GEOLOGY OF PORTIONS OF THE HUMPHREYS AND SYLMAR QUADRANGLES

Thesis by

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ILLUSTRATIONS

ABSTRACT

The portions of the Sylmar and Humphreys Quadrangles studied consist of Jurassic? "basement complex" and sediments of Miocene age and younger. These are brought together along the San Gabriel fault. The Tertiary sediments comprise the Mint Canyon formation, the Modelo formation, the Pico formation, the Saugus formation, and Quaternary terrace and alluvial material. These are listed in order of decreasing age. All the contacts between the various sedimentary formations are unconformable.

The Miocene formations are highly folded and faulted, and a large vertical fault displaces upper Miocene beds. The Pliocene and younger formations also are folded, but to only a minor degree.

The abundance of shale in the Tertiary section makes the region one of numerous landslides. In addition, unusual erosive action and succession of units has resulted in the carving out of a small-scale natural bridge.

There is no production of economic materials from the area at the present time, but the possibilities of petroleum development are now being given serious consideration.

LEGEND

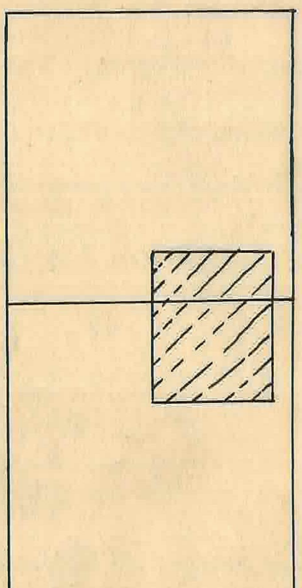
Rock Units

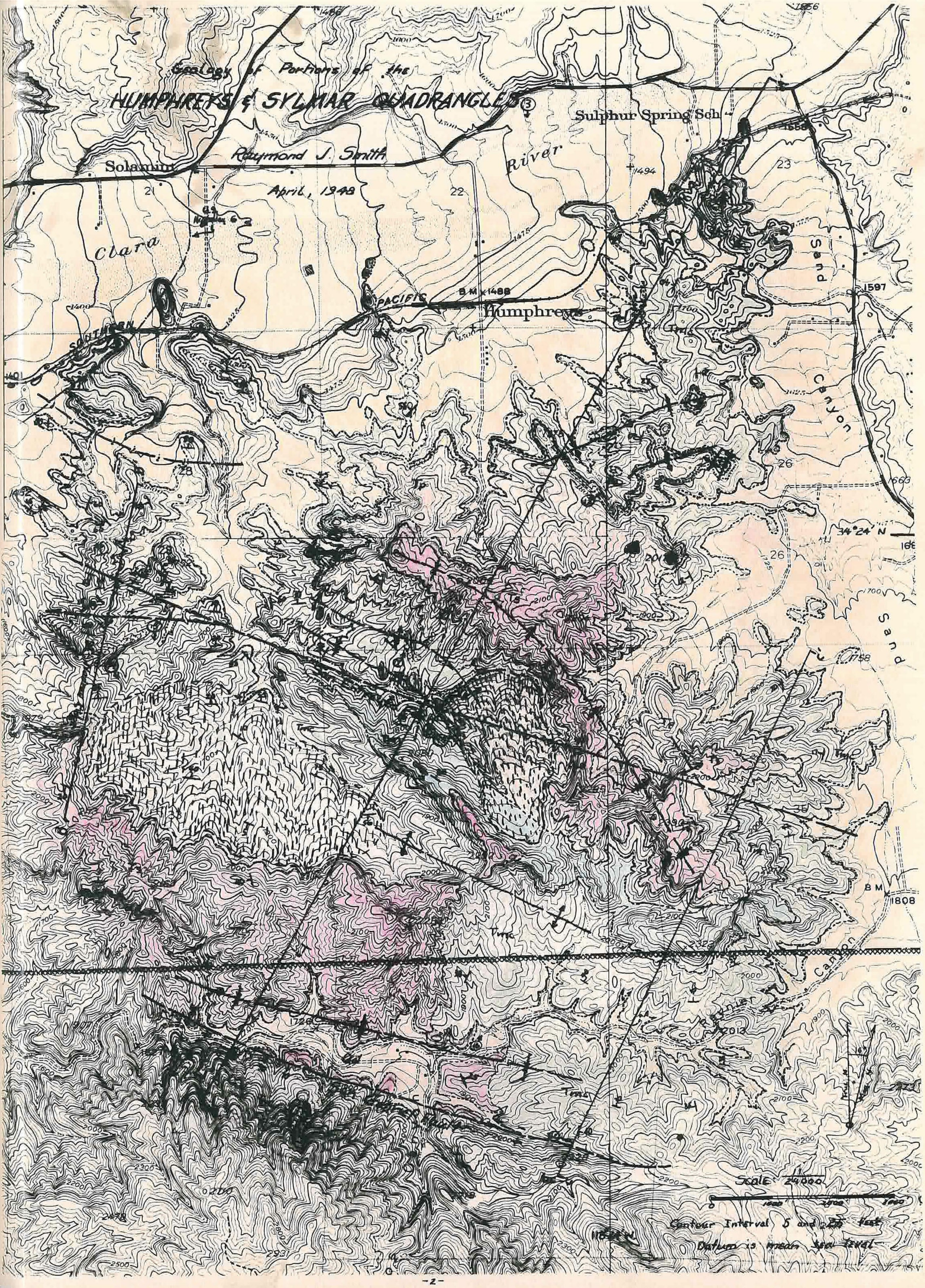
- Alluvium
- Terrace
- Saugus fm.
- Pico fm.
- Modelo fm.
- Mint Canyon fm
- Basement Complex

Structural symbols

- Faults
- Folds
- Contacts
- Landslides
- Photograph points

AREA MAPPED




Geology of Portions of the
HUMPHREYS & SYLMAR QUADRANGLES
Raymond J. Smith
April, 1948
Sulphur Spring Sch
Clara
River
SOUTHERN
PACIFIC
Humphreys
Sand
Canyon
34°24' N
Scale 1/24000
Contour Interval 5 and 25 feet
Datum is mean sea level

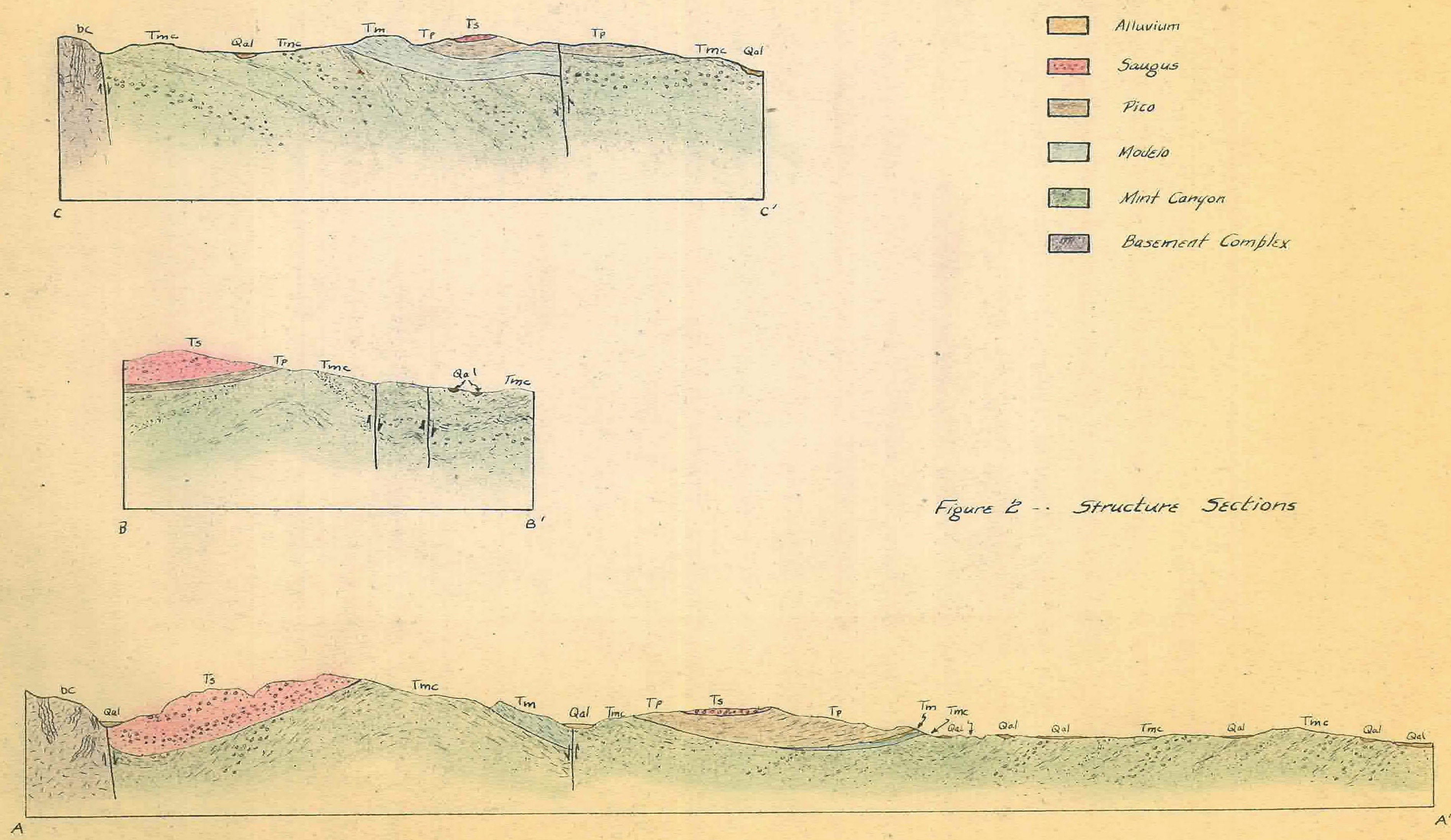


Figure 2 -- Structure Sections

INTRODUCTION

Purpose of Investigation

It has been the practice of the Geology Department of the California Institute of Technology to assign to their graduate students areas in which original geologic mapping may be done. The area covered in this report was previously mapped on a small scale by Kew[1], but the large size of his area naturally limited the accuracy of the work. This report summarizes the results of a detailed study in a selected portion of Kew's area.

There are several reasons why it was considered important that this work be conducted. First, the stratigraphic relationships in the Southern California area are still a matter of dispute. As yet, the associations between the faunal assemblages and the lithologic units are not fully understood. Finally, the possibilities of economic production from the area are almost completely unknown. The purpose behind the mapping of this relatively small segment is to find the answers to these questions; to add another chapter to the rapidly growing volume of geological knowledge of the entire region.

Location of Area

The area mapped lies in the south-central part of the Humphreys Quadrangle and the north-central part of

1. Kew, W.S., Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California: U.S. Geol. Survey Bull 753, 1924.

the Sylmar Quadrangle, in Los Angeles County, California. It is bounded on the north by the Santa Clara River, on the east by Sand Canyon, on the south by Placerita Canyon, and on the west by Nadeau Ridge (Fig. 1). The area is therefore one roughly included by latitudes N34°23' to N34°25', and longitudes W118°27.5' to W118°25.5'; thus having a size of approximately ten square miles.

The region lies approximately 35 miles northwest of Pasadena, and about 40 miles north of Los Angeles. It can be reached over U. S. Highway 6, which lies a short distance to the west.

The town of Solamint, in the extreme northwest part of the area, lies at the intersection of the Mint Canyon and Soledad Canyon highways. The settlement of Humphreys is in the north-central part of the area along the tracks of the Southern Pacific Railroad. Both towns are very small, and neither consists of more than a dozen houses.

Physiography

The physiography of the mapped area is typical in most respects of that in the remainder of the Ventura Basin. The elevations of the region are not excessive, varying from 1400 feet in the bed of the Santa Clara River to 2390 atop the highest ridge in the central part of the area.

The slopes vary to a considerable degree. In the

FIGURE 3. General View of the Area. In the foreground is the Santa Clara River, in the background is the San Gabriel Block, and in between are the Tertiary sediments discussed in this report.

shaly members they rarely exceed five degrees, whereas in the harder formations, verticality is sometimes approached. On the average, however, the degree of slope ranges from fifteen to twenty-five degrees.

The major part of the drainage trends north and south. In the northern part of the area, the streams flow northward and empty directly into the Santa Clara River. In the southern portion, into Sand Canyon. Both Placerita Canyon and Sand Canyon eventually empty into the Santa Clara River. These streams flow only during the rainy season. A stream that flows in a direction contrary to the general north-south trend, is the one which flows along the San Entreyes fault (Fig. 1). It is believed that this stream-cut valley has been formed in the softer material of the fault zone.

With the exception of the extreme northernmost part of the area, exposures are fairly good. In this northernmost part a thick mat of chaparral is present. This obscures the contacts to a considerable extent, and makes detailed geological mapping very difficult. The covering of vegetation on the slopes of the rest of the area is light. In places where an extremely shaly formation crops out, the only vegetal cover is a thin grass. In some places the contact lines between the plant types follows the lithologic contacts, but in other cases there seems to be no possibility of correlation.

Good bedrock exposures were observed in the almost vertical cliffs that are found in certain locations. In one place, the contacts between four different formations can be seen in one cliff (Fig. 5). Bedrock exposures also occur in the numerous cuts made in the construction of the two dirt roads that extend across the area. In the extreme northern part of the region, the cuts of the Southern Pacific Railroad furnish excellent exposures of the Mint Canyon formation.

Method of investigation

The actual geologic mapping was done on enlarged topographic maps of the U. S. Geological Survey. Air-photographs were also used to a small extent for checking locations and examining selected parts of the region.

The process used in the geologic mapping was that of walking out the contacts between the adjacent formations, thus insuring the greatest accuracy possible. At the same time, notes on the lithologic characteristics of the rocks were recorded. All measurements of the dip and strike were made with a Brunton compass. In some parts, where lack of bedding makes it impossible to obtain dips and strikes, their true values were of necessity estimated.

Laboratory work

Laboratory work was conducted in both the petrographic laboratory and in the paleontology laboratory of the

California Institute of Technology. Throughout the course of the mapping, samples typical of the various formations were collected and studied megascopically. A few were studied microscopically, as well.

Invertebrate fossils also were collected as the mapping progressed. These were taken to the paleontological laboratory and were classified both as to type and age. The age was a factor of particular importance, as the stratigrpahy of the Tertiary units in the Ventura Basin is a controversial issue.

Acknowledgments

I would, in general, like to thank the Geology Department of the California Institute of Technology for their aid in furnishing base maps, aerial photographs, the required laboratory facilities, for the use of the geologic library, and for supplying other minor materials to aid in the investigation. In particular, I would like to thank Dr. R.H. Jahns for pointing out the formations to be found in the area, together with the problems which might arise in the course of mapping. I should also like to thank Dr. R. P. Sharp for his aid in explaining the geomorphological phenomenon, and Dr. C. R. Stauffer for aiding me in the classification of the invertebrate fauna.

STRATIGRAPHY

Description of Units

The lithologic units encountered in the portions of the Humphreys and Sylmar Quadrangles mapped are: "Basement complex" of Jurassic? age, Middle Miocene Mint Canyon formation, Upper Miocene Modelo formation, Lower Pliocene Pico formation, Upper Pliocene Saugus formation, and Quaternary terrace and alluvium.

"Basement complex"

On the south side of the San Gabriel fault lies the crystalline "Basement complex" of probable Jurassic age. The uplifting movement on this fault started in about Jurassic time and is continuing today, thus giving the Basement a fault contact with all of the Tertiary sediments. Outcrops of this material are abundant, as it is extremely hard and resists erosion to a considerable extent. The color varies from basic green dikes, through grey metamorphic complex, to white felsic intrusions. In places, evidence of bedding prior to metamorphism was exhibited by some of the altered material, but it was so rare that no regular pattern could be deduced from it.

The composition of the rocks is what is to be expected in a mixture of metamorphic and igneous materials. It consists mainly of a mixture of plutonic igneous and metamorphic types in very intimate association, so much

FIGURE 4. Basement Complex. A large amount of faulting, folding, and intrusion has affected these igneous and metamorphic rocks. Scale designated by geology pick.

so in fact, that mapping of contacts between the two was out of the question in the present investigation. A good deal of the igneous material approaches a dioritic composition; nevertheless, dikes of feldspar, quartz, and chloritized rock are prevalent. In most of the rock types, however, the absence of quartz is noteworthy. Of the metamorphic types, gneisses are prominent, together with small stringers of calcareous material. Weathering processes have affected most of the rock exposures, resulting mainly in the alteration and removal of the ferromagnesian components.

At the present time, the age of the "basement complex" is still a matter of speculation. From geological relationships, it is tentatively regarded as Jurassic, but no evidence as to the validity of this interperatation could be obtained from the mapping done in this area.

Mint Canyon formation

With the exception of the "Basement complex", the oldest rocks in the area compose the Mint Canyon formation. These non-marine beds underlie all of the other Tertiary sediments in the area, and are exposed chiefly where erosive action has removed this overlying material. Examination of the map, Figure 1, reveals that the members of the Mint Canyon fringe the area on all sides, thus forming a foundation on which the younger Tertiary formations have been

FIGURE 5. Pico Cliff. In this photograph, four formations may be seen. These are Saugus, Pico, Modelo, and Mint Canyon.

deposited. On the north and east, this formation passes beneath the gravels of the Santa Clara River and Sand Canyon, respectively, whereas on the west, it passes beneath the overlying Pico and Saugus formations. On the south, the Mint Canyon beds are in fault contact with the "Basement complex" previously described.

In general, this formation expresses itself in a low, relatively smooth type of topography, with wide ridges formed by the more resistant beds. In no place is it a cliff former, hence its best cross sections are those exposed in road cuts. As will be seen on the accompanying map, a more shaly facies of this formation forms one of the landslide areas. These landslides will be discussed in greater detail in the section on Geomorphology.

The color of the Mint Canyon formation is generally distinctive, almost all of the beds being some shade of green. Some of the coarser sandstones have a general grey-green appearance, as do some of the conglomeratic members. On the other hand, most of the shale encountered is all a typical deep green. The problem of locating the contacts of this formation with the overlying formations was relatively simple. This is due to the fact that the uppermost Mint Canyon beds are all of this deep green color, whereas the overlying Modelo and Pico are colored grey and brown.

The texture of this formation is typical of non-marine sediments. The sorting in the conglomerate and sandstone members is relatively poor, and the beds consist mostly of a heterogeneous accumulation of rocks of all sizes. It should be noted, however, that there is apparently a size limit on the maximum diameter of these particles. Few boulders are found of a size larger than twelve inches. The bedding is irregular, as might be expected in a non-marine deposit. Such is not the case with the green shales, thus leading one to believe that they are probably of lacustrine origin. Although these shales are very well sorted and roughly bedded, they are extremely uncompacted, and are easily eroded to form depressions between the more resistant members. The shape of the rocks making up this formation also varies to a considerable extent. Some beds have extremely well rounded particles, others are sub-rounded, and still others are of a very angular nature.

The conglomerates are composed mostly of felsic igneous rocks. Specifically, these are granite, quartz, biotite-quartzite, and rhyolite. The sandstones are composed of coarse, medium, and fine-grained particles of quartz, feldspar, biotite, and muscovite, with other accessories in minor amounts. The shales are composed of mixtures of siliceous and argillaceous material in varying percentages depending upon the horizon chosen. Scattered throughout the bedding planes and joints are layers of caliche. Judging from its appearance, it is believed that this material is of Recent rather than of Miocene age.

The thickness of the Mint Canyon in this region is unknown. This is due to the fact that the lower limit of the formation is not exposed to view. Based on the thickness seen, however, it is calculated to be more than 1000 feet.

The nature of the contact of the Mint Canyon with pre-Miocene beds is unknown. As was previously stated, however, the Mint Canyon lies in fault contact with the "basement" rocks on the south side. A more detailed discussion of this faulting will be found in a later section. Due to the amount of folding, faulting, and erosional work that occurred subsequent to the deposition of the Mint Canyon, the upper contact with the overlying Modelo is that of an angular unconformity.

The age of this formation is designated as Middle Miocene by Kew. A fairly detailed search of the area revealed no evidence of fossils, either vertebrate or invertebrate. For this reason, it was impossible to positively date the formation from field evidence in this area.

Modelo formation

Above the Mint Canyon formation, a 300-foot thickness of marine Modelo formation was found. It is exposed on both sides of the San Entreyes fault. On the north side, however, the uplift of the fault has resulted in the erosion of the major portion of this formation off of the surface of the Mint Canyon. Here and there on the north side, nevertheless, outcrops of Modelo are found. The above mentioned thickness refers to the Modelo on the south side of the fault, where the unit appears to have suffered negligible erosion.

The difference in the sections on the two sides of the fault necessitates a separate discussion of each. For example, the Modelo on the north side is represented by a very resistant sandstone bed, which in places overlies a relatively resistant conglomerate-snadstone layer. As the soft Mint Canyon shales are directly below it, cliffs are often formed. Such is not the case on the south side of the fault. Here the Modelo is represented in large measure by very soft, uncompacted shales. As would be expected, their physiographic expression here consists mainly of large, gently sloping areas, with numerous small landslides.

There is also some difference in color. On the north, the resistant sandstone is a brilliant white, and so can be immediately recognized, even at a distance. The brown

FIGURE 6. Modelo formation. The fact that the Modelo was deposited on an irregular Mint Canyon surface can be seen by the change in dip of the beds at different horizons in the section.

sandstone which underlies it also has a rather typical, chocolate-brown color, which when combined with its lithologic properties, quickly makes it discernible as Modelo.

The texture and composition of the white Modelo sandstone is unusual. Its twenty-foot thickness is made up completely of well-rounded quartz particles of about medium sand size. There are also quartzite and felsic igneous rock particles, also extremely well rounded. These pieces of rock are usually between one-half to one inch in diameter, only rarely attaining a larger size. Such properties suggest that the conditions of deposition of this sandstone were unusual. It is suggested that perhaps this sandstone was formed from a previously existing sandstone, as was the St. Peters sandstone of Minnesota and Wisconsin. It is relatively easy to explain the majority of its properties on such a mode of formation.

Beneath this sandstone is about forty feet of a brown-colored combination of sandstone and conglomerate. It is in this layer that the invertebrate fauna which date the formation are found. The sandstone appears to be a mixture of quartz and feldspar particles, with an argillaceous cement. It is suggested that perhaps there is also some iron cement present, which gives these rocks the distinctive brown color. The rocks composing the conglomerate are quartz in most cases. Rarely do they achieve a size of one-half inch in diameter, with the majority less than one-quarter inch. These particles, as well as those composing the sandstone, are more or less subrounded. A definite lack of bedding is noted in both lithologic types on this side of the fault.

The texture and composition of the material on the south side of the fault are different. In the first place, the beds have a grey to buff color, are fine textured, and appear to be extremely well sorted. They are composed of a mixture of siliceous and argillaceous material, which is regarded as typical marine Modelo. The formation is very thinly bedded in most spots, perhaps due to the fact that it has been affected by faulting and folding. This extensive bedding tends to make it a very soft and friable formation, causing the landslides noted above.

The thickness of Modelo previously noted is 300 feet. This value was obtained by calculations from the structure section.

As noted in the preceding section, the Modelo rests unconformably on the Mint Canyon formation. There is little or no evidence of a basal conglomerate, the fine material of the Modelo resting directly on the underlying, green Mint Canyon beds.

The age is established as Upper Miocene from the faunal evidence present. Wherever the Modelo was found, the Ostrea Titan and Pecten Crassicardo were abundant, thus fairly accurately dating it. At selected locations, points A and B on the map, bones suspected as being those of the Manutus were noted. The preservation is poor, however, so that nothing of importance has been learned from their occurrence to date. The relative abundance of these remains designates this area as one potentially capable of solving some of the problems of Coast Range stratigraphy.

Pico formation

Overlying both the Mint Canyon and the Modelo formations is the Lower Pliocene Pico formation. It is composed of approximately 250 feet of non-marine sediments, which have a lacustrine appearance in this particular area. In general, they are found in the center of the mapped area, and outcrop roughly in the form of a ring. Overlying the Mint Canyon in the extreme western part of the area is another thin sliver of this formation.

Being of soft material, the rocks of the Pico are easily eroded. However, it is overlain by extremely resistant Saugus beds; an ideal set-up for the formation of cliffs. Such is the case in this area. An example of the cliffs formed of this material can be seen in Figure 5. Where the overlying resistant cover has been stripped off, the Pico also occurs as gentle slopes and landslide areas.

The color of this formation varies considerably over the extent of its exposures. In the eastern part of the map, the color is grey-green, whereas in the western part, it is of a red-brown color. No difference can be seen in the composition of the material, so it is believed that this is just the product of some external coloring agent. Perhaps the red-brown color results from the leaching of local concentrations of iron from the Saugus formation.

As would be expected in a lacustrine deposit, the texture of this formation is everywhere relatively constant. The size of the particles is estimated to be from silt to very fine sand. The composition is mainly argillaceous, although there is undoubtably a large amount of silica also present. Scattered throughout this shale (or siltstone) are numerous chert nodules. They average about one inch in diameter and, in most cases, are very well rounded. They appear to be rather heterogeneously scattered in the formation, and do not lie in any definite horizon.

The thickness of 250 feet, as was previously recorded for this formation, was calculated from the cross-sections. The outcrop in the western part of the area is much thinner, being probably not more than twenty feet in thickness.

In spots, the contacts with the underlying Modelo beds are somewhat indefinite. There seems to have been a certain amount of re-working of the Modelo into the lower part of the Pico, as can be seen in Figure 13. This does not appear to be the case over the whole area, nor does this situation exist where the Pico beds overlie the Mint Canyon.

The age relationships of the Pico have apparently been definitely established. This was done by finding the fauna Tellina idae Dall. and Ficus (Trophosycon) ocoyana, all through the formation. While engaged in the process of digging out these shells, the author uncovered what has been identified as a shark tooth. A short time previously, Mr. Wayne A. Roberts of the California Institute also discovered one of these in this same formation. Thus there is some doubt as to the non-marine, lacustrine origin of these sediments.

Saugus formation

The uppermost formation in the area is the 700-foot Saugus formation. These terrestrial beds are found capping the ridges with a fairly resistant rock, in both the central and in the southwest corner of the region. It outcrops as a very resistant conglomerate, which where it overlies the softer Pico beds, forms the major cliffs of the area.

The formation as a whole is reddish. It is believed that this is primarily due to the fact that a strong ferruginous cement is used in binding together the cong-

FIGURE 7. Cliffs of the Saugus formation. The height of this cliff is approximately 100 feet. Pico beds are in the foreground.

lomerate particles. The sorting of the sub-rounded rocks is poor, as might be expected in terrestrial deposits such as these. The rocks making up this conglomerate vary greatly in size, and are as much as a foot in diameter. There is apparently no bedding at all in this formation, at least none that could be recognized with any degree of assuredness.

The rocks composing this conglomerate are primarily the felsic igneous rock types. Some quartzites and extrusive igneous rocks also are in evidence. Also noted in this formation are anorthosite and some ilmenite rocks, both coming originally from rock masses found within the San Gabriel range.

The thickness of 700 feet was calculated by considering the two points at which outcrops occurred, and taking the maximum value. It is probable that a considerable portion of these beds have been eroded off subsequent to their deposition, but this could not be accounted for in the calculations.

The Saugus lies unconformably on the Pico and Mint Canyon formations. The unconformity with the Mint Canyon is quite evident, but that with the Pico is very hard to distinguish. This is the only formation in the area which exhibits a basal conglomerate. It consists primarily of boulders of fairly large size, with maximum diameters up to two feet, occurring in a bed immediately above the

Pico. Its continuity over quite a large area marks it as the probable basal conglomerate of the Saugus.

The only evidence of life found in these beds, despite an extensive search, consisted of a small piece of unidentifiable bone found by Mr. W. A. Roberts. Although fossiliferous, it was weathered to such an extent that all of the important characteristics had been removed. The age of these beds is therefore regarded as Upper Pliocene, as established by previous investigators in the area.

Terrace material

Overlying the Pico in two small places in the northern part of the area is some material tentatively regarded as of terrace deposition. It may very well be Saugus, but its lack of a basal conglomerate, its lack of interstitial cementing material, and its generally poor lithification are regarded as evidence of probable terrace origin. It lies as a capping on top of the higher ridges, and is composed of the same type of rocks as are found in the Saugus. The maximum thickness is probably not more than five feet.

Alluvium

In the Santa Clara River, Sand Canyon, and all of the small valleys and washes in the area, is found a mantle of alluvial material. As is to be expected, the material composing this varies with the formations in the areas which the streams drain. The alluvial material in a streambed that drains three or four formations will obviously be a mixture of rocks from all of them. Identification of alluvium is not very difficult, as it is a heterogeneous assemblage of a very uncompact nature. It is believed that the alluvial material in the bed of the Santa Clara River attains considerable thickness, but no reasonable estimate of its value can safely be given.

COLUMNAR SECTION

Age	Name	Thickness	Description
Quat.	Alluvium & Terrace	?	Loose, uncompacted, gravels All rock types Poor sorting
	Unconf		
Pliocene	Saugus fm.	700'	Relatively resistant ss & cg. All rock types Cement gives reddish color Fair degree of sorting in both rocks and matrix
	Unconf.		
Pliocene	Pico fm.	250'	Loose, lacustrine ?, shales Color varies - bwn - green High degree sorting
	Unconf		
Miocene	Modelo fm.	300'	Capped by resistant white ss. Mostly brown, marine shale High degree of sorting Mainly argillaceous
	Unconf.		
Miocene	Mint Canyon fm.	?	Beds of ss, sh, & cg. Sorting varies, good in some cases, poor in others. Color varies from grey to green Much folding & faulting
Jurassic ?	Basement Complex	?	Metamorphosed sediments Igneous intrusives Faulted against Tert seds Mostly diorites, gneisses and gabbros. Highly faulted

Figure 8

STRUCTURE

Folds

The oldest folds in the region occur in the "Basement complex" of Jurassic? age. These rocks have the appearance of once being sedimentary, but the folding, faulting, and general metamorphic processes have obliterated most of the evidence. Due to their very complex nature, no attempt was made to map the folds in this material. It is probable, however, that very detailed work of the future will disclose mappable structures in this basement rock.

The stucture existing in the Mint Canyon formation also is very complex. Examination of the dips and strikes on the map will show that prior to the deposition of the Modelo, the Mint Canyon was subjected to considerable folding and faulting. In general, this was not carried through into the overlying formations, as they rest unconformably on eroded surfaces. Several kinds of folds are found in this formation, not excluding some drag folds. Some of the relationships are best seen by following marker beds in the field and noting the shifting that has occurred since their deposition. Only where folding in the Mint Canyon has affected the overlying beds was any attempt made to map them in the field.

There are in general, two sets of folds in which the Modelo is involved. It takes part in the large syncline which forms the main ridge in the central part of the

FIGURE 9. General Folding in the Mint Canyon Formation. This shows the small-scale warping that has taken place throughout this formation.

mapped region. This fold is also shown in the structures of the Pico and Saugus formations, consequently a discussion of it will be reserved until later. The other fold in the Modelo occurs where it intersects the San Entreyes fault. This is primarily a drag fold, exhibited by the bending of the shale beds in this part of the section. In some parts, the bedding has been completely distorted, and only a crumpled mass of rock is now evident. The bedding appears almost horizontal adjacent to the fault, but its dip changes to about forty-five degrees to the north a short distance away. This is, of course, additional evidence as to which way movement of the fault occurred. The folding relationships are beautifully shown in the walls of the small canyons that eat into the Modelo perpendicular to the direction of the main fault.

The folds existing in the Pico formation are much easier to map than those in the Mint Canyon. One the whole, they are gentle, and are detected mainly by the fact that they result in outliers of Pico on top of the Modelo. Were it not for these outliers, it is doubtful that these folds would have been located. In most cases, the dips of the beds are so gentle that no degree of certainty could be placed in locating the folds with the use of the Brunton Compass. Due to this gentleness, it was also impossible to determine whether or not there was any plunge. The trend of the folds is roughly east-west, with

FIGURE 10. Folding of the Mint Canyon. This sharp folding of the beds occurs on the immediate south side of the San Entreyes Fault. This serves as an aid in determining the direction of fault movement.

a slight tendency toward the northwest in some places. The results of this folding can best be seen in the outliers of Pico and Modelo, which overlie the Mint Canyon beds in a southwest direction from the town of Humphreys. Similar outliers can be seen adjacent to the San Entreyes fault, in which Pico overlies the Mint Canyon.

In only two areas does the Saugus formation show signs of flexural stresses. The most obvious is the synclinal ridge which extends in a northwest-southeast direction across the center of the area. Here, both of the Tertiary epochs show signs of a formation of a roughly synclinal structure. The fold cannot be seen from any one vantage point, but was detected by noting that the bedding dipped into the hill on both sides of t he ridge. This therefore meant that the axis of a syncline runs the length of the ridge, even though the actual fold cannot be seen. As is the case with a previously noted fold, there is probably some plunge, but the surface exposures are so poor that no value or direction can be given for it.

The Saugus also is folded where it abuts against the "Basement complex". As this contact occurs along the San Gabriel fault, it seems natural that there would be some drag affect due to the uplifting of the mountain block. This fold trends approximately parallel to the fault, that is, about N75W, and the relationships between the two are easily seen both in the field and on the geologic map. The beds are horizontal some distance from the fault, and as it is approached, these beds acquire a north dip. This is an excellent example of the drag affects caused by the movement of one fault block upward in relation to another.

Faults

The largest fault in the area is known as the San Gabriel fault. It is essentially a dip-slip falut, which elevates the "basement complex" above the Tertiary sediments. In general, its trend of N70W parallels the San Andreas fault, which lies a short distance to the north. The movement on this fault is essentially vertical however, whereas the slip is horizontal on the San Andreas. Its dip is unknown, as it varies by a wide andle at different outcrops.

As was stated previously, the San Gabriel block was elevated along this fault, thus making the movement one in which the south side went up and the north side down. The absolute direction of movement is not known. From the nature of the Tertiary sediments, however, there is a probability that both sides went up, with the south side going up more than the north. The amount of movement is subject to speculation. Judging from Kew's cross sections, it was deduced that the total displacement was

FIGURE 11. San Gabriel Fault Trace. On the right is weathered granitic material, whereas on the left are Mint Canyon sediments. This feature continues in a straight line for several miles.

probably in excess of a thousand feet, but it is difficult to say by how much. Movement on this fault began in the early Tertiary and is continuing to this day. In places the Mint Canyon formation is faulted against the "basement", whereas in other cases Saugus is so located.

The other major fault in the area is that designated as the San Entreyes fault. Its trend roughly parallels that of the San Gabriel fault, but the relative movement here is reversed. Here the north side went up and the south side down. Upon completion of field work, no definite information could be obtained as to the dip of the fault. The fact that the slippage appears to have occurred along a fairly wide zone makes it a difficult procedure to assign a definite angle to the feature. It is probable, however, that the fault has approximately a vertical dip. The average width of the zone is estimated to be about twenty feet. The presence of this fault was decided on the evidence of the irregular dips encountered along the fault line, the uplift seen in the Modelo, and the excellent evidence of drag folding also seen in the Modelo. By assuming the base of this Modelo formation on the north and south sides of the fault to be of the same age, the amount of movement is calculated to be about 300 feet. The fact that the fault cuts the Mint Canyon and the Modelo formations and does not affect those above, dates the time of movement as post-Miocene, pre-Pliocene.

There are other small faults present in the area, particularly in the "basement complex" and in the Mint Canyon formation. These structural features were neglected in this investigation, however, owing to the limited amount of time available.

Unconformities

The most evident unconformity existing in the area mapped occurs between the Mint Canyon formation and the beds that overlie it. In some places these beds are Modelo, in others Pico, and in still others, Saugus. An excellent example of this unconformity can be seen in Figure 12, in which the Mint Canyon formation is transected by Modelo beds. The material found at the base of the unconformity is no different from that found in the rest of the section. That is to say, there is no basal conglomerate anywhere on this contact. In spots, however, the white Modelo sandstone previously described can be found. Perhaps this is locally a basal conglomerate, but it is unlike those that are described as typical.

The dip and strike of the surface of the unconformity parallels the bedding that is found in the Modelo and overlying formations. The angle between this contact and the bedding in the Mint Canyon formation is about forty degrees, but generally its value varies in different locations. In mapping, the units were fairly easily

FIGURE 12. Unconformity between the Mint Canyon and Modelo formations. When viewed from the proper direction, the angle between the two formations can be seen; it is approximately 40 degrees.

distinguished. As has been previously stated, the color of the Mint Canyon is mostly green, whereas the colors of the others are quite different. This is valuable, as it enables the geologist to locate the exact point of unconformity with reasonable accuracy.

In most of the area, the contact between the Modelo and the Pico formations is a disconformity. In most of the places where these two formations outcrop, neither show good bedding, so no angular difference can be noted. As can be seen in Figure 13, the Modelo appears to have been reworked into the Pico in some spots. In no place on this contact, however, was a basal conglomerate found. The two units were distinguished chiefly by color, the Pico being a brown-green, and the Modelo being a whitish color.

The contact between the Pico and the Saugus formations is the only marked by a basal conglomerate. This conglomeratic material, already described in detail, occurs spottily along the base of the Pico formation, over the entire extent of its outcroppings. The angular relationships between the Pico and the Saugus beds appear to be those of a disconformity. Distinguishing the units on both sides of the contact is not difficult, as one is a dark brown shale, and the other consists of a red, coarse conglomerate. No reworking of the Pico was done in the Saugus, as the upper beds are primarily of terrestrial deposition.

FIGURE 13. Grading of Pico formation into Modelo. The dark-colored beds appear to be of the same material as the overlying Pico, whereas the light-colored beds compare with the Modelo formation directly underneath.

GEOMORPHOLOGY

Of the geomorphological features to be found in the area, the largest and most conspicuous are the two regions of landsliding. In both places, the slipping occurred primarily in shaly formations, and probably was caused by a high moisture content. As can be seen by studying the topographic map, its form in the easternmost area is primarily one of a flat-topped segment, which has shoved its base out over the underlying land. That this slip occurred long ago is shown by the fact that the sharp features of the topography have all been worn away, and that relatively large trees are found growing in some spots on the slide. Due to its exceptionally large size, the writer was somewhat skeptical as to whether the topography was the result of landsliding or not. Further examination of the phenomenon by Dr. Sharp verified the opinion that it is probably of landslide origin. A distinctive feature of this flow is the fact that two different formations are involved in the movement that has occurred. As can be seen from the map, these are the lacustrine Pico and the marine Modelo formations, both very loose shales.

A short distance to the west of the above described feature is another landslide region of an entirely different type. Here the Mint Canyon formation is distinctly shaly,

FIGURE 14. Landslide area in the Mint Canyon. This small landslide is typical of the small-scale landslides that cover the surface of the Mint Canyon formation in this particular region.

with a particular abundance of the green shales previously described. This results in a situation in which the entire exposure of the formation is covered by many small landslides. Owing to anomalous dip readings, the writer is of the opinion that the whole slope has moved downhill as an essentially single mass. The only proof of this is the apparently unsystematic arrangement of the bedding units, and the fact that the topography is one favorable to landsliding. In Figure 14 is pictured one of the more recent small-scale landslides that has occurrred. Examination of the photograph will reveal that these features are "typical" landslides, in that they have all of the physical features usually described in accounts of similar earth movements. As in the previous case, the phenomenon is attributed to the presence of an oversupply of moisture in loose, shaly beds.

In Figure 15 is exhibited another type of earthflow. In this case, the same Mint Canyon member previously described appears to have flowed down a canyon. The evidence for the existance of this feature is much more speculative than that for the two previously described. Nevertheless, it apparently possesses the physiographic expression required for such a flow, and hence is tentatively regarded as such.

At isolated places in the area, evidence of cavernous weathering in sandstones was noticed. Lack of field time prevented the writer from making an exhaustive study of

FIGURE 15. Mudflow Phenomenon. Here a more shaly facies of the Mint Canyon formation has flowed down a small canyon. Note the "island" and the breakaway scarps in the background.

the problem, but some definite features were recorded. First, the weathering appears to occur in almost homogeneous rock. It is possible that holes left when boulders or pebbles fell out started the weathering processes, but it is not probable. In some cases this feature was observed in places quite protected from the wind. The bottoms of these caverns were shaped so that material shed from the sides and roof would be removed almost immediately by the action of gravity. From the evidence seen here, it is believed that these features were formed by differential erosion due to water, but a much more intensive survey would have to be made before a definite answer to the problem could be given.

In the Mint Canyon formation, very close to the Saugus contact, a favorable set of conditions has produced a natural bridge. This feature is about twenty-five feet high, with a gap of six feet at its widest point. The mechanics of its formation are roughly outlined as follows. A small stream was eroding through the Mint Canyon formation. Working downward, it encountered a hard sandstone bed about 3' in thickness, which overlay a loose, uncompacted shale. The extremely slight dip, coupled with the different degrees of resistance of the two units, resulted in this feature. The stream started cutting on the sandstone, but its extremely resistant character prevented much erosion. Locally, however, the stream was free to enter and flow through the porous, uncompacted shale. Before long, the shale had been eroded to a large degree, while some of the sandstone was hardly affected. When the shale had been removed, the stream began working on the lower units, naturally leaving the uneroded portions of the sandstone standing intact. It is probable that this feature will remain for a considerable period of time, as close observations reveal that extremely little weathering has taken place in the resistant unit.

FIGURE 16. Natural Bridge. The distance from the streambed to the top of the bridge is approximately 25 feet.

GEOLOGIC HISTORY

The oldest rocks in the area consist of the Jurassic? metamorphic complex combined with its associated igneous intrusions. The uplift of the fault block in which these are found was started in early Tertiary time and is still taking place today. This means that Tertiary sediments are not to be found overlying the complex block, but occur around the base in fault contact with it.

The oldest layer of sedimentary rocks in the region consists of the Middle Miocene Mint Canyon formation. These rocks are made up primarily of land-laid conglomerates and sandstones, alternating with fine-grained lacustrine beds. Upon completion of deposition, the region was subjected to much orogenic stress, which resulted in movement. At this time there were many small folds and faults formed in these recently deposited beds. Considerable erosive action followed this movement, during which most of the folds were truncated and the region generally developed into one of moderately low relief. It is probable that in some spots there were hills and depressions, as the base of the overlying Modelo is somewhat irregular.

The region then sank beneath the sea, and the deposition of the marine Modelo formation was begun unconformably on the surface to the Mint Canyon. Under these conditions, the region was covered by layers of shale, sandstone, and some pebble conglomerates. These sediments filled up the low spots left in the somewhat irregular Mint Canyon surface, developing a fairly smooth plain. Prior to uplift, or perhaps after uplift and prior to deposition of the overlying Pico formation, a layer of white snadstone, probably of marine origin, was deposited on the surface. This is noted as it serves as an excellent marker for the Modelo-Pico contact.

Movement then took place on what has been named the San Entreyes fault. This movement was primarily one of dip slip, in which the southern block slipped downward a distance of about three hundred feet relative to the northern block. This displacement began after deposition of the Modelo was completed, but before the Pico started to accumulate. Minor folding, probably associated with the faulting, also occurred at this time.

The region was then uplifted from its marine enviornment, this movement probably also associated with the faulting. The major portion of the Modelo was eroded from the upthrown block, leaving only minor remnants of that formation. Such was not the case with the downthrown block. It is probable that here also a considerable amount of Modelo was eroded, but enough remained to mark it as one of the major lithologic units in the area.

In lower Pliocene times, the deposition of the Pico beds was started. The sediments deposited during this interval consist primarily of fine-grained material. It is believed that they might have been deposited in a lake or marsh adjoining the sea, upon its retreat following the Miocene marine deposition.

Uplift of the region continued, and the deposition of the Upper Pliocene Saugus formation occurred disconformably on the surface of the Lower Pliocene beds. This deposition was carried on under non-marine conditions, and the resulting conglomerate is strictly of a non-marine character. Upon cessation of Pliocene deposition, gentle folding occurred in all of the Tertiary formations. It is believed that this folding originated with a continued uplift of the basement block.

Subsequent to the deposition of the Saugus, Quaternary alluvial material and terrace material were deposited. These sediments are associated with the Pleistocene physiography and the dissection that started then and is going on at the present time.

ECONOMIC SUMMARY

The region covered in this report contributes notably to the early gold mining history of California. This is shown by the State monument on the western edge of the mapped area, which designates this as the location of one of the early gold discoveries. The plaque on this monument reads as follows:

> In Placeritas Canyon, March 1842, Francisco Lopez y Arbollo, while gathering wild onions from around an old oak, discovered gold particles clinging to the roots of the bulbs. It is estimated that $80,000 in gold was recovered as a result of this discovery.

It is believed that the major portion of the gold-bearing ore came from the alluvial material washed down from parts of the upfaulted igneous and metamorphic "basement complex". Examination of this complex near the area mapped revealed many irregular quartz veins scattered throughout. Further investigation of these may reveal them as the source of the gold-bearing rock. No active mining work has been carried on for a considerable period of time.

The only other material of minable possibilities in the area is the gypsum to be found in relatively large concentrations in the Pico formation. It generally occurs in crystalline form, in sizes varying from one to two inches in diameter. It is believed that at the present price, this material could not be profitable worked due to the small amount present. At some future date, however, its proximity to Los Angeles, combined with the ease of separation, might offset the above disadvantage. It must be realized that such an operation could be conducted only on a very minor scale.

The future of petroleum production from the area is problematical. At the present time, a private concern is engaged in a drilling operation a short distance to the west of the mapped area. To the time of writing this report, no indications of oil had been obtained. The structure consists primarily of an anticline between two fault blocks. On the north side of the well lies the San Gabriel fault, and on the south side is a minor fault. The anticline in in the Saugus formation, and is easily discernible from road cuts along U. S. Highway 6, in the vicinity of Placerita Canyon. Based on the geology of the area to the east of the well, it is doubtful that the anticlinal structure extends deeper than the Saugus formation. The owner of the area covered in this report states that a short time ago, an undisclosed major oil company leased his land in preparation of drilling operations. At the date of this report, such operations had not yet started. Study of the surface geology reveals the possibility of locating oil along the vertically displaced San Entreyes fault, or along any of the gentle anticlines found in the area.