GEOLOGY OF THE FERNANDO PASS REGION

A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree

of

Bachelor of Science

California Institute of Technology, Pasadena, California

by

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1938

C O N T E N T S

ILLUSTRATIONS

THE GEOLOGY OF THE FERNANDO PASS REGION

INTRODUCTION

Location of area

The Fernando Pass region is located in the low pass between the San Fernando and upper Santa Clara Valleys, and southeast of the town of Newhall. The bounding meridians are Lat. 34° 16' - 34° 22' 45" N. and Long 118° 28' - 118° 32' W. The area includes about thirty square miles and lies between the western end of the San Gabriel and the eastern end of the Santa Susana Mountains. It is bounded by Placerita Canyon on the north and the San Fernando Valley on the south. Refer to Fig. 1 for more general location.

Purpose of the work

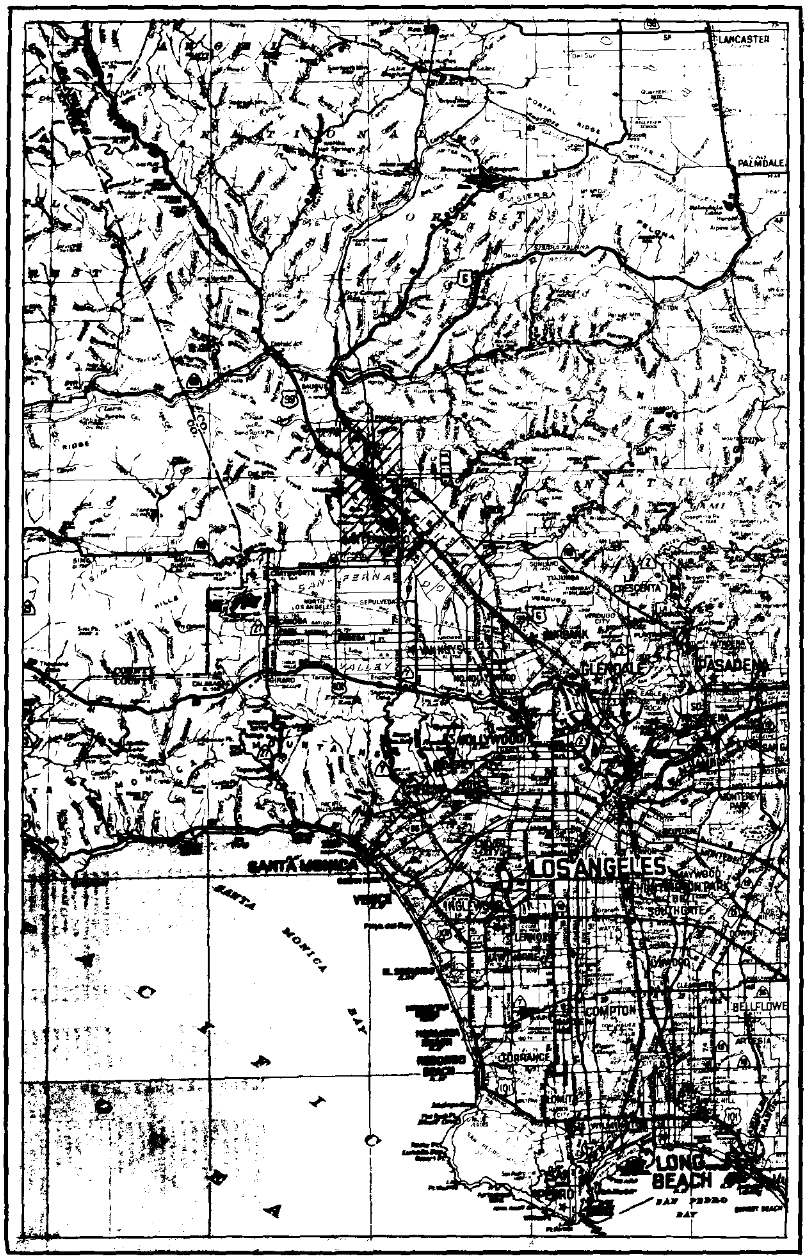
The work was done in partial fulfillment of the requirements for the degree of Bachelor of Science at the California Institute of Technology.

The essential purpose of the work was to gain a more detailed knowledge of the stratigraphic and structural relationships of the rocks in the region.

Field work

The geology was plotted in the field on United States Geological Survey topographic maps. The rock exposures were traced on foot and locations were determined by topographic features and by Brunton Compass shots. Dips and strikes were carefully taken with the Brunton Compass and Clinometer. Four days preliminary work in the fall of 1937 and twenty-one days during the spring of 1938 were required to complete the field studies.

Fig. 1



Index map showing general location of the area.

Cross-hatched portion represents the part studied.

Previous work

The most significant geological work done in the area during recent times was that done by W. S. W. Kew[1] in his extensive mapping in the Los Angeles and Ventura Counties. The paleontological work done by W. A. English[2] and H. M. S. Rice[3] was important in age determinations. For the most part, the structural nomenclature of Kew has been adopted in this report for the purpose of uniformity.

Acknowledgements

The writer wishes to express his appreciation for the helpful advice given by Dr. J. H. Maxson in the field studies and for the aid given by W. P. Popenoe in fossil determinations. Thanks are extended to Mr. A. H. Weldon for the loan of his fossil collection.

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1. Kew, W. S. W., Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, Calif.; U. S. G. S. Bull. 753.
2. English, W. A., The Fernando group near Newhall, Calif.; Calif. Univ. Dept. Geology Bull., vol. 8, 1914.
3. Rice, H. M. S., Minor Doctorate Thesis; Calif. Inst. of Tech., 1934.

GEOGRAPHY

Surface forms and drainage

For the most part, the area mapped has a rather rugged topography and is deeply disected. The southern and southeastern parts have characteristic low rounded hills of the Saugus formation and also gently southward sloping alluvium deposits. The relief of these hills varies from 100 - 200 feet.

The northwestern portion has a somewhat higher relief, 200 - 300 feet, cut on gently northwestward dipping strata of the Saugus formation. The erosion here is in a more youthful stage than in the south.

The western end of the San Gabriel Mountains forms the highest relief in the area, being of the order of 600 - 1700 feet.

The eastern end of the Santa Susana Mountains has a relief of from 400 - 800 feet, is in the youthful stage of erosion, and has several deep canyons.

The central part of the area has a relief of from 300 to 600 feet and is rather rough, approaching a "bad-lands" topography.

The drainage has a somewhat complicated pattern because of the varied structural relationships. In general, the northern part of the area drains northwestward into the Santa Clara River and the southern part drains southeastward into the San Fernando Valley, the dividing line being the ridge which runs roughly east and west of the Fernando Pass tunnel.

Climate

The region lies in a semi-arid zone, experiencing rather wet winter and spring months and hot, dry summer months. The average yearly rainfall is about 15 inches.

Vegetation

Although there are numerous exposures due to erosional features, the major part of the region is covered with a heavy growth of chaparral which makes field work difficult.

The soil on the Basement complex is coarse and rocky and consequently supports only a heavy brush growth.

The soils on the Saugus formation are sandy and also support only chaparral and grasses except in the canyon bottoms where oak trees are found.

The soil on the Modelo shales is generally of the heavy clayey type and supports a lush growth of grass and many oak trees.

The soil on the Pico formation is intermediate between that of the Saugus and Modelo and consequently the vegetation consists of brush, grasses, and trees of various kinds.

Figures 2 and 4 show the general appearance of the brush covered areas.

Culture

The only paved roads in the region are Highway 99 and San Fernando Road. There are however, a few private dirt roads which facilitate transportation considerably. Two large reservoirs have been constructed in the low hills in the southeastern part of the area.

The alluviated areas in the southern part have been cultivated with citrus fruits, olives, grapes, and hay.

Economic Resources

The economic resources of the area are limited to oil production. Production first started in the 1860's and has continued intermittently to the present time.

STRATIGRAPHY

The rocks of the area consist of strongly folded and faulted sediments of Miocene to Quaternary age which lap up onto the crystalline basement rocks to the east.

Basement complex

The Basement complex in the area represents a "nose-like" mass exposed in the northwestern part of the region. There are good exposures of the complex in the canyon north of Rancho Sombrero, at the head of Grapevine Canyon, in Elsmere Canyon and in Whitney Canyon. The rocks consist of schists of a varied composition which have been intruded by a dioritic rock. No attempt was made to determine the relationships of these two rock types.

The schists are sedimentary in origin and are presumably the same as the Pelona schists. It is notable that there is a considerable amount of white limestone in the schists in the area. The limestone contains small flecks of graphite and has been recrystallized. In places there is a very well cemented breccia of angular fragments of a horblendite-like rock.

The age of the complex is not very well known. It is fairly definite that it is at least pre-Cretaceous[1]. The intrusion is thought to be associated with the Jurassic Sierra intrusion. More recent work in other parts of the schists seems to indicate that the original sediments were probably of pre-Cambrian age.

Modelo formation

The Modelo formation of the area has been subdivided into two units, the Modelo shales and the Modelo sandstone.

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1. Hill, R. T., Geology of reservoir sites, 1928.

Modelo shale: The lowest and thickest part of the Modelo exposed in the area consists primarily of buff and white siliceous shale and brown clay shale.

The buff siliceous shale is the lowest member exposed and consists of hard plates $\frac{1}{4}$ - $\frac{1}{2}$ inches thick, and of thin, soft, "paper" shales. The total thickness of this member is not exposed but is at least 750 feet thick.

Above the siliceous shale is a member consisting of brown clay and silt shales. These shales have some gray layers, are considerably sulphur-stained, and are gypsiferous. Numerous hard, siliceous sandstone lenses of a buff color are interbedded in these shales. These lenses are seldom more than one and a half feet thick and vary from one foot to ten or fifteen feet long. The thickness of this member is about 450 feet.

Both of the shale members have been highly contorted in some places because of their finely laminated character.

Modelo sandstone: The Modelo shale grades into the Modelo sandstone. This sandstone unit is well exposed along the north side of Bee Canyon where it forms the north flank of the Bee Canyon Anticline.

The member consists of rather massive, medium-grained, brown to buff and gray sandstone. For the most part, the sandstone is well consolidated and in some places in the lower part it has been indurated. The sandstone contains a few thin beds of brown shale in the lower part. The upper part becomes coarser and contains some conglomerate. In this respect it is similar lithologically to the overlying Pico and its upper limit has been set where the conglomerate with limonitic staining and concretions begins. The thickness is about 800 feet.

No unconformity between the Modelo and the Pico was observed in the section but one probably exists as there is a considerable overlap of the Pico onto the Basement to the northwest.

Summary of the Modelo.

Thickness: The total thickness of the Modelo exposed in the area is about 2000 feet, but as previously stated the lower limit was not observed.

Correlation: Lithologically this formation is similar to the known Modelo in other parts of the Los Angeles and Ventura Basins.

Age: No fossils were found in the formation in the area. Fossils found in the Topanga formation just west of the area in Aliso Canyon indicate that this formation is middle Miocene in age.[1] Since the Modelo is stratigraphically directly above the Topanga it is probably upper Miocene in age.

Origin: Lithology and Diatoms found in the shales indicate a marine origin.

Pico Formation

The base of the Pico Formation, as has been stated, has been placed at the lower extent of the iron-stained boulder conglomerate with limonitic concretions. This contact is exposed along the top of the north ridge of Bee Canyon. The Pico formation overlaps the Modelo and lies directly on the Basement complex in Elsmere and Grapevine Canyons.

On paleontologic and lithologic evidence the formation has been divided into two zones as suggested by Grant and Gale[2] and by Rice[3].

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1. Kew, W. S. W., Geology and Oil Resources of a Part of L. A. and Ventura Counties, Calif.; U. S. G. S. Bull. 753, 1924.
2. U. S. Grant and H. R. Gale, Plio. and Pleist. Mollusca of Calif.; Vol. 1, Memoirs of the San Diego Soc. of Nat. Hist.
3. Rice, H. M. A., Minor Doctorate Thesis; Calif. Inst. of Tech.,1934.

The lower and by far the thickest and most extensive zone as exposed in the area seems to correspond to the Jacalitos zone. The upper zone corresponds to the San Diego zone. A section of white and gray diatomaceous shale is faulted up against the Saugus formation near the Lower San Fernando Reservoir. The stratigraphic relationship of these shales to the two zones mentioned above was not determinable in the area.

Jacalitos zone: The strata belonging to this zone vary considerably both horizontally and vertically.

At the lower limit is a basal boulder conglomerate. This conglomerate is iron-stained and contains limonitic concretions. The constituents range in size from sand to boulders a foot in diameter. Most of the boulders and pebbles are well rounded. Their composition is varied, both crystalline intrusive and volcanic rocks being found. One white banded agate was found. This conglomerate lenses out toward the west.

The contact of the Pico with the basement complex is between the schist and chocolate colored sandstone and shales. There are several isolated patches cut off from the main formation by erosion. In Elsmere Canyon there is a basal conglomerate at the contact but in other places this is lacking. The dark color of the rocks is due to staining by oil which in some places seeps out of the ground as tar. The character of the sandstone varies from a very coarse grained to a fine grained, compact, indurated sandstone. This sandstone contains a considerable fauna of invertebrate fossils with some shark's teeth and some vertebrate bones, probably whale. Extensive collections of these fossils were made and determined by English[1]. This

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1. English, W. A., The Fernando group near Newhall, Calif.; Calif. Univ. Dept. Geology Bull., vol. 8, 1914.

sandstone pinches out toward the west.

Above the oil-stained sandstone lies some poorly laminated sandy shale also oil-stained. In the lower part, these shales contain buff-colored sandstone concretions which range in size up to a foot thick and several feet broad. In Elsmere Canyon these shales have a considerable quantity of charcoal fragments up to one half an inch long incorporated in them. These shales also lense out toward the west.

The upper part of the Jacalitos is composed of light colored, soft, laminated siltstones and sandstones on the east side of San Fernando Road. South of Weldon Canyon these sandstones and siltstones grade into poorly laminated siltstone and grayish brown clays with several beds of soft, and quite pure, white sandstone. The clays are gypsiferous, sulphur stained, and contain organic material. At the western edge of the area these clays lie on the Modelo sandstone.

The total thickness of the Jacalitos zone in the area reaches about 2150 feet.

<u>San Diego zone</u>: This zone is limited in the area and is exposed in Weldon Canyon and on the ridge north of the canyon. The beds are very fossiliferous and evidently represent deposition in the southeastern end of a small basin.

The base of this zone consists of a series of well rounded and sorted conglomerates interbedded with light colored sandstone. This member contains numerous well preserved invertebrate fossils.

Above the conglomerate is a section of fine grained, soft, buff sandstone which becomes thicker toward the west and grades into a grayish unconsolidated siltstone. This member is exceedingly fossiliferous and in some places probably represents a shell reef.

As exposed in the area, the upper part of the zone consists of another conglomerate and sandstone member which is only three-fourths of a mile long, lensing out at both ends.

The maximum thickness of the exposed San Diego zone is about 950 feet.

Pico near the San Fernando Reservoir:

The Pico here is composed of white and gray "paper" and sandy shales. These shales contain remains of diatoms. Their total thickness is not exposed but it is more than 700 feet.

Summary of Pico:

Thickness: The total thickness of the exposed Pico reaches a maximum of 3,100 feet.

Correlation: The Pico in this area is just a few miles east of the type section in Pico Canyon. The diatomaceous shales have been correlated lithologically with the Pico shales near Calabasas by Kew[1].

Age: Fossils collected in the area indicate a lower and middle Pliocene age for the formation.

Work done by Grant and Gale [2] and by English[3] indicates that the area called Jacalitos here corresponds closely to the Jacalitos formation near Coalinga.

Following is a list of specimens collected and identified by the author from the San Diego zone:

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1. Kew, W. S. W., Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, Calif.; U. S. G. S. Bull. 753, 1924.
2. Grant and Gale, Plio. and Pleist. Mollusca of Calif.; vol. I, Memoirs of the San Diego Soc. of Nat. Hist.
3. English, W. A., The Fernando group near Newhall, Calif.; Calif. Univ. Dept. Geology Bull., vol. 8, 1914.

*Arca trillineata (Conrad)

Laevicardium quadrogenarium (Conrad)

Cardita menilicosta Gabb

*Chione fernandoensis English

Crepidula princeps Conrad

Dosinia acutilineata Conrad

Fusinus barbarensis Trask

Lucina excavata Carpenter

Lucina xantusi (Dall)

Neptunea humerosus Gabb

Neverita recluziana (Deshayes)

*Pectin purpuratus Lamark

*Pectin cerrosensis Gabb

Pectin sp. cf. Pectin cerrosensis Gabb

*Pectin healeyi Arnold

Schizotherus nutallii Conrad

Solen sicarius Gould

*Terebra martini English

Turritella cooperi Carpenter

The species marked with an asterisk are among the ten characteristic species that Grant and Gale[1] designate as being characteristic of the San Diego fauna. Since such a large number of these characteristic species are represented in this incomplete collection it appears fairly conclusive that the beds belong in the San Diego zone. The specimens collected compare with a more complete fauna collected by Rice[2] in Gavin Canyon to the west of

1. Grant and Gale, Plio. and Pleist. Mollusca of Calif.; vol. 1, Memoirs of the San Diego Soc. of Nat. Hist.
2. Rice, H. M. A., Minor Doctorate Thesis; Calif. Inst. of Tech. 1934.

the area. The beds are then middle Pliocene in age.

Origin: The Pico is clearly of a marine origin as indicated by its fossil content.

Saugus formation

Unconformably overlying the Pico is exposed some 4,700 feet of more or less unconsolidated sands, gravels, and conglomerates belonging to the Saugus formation. The major part of the exposed Saugus-Pico contact is a faulted contact. However, in Elsmere Canyon the exposed contact is depositional and the unconformable relationship is clearly seen. (See Fig. 2). The unconformity is slight however, amounting to only a few degrees difference in attitude. At the upper end of Elsmere Canyon the Saugus overlaps the Pico and lies directly on the Basement.

The formation is considered entirely terrestrial in origin and represents a characteristic fanglomerate type of deposition. No attempt was made to differentiate any individual members of the formation.

In the northern part of the area the base of the Saugus has a marked lithologic difference from the underlying Pico. The beds change abruptly from soft marine shales to coarse sands and gravels.

Farther to the south the contact is less marked, the division being made by the coarser and unsorted character of the sand and gravel.

The conglomerate and gravel is composed mainly of sub-rounded, unsorted rocks of granitic types with some volcanic material.

Just north of the first sharp bend in Elsmere Canyon there is some fine, greenish gray silts and sands.

The Saugus has been locally stained with oil in Elsmere and

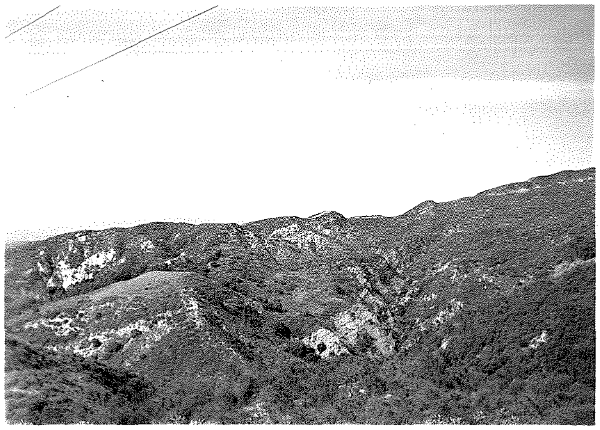

Fig. 2

View northeastward showing contact between the Saugus and Pico formations in Elsmere Canyon. The lower cliffs are Pico and are overlain by Saugus conglomerate and sandstone. The Saugus formation overlaps the Pico and rests directly on the Basement complex below the road cut in the upper right.

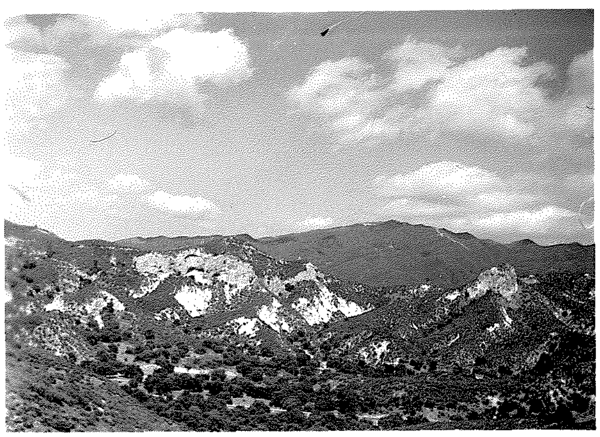

Fig. 3

View eastward of cliffs of Saugus formation on the Elsmere anticline. Note oil staining of the upper part of the cliffs.

Placerita Canyons thus making it appear much the same color as the Pico.

In the southern part of the area the Saugus consists mainly of gray to buff unsorted gravel and coarse sandstone with some silt and greenish clays. The material is not consolidated and weathers to a reddish brown color.

Summary of Saugus:

Thickness: The total thickness exposed in the area is about 4,700 feet.

Correlation: The formation is directly correlated with the type Saugus a few miles to the north.

Age: The Saugus is considered to be upper Pliocene and Lower Pleistocene in age.

Origin: The lithologic character of the formation seems to indicate a terrestrial origin.

Terrace Deposits

At several places in the area are found terrace deposits of conglomeritic material. The conglomerate is unsorted and is angular to subangular. The deposits have a horizontal attitude. Their age is considered to be late Pleistocene for two main reasons. (1) They escaped the structural deformation at the end of Saugus time. (2) They are evidently older than Recent because of their present elevated position. They reach a maximum thickness of approximately 200 feet.

Alluvium

The alluvium cohsists of light colored sands, gravels, clays, and loam derived from the erosion of the neighboring hills. The material is unconsolidated and undeformed.

GEOLOGIC STRUCTURE

The structure of the Fernando Pass Region is characterized by a rather complicated system of folding and faulting. In general the major part of the structural deformation took place at the close of the Saugus deposition. The axis of the folds and trend of the faults is for the most part in a rough east-west direction indicating stresses acting in a north-south direction. This generalization has been complicated by the proximity of the sedimentary rocks to the crystalline mass of the San Gabriel Mountains.

Faulting

Santa Susana Fault: As with most of the faults in the area this fault is of the reverse type with the northern block rising in comparison to the southern block. The fault enters the area at the southwestern edge as a "split" fault with a block of Modelo shale and sandstone between the two fault planes. The southern fault is the main fault and it dips at an angle of about 35° to the north while the northern branch dips to the north at an angle of about 55°. Near the head of Bull Canyon the main fault makes a rather sharp bend to the northeast and is joined by the branch fault. From this point it trends N. 45° E. to Grapevine Canyon where it joins with the Sierra Madre Fault. No actual measurement of the attitude of the fault was possible between Bull and Grapevine Canyons, but the trace of the contact across the topography indicates that it dips very steeply toward the northwest. As is shown in structure section AA', the displacement on the southern branch has been the greatest. The sharp bend in the fault can probably be attributed in part to complications in the stresses caused by the crystalline rocks.

The main result of the fault has been to raise the Modelo and Pico formations up against the Saugus formation.

Sierra Madre Fault: The Sierra Madre Fault has a general east-west strike and enters the area just south of the Rancho Sombrero. The fault is not exposed except by contact relations and consequently its attitude cannot be accurately determined. From the meager evidence available it is probable that the fault is nearly vertical. The northern block has again gone up with respect to the southern block thus bringing the Pico up against the Saugus.

Thrust Fault at Head of Grapevine Canyon: In the east fork of Grapevine Canyon is exposed a fault plane in which the Basement complex has "ridden" out over the sediments of the Pico formation. The plane of the fault is a very uneven one varying in dip from about 15° to 60°. At a point where the 60° dip was taken the strike of the plane was N. 12° W. (See Fig. 4).

In its westward extension the exposed fault passes into the sediments of the Pico. Fig. 5 shows an exposure of the fault at the head of the west branch of Grapevine Canyon. Here coarse oil-stained sandstone has been faulted up against buff-colored, fine-grained, bedded sandstone with clay between the bedding planes. At this point the strike of the fault plane is N. 2° E. and it dips 45° to the southeast. It is interesting to note that the patch of terrace material extends across the fault plane and has been unaffected by any displacement.

At the head of the east branch of Grapevine Canyon is an "isolated" area of Basement Complex. This patch of Basement is reverse faulted on its western side by a fault which strikes approximately

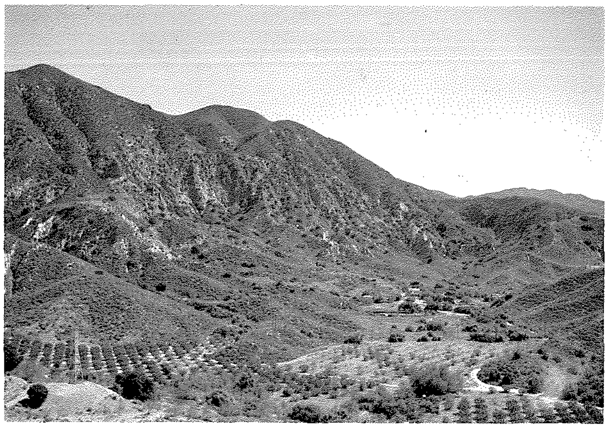

Fig. 4

View eastward showing Pelona Schists(?) thrust faulted over Pico Formation. In the foreground is Grapevine Canyon.

Fig. 5

View looking north showing extension of fault in Fig. 4 into the Pico Formation. The darker beds to the right are oil stained.

north and south and which dips 60° E. The south end of this patch has also been faulted by the Sierra Madre Fault.

This Basement area forms a small hill which is set off from the main mountain mass by a low saddle. The rocks in the saddle are of the Pico formation but they are not of the same stratigraphic level on the eastern and western sides because of the faulting along the west side of the patch of Basement.

The exact structural details involving this area have not been completely determined. It is believed that the small patch was faulted up along its west-side fault with more displacement on the southern than on the northern end. It is probable that this faulting took place before the thrusting of the Pelona Schists over the Pico sediments.

San Gabriel Fault: A branch of the San Gabriel fault extends a short distance into the area in Placerita Canyon. The strike of the fault is slightly north of east and its attitude is practically vertical. The Basement Complex is faulted against the Saugus formation by this fault. The fault cannot be traced farther into the area than shown on the map.

Fault North of Weldon Canyon: On the north side of the ridge to the north of Weldon Canyon is a prominent faultline scarp. The fault trends roughly northwest and dips steeply towards the south. The more consolidated beds of the Pico formation to the south were faulted up against the softer beds of the Saugus formation on the north. The present scarp has been caused by the more rapid weathering of the Saugus leaving a cliff from 100 to 200 feet high formed in Pico sandstone and conglomerate. (See Fig. 6)

Fig. 6

View southward of the faultline scarp north of Weldon Canyon. The San Diego zone of the Pico forms the cliffs. The Saugus formation lies in the foreground.

Fault West of Reservoir: Just west of the Lower San Fernando Reservoir the diatomaceous shales of the Pico formation have been reverse faulted against the sandstone and gravels of the Saugus. The fault is well exposed in the new road-cut as shown in Fig. 7. The fault strikes N. 73° E. and dips 52° to the south. The fault can be traced southwest along the edge of the reservoir but then it apparently disappears under the alluvium into the valley.

Minor Faults: There are a number of minor faults in the area which cannot be traced more than several hundred feet. For this reason only two of the faults have been mapped.

The fault near the head of Elsmere Canyon strikes about N. 30° W. and is nearly vertical. The displacement is of the order of 10 feet, the northeast side moving down in relation to the southwest side.

The fault exposed in the road-cut about 500 feet north of the tunnel near the Airway Beacon trends N. 38° W. and dips 34° to the south. (See Fig. 8). The reverse nature of the fault is beautifully indicated by the "dragging" of the beds of the south block against the north block. The fault is only traceable about 500 yards.

Folding

The sedimentary formations in the area have undergone considerable folding due to compression in a general north-south direction. Only the more important folds will be discussed. Special names have been designated to some of the folds for convenience.

Elsmere Anticline: The Elsmere Anticline is a broad anticline exposed in Elsmere Canyon. The structure is probably controlled by the "nose" of Basement Complex which extends below the Pico formation here. The

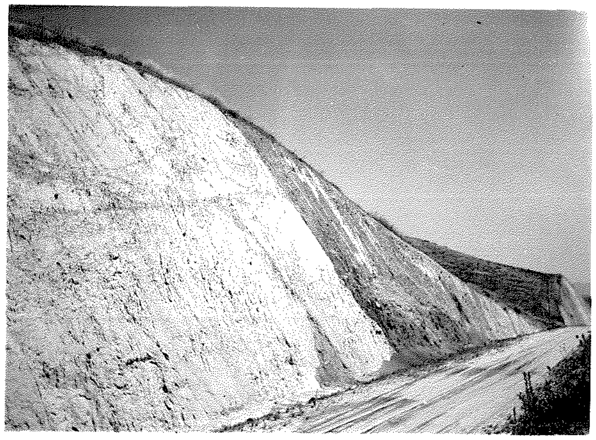

Fig. 7

View looking south on Sepulveda Blvd. extension showing reverse fault between gray Pico shales and white Saugus gravels.

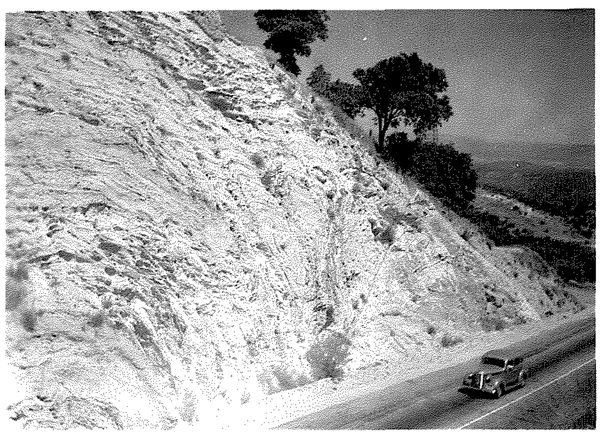

Fig. 8

View northward of reverse fault in the Saugus formation near Fernando Pass tunnel. Note the bending of the beds on the left due to drag on the fault.

axis of the fold extends northwest across San Fernando Road where it is soon lost in the Saugus formation.

Weldon Syncline: This syncline is located in Weldon Canyon. The rocks of the San Diego zone of the Pico lie along the axis of the syncline. The syncline "flattens out" toward the west.

Pico Anticline: The Pico Anticline is continuous from Pico Canyon a number of miles to the west. It is one of the most important folds in the general region in connection with oil production. The western end of the anticline in the region is formed in the Modelo formation and is illustrated in Fig. 9.

Bee Canyon Anticline: The northern flank of this anticline forms one of the striking topographic features of the area, namely the 500 foot canyon wall cut in the Modelo sandstone. The anticline parallels the canyon for nearly a mile and then takes a sharp bend across the canyon.

Sylmar Syncline: This low, broad syncline lies between the hills surrounding the San Fernando Reservoirs and the Santa Susana - Sierra Madre Faults. The axis of the structure is not exposed but it can be drawn in by projecting the dips and strikes. The syncline lies in the Saugus formation.

Anticline South and West of the Reservoir: This anticline is also formed in the Saugus formation with one end extending into the diatomacious Pico shales. (See Fig. 10). The structure is a low broad type and is nearly four miles long.

Fig. 9

View looking east of the Pico Anticline on the extreme western side of the area. A white bed in the anticline is faintly discernable on the right and left sides.

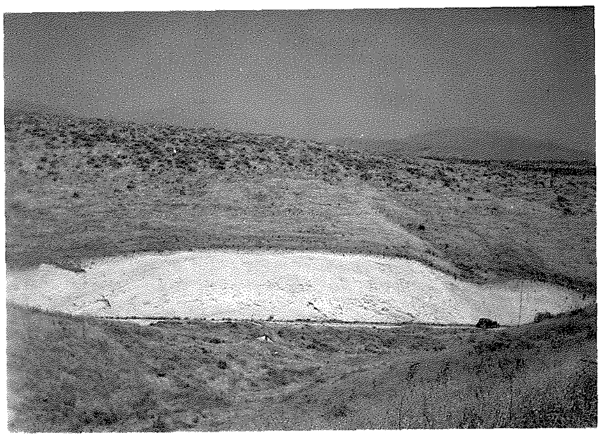

Fig. 10

View of anticline in Pico shales on east side of the Sepulveda Blvd. extension. Compare with size of automobile in lower right.

GEOLOGIC HISTORY

(1) Pre-Cretaceous (?). Deposition of sediments with later intrusion and metamorphism by igneous rocks to form the Basement Complex. Erosion of the complex.

(2) Miocene. Deposition of the Modelo formation under uniform marine conditions.

(3) Slight erosion followed by deposition of the Pico formation under varying marine conditions.

(4) Uplift during the Upper Pliocene followed by terrestrial deposition of the Saugus formation.

(5) Pleistocene. Extensive folding and reverse faulting experienced by all formations.

(6) Late Pleistocene. Uplift and erosion followed by deposition of terrace deposits.

(7) Erosion to present surface with stream deposition.