirement for business men of the Eastern United States. The work is so regulated, and so much of it is done through cooperation and the service of outside experts, that there is nothing arduous in the undertaking. The value of the groves within the region is therefore often high compared with their return, and this is especially true because much of the land has a speculative value for residences. Orange groves sell for from 3000 to 4000 dollars an acre. Even at this price they may occasionally show
a profit. In some years 1000 dollars an acre gross return is received, but an ordinary yield is about 150 boxes per acre from 90 trees, at prices of from 2 to 4 dollars a box. As a purely business proposition probably few groves pay.

It is very common for an orange grower to have his entire holding in oranges, with only the space of a city lot reserved for a house and garage. There are few fences, for they would take up space. Water for small holdings is bought from some water company. Generally the water right accompanies the land, and the owner takes his turn at the irrigation supply about once every thirty days. The water is piped to the ranch in concrete conduits, and is put on the land in small streams running in furrows. Some groves are supplied with overhead sprinklers. The ground is kept under clean cultivation, or sometimes a winter cover crop is raised and plowed under.

The owner keeps the ground cultivated, fertilized, and watered. He belongs to a cooperative selling association and can not sell a single fruit independently. The crop is picked by the association, which employs gangs of Mexican labourers. The fruit is graded, packed, and shipped by the association. There is a complete organization for advertising and directing the fruit to the best markets. Cars are directed to the different cities by wire, after they have started east, and a glut is carefully avoided.
The grower receives the average price of the season for his grade of fruit.

After the oranges are picked the trees are fumigated under canvas covers. They are pruned lightly, though the Valencias and Navels require little pruning attention. In the winter, preparations are made for heating. This is nearly universal in the Los Angeles region. There are some areas which are called "frostless", but none is actually without frost hazard, and it usually pays to heat the orchards. Practically the only method of heating is by small "smudge pots" - approximately one to each tree. A carefully organised frost warning system is maintained by the growers and the United States Weather Bureau. Oranges will stand a temperature of 26 degrees for an hour with injury; lemons are more sensitive.

Fuel oil is the only fuel used. This costs something less than two cents for an American gallon. Electricity has been used experimentally with great success, but the installation is too expensive, and sufficient current is not usually available. It takes one horsepower to warm each tree.

In case of frost the oil heaters are lighted, and everyone in the district stands by to watch the fires and, if necessary, refuel. The term "smudge pot" is descriptive, for these necessarily cheap stoves do not entirely consume the heavy fuel.
The desire is to produce smokeless heat; the production of a cloud to prevent radiation counts for little. The soot is undesirable on the leaves and fruit, and is appalling in its effect within houses. In the spring the smudge pots are piled out of the way, and cultivation is resumed.

Orange production has practically surmounted geographical controls. Few of the valley soils are too rocky to be cleared, too poor to be fertilised, or too indurated with hardpan to be blasted. Water can be raised as much as 300 feet with profit. For comparison, it may be noted that water can be raised only 40 or 50 feet for alfalfa. Lastly, frost can be warded off with heaters. This last may cost as much as one hundred dollars an acre per year but, with the present prices of fuel and oranges, it pays.

Walnuts.

The orchard crop second in value per acre is English walnuts. They are more truly Persian walnuts, but are universally known as English, in America. There are 64,419 acres of walnuts listed for the four counties in 1928. Nearly all of these must be within the region. The walnut does best with a long, fairly cool growing season, and so it is best adapted to the Vega or the San Gabriel Valley. It is generally planted on the lower lands where oranges would be subject to frost, though since heating has become common, it is
probable that many walnut plantings are on land that would be suitable for oranges. The position below the oranges is in one way an anomaly, for the walnut has a tap root and requires that the water-table be at least twelve feet below the surface, whereas oranges will thrive with one six feet in depth. The high water-table restricts the planting of walnuts on the Vega.

The walnut trees are large and form a leafy canopy. The groves have neither the sunny aspect nor the perpetual beauty of an orange grove. They are also relegated to places of poorer climate and less desirable residential conditions, so that they have not become luxury holdings. The yield varies greatly with soil and climate. The highest averages are a ton to the acre, but many orchards yield not much more than half of that. The crop is handled by co-operative societies and in 1928 brought 420 dollars a ton.

Grapes.

Grapes were probably the first commercial fruit crop in the Los Angeles region. The missions brought cuttings and raised grapes for wine, while in the early days of the pueblo, the vineyards were given the choicest location in the irrigated fields. In 1856 the Anaheim colony was established on the basis of commercial wine production. There was
probably little else that would stand the cost of shipment.

In the early days grapes were irrigated, but it was found later that they would do well on sandy soils without irrigation. The upper parts of the alluvial cones in all the valleys were largely planted in grapes. The largest block was on the Cucamonga plains in the San Bernardino Valley, where one Italian-American company had 5000 acres.

The vineyards in 1928 covered 48,309 acres in the four counties, and the largest part of these is within the region. Sixty-four per cent are raisin grapes and the remainder table grapes, though most raisin grapes can be used as table grapes, and are probably so marketed in the Los Angeles region.

The competition of grapes on the unirrigated land; and on cheaply irrigated land over large areas of the Great Valley, has driven the vineyards from areas under water. The grape industry may be said to be waning in the Los Angeles region. The grapes are located in places that are most desirable for building sites, and both the development of water resources and the subdivision of land for residences tend to drive them to other regions.

Deciduous Fruits.

Apples and pears are but little grown in the
Los Angeles region. Peaches and apricots are the principal deciduous fruits. They are grown under irrigation in the lower parts of the San Fernando Valley, where the winters are too cold for citrus culture and the summers too hot for walnuts. Many peaches are also grown without irrigation on the deep, sandy wind-blown soils of the lower part of the Cucamonga plains, in the San Bernardino Valley. In this district they compete with grapes. The production of unirrigated fruit here, with about twelve inches of rainfall, is a monument to someone's courage, and a triumph for cultivation.

There are about 32,000 acres of peaches and apricots in the four counties, but probably not over half of them are within the region. There are about twice as many peaches as apricots, and of the peaches, about half are canning varieties. There is a small amount of canning within the region, but it counts for little in the total of the State, and is not of great consequence in the local economy.

There are a few hundred acres of other fruits — avocados, persimmons, plums and so forth. There are also a few patches of berry fruits, and rather large areas of strawberries. The latter are chiefly grown by Japanese, on the old lagoon plain of the Orilla. Vegetables, melons and flowers are grown for the local market and supply it only in certain season.
Vegetable production for canning and shipping has developed in the less populous parts of California.

The only field crops worth mentioning are lima beans and sugar beets. Lima beans require a long, cool summer. They are natural perennials and can be harvested only where the vines will dry quickly after cutting. They are restricted to the fog-covered coastlands of Southern California, and considerable quantities are grown on the lower lands of the Vega. They will make a crop under the Vega conditions without irrigation, but water is generally profitably available for them in the Los Angeles region. A few years ago they were grown, to some extent, just west of Los Angeles, but the City has advanced over that territory. Now they are almost entirely restricted to Orange County, where 23,000 acres were grown in 1928.

Sugar beets occupy the lower lands of the Vega where the soil is too alkaline to grow other crops. There is a decreasing acreage of them in the region—chiefly in Orange County, but there are no figures available. One sugar factory operates at Anaheim. The above listing has accounted for the following acreages:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus</td>
<td>170,000</td>
</tr>
<tr>
<td>Walnuts</td>
<td>60,000</td>
</tr>
<tr>
<td>Grapes</td>
<td>35,000</td>
</tr>
<tr>
<td>Peaches and Apricots</td>
<td>16,000</td>
</tr>
<tr>
<td>Avocados, etc.</td>
<td>23,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>306,000</strong></td>
</tr>
</tbody>
</table>
There are about a million acres of lowland within the region, and the above listing had accounted for only one-third of it. Unlisted are considerable areas of alfalfa, sugar beets, and unirrigated barley and oats, which are used for grain, or hay. The remainder, which must amount to several hundred thousands of acres, is occupied by cities, roads, and waste lands.

There is a large area that should be classed as waste land, and one item of this is characteristic of a rapidly growing city; that is the land in vacant lots. Even in the older districts of the City of Los Angeles there are many vacant lots which run to waste among fine residences, while in every direction from Los Angeles, the country is subdivided far in advance of any necessity for building.

It is probably conservative to estimate that the land held vacant for building purposes in the Los Angeles region amounts to 50,000 acres.
Industries.

Los Angeles is rapidly growing to be an industrial City. Its advantages are manifold. In itself it provides a market with a buying power out of all proportion to the population. Its hinterland, though poorly populated, is large, and railways give rapid transportation to all parts of North America, while the port affords cheap ocean connections. There is no coal nor iron ore, and very little in the way of heavy industries. There is, however, cheap heat and power, a climate that allows for economical housing, plenty of sunlight, and favorable working temperatures. In regard to labour, there is chronic unemployment; an "open shop" or non-union system of employment; an abundance of workers of low-living standards (chiefly Mexicans and negroes); and thousands of eastern Americans, many of whom have an outside income and are willing to sacrifice wages to live in Southern California. Living costs are fairly low, but pleasure spending is maintained at a fever heat, while the crescendo of activity in the region results in a very high work speed. A Mexican who never did a day's work in his life in his home country will doggedly work hard eight or nine hours a day in Los Angeles to keep up with his fellow workers, and to pay for his second-hand automobile.

The chief industry, however, does not depend on
the cheapness of power nor labour. Motion picture production is a child of this region. In this industry Los Angeles not only ranks unrivalled in the world, but in the United States it stands alone. The most important factor in starting the motion picture industry in Hollywood fifteen years ago, was the climate. The first producing companies were poor. They took their pictures in a sunlit room, or in the field, or streets. The constant sunlight and the long season without rain made this region especially suitable. In addition, there was a great variety of scenery to be used at little cost - snowy mountains, tropical gardens, broad plains for cowboy pictures, sea coasts and desert sands.

There are other places in California as well situated, but Los Angeles was the largest City with these advantages, and once the industry was established here, it attracted all producers.

The advantages in being at the main center of production lay in the ability to keep in touch with the rapidly changing technique, and the availability of plenty of artists and "extras" - people used in crowd scenes. The advantage of climate and scenery for the early producers is of much less importance now, for artificial settings have replaced natural scenery. Pictures are now taken almost entirely within the studio lots. In these there are railway
trains, castles, English villages, snow-covered Russian forests, and pirate ships. Artificial lighting can replace sunlight for even out-of-door scenes. The lack of rain is an advantage for outside settings, but natural geographical control is no longer of paramount importance. The compelling factor has come to be the availability of properties, not only in the matter of settings, but also in the costumes for huge crowd scenes. Los Angeles has accumulated the paraphernalia of the world. It is this factor more than anything else, which has made it impossible for any producing company to remain away from Hollywood. In 1927 the last of the studios closed in New York.

The district of Hollywood was the original location for the industry and it is still centered there. However, property values have increased so enormously that most companies have sold their land and moved farther out, especially to the San Fernando Valley.

The introduction of sound has changed the situation since October 1927. If it continues to convert the moving picture into reproductions of stage plays, the supremacy of Hollywood may be lost. There is not sufficient population for any great theatrical business in Los Angeles, and if the cinema depends upon the stage for its inspiration, it may well move to New York, London, Paris, Berlin or Moscow. There has been little tendency to this so
far, and the talking pictures may develop as independent of the legitimate stage.

The Hollywood Chamber of Commerce states that in 1928 the gross value of the motion picture production was 200,000,000 dollars, and that a staff of 25,000 to 35,000 people was employed regularly, while 18,000 were registered as extras.

The other industries of the region are not of such world-wide importance. Some of them, such as the manufacture of furniture, plumbing supplies, cement, and structural steel, exist largely to supply the large, isolated, local market. Automobile assembling plants are also more or less in this class.

Rubber manufacturing has developed beyond local demands. California and Arizona long staple cotton, and oriental rubber are easily brought together here, and there is an abundance of water, cheap power, and an easily satisfied labor supply. Several of the United States rubber companies have established branches in the last year, and Los Angeles is second only to Akron, Ohio, in rubber manufacturing in the United States.

Other industries have built up an export business through their initiative in developing new products; Los Angeles oil machinery, for example, has a wide sale because of the technical achievements in oil production in Southern California. There are
innumerable other small industries which have started here because of the ready sale for novelties. Odd toys, strange tools, unknown household utensils are readily given a trial in this new country. Small concerns are manufacturing everything from cosmetics to aeroplanes. The latter industry is of considerable size.

Commercial sea fishing from the port of San Pedro has made great strides in recent years. The fish are used largely for canning. The fishing boats and the canneries are manned almost entirely by foreigners, largely Japanese, Portuguese, and Italians. The fishing is carried on from Point Conception to far down the Mexican Coast. The catch consists of tuna, mackerel, and sardines.

The recent development of winter vegetables growing in California has been of great benefit to the fishermen, for dried fish meal is valued at from sixty to eighty dollars a ton for fertilising vegetables. There would often be more profit in making fertilizer than in canning fish, but the government has restrictions against the destruction of edible fish, so a pound tin of San Pedro canned sardines is for sale in Edinburgh at six pence.
Oil.

Petroleum has been one of the natural products of the Los Angeles region from time immemorial. The Indians used the pitch which accumulates around oil seepages to seal their canoes. The Spanish, who called this pitch "la brea", used it on their house roofs. The first navigators along the coast mention the odour of oil, and there is one offshore seep, rising three miles northwest of the San Pedro Hills, which is so noticeable that it calls for mention in the pilot charts.

The first commercial production in the Los Angeles region came in 1882 with two small wells in the Puente Hills, though just north of the region, in the Santa Monica Mountains, there had been production for some time previous. The early wells were drilled near seepages and were shallow. In 1892 oil production was started in the Los Angeles Field, in the hills just north of the center of the City. The first of these wells was dug by hand, and at under a hundred feet in depth they would produce a few barrels of oil a day. As an indication of the youth of the industry, and the extravagance of the returns, it is reputed to have yielded, it might be mentioned that one of these wells was dug by Mr. Doheny who still lives in Los Angeles and is now popularly credited
with wealth amounting to a billion dollars (two hundred million pounds).

Some of the Los Angeles Field wells are still producing, and one of the odd sights of Los Angeles is the old oil well derricks, a few blocks from the business center, slowly pumping as they have done for forty years, among all the change and hustle of the City.

The first oil production, in the light of present discoveries, looks unspectacular, and was certainly not particularly profitable. The oil was a drug on the market, though the amount produced was very small. The oil of the Los Angeles Field was trapped by faults in a tilted block. Drilling here has long since been prohibited, but this did not require any great sacrifice for the sake of beauty, for the field was known to be shallow.

The Salt Lake Field, eight miles west of the City, was discovered in 1894, and oil production, refining, and shipping were put on a solid basis. In 1900 the Los Angeles basin production was about 1,500,000 barrels for the year. By 1910 it had increased to 10,000,000 barrels. The wells were still shallow and drilled haphazardly near oil seepages. The oil was heavy and with the refining methods then in use, yielded a small percentage of the valuable lighter products. The Los Angeles basin, at this time, was of small consequence in the State production which amounted to 80,000,000 barrels, and it was a mere bagatelle nationally.
As drilling methods were improved, deeper drilling became possible and "wild catting" became general wherever anticlines could be located, even though no seeps were visible. In 1909 the field of West Coyote Hills was located by the Standard Oil Company; in 1916 the Montebello Field at Merced Hill was discovered. In 1919 the first field on Dominguez Range was located at Huntington Beach, and the boom began. In 1920 only 30,000,000 barrels were produced, but there was feverish drilling everywhere. The whole area of the Vega and Orilla has been searched with wildcat wells which were put down blindly even where there was not the slightest indication of an underlying anticline.

In 1920 the discovery well of the Signal Hill or Long Beach Field was brought in by the Shell Company, and the period of almost criminally wasteful oil production started. This has been largely due to what is known as "town lot" drilling, and since it is more or less confined to the Los Angeles region, it needs some explanation.

A few years previous to the discovery of oil on Signal Hill, this district had been subdivided into town lots. Fortunately for the City of Long Beach, it had acquired a considerable area for a water reservoir, but the bulk of the area was owned by individuals holding only single lots, 50 by 150
There are many derricks in these fields so close together that a twenty foot plank is used as a bridge between them. Under these derricks are holes 6000 to 8000 feet in depth, and with California drilling methods, the hole may have a bend of as much as forty degrees. It has happened several times that one well has been drilled into another.

The situation would not be so bad if an enormous production were not concentrated into such a small area. The top oil sand of the Santa Fé Springs field covers only forty acres; the whole field is confined to 640 acres, but under much of this there has already been discovered a thickness of more than 1000 feet of producing sands. Many fields east of the Rockies produce from sands a few inches thick.

In all the highly productive fields of the Los Angeles area, there are several producing sands. The deeper sands produce lighter oil, which is often under high gas pressure. The 8000 foot sand at Santa Fé Springs is under a pressure exceeding 2000 pounds to the square inch. In 1928 two wells drilled into this sand caught fire. A gas and oil flame 100 feet in height could be seen for 50 miles at night. Near the well the roar drowned the clatter of the neighboring wells, which were being drilled twenty-four hours a day to reach the same sand and bring up more unneeded gas and oil. The burning wells
feet. Mineral rights were included in the surface holding. In the ordinary procedure in oil production, the producing company leases the land. In the lease, the property owner signs over the mineral rights for an indefinite period, which can be continued in perpetuity as long as a fee is paid. East of the Rocky Mountains the fee is from ten cents to one dollar an acre per year. In the Los Angeles basin it is generally a dollar an acre per month. When oil is produced, the land owner receives a royalty, generally a sixth or an eighth of the oil.

Since oil can be drained from under any property by an adjacent well, the law requires that the neighboring lease holder must drill an "offset" to counteract any nearby production. Throughout the United States, this has led to an enormous amount of useless drilling. In many cases two wells are put down where one could recover all of the oil, but in the Los Angeles region it has resulted in what can be described only as mad drilling. Every field in the region shows as a surface anticline, and, as the surface anticlines stand above the plain, they were favorite town sites. Not only Long Beach, but also Huntington Beach, Seal Beach, and Santa Fe Springs had been largely sold off in town lots before oil was discovered. As a result, a well could be demanded for every separately owned lot in these fields.
Production of Fields
(A. Date of Discovery
B. Production to the end of 1926
in thousands of bbls)

Total Production to end of 1926
1,534,662,000 bbls
App. 200,000,000 Tons

1926 production 1,514,757,227 bbls

There are no figures available for natural gas

MAP OF OIL FIELDS AND PIPE LINES
OF SOUTHERN CALIFORNIA
Showing pipe lines connecting the oil fields with the refineries and terminals of the City and harbor of Los Angeles.
Showing also pipe line facilities

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Los Angeles, California
APRIL 1, 1928
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A. 1926
B. 1927
C. 1928

HARBOR FACILITIES
- Ship Loading Plant
- Marine Loading Station
- Export Terminal

UNION OIL COMPANY
STANDARD OIL CO
SHELL OIL CO
ASSOCIATED OIL CO
ASSOCIATED OIL CO
CALIFORNIA PETROLEUM
CITY OIL CO
CRAWFORD OIL
DELAWARE OIL
FROST OIL CO
GABRIEL OIL
GENERAL PETROLEUM
HERITAGE OIL
HOLLY OIL
HUNT OIL CO
IBANEZ OIL CO
INDEPENDENT OIL CO
INTERNATIONAL OIL CO
JACOB OIL CO
KERN OIL
KNOX OIL CO
LITTON OIL CO
LUCAS OIL CO
MACHADO OIL
MARICopa OIL CO
MCGUFFEY OIL CO
MESA OIL CO
MEXICAN OIL
MOREHEAD OIL
NEVADA OIL
NEW YORK OIL
PARKER OIL CO
POTOMAC OIL CO
PRODUCER OIL
RHYOLITE OIL
ROCKWELL OIL
STANDARD OIL
SUN OIL CO
TODD OIL
TRES OIL CO
U.S. OIL CO
UNITED OIL CO
WELLS OIL CO
WESTERN OIL
WILSHIRE OIL CO
WILSON OIL CO
WILSON OIL CO
WYOMING OIL CO
ZEPHYR OIL CO

November 21, 1928
1920
1921
1922
continued to run wild for six weeks. All the resources of this highly developed oil region could not stop them sooner. In 1930 the Santa Fe' Springs Field produced about 300,000 barrels a day.

The Los Angeles region produced 157,000,000 barrels in 1928. Of this 62,000,000 came from the single field of Long Beach; 19,000,000 from Huntington Beach; and 16,000,000 from Santa Fe' Springs. There is literally a flood of oil. It is practically given away; prices are about a dollar a barrel (42 American gallons) for the best oil at the well. After it is refined by methods that produce only a part of the possible gasoline, the fuel oil residue is loaded into ship bunkers for less than four dollars a ton.

138,000,000 barrels were shipped from the port of San Pedro in 1929, but, even so, the oil accumulates. Expensive above-ground storage has to be provided for millions of barrels. This not only constitutes a danger, especially in case of an earthquake, but there is great loss by evaporation, not to mention the cost of building what are in reality unnecessary storage tanks. Nor is this all of the waste. In California (there are no figures available for Los Angeles) 800,000,000 cubic feet of natural gas were wasted every day in 1928. Probably not much of this came from the Los Angeles region, for the well organised fields here run the gas into the City mains.
During the past year the State of California has tried, by prohibiting gas waste, to put a curb on oil production. This will probably have little effect on the Los Angeles region where there is such a large market for gas.

The future of oil production in the region defies any predictions. However, all anticlines showing on the surface have been explored to some depth. Future discoveries will come, either by very expensive "wild catting", or by some refined geological method by which buried anticlines can be located. Deepening of known fields may produce unknown quantities. Not all of these fields have been developed as recklessly as Long Beach, Huntington Beach, and Santa Fe Springs, and there is certainly plenty of oil here for generations.
Los Angeles Harbor 1929.
The Harbour.

On October 3rd, 1542, Cabrillo bumped over a bar which had less than four feet of water at low tide, into a lagoon which he called "Bahia de los Pumos" (Bay of the Smokes). This is supposed to have been Wilmington Lagoon. The title was a descriptive one; the original smoke was made by the fires of the Indians. Except in time of storms, a sea breeze, mainly from the west, is the only wind in the vicinity and in the lee of the San Pedro Hills there seems to be a body of stagnant air. A view from the Hills generally shows the harbour under a blanket of oil refinery fumes.

The Lagoon was little used in its natural state, and ships were anchored in a roadstead to the east of the Hills. This port was named San Pedro. Its condition at this period is shown in the United States Coast Survey chart of 1859.

In 1909 the City of Los Angeles decided to develop the harbour, and in order to obtain legal control, it annexed a "shoe string" of territory leading down to Wilmington and San Pedro, which were also incorporated in the City. The eastern part of the Lagoon was within the City of Long Beach and has been developed independently, though ultimately these two parts must have a common outer harbour. Negotiations have been proceeding for some years to
unite the two. The United States Government built a breakwater for the outer harbour; the City dredged channels in the Lagoon, filled in the waterfront land, and built docks. The situation was very favorable for such work. The bottom was only forty to forty-five feet in depth where the breakwater was built and the silt of the Lagoon was easily pumped out. The only solid obstruction was Dead Man's Island which has recently been removed by dredging. The tide here is about five feet, so that there was no necessity for basin docks, and the Los Angeles River was easily canalised to enter the ocean east of the harbour.

The people of Los Angeles are proud of the fact that they have built an artificial harbour. It is a matter of note that the inland City of Los Angeles, with great problems and expenses in building a City and providing a water supply, should extend itself twenty miles to the Ocean, and build a port. At the time that this was started, there was comparatively little shipping in sight. Oil was of little consequence, while manufacturing and the great increase in population existed only in the unbounded faith of the citizens.

As a man-made harbour, too, San Pedro is remarkable in North America. San Diego, San Francisco, Portland, Seattle, and Vancouver are more natural harbours, as are those on the eastern coast, but as
a world port Los Angeles harbour is by no means the least endowed by nature. Ships now ascend the Clyde to Glasgow over places where the River naturally had a low water depth of fifteen inches. The big tides at London and Liverpool have necessitated enclosed docks, which will never be needed at San Pedro, while the dredging of such ports as Rotterdam, Amsterdam, and Buenos Aires were gigantic tasks in comparison with the deepening of Wilmington Lagoon. Also it must be remembered that Los Angeles harbour was built with great ease in a machine age. It was the foresight on the part of the citizens in building a harbour to attract commerce, rather than extending a harbour to accommodate shipping, that is remarkable.

The growth of the port has been extraordinary. Unfortunately the figures given by the harbour authorities are of little value for analysis. Inborne commerce is given for the year June 30, 1928-29 as 6,123,789 tons. Nearly a third of this was lumber, mainly from Washington and Oregon. The lumber amounted to about 100,000,000 cubic feet, with a value of only 32,000,000 dollars. Other large items were 537,000 tons of pipe, chiefly for oil, with a value of 59,000,000 dollars; 35,000 tons of crude rubber valued at 18,000,000 dollars, and about 50,000 tons of print paper. Vegetable oils, chemicals (especially fertilizer) and bananas are other important imports.
The bulk of the exports are petroleum products. Of these there were shipped 138,140,648 barrels of 42 American gallons. There is no weight nor value given for this item, but if it were all gasoline, which is the lightest product shipped in bulk, it would amount to over 17,000,000 tons. The total outbound commerce was about 20,000,000 tons. Oil products are the item that make the port bulk large in tonnage. A considerable quantity of this oil is probably piped from fields outside of the Los Angeles region, but the local production is large enough to supply most of it, as well as that used locally, or forwarded by rail.

The people of Los Angeles take great pride in this large tonnage, yet it is in reality a measure of the speed at which they are squandering a valuable patrimony.

Other exports consist of 168,000 bales of cotton, 774,000 boxes of citrus fruit, 55,000 tons of borax, and 44,000 tons of old newspapers. The latter are shipped to the Orient.

As a port of entry for the United States, Los Angeles rivals San Francisco in proximity to the East Indies, Australia, and New Zealand. Seattle is to Japan and China and somewhat closer much closer to Singapore. The great disadvantage for Los Angeles in Oriental trade lies, not so much in the matter of direct distance to the port of San Pedro, as in its relation to ocean routes. Regular freight lines across the Pacific Ocean call at Japanese ports, and then the great circle route takes them past Seattle.
The only ships that can make Los Angeles a port of call are those going through the Panama Canal. The Hawaiian Islands might form an alternative route across the Pacific, but their trade to the United States may be carried only in American ships.

All the western coast ports of South America are closer to New York than to Los Angeles. Los Angeles is 3000 miles from the Panama Canal while New York is only 2000.

There is much glib talk in Los Angeles about "westward moves the star of empire" and the "age of the Pacific", but the City is definitely on the periphery of the land hemisphere of the world. It has a permanent geographical disadvantage in this respect, though the great advances in transportation are making distances of less importance.
The City.

The Los Angeles region is more than a topographic unit; it is a city unit. Never, since the Mexicans secularised the Missions, has there been a rival to Los Angeles in this region. The ranches of the Spanish may have carried on the functions of a village, but they never had the spirit nor the organisation of a town.

The Americans were late in coming to the Los Angeles region. A half century ago this was still, for all practical purposes, a pastoral Spanish settlement. The Los Angeles region has been populated during a period of urbanisation. The City fills the whole area. It has grown, not by the slow agglomeration of time honoured communities, but like a bacterial colony in an amorphous medium, it has spread without interference. Of course there were other points of community infection, but they had no time to mature and harden. For the most part, this region has not been developed by the individual nor the small community; the City has been pioneer. Many a Spanish ranch has changed, without an intervening step, from a 10,000 acre holding to town lots a fifth of an acre in size.

People jest about the widely flung municipal boundaries of Los Angeles. The 442 square miles
within the City limits are in truth only one-fifth of the City's area - not one-fifth of the "sphere of influence", but one-fifth of its actual hearth. Los Angeles is, however, less fettered by its municipal boundaries than most cities.

After all, the 2000 square miles of the Los Angeles region are only the size of a citadel in the modern field of even the retail business. Chain theatres, chain banks, and chain stores do nearly all of the business. Of course these are not chains with each link equally responsible; they are stars. The points diminish in importance as they increase in number, and they all unite with one growing center which is the City.

There are some place names other than Los Angeles that are widely known, but the most important of these - Hollywood - only proves the preponderance of the City, Hollywood politically and physically being within the City. There used to be a little cross-road town called "Cahuenga". It became "Hollywood" because real estate promoters considered that an attractive name. There are a few pioneers who remember it as a local community, but it has ceased to have any unity. The people in Lankershim, at the San Fernando end of Cahuenga Pass, changed the name
of their post office to "North Hollywood". There is a West Hollywood, and a Hollywood Riviera, but these do not indicate the potency of the community, only of the name. Beverly Hills and Waverley Knolls are names of the same class, designed to sell lots; neighborhoods for a few years until the City floods over them.
Supplement on Names.

Los Angeles Region.

The name Los Angeles Region has never before been used as far as I am aware, but it so readily suggests itself, because of the dominant position of the City, that it seems to need no precedent.

The region as a unit has been outlined in several publications, much the same as it is in this paper. The first that has come to my notice is a California State publication, "Irrigation in Southern California", (1888) by Wm.H.Hall, the State Engineer. There is in this book a map which includes exactly the same lowlands as this study. It is entitled "Irrigation Region of Los Angeles and San Bernardino Counties". This was before Orange and Riverside Counties had been carved out of these two original counties of the area.

The next official description is by Mendenhall who wrote a series of "Water Supply Papers" for the United States Geological Survey. No. 137-138-139-142, (1905). No. 219, (1908). In the first sentence he speaks of the "Valley region near Los Angeles", but he goes on to name the region "The Valley of Southern California". This is unfortunate; if the word "valley" is to mean anything more than simply flat land, then a large part of the area is certainly not valley, and by reducing the name to the singular he makes a
totally unfounded comparison with the unit structural basins, or "valleys" of Northern California. This false analogy is carried still further by the title "Great Valley of Southern California" which is used in some government publications. Mendenhall entirely ignores the San Fernando Valley in his "Valley of Southern California". His valley on the north runs from "Santa Monica to Redlands" and "toward the west opens directly to the Pacific". Toward his south—more nearly toward the east— he includes the isolated valleys on the low plateau of the Perris—San Jacinto block.

This shifting of the region toward the east can not be justified. It can only be accounted for, in the case of Mendenhall, by his interest in artesian water basins which are present on the Perris—San Jacinto block, but not to so large an extent in the San Fernando Valley.

Mendenhall's geography was entirely incidental in his work, but the publications of the United States Geological Survey are so readily available that his geography has been widely accepted. Bowman follows him both in the names "Valley of Southern California" and in illustrating it by a map which includes the


Bowman, I., Forest Physiography of the United States,
Ferris-San Jacinto block; but only half of the San Fernando Valley. The name "Valley of California" has been used also by Fenneman.

The Mountains.

Sierra Madre.

The United States Geological Survey puts names for many of the mountain ranges on their maps, but does not name mountain chains. The need for a name to include the mountain wall from Point Conception to the Colorado River, therefore, brings up some difficulties. Blake, in the Coast Survey Report, 1855, calls attention to the east-west trend of the western part of this line, and the position it has in the east as the bounding wall of the Great Basin. This latter fact had been pointed out the year before by Williamson, who had made a survey for a transcontinental railway. Blake suggests the name "Conception-Bernardino Sierra" or "Bernardino Sierra". This never seems to have taken hold. The term Sierra Madre is used by Hall, and in many subsequent papers, though never delimited. A broad chain of mountains extending from Santa Barbara County to the eastern and southeastern side of the Colorado Desert, with a general trend...
west-northwest, and including the San Rafael, Santa Inez, Santa Susana, Santa Monica and San Gabriel, - a chain, parts of which are known locally as the Sierra Madre, although the application is neither uniform nor clear."

Locally the name Sierra Madre is sometimes used for the ridge between the San Gabriel Valley and the west fork of the San Gabriel River. Saunders, in "The Southern Sierra," 1924, uses Sierra Madre as equivalent to San Gabriel, but this seems entirely uncalled for.

In delimiting the Sierra Madre as used in this thesis, the place that presents the most difficulty in the southern boundary is between Ventura and the San Fernando Valley. If the Santa Monica Mountains are linked with the Islands, then they can not well be included. The most natural limit seems to be the Simi Valley, which does not correspond to any geological boundary, but is a natural one topographically. Geological lines here would be impossible from a topographical point of view. There has been no effort to delimit the Sierra Madres on the north, and its extension toward the southeast is a question which it is unnecessary to take up in this thesis.

Santa Monica-Santa Ana Range.

The topographical continuation of a line of height from the Santa Monica Mountains, through the
Repetto Hills, to the Puente Hills, and the Santa Ana Mountains, seems never to have been recognised except in connection with underground water retention. The water supply engineers speak of this line as the "Intermediate Range", Dominguez Range being called the "Outer Range". The term Intermediate Range could never be a very satisfactory title, though it might be a possible one if the Range did not cease to be intermediate as soon as it passes the ends of Dominguez Range. The term fails to recognise the obvious continuation of the ranges beyond the region. It seemed better to adopt no title and simply hyphenate the names of the principal ranges, than to use an inadmissible one.

The separate parts of this Range also gave some trouble in regard to names. The part running west from the Los Angeles River is universally known as the Santa Monica Mountains, but the group of hills connecting the Santa Monica Mountains with the Puente Hills has no accepted title. The term Repetto has been rather indefinitely applied to some of this group and it is here extended to the whole line.

The northwest-southeast chain which starts with the Puente Hills and continues through the Santa Ana Mountains to the ranges of Lower California, was called the "Peninsula Sierra" by Blake in 1855. He seems, however, to have included the San Jacinto Mountains in the name. The Range has much more unity
in its northwestern end if the San Jacinto Mountains are not included.

Perris-San Jacinto Block.

_{English recognises two crustal blocks in what has been called in this thesis the "Perris-San Jacinto Block". The mountainous northeastern part he calls the "San Jacinto Block", and the low plateau "the Perris Block". These two are divided by a well marked fault zone, but they form a topographical unit as described in this thesis. In the horizontal drift theory they may warrant separate treatment._

Dominguez Range.

_Dominguez Range seems to have been first so called by R.T.Hill_. Part of it is known to geologists as the "Newport-Inglewood Uplift", and to the water supply engineers as the "Outer Range". Hill does not include the San Joaquin Hills in the Dominguez Range, but it simplifies the description of the country to include the whole line between the Santa Monica and Santa Ana Mountains._

The Lowlands.

San Fernando Valley.

_The Geological Survey has been slow in naming lowland units, though in California they are as definitely marked topographically as the mountains._

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_Hill, R.T., Geology of Southern California, p.185._
only lowland name within the region, carried on the official maps, is the San Fernando Valley.

San Gabriel Valley.

The San Gabriel Valley probably dates its name back to mission times. In some ways it is a confusing title, for the River of that name flows through the Valley for only a short length of its course, and is in no way connected with its formation. The name is not as commonly used as might be expected, for the importance of the routes, in the maze of city streets that now traverse all the western side of it, diminishes peoples' appreciation of the natural topography.

San Bernardino Valley.

The San Bernardino Valley presents a difficult situation with regard to a name, and I am not altogether sure of the proper title. The name San Bernardino Valley is actually applied locally to that alcove of the larger Valley that lies to the east of the City of San Bernardino. Hall seems from his writing to have had little, if any, precedent for applying this name to the whole plain between the Puente and the San Bernardino Mountains. In fact, there are two maps in his book, and in one, this area is marked as the Santa Ana Valley; in the other, the larger, it is marked as the San Bernardino Valley. He uses the latter name throughout the text and says he will use the term "San Bernardino Basin" for the San Bernardino
Valley proper. In this, however, he fails and Valley is often used for the smaller area.

Mendenhall uses the term "San Bernardino Valley" for the smaller unit and seems never to have recognised the larger unit. In one paper he uses San Bernardino Basin in the same sense as Valley, but in the same paper refers to "San Gabriel Basin" for San Gabriel Valley.

English quotes Mendenhall as authority for using basin for the smaller unit and applies San Bernardino Valley to the larger one. It might be advisable to find a new name for the larger unit, but none readily suggests itself and so I have adopted Hall's names here.

The Vega.

The two remaining lowland regions have been poorly treated in the matter of names. Hall refers to the central part of the Vega as the "Coastal Plain" subdividing off a Mesa along the full length of the Santa Monica Mountains, and dividing the Orilla into several valleys and mesas.

Mendenhall uses "Coastal Plain" for the whole area between the Santa Monica-Santa Ana Ridge and the San Pedro Hills. Bowman and English follow him. Others have applied the term "Los Angeles Valley" to this area.

In 1882 real estate men referred to the townsite of Long Beach - then the American Colony site - as being "situated in the beautiful Los Angeles Valley". McAdie

Mendenhall, Water Supply Paper, 142.
McAdie, Univ. of Calif. Publ. In Geography, No.4,1914.
mentions the Los Angeles Valley incidentally in a rainfall paper as follows:

"The San Gabriel River......then flows southward through the San Gabriel Valley and the Los Angeles Valley, emptying in the Pacific in a delta east of Long Beach". This gives some idea of the loose use of names and the inaccuracy of the knowledge of the region at that late date.

Los Angeles Valley seems entirely inappropriate to the area. Coastal Plain is hardly applicable to the Vega which is in reality an alluvial plain retained and protected by a line of hills.

The Orilla.

The Orilla has never been recognised as the physiographic form described in this thesis. It is somewhat difficult to describe because there is no term that includes the whole formation between a land-tied island and the mainland. Tombolo refers only to a causeway beach, and two tombolos enclosing a lagoon lack a name. I have selected Orilla for this subregion from the Spanish word meaning shorelands.

The San Pedro Hills.

The San Pedro Hills are named officially on the U.S.G.S. maps. They are often locally referred to as the Palos Verdes Hills from the name of the Rancho of which they were part.
Supplement on Soils.

The field surveying and mapping of the soils of the Los Angeles region were early undertaken, and most of the area has now been twice surveyed. The first bulletins were "Soil Survey around Santa Ana", 1900 - "Soil Survey of the Los Angeles Area", 1903 - and "Soil Survey of the San Bernardino Area", 1903.

In these bulletins the soils were simply divided into soil types though these were somewhat grouped by name into what are now called "soil series". Thus, "San Gabriel gravelly loam" and "San Gabriel gravelly sand" are treated as entirely separate soils though carrying the same proper name.

There is some mention of the variety of underlying soil forming material, but no recognition of different stages of development on the same material. These early bulletins are frankly intended for incoming settlers in a new region, and contain much incidental information on history, climate, transportation, land values and crops.

In 1915 and 1916 the region was again surveyed, this time including the San Fernando Valley. The bulletins divide the region as shown on page 47. In these later bulletins the soils are classified first into four broad groups, namely - residual soils, soils derived from "old valley-filling", soils derived from recent alluvial material, and soils from
wind-laid deposits. Thus, in these bulletins, there is some classification on the basis of origin of material, i.e. rocks in place (residual soils), alluvium, and wind-laid sands. Also, there is some recognition of stage — "old valley filling" and "recent alluvial deposits".

The soils are further subdivided into series. "A soil series consists of closely related soils having similarities of color, origin, subsoil conditions, and other features which serve to establish their relationship and at the same time to differentiate them from the other soil series of the same province. The soil series are further subdivided into soil types, this separation being made on the basis of texture, or the relative quantities of sand, silt, and clay present." (Soil Survey of Anaheim Area, p.19). The soil type is still the unit for mapping and the types are differentiated by colors on the maps. There is no attempt to correlate series nor groups by colors. There is very much greater subdivision in the later bulletins than in the early ones and the soils of the Los Angeles region are classified in nineteen different series bearing proper names generally taken from the locality in which they were first described. There are about fifty types described and mapped on the scale of 1:62,500 in the bulletins.

The region is again covered in a bulletin entitled "Reconnaissance Soil Survey of the Central
Southern Area, California", 1919. In this the types are grouped somewhat as compared with the detailed area bulletins, and are mapped on the scale 1:125,000.

The further classification into stages of development was carried out by C.F. Shaw in the paper "Profile Development and Relationship of Soils in California", given at the first International Congress of Soil Science, Washington, 1927, and published in Vol. IV of the proceedings.

In this paper Shaw suggests the classification of California soils with similar parent material into families and the division within the families on the basis of stage of development. He outlines the family of soils that develops on alluvium from granitic rocks. Such material covers great areas in California, for the granitic Sierra Nevadas have supplied most of the alluvium for the Great Valley just as the Sierra Madres have been the main source of the valley-filling material of the Los Angeles region.

Where this material is being actively laid down and rearranged by streams, it is mapped as river-wash and is not classified as a soil. However, due to the frequent shifting of stream beds, there are considerable areas of alluvium so recently deposited that it shows only slight discoloration in the top few inches. At this stage the soil is placed in the Tujunga series. There are large areas of Tujunga soil
in the San Fernando Valley and also along all the streamways descending from the Sierra Madre Range.

The first development of a soil from the practically raw parent material of the Tujunga series is the addition of organic matter from plant remains. Gradually the soil develops a brown color for a depth of two to three feet but without any apparent alteration or rearrangement of the soil particles. At this stage the soil is mapped in the Hanford series. This is a very wide-spread series in the Los Angeles region. In this thesis the Hanford and Tujunga series were classed together as young granitic alluvium soils.

A succeeding stage recognised by Shaw, the Greenfield series, has not been mapped in the Los Angeles region, so the Ramona series which is the next stage shows a marked development beyond the Hanford soils. The Ramona has been classified as an old soil in this thesis. It shows very definite development of soil horizons due to weathering. A surface layer from ten to twenty-four inches in depth has been losing material through the breaking down of soil minerals and the washing downward (eluviation) of the very fine clay particles and colloidal material. These latter accumulate in a lower layer which becomes much more compact. This is called the "B horizon". It is sticky and impermeable when wet and becomes flinty hard and cracks when dry. Below the B horizon which
may be several feet thick, the soil is less compact, and gradually merges into the parent material.

The Ramona group is very important in the Los Angeles region and may be taken as representing the surface of former alluvial fans which are now dislocated by tectonic action and in some places dissected by stream erosion and in others partly buried by new deposits.

The Pleasanton series along the foot of the Santa Monica Mountains near the City of Santa Monica, may be considered as of the same family and stage as the Ramona. It is distinguished by subsurface gravels.

The next stage in development is considered to be the Placentia series. This has normally a much more compact B horizon which in places is a hardpan. The series is somewhat distinguished from the Ramona because of its red color. Whether or not this is the normal development from Ramona has been questioned. There seems to be a good basis for considering it an older formation, and it has been classed as a very old soil here. The Madera series which corresponds in stage to the San Joaquin series in other places, has been classed with the Placentia in this paper as very oil soils. Shaw names this family the "San Joaquin" from what he considers to be the final stage.

The Chino is a development of granitic alluvium under moist conditions. It corresponds in age to Hanford, but is darker in color. Probably in some
areas the series surveyed as Montezuma corresponds to the Ramona stage in this sub-family, but the Montezuma series does not fit well into the classification.

In the wind-blown sub-family, the Hanford stage is classed as the Oakley series which on development of the profiles is classed as Ramona sand.

Shaw classified only the San Joaquin, or as it is called in this thesis, the "granitic-alluvium family." The suggested sub-families, and other families based on different parent material are the natural accompaniment of the granitic-alluvium family.

The corresponding family, developed on parent material derived from sedimentary rocks, has as young soils the series Laguna and Yolo which correspond in stage to Tujunga and Hanford. The old soil in this family would now be classed as the Rincon series, but during the mapping of the area, it was actually included with the Ramona. Differences in soils due to parent material are not so pronounced in the older stages. Theoretically, according to the Russian school, mineralogical differences will eventually be entirely wiped out by weathering. Though areas surrounded by Yolo soils were mapped as Ramona, they are distinguishable from that series. In such cases, the soils are mapped as old soils of the sedimentary alluvium family in this paper. A further stage might be recognised in the Antioch series. This series occurs only in the
Diagram of Soil Series of the Los Angeles Region.

Arranged in Families after C.F. Shaw.

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<tr>
<td>(San Joaquin Family)</td>
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<td></td>
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</tr>
<tr>
<td>Poor drainage</td>
<td>Good drainage</td>
</tr>
<tr>
<td>Young Chino</td>
<td>Tujunga</td>
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<tr>
<td>Old Montezuma</td>
<td>Romona</td>
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<tr>
<td>Very Old</td>
<td>Placentia</td>
</tr>
<tr>
<td>Old Montezuma</td>
<td>San Joaquin</td>
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<td>Holland</td>
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<td>Sierra</td>
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southern part of the San Bernardino Valley, and is mapped here as very old sedimentary alluvium soil. The sub-family, due to poor drainage, includes the Dublin which corresponds to Chino in the granitic-alluvium family, and possibly also the Montezuma should be included as a further stage in this family.

The residual soils are not widely mapped, for the exposed rocks have generally eroded so fast that they have been classed as rough stony land in the soil bulletins. Where they are mapped, the granitic soils that are less developed in profile due to soil movement down the slope are classed as Holland, and the older soils, as Sierra. On the sedimentary rocks the corresponding series are Altamont and Diablo.
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