GEOLOGY OF THE

REPETTO AND MONTEBELLO HILLS

By Miller Quarles Jr.

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ILLUSTRATIONS

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ABSTRACT

The Repetto and Montebello Hills are an east-west band of low hills four miles east of the Los Angeles city hall. As the hills lie well within the oil producing Los Angeles basin, their geology is of interest to petroleum geologists as well as to residents of the area.

Only sedimentary rocks are exposed, ranging in age from upper Miocene to Recent. The only Miocene formation in the area is the Puente, which is divided into three members; a white diatomaceous lower shale, a middle sandstone with shale lentils, and a silty upper shale.

Conformable above the Miocene is the Pliocene series, represented by two formations: 1) the lower Pliocene Repetto; and 2) the upper Pliocene Pico. The type locality of the Repetto formation lies within the area where it is composed almost entirely of foraminifera-bearing massive siltstone. The Pico formation is represented by siltstones and is divided into an upper and lower member by means of foraminifera and megafossils. The top of the Pliocene section is marked by an angular unconformity.

The two Pleistocene formations are the Saugus and the terrace gravels. The Saugus conglomerates and siltstones, of lower Pleistocene age, are separated from the upper Pleistocene to Recent non-marine terrace gravels by an angular

unconformity.

The two Pleistocene conglomerate formations are distinguished from one another by the petrology of their pebbles. The Saugus contains pebbles of dacite porphyry; the terrace gravels are characterized by a granite with pink orthoclase and a distinctive "dappled" diorite.

Foraminifera are used to fix accurately the gradational Miocene-Pliocene contact and to divide the Pliocene into Repetto and Pico formations. Molluscs as well as foraminifera are abundant in the Pico and make possible a division into upper and lower Pico members in spite of uniform lithology. The Molluscan faunas of the lower Pico are warm water types; the upper Pico contains a cold water assemblage. Megafossils from four of the sixteen new localities were studied, and several species not previously found in the Los Angeles basin were recognized.

Two east-west anticlines with a poorly defined syncline between them are the principle structural units in the area. Only the eastern closure of the large East Los Angeles Anticline is found in the northwestern part of the area. A short strip of lower Puente shale is exposed along the axis of this anticline. The 8000-foot series of Puente and Pliocene formations dip away from the axis to the south. Only the lower 1000 feet of the Puente section is exposed on the north limb of the anticline.

The oil-producing Montebello anticline in the southwestern part of the area has a complex structure and history. The surface exposures of Pico siltstone and Saugus conglomerate show an asymmetric fold with a steep south limb. Sub-surface contours on Repetto horizons, however, show that, at depth, the steeper flank of the fold is on the north. This anomaly is caused by post-Saugus movement on a north dipping normal fault parallel to, and 600 feet south of, the anticline's crest. The Saugus beds which were previously on the flat top of the anticline were dropped 700 feet and are now adjacent to steeper dipping Pico sediments.

Three major disturbances dominated the structural history: 1) after the Pico was deposited, 2) after Saugus deposition, and 3) after the terrace gravels were deposited. Uplift to dry land and slight folding caused the erosion of the Pico siltstone to a surface of low relief. The ensuing subsidence and overlap of cross-bedded Saugus conglomerate produced an angular unconformity above the Pliocene series.

The second deformational period, which occurred after the Saugus formation was deposited, was the most intense. Both the major anticlines in the area were formed, and the beds in the Repetto Hills were steeply tilted to the south. A very long or very active period of erosion followed, for apparently 8000 feet of sediments were stripped off the East Los Angeles Anticline to expose the lower Puente shale beds. The final post-Saugus erosion surfaces before the terrace gravels were deposited were 1) in the Repetto Hills a topography similar to the present, and 2) a near-peneplain where the Montebello Hills now stand.

The nature and amount of movement during the third major uplift, in post-terrace or early Recent time, can be accurately determined by the positions of numerous remnants of a terrace surface. The entire Repetto Hills area was raised about 150 feet along the southern border and tilted as a block to the northeast. At the same time the present Montebello Hills were formed when the flat terrace surface was uplifted by folding at least 300 feet, forming an anticline whose crest roughly coincided with the axis of the earlier post-Saugus anticline. The present topography is that anticlinal ridge modified by recent erosion.

INTRODUCTION

The geology of the Montebello and Repetto Hills was chosen as a Master's Thesis problem at the California Institute of Technology because these hills comprise one of the important and undescribed outcrop areas in the Los Angeles basin. The writer also wished to compare the geology of this area with that described in an earlier thesis problem on the Whittier Hills which lie just across the San Gabriel Wash to the east.

The brunton-pace method was used on the El Monte and Alhambra Quadrangle maps of the United States Geological Survey. Samples of conglomerate pebbles, foraminifera, and megafossils were taken to the laboratory for study.

The work was done in the summer of 1940 under the supervision of Dr. F. D. Bode of the California Institute. His interest and suggestions have been a continual source of encouragement to the writer in preparing this report for publication. Others who have given suggestions and advice are Dr. Hampton Smith, Dr. W. S. W. Kew, Mr. R. G. Reese, Dr. Everett Edwards, Dr. W. P. Popenoe, Dr. Ian Campbell, and Mr. W. H. Holman.

Mr. J. M. Hamill of the Micropaleontology Department of the Texas Corporation washed the sixty-one foraminifera samples collected. Mr. H. L. Driver of the Standard Oil Company made a rapid examination of the material, and his preliminary report is included in this paper. As the time available was not adequate for a detailed study of the faunas, Mr. Driver wishes it to be understood that the conclusions derived from his report should be considered as tentative and subject to revision.

Previous publications

No report on the areal geology of the locality has been published. A number of references to the area, however, have appeared in print. In 1926 the eastern tip of the Montebello Hills was mapped as "undifferentiated Fernando" by English (5).[1] In 1932 Soper and Grant (4, p. 1056) mentioned the type Repetto section as containing a meagre but as yet not studied megafossil fauna. The type locality of the Repetto formation along Atlantic Boulevard was first described by Reed in 1933 (12, pp. 30-33) along with a brief description of the adjacent formations. Reed's Geology of California, published in 1933, (13, pp. 228, 239-240) contains several references to the Repetto Hills and gives the petrology of the type Repetto siltstone. In 1934 Edwards (2, 3) included the area in his report and described sections along Atlantic Boulevard and Garfield Avenue. In 1938 Woodring (15, p. 20) described two Pico megafossil localities near Atlantic Boulevard and several Repetto fossils from well-cores in the Montebello Hills (15, p. 9). Woodring also briefly quoted Reed's description of the Atlantic Boulevard section (15, pp. 2, 9). A short statement on the underground structure and development of the Montebello field was published in 1940 by Atwill (1, pp. 1119, 1122-1124).

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1. Numbers in parentheses refer to bibliography in appendix.

GEOGRAPHY

The Repetto and Montebello Hills are located six miles south of Pasadena and four miles east of the Los Angeles City Hall (see road map). The Repetto Hills form a low east-west ridge five miles long and a mile and a half wide. The Montebello Hills lie to the southeast of the Repetto Hills and are separated from them by an irregular lowland through which Third Street and Mesa Drive were built. The Montebello Hills are also an east-west mature ridge which is three miles long and about a mile wide. The combined area is completely surrounded by valley alluvium except along parts of the western boundary.

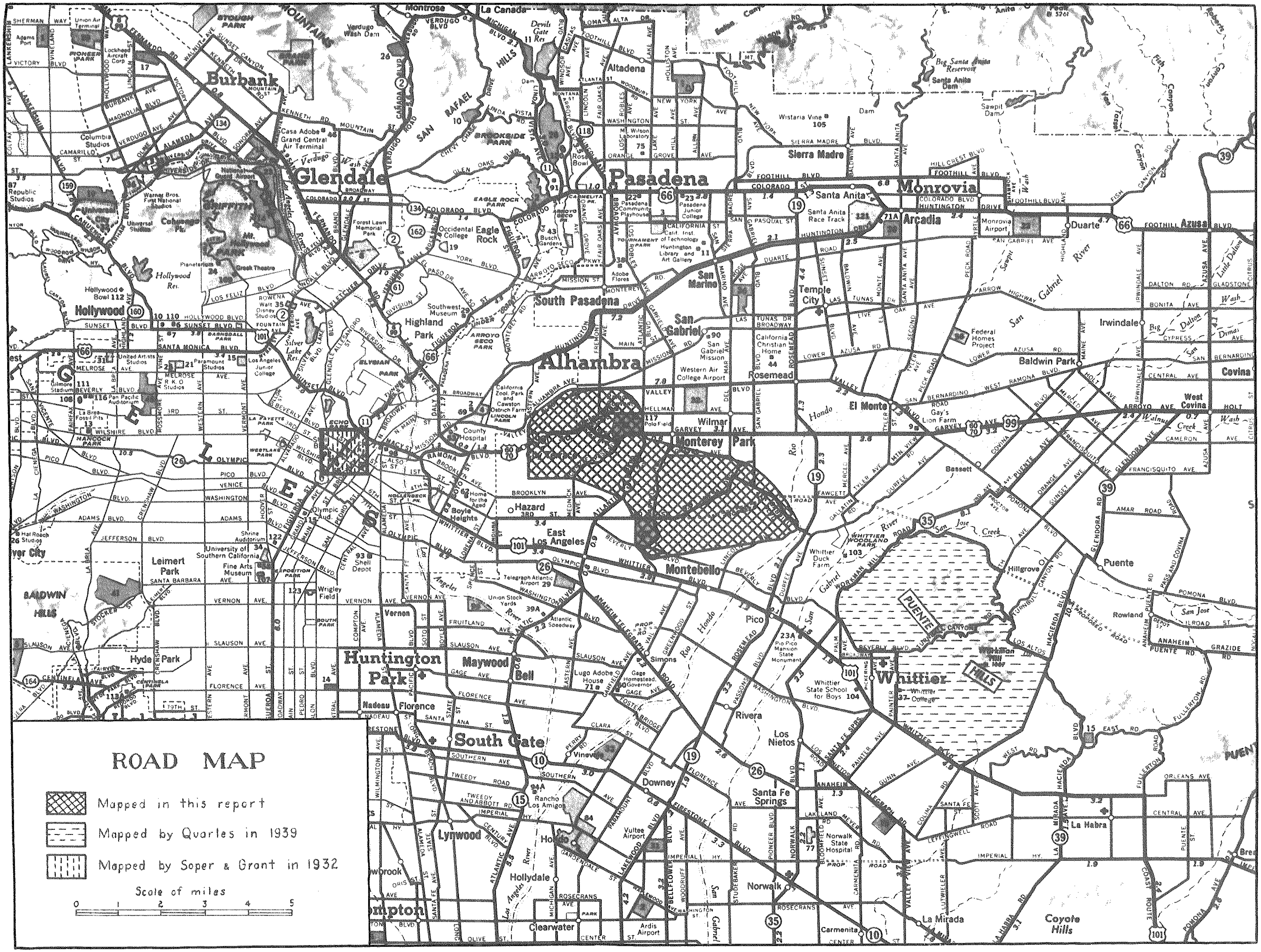
Altitudes range from 200 feet to 740 feet with an average relief of 200 feet. Although the hills are higher in the west, the topography is more rugged among the conglomerate beds in the east.

Numerous north-south valleys cut into the Repetto Hills, forming the dominant drainage pattern. Only two streams run through the hills: one at Atlantic Boulevard, and the other near the east boundary of the area in what the writer calls Repetto Canyon. The north slope of the Montebello Hills drains north and east into the Rio Hondo. The Los Angeles River at the southwest and the Rio Hondo at the southeast receive the little drainage south of the area that is not absorbed by the valley alluvium.

Low grass used for pasture covers most of the area. Patches of prickly pear cactus are common on conglomerate slopes. Trees are rare except where planted in residential or subdivided areas.

Poison oak, castor bean trees, and low shrubs may be found in some of the gullies.

Isolated exposures are numerous. The actively cutting seasonal streams bare strata in many of the valleys. Many road cuts, gravel quarries, and excavations for oil wells leave the bedrock exposed. Differential erosion between hard conglomerates and soft siltstones makes steep slopes where outcrops are common. However, several districts contain none of the above mentioned types of exposures, and a thick mantle of soil effectively hides the geology. Here, thin beds and faults are difficult to trace because one must rely upon exposures found at widely separated localities.


ROAD MAP
Mapped in this report
Mapped by Quarles in 1939
Mapped by Soper & Grant in 1932
Scale of miles
0 1 2 3 4 5
Burbank
Glendale
Pasadena
Altadena
Sierra Madre
Monrovia
Arcadia
Santa Anita
Duarte
Azusa
Hollywood
Eagle Rock
Highland Park
South Pasadena
San Marino
San Gabriel
Temple City
Alhambra
Rosemead
El Monte
Baldwin Park
Irwindale
Covina
West Covina
Monterey Park
Wilmar
Bassett
Puente
Hazard
Boyle Heights
East Los Angeles
Montebello
Vernon
Huntington Park
Maywood
Bell
Florence
South Gate
Lynwood
Hollydale
Clearwater
Downey
Pico
Rivera
Los Nietos
Santa Fe Springs
Norwalk
Whittier
La Habra
La Mirada
Coyote Hills
Leimert Park
Hyde Park
PUENTE
HILLS

STRATIGRAPHY

General features

The sedimentary rocks exposed in the area range in an almost unbroken sequence from upper Miocene to Recent. The formations in the Repetto Hills form roughly, a south-dipping homocline. The upper Miocene Puente shale outcrops at the north, and the beds outcropping successively southward are lower Pliocene Repetto siltstone, upper Pliocene Pico siltstone, lower Pleistocene Saugus conglomerates and shales, late Pleistocene terrace gravels, and Recent alluvium. The formations in the Montebello Hills form an anticline with Pico siltstone along the surface axis and Saugus conglomerates at the sides.

Except for outstanding differences in the thickness and the lithologic nature of the Repetto, the same stratigraphic sequence occurs in the Puente Hills (5, 11) to the east.

Puente Formation

Name of formation

The Puente formation (upper Miocene) was named from sections in the Puente Hills in 1907 by Eldridge (4, p. 103). The type section, as summarized in the "Lexicon of Geologic Names of the United States" (U. S. Geol. Survey Bull. 896), is divided as follows:

Members of type Puente formation

	Thickness
Upper shale	
Earthy chalk-like shale with a few beds of fine yellow ferruginous sandstone and quartzose calcareous concretions.	200-2000
Middle sandstone	
Moderately coarse gray and yellow heavy-bedded sandstone separated by minor bands of organic silicious shale.	200-2000
Lower shale	
Chiefly earthy shale, but with minor members of silicious nature, the whole gray or brown, from presence of iron and bitumen. Thin fine-grained sandstones interbedded from top to base, and lentils of gray limestone.	2000
Total	2400-6000 feet

The Modelo formation (upper Miocene) also was named by Eldridge (4, p. 17) from the Modelo canyon on the north side of Santa Clara Valley. The Modelo differs from the Puente mainly in having an additional sandstone member 200 to 2000 feet below the lower shale. Kew (8) correlated the two formations as the same, but both names are still locally used. The name Puente will be used in this paper following the precedent set in 1933 by Reed (12).

Lithology and thickness

Three mappable members of the Puente formation are exposed in the northwest portion of this area. The upper two units are well exposed on the limbs of an anticline,[2] but only the top of

2. Referred to as the East Los Angeles Anticline in this paper. It is probably the east end of the Elysian Park Anticline, named by Arnold (4, p.155).

the lowest unit is exposed along the anticlinal axis. A description of the members and their correlation with the type Puente section are given below:

Puente section[3]

	Thickness (Scaled from map)
Upper shale White, gray, and light yellow finely laminated, fine grained shale containing a few concretions and beds of yellow siltstone and, rarely, sandstone laminations. White to gray, spotted diatomaceous shale at top and base. Twenty foot sand and conglomerate bed 350 feet from base. (Plate I, A)	2300
Middle sandstone White and yellow, nearly massive, quartzose, fine to coarse, friable sandstone with shale stringers. (Plate I, B and C)	1050
Lower shale - uppermost part White fine grained diatomaceous shale in ½ to 2 inch-thick strata. No sandstone.	250+
Total	3600+ feet

The uppermost 250 feet of the lower Puente shale member has a remarkably uniform lithology. It is a white to light gray fine-grained compact shale which weathers into hard angular slabs and flakes. The tightly cemented cherty texture and the noticeably light weight suggest a siliceous and diatomaceous composition. A complete absence of medium and coarse grained strata distinguishes this member from the upper Puente shale.

The middle Puente sandstone is easily distinguished from the adjacent shales by its heavy bedding and friable texture. Thin shale bands up to a foot thick comprise from five to thirty

3. For detailed lithology see appendix II.

percent of the volume (pl. I, B and C). Both the lower and upper (pl. I, D) contacts with diatomaceous shale are gradational, each requiring about thirty feet for the change.

The upper Puente shale can be divided into four units. The lower 350 feet is a white diatomaceous granular shale with a few sandy and silty layers (pl. I, A). The next overlying unit is a 15 to 30 foot series of conglomerate, sand, and shale beds. This conglomeratic unit cannot be continuously traced but is found at three separate localities in about the same stratigraphic position. The 1650 feet of strata above the conglomerate is a finely bedded silty shale with a few sandy layers. The top 300 feet is a fine grained diatomaceous shale interbedded with compact siltstone and cherty layers. White powdery discs from one to three millimeters in diameter lie on the cleavage surfaces of the diatomaceous beds.

The two diatomaceous units of the upper Puente shale have few differences. The upper unit is more compact and has more interbedded siltstone than the lower unit. Both these units, however, can easily be distinguished from the lower Puente shale which has very fine, uniform laminae and is free of sand or silt layers.

Relations to adjacent formations

The base of the Puente is not exposed in the area. Its upper contact with the Repetto formation is exposed at four localities along Garvey Avenue. The lithologic change from Puente shale to Repetto siltstone appears to be gradational; the fine-bedded shale becomes silty and the silty shale grades into bedded and massive siltstone. This gradation can be seen at two localities: 1) on the Garvey Avenue road cut east of Eastern Avenue, and 2) 200 feet north of Garvey Avenue and 500 feet west of Fremont Avenue. On Garvey Avenue just west of Atlantic Boulevard the exposure of well bedded siltstone could be either Repetto or Puente. A good foraminifera sample collected here (number 17)[4] has a transitional fauna which Mr. Driver could not fix definitely as either Repetto or Puente, but he believed the stratigraphic position was less than fifty feet above or below the contact. As an accuracy of fifty feet is well within the limits of lithologic mapping, this locality will be considered as the base of the type Repetto section. The age of foraminifera samples collected along the transition zone in other parts of the area agree with the approximate lithologic field location of the Repetto-Puente contact.

Age and correlation

Lithologic similarity and stratigraphic succession can be used to correlate nearly certainly the Puente formation of this area with the type Puente formation described on page 10 and with the Puente members described by English (6, pp. 33-39) in the Puente Hills. Apparently the same upper Puente shale member is described by Soper and Grant (14, pp. 1045-1047) near the center of Los Angeles.

According to Mr. Driver, the microfossil faunas (foraminifera, radiolaria, and sponge spicules) show the age of the upper shale member to be uppermost Miocene.

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4. See Appendix I for complete report on foraminifera samples.

Repetto Formation

Name of formation

The name, Repetto formation (lower Pliocene), was proposed in 1930 by a committee of the Pacific section of the Society of Economic Paleontologists and Mineralogists and was first used in a publication by Reed (12, p. 31). The type locality lies within the area described in this report along the west side of Atlantic Boulevard. Although Reed did not consider the base of the formation to be present here, a virtually complete section is actually exposed (perhaps because of a later road cut at Garvey Avenue). The top of the type formation was placed by Reed just above the highest of 3 coarse feldspathic sandstone beds a few feet thick.

Lithology and thickness

The best Repetto exposures are at the type locality along Atlantic Boulevard. The lithologic units and the thickness of the type section are as follows:

Repetto section at type locality

	Thickness
------ Apparent conformity with Pico siltstone.	
Coarse brown friable sandstone. Mostly subangular quartz and feldspar grains about 2 mm in diameter.	5
Massive buff siltstone, some concretions.	87
Coarse brown friable sandstone with a few scattered granitic pebbles one inch in diameter (pl. II, A).	3½
Buff to light yellow massive to poorly bedded siltstone. Scattered concretions and concretionary layers from one inch to four feet thick.	2500
------ Gradational change to Puente shale.	
	Approx. 2600 feet

A pace traverse was used to measure the upper three beds, and the thickness of the lower siltstone member was calculated from distances scaled from the areal map.

Both Reed (12, p. 31) and Edwards (2, P. 795) reported three sandstone beds at the top of the Repetto, but the lowest one is now apparently hidden by landslides. The only other outcrop of one of the Repetto sandstone beds is about sixteen hundred feet north from the mouth of Repetto canyon. Here, an eighteen inch, coarse brown friable arkosic sandstone bed stands nearly vertical and is interbedded with massive siltstone (pl. II, B). Under the sandstone is a three inch chert layer. Because of its lithology and stratigraphic position, this sandstone bed is considered to mark the top of the Repetto formation.

Because of landslides, fracturing, and the massive nature of much of the siltstone, attitudes are difficult to obtain even along road cut exposures. Faults might exist undetected because they can not be located in the large, poorly exposed areas of nearly massive siltstone. The upper sandstone marker beds at the type Repetto locality can not be traced more than a few feet, due to the thick soil mantle.

The colors of the Repetto siltstone are mixed shades of yellow, cream, and gray. Reed (13, p. 239) described the mineral content as follows:

> "The finest material seems to consist largely of chlorite, but such minerals as quartz, feldspar, apatite, opaque ores, green hornblende, zircon, and epidote may be panned from it."

The particles are tightly packed together apparently without cement. The rock is easily broken with a hammer but is neither crumbly nor friable. Bedding is poor or absent, but visible orientation of fine mica flakes may give a rough clue to the dip of the rock.

Beds of flattened siliceous concretions a few inches thick are present at eight or ten stratigraphic levels. The concretions are generally white on the outside, grading through buff to gray in the center.

Comparison with Repetto of Whittier Hills

The type Repetto section is very different from the lower Pliocene sections in the Whittier Hills[5] (pl. IX). Of the two good sections in the Whittier Hills, the better extends from Turnbull canyon westward to the San Gabriel wash. The section contains good exposures of an unbroken series of formations including the Puente, the Sycamore Canyon (10), all of the Repetto, and the base of the Pico. The other Repetto section in the Whittier Hills lies southeast of the mouth of Turnbull canyon and contains only the Repetto formation. Both Repetto sections in the Whittier Hills are nearly twice as thick as the type section in the Repetto Hills. They also contain numerous thick marine conglomerate beds.

The problem of finding definite limits to the Repetto formation is more difficult in the Whittier Hills than in the Repetto Hills. In spite of the complete and well exposed section west of Turnbull canyon, an agreement has not yet been reached as to the lower limits of the Repetto. Between the

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5. Name of the peninsular-like west end of the Puente Hills lying north and east of Whittier.

massive siltstone above which has a definite Repetto lithology and the typical fine bedded Puente shale below are 2300 feet of conglomerates, sandstones, siltstones, and shales. The problem is that of determining just where in this doubtful zone the most pronounced and logical Puente-Repetto division occurs. The following section is used to show where the contact was placed by different men who have mapped the area:

Miocene-Pliocene
transition section in Whittier Hills

		Approx. thickness
	---Massive siltstone of Repetto age---	700-2000
9.	Series of 6 thin conglomerate beds interbedded with siltstone and shale	420
8.	Siltstone, with some bedding	500
7.	Well rounded, well sorted, brown conglomerate	200
6.	Siltstone, with some bedding	150
5.	Well rounded and sorted brown conglomerate	180
4.	Shale, white to yellow, silty	200
3.	Sandstone, white to yellow, bedded	250
2.	Conglomerate, angular, poorly sorted, mostly decomposed granite	150
1.	Sandstone, fine yellow	250
	---Fine bedded Puente shale---	1600+ feet

In 1907 Arnold (4, map, p. 102) placed the Puente-Fernando (Pliocene) contact between the fine bedded shale and the overlying fine yellow sandstone (bed no. 1 in the above section).

In 1926 English (5, pp. 38 and 40) mapped the base of the Fernando at the bottom of the distinctive angular granitic conglomerate bed no. 2. He based his decision upon the abrupt change in lithology. English also stated that no unconformity was apparent at the contact, but that some irregularity at the base of the sandstone bed no. 1 possibly indicated an unconformity there.

In 1936 Kreuger (10) published an abstract introducing a new Miocene formation which he named the "Sycamore Canyon" and designated this section in the Whittier Hills as the type locality. The original manuscript, which Mr. Kreuger showed the writer in 1940, shows the formation to include beds no. 2 through no. 9 and places the new Miocene-Pliocene contact about 2000 feet above English's contact. A new formational unit was considered justifiable when a foraminifera sample near the top of bed no. 8 was identified as Miocene by Wissler. As this locality was approximately 2000 feet above what English called upper Puente, the interval from English's Puente-Fernando contact to the top of conglomerate bed no. 9 was described as a post-Puente, Miocene formation. Kreuger mapped an unconformity at the base of the no. 2 conglomerate bed which he used as the lower limit of the formation.

In 1939 the writer mapped the area and, without knowing the limits of the Sycamore Canyon formation, placed the Miocene-Pliocene contact at the base of conglomerate member no. 5 for the following reasons: 1) this conglomerate is a typical Repetto type of conglomerate when compared to conglomerates higher in the section and is distinctly different from member no.2; 2) a definite lithologic break could not be found at the base of conglomerate member no. 2, and lenses of conglomerate were found in the sandstone of member no. 1; 3) the succession of shale, sandstone, conglomerate, sandstone, and shale (the Puente shale and members nos. 1, 2, 3, and 4) is gradational and consequently affords no clear-cut boundaries; 4) the shale member no. 4 is the highest typical well-bedded Puente-type shale in the section; and 5) an abrupt change is found between the shale member no. 4 and the conglomerate member no. 5. The writer concludes that, if there is an important break in deposition in the lower part of the transition section, it occurs at the base of conglomerate member no. 5 rather than below conglomerate member no. 2. However, as Mr. Kreuger believes that his Miocene foraminifera sample in bed no. 8 is sufficient evidence for a new formation, the writer believes that the base member of such a formation should be conglomerate bed no. 5 instead of member no. 2.

The writer would locate the top of the Sycamore Canyon formation at the top of bed no. 8 rather than at the top of no. 9 because 1) the conglomerate lentil mapped by Kreuger at the top of member no. 9 is discontinuous and completely lenses out west of the type locality; 2) a conglomerate bed is more apt to mark the base than the top of a formation; 3) the base of member no. 9 is marked by an abrupt lithologic change; and 4) the eastward thinning of the entire unit has the appearance of a transgressive overlap. The writer believes therefore, from the evidence at the type locality, that the proposed Sycamore Canyon formation should include only beds numbering from 5 to 8 inclusively.

In April, 1941, the writer again discussed the Sycamore Canyon formation with Mr. Kreuger and the following pertinent facts were disclosed: 1) the critical foraminifera sample near the top of member no. 8 could only be identified as Miocene and could not be further classified; 2) foraminifera samples in the typical Puente shale below sandstone bed no. 1 have shown a probable lower Puente fauna rather than upper Puente; and 3) Mr. Kreuger's evidence for an unconformity below conglomerate bed no. 2 lies in another area east of the Whittier Hills. Apparently, then, the Sycamore Canyon formation is not necessarily of a post-Puente age, but can be a part of the middle Puente sandstone or upper Puente shale. The writer concludes that the Sycamore Canyon formation contains no definite lithologic, stratigraphic, or faunal characteristics which permit its separation as a new formation, and its name should not be further used in the literature.

Origin

The numerous thin conglomerate beds in the Repetto formation of the Whittier Hills suggest a near shore deposit, and, on the other hand, the absence of conglomerate in the siltstone section of the Repetto Hills suggests off-shore deposition. Deep water deposition in the Repetto Hills is shown both by Mr. Driver's foraminiferal determinations and by Woodring's paper (15, p. 16) on the megafossils of the Repetto siltstone.

Not only does the Repetto formation lack conglomerate beds towards the west, but it is noticeably thinner. Continued westward thinning is shown by thicknesses given in Soper and Grant's paper (14) and in Woodring's (15, p. 5). The differences in thickness and lithology suggest that the Whittier Hills locality was near the margin of the upper Miocene and lower Pliocene seas, and the Repetto Hills deposition took place in deeper water to the west.

Relation to overlying formation

The Repetto is conformably overlain by the upper Pliocene Pico formation. By Reed's definition (12, p. 31), the top of the Repetto is above the third sandstone bed at the type locality. Reed states:

> "Siltstone similar to the siltstone of the Repetto formation overlies the sandstone. It carries a mixture of Repetto foraminifera, possibly re-worked, and others characteristic of younger horizons and probably represents the lower part of the Pico formation."

No significant differences in dip or strike can be detected between the sandstone bed and the overlying siltstone. That continuous deposition took place is confirmed by Mr. Driver from his own researches (7) as well as by a study of the writer's foraminifera samples.

The only localities where the sandstone marker bed at the top of the Repetto can be found are along Atlantic Boulevard and in Repetto canyon. Interpolation of foraminifera determinations is relied upon to locate the Repetto-Pico contact in much of the area. The northward projection of the contact east of Atlantic Boulevard is based upon the attitudes of strata as they appear on the areal map.

As shown above, the top of the Repetto cannot be located by lithology and is not definitely described by its fauna.

Consequently micropaleontologists of different oil companies are not in agreement in locating the contact. The writer's division of the Pliocene into Repetto, lower Pico, and upper Pico is in accord with Reed's definition and with the micropaleontologists of the Texas Company.

Mr. Driver of the Standard Oil Co. of Calif. however, extends the Repetto higher in the section so that it includes all of the writer's lower Pico and a small part of the upper Pico. For the writer's convenience Mr. Driver classified the foram samples in this report according to Reed's original definition.

Mr. Wissler of the Union Oil Co. extends the Repetto upward to include the lower Pico of this report. His complete report on the limits of the Repetto formation is now being published in the California State Mining Bureau Bull. 118.

Age and correlation

The Repetto has been dated as lower Pliocene mainly by the use of foraminifera, although most of it may be distinguished from the upper Miocene by lithology. As the Repetto and Pico formations in this area have nearly the same lithology, foraminifera are used for their separation. However, if the limits of the Repetto are extended upward to include the lower Pico of this report, megafossils may be used in separating the Repetto from the upper Pico.

Fifteen of the foraminifera samples collected in the Repetto Hills were identified as Repetto by Mr. Driver. Their localities are given on the areal map, and their stratigraphic position is shown in the columnar sections.

The Repetto of the Whittier Hills is correlated with the type formation in the Repetto Hills mainly by foraminifera and, less convincingly, by a similarity in lithology. The stratigraphic succession in the Whittier Hills contributes very little to the correlation, and a definite base for the formation is difficult to establish.

The type Repetto is probably the same formation as Soper and Grant's lower Pliocene (14), just six miles to the west in the heart of Los Angeles City. The correlation may best be demonstrated by comparing the complete sections from Puente to Pico in the two areas (see pl. IX). In the Los Angeles City area, the columnar section is separated into four units: 1) typical finely laminated Puente shale, 2) lower Pliocene siltstone (the name Repetto had not yet been introduced), 3) middle Pliocene siltstone, and 4) upper Pliocene siltstone with horizons of cold water megafossils. Thus the stratigraphic succession is similar in both the Repetto Hills and Los Angeles City sections[6].

Pico Formation

Name of formation

The Pico (upper Pliocene) was named by Kew in 1923 (9, pp. 418-419) from Pico canyon, four miles west of Newhall, Los

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6. Mr. Driver and Mr. Holman have recently told the writer that foraminifera can be used to correlate both the lower and middle Pliocene units in Soper and Grant's area as Repetto.

Angeles county. He defined it as a marine formation in the lower part of the Fernando group lying unconformably between the Modelo and Saugus formations. In 1932 Gale (12, pp. 5 and 7) restricted the age of the formation to middle and upper Pliocene. In 1937 Woodring determined the age of the Pico formation as upper Pliocene, and that is the present definition accepted by the United States Geological Survey.

Lithology and thickness

In the Repetto and Montebello Hills the lithology of the Pico formation is almost identical to that of the Repetto formation. If field evidence alone were used, the entire Pliocene series would be mapped as a single formation. In this report, stratigraphic position and minor lithologic peculiarities are used along with foraminifera and megafossils to separate the Pico from the Repetto and to divide the Pico into an upper and lower member.

Edwards (3, p. 39) recognized a disconformity between the upper and lower Pico members in the Atlantic Boulevard section. He believes this hiatus to be represented by 700 to 900 feet of siltstone found in cores from wells drilled near the center of the Los Angeles Basin. Driver recognized a definite faunal difference between the upper and lower Pico in the Atlantic Boulevard section, but he could not say how much section, if any, was absent.

In the Repetto Hills, the lower Pico member contains 730 feet of siltstone lying between the uppermost Repetto sandstone bed (at its type locality) and the top of a one-foot fossiliferous conglomerate bed. The buff colored, concretionary siltstone of the lower Pico cannot be distinguished lithologically from that of the Repetto below or the upper Pico member above. At some localities in the area, however, the top of the lower Pico is marked by a thin, sandy, fossiliferous conglomerate bed. In the Atlantic Boulevard section the bed is one foot thick and is cemented with calcite (megafossil locality no. 1). At another locality 1000 feet up Repetto canyon from its mouth the horizon is marked by four thin conglomerate beds within a ten foot zone (megafossil locality, pl. II, C).

The upper Pico member (uppermost Pliocene) is a nearly massive buff siltstone containing several thin fossiliferous sandstone and conglomerate beds (pl. II, D). The member is 1180 feet thick at Atlantic Boulevard and at least 700 feet thick in the Montebello Hills. It is unconformably overlain by Saugus conglomerates.

Age of the Pico

Foraminifera are used to date the formation as upper Pliocene and to divide it into an upper and lower member. Three samples with lower Pico foraminifera were collected at the Atlantic Boulevard section. Six samples with upper Pico foraminifera were found in the Repetto Hills and five were found in the Montebello Hills.

Megafossils are found in the Pico formation at fifteen localities , ten in the Repetto Hills and five in the Montebello Hills. Fossils from one locality along Atlantic Boulevard and from three localities in the Montebello Hills were collected, prepared, and identified. The faunas are used both to determine the age of the Pico as upper Pliocene and to help separate the Pico into an upper and a lower member.

According to Grant and Gale (6, pp. 21 & 22), from the middle Pliocene to the Recent the use of temperature facies in fixing the age of a fauna is almost as important as the geologic ranges of individual species. The lower Pico member is characteristically a warm water deposit. The upper member carries a cold water fauna (14, pp. 1065 and 5, pp. 22, 60, and 70). In the absence of the middle Pico member, the break in the temperature facies and the corresponding faunal differences are readily apparent.

Grant and Gale's catalogue of Pliocene and Pleistocene mollusca (5) is the reference used for the names, geologic ranges, temperature affinities, and occurrences of the fossils. Pliocene and Pleistocene megafossil collections at Caltech and the Recent Golisch collection were used to advantage. A detailed description of each collection follows:

Megafossil locality no. 1

This locality is in the Repetto Hills 1000 feet west of Atlantic Boulevard and 700 feet north of the Edison power line. It is found in a gully 100 feet west of the north bend in a dirt road.

The fossils are in a hard, sandy, calcareous conglomerate bed one foot thick. The bed lies about 1180 feet below the Saugus conglomerate contact and 730 feet above the sandy bed marking the top of the Repetto formation. The fossils are poorly preserved, but many leave good external molds. Identifiable casts from some of the molds were made with dentist plaster.

The stratigraphic ranges of many of the species definitely place the fauna as post-Miocene, and its Pliocene age is shown by the presence of Cantharus humerosus, Arca trilineata?, Venus securis var. fernandoensis?, and Cancellaria clavatula?.

The fauna is very probably of warm water facies. Ostrea vespertina is characteristic of warm water, and the other species live both in cool and warm water.

The warm water facies of the fauna indicates an age of either middle or lower Pico. As the middle Pico is absent in this locality, the bed may be placed near the top of the lower Pico and probably marks the lower-upper Pico contact.

The two fossil localities described by Woodring (15, p. 20) lie about 100 feet lower stratigraphically than this horizon; one is 1000 feet west and the other 300 feet east of this outcrop. Of their age Woodring concluded,

> "Though these localities appear to fall in the Repetto formation as originally defined, they are, according to Clark, assigned by micropaleontologists to the transition zone between the Repetto and Pico formations."

Fossil locality #1

Name	O	M	P	Pt	R	Temp. range
Pelecypoda						
Ostrea vespertina Conrad	-	c	c	c	c	w
Nuculana taphria Dall	-	?	c	c	c	cl-w
Cardita ventricosa Gould	-	c	c	c	c	cd-w
Schizothaerus nuttallii (Conrad)	-	c	c	c	c	cd-w
Nucula castrensis Hinds	-	r	c	c	c	cd-w
Lucina excavata Carpenter	r	c	c	c	c	w-h
Panope generosa Gould	-	c	c	c	c	cd-w
Ostrea lurida Carpenter ?	-	?	c	c	c	cd-w
Arca trilineata Conrad ?	-	c	c	-	-	?
Venus (Chione) securis Shumard var. fernandoensis English ?	-	-	c	?	-	?
Tellina idae Dall ?	-	c	c	c	c	cl-w
Gastropoda						
Turritella cooperi Carpenter	-	-	c	c	c	cl-w
Turritella jewetti Carpenter	-	-	c	c	c	cl-h
Polinices reclusianus (Deshayes)	r	c	c	c	c	cl-h
Nassarius perpinguis Conrad	-	?	r	c	c	cd-w
Calyptrea trochiformis (Gmelin)	-	c	c	c	c	h-cl
Calyptrea mamillaris Broderip	-	c	c	c	c	cd-h
Crepidula princeps Conrad	-	c	c	c	-	?
Conus californicus Hinds	-	-	c	c	c	cl-w
Calliostoma canaliculatum (Martyn)	-	-	c	c	c	cd-w
Kelletia Kelletii (Forbes)	-	-	c	c	c	cl-w
Cantharus humerosus (Gabb)	-	-	c	?	-	?
Tritonalia lurida (Middendorff) ?	-	-	r	c	c	cd-cl
Mitrella carinata (Hinds) var. gausapata (Gould) ?	-	r	c	c	c	cd-h
Mitra idae Melvill ?	-	-	c	c	c	cd-w
Cancellaria clavatula Sowerby ?	-	-	r	-	r	h-cl
Bittium sp. ?						

Abbreviations

Time range	Temperature range
O - Oligocene	cd - cold (Puget Sound and north)
M - Miocene	cl - cool (Puget Sound to San Pedro)
P - Pliocene	w - warm (San Pedro south through Lower California)
Pt - Pleistocene	h - hot (Below Lower California)
R - Recent	

Frequency of occurrence

c - Occurrences common
r - Found at only a few localities
? - Occurrence doubtful

Megafossil locality no. 2

This locality is in the Montebello Hills 500 feet east from the west edge of the El Monte Quadrangle map and 1200 feet north of Avenida de la Merced. It is on the west side of the gully on a Standard Oil maintenance road cut sixty feet below a Saugus conglomerate bed.

The zone is a one-to-three inch conglomerate bed with a two-inch fossiliferous silt layer just above it. The preservation is good for the pectens but generally poor for the other fossils.

The ranges of most of the species place the zone as post-Miocene. Pecten deserti var. invalidus and Pecten bellus var. hemphilli are known only from the Pliocene. Pecten bellus var. bellus is limited to middle and upper Pliocene, and Pecten caurinus is not found earlier than upper Pico. Three good specimens of the very rare Pecten alaskensis were found.

The fauna is definitely of a cold water facies. Pecten caurinus and Panope ampla now live only in cold water and most of the remaining species now range up into Alaskan waters. This temperature facies combined with the stratigraphic position and range of species places the fauna certainly in the upper Pico.

Fossil locality #2

Name	O	M	P	Pt	R	Temp. range
Pelecypoda						
Pecten bellus (Conrad)						
var. bellus s.s.	-	-	c	-	-	?
var. hemphilli Dall	-	-	c	-	-	?
Pecten hastatus Sowerby	-	r	c	c	c	cd-w
Pecten alaskensis Dall	-	-	r	c	c	cd-w
Pecten islandicus Muller						
var. jordani Arnold	-	-	c	c	c	cd-w
Pecten deserti Conrad						
var. invalidus Hanna	-	-	c	-	-	?
Pecten caurinus Gould	-	?	c	c	c	cd-cl
Nuculana taphria (Dall)	-	?	c	c	c	cl-w
Pododesmus macroschisma (Deshayes)	-	-	c	c	c	cd-w
Panope ampla (Dall)	-	r	c	c	c	cd-cd
Arca multicostata Sowerby ?	-	-	c	c	c	w
Cryptomya californica (Conrad) ?	-	c	c	c	c	cd-h
Psephidia lordi (Baird) ?	-	-	c	c	c	cd-w
Mactra sp. ?						
Macoma sp. ?						
Gastropoda						
Calyptrea mamillaris Broderip	-	c	c	c	c	cd-h
Turritella cooperi Carpenter	-	-	c	c	c	cl-w
Crepidula princeps Conrad ?	-	c	c	c	-	?
Polinices reclusianus (Deshayes) ?	r	c	c	c	c	cl-h

Bryozoa sp. ?

Echinoidea sp. ?

Fossil locality #3

Name	O	M	P	Pt	R	Temp. range
Pelecypoda						
Lucina acutilineata Conrad	c	c	c	c	c	cd-w
Thyasira bisecta (Conrad)	c	r	r	c	c	cd-cl
Gastropoda						
Mitra idae Melvill ?	-	-	c	c	c	cd-w
Neptunea scotiaensis (Martin) ?	-	-	c	-	-	?
Four species, unidentifiable						

Megafossil locality no. 3

The locality is in the Montebello Hills (El Monte Quadrangle) 300 feet south of the southern tip of the Standard Oil field office and 1000 feet slightly south of west from locality no. 4. The fossils are on the west bank at the end of the road leading to the abandoned oil well number 80 of the Baldwin lease.

The stratigraphic position is estimated to be 300 feet below the Saugus conglomerate contact and up to 100 feet above fossil locality no. 4. The fossiliferous zone is several feet thick in massive siltstone. The shells are crumbly.

The fauna is easily correlated in spite of the small number of species represented. The range of the questionable *Neptunea scotiaensis* confines the horizon to the Pliocene. About fifty specimens each of *Lucina acutilineata* and *Thyasira bisecta* were collected, but only one specimen of each of six gastropod species was found. *Neptunea scotiaensis* and *Thyasira bisecta* have not hitherto been found in the Pliocene of the Los Angeles Basin.

Thyasira bisecta is definitely a cold water form. Combined with the stratigraphic position and ranges, the cold water affinity dates the fauna as upper Pico.

Megafossil locality no. 4

The locality is in the Montebello Hills within the El Monte Quadrangle. The bed is exposed 800 feet slightly south of east of the Standard Oil field office at the north bend of the maintenance road.

The bed is about 400 feet stratigraphically below the Saugus conglomerate contact. The fossils are crumbly but otherwise well preserved and abundant in a three-inch coarse white sandstone bed.

The specific ranges limit the fauna to the Pliocene. About nine species first appear in the Pliocene, one dies out during the epoch, and five are confined to it.

The temperature facies of this fauna is not distinctly shown. The only probable warm water species is Cancellaria tritonidea var. tritonidea (see 6, p. 617). The remaining definitely identified species have no diagnostic temperature affinities.

Fossil locality #4

Name	Range					Temp. range
Pelecypoda	O	M	P	Pt	R	
Nuculana taphria (Dall)	-	?	c	c	c	cl-w
Nucula castrensis (Hinds)	-	r	c	c	c	cd-w
Panope generosa (Gould)	-	c	c	c	c	cd-w
Cardita ventricosa Gould	-	c	c	c	c	cd-w
Solen sicarius Gould	-	c	c	c	c	cd-w
Lucina nuttallii Conrad	-	r	c	c	c	cl-h
Venus securis Shumard						
var. fernandoensis English	-	-	c	?	-	?
Mactra catilliformis (Conrad)	-	c	c	c	c	cl-w
Clementia subdiaphana Carpenter	-	?	c	c	c	cd-w
Dosinia ponderosa (Gray)						
var. jacalitosana Arnold	-	c	c	-	-	?
Macoma nasuta (Conrad)	?	c	c	c	c	cd-w
Cryptomya californica (Conrad)	-	r	c	c	c	cd-h
Pecten bellus (Conrad)						
var. slevini Dall and Ochsner	-	-	c	-	-	?
var. hemphilli Dall	-	-	c	-	-	?
Pecten latiauratus Conrad ?	-	-	r	c	c	cl-w
Thracia trapezoides Conrad ?	c	c	c	c	c	cd-cd
Tivela stultorum (Mawe) ?	-	-	r	c	c	cl-w
Saxidomus nuttalli Conrad ?	-	c	c	c	c	cl-w
Apolymetis biangulata (Carpenter) ?	-	c	c	c	c	cl-w
Psephidia lordi (Baird) ?	-	-	c	c	c	cl-w
Tellina sp. ? and Anomia sp. ?						
Pandora sp. and Mytilus sp. ?						
Gastropoda						
Crepidula princeps Conrad	-	c	c	c	-	?
Polinices reclusianus (Deshayes)	r	c	c	c	c	cl-h
Nassarius perpinguis Conrad	-	?	r	c	c	cd-w
Calyptrea mamillaris Broderip	-	c	c	c	c	cd-h
Cancellaria tritonidea Gabb						
var. tritonidea, s.s.	-	-	c	c	-	w
var. fernandoensis	-	-	c	-	-	?
Cancellaria clavatula Sowerby	-	-	r	-	r	h-cl
Calliostoma gemmulatum Carpenter	-	-	r	c	c	cl-w
Calliostoma canaliculatum Martyn	-	-	c	c	c	cd-w
Mitra idae Melvill ?	-	-	c	c	c	cd-w
Surculites carpenterianus Gabb						
var. carpenterianus ?	-	-	?	c	c	cl-w
Surculites remondii Gabb ?	-	r	c	c	c	cl-w
Bittium eschrichtii (Middendorff) ?	-	-	r	r	r	cd-cl
Littorina scutulata Gould ?	-	-	-	c	c	cd-w
Mitrella carinata (Hinds)						
var. gausapata (Gould) ?	-	r	c	c	c	cd-h
Calyptrea trochiformis (Gmelin) ?	-	c	c	c	c	h-cl
Astraea sp.	-	c	c	c	c	?
Scaphopoda						
Dentalium neohexagonum Sharp & Pilsbry	-	-	r	c	c	cl-h

Correlation of Pico

The upper Pico faunas from localities two and three can be correlated with Soper and Grant's upper Pliocene faunas in Los Angeles (14). The warm water lower Pico fauna of locality one is probably equivalent in age to Soper and Grant's middle Pliocene in Los Angeles. Similarity in lithology, stratigraphy, and structure affords further evidence for correlating the two Pico members of this area with the middle and upper Pliocene in Los Angeles. A probable disconformity is found between the two units in both areas.

The lower Pico is probably equivalent to that part of the Fernando in the vicinity of Brea and Olinda canyons which was considered by English (5, p. 44) to be middle Pliocene. The fauna listed there by Eldridge (5, p. 43) contains the warm water Pecten healyi and Ostrea vespertina as well as many other species found in localities one and four of this report.

Saugus Formation

Name of formation

The Saugus formation was named by Hershey in 1902 from Soledad Canyon near Saugus (Am. Geol., Vol. 29, pp. 349-372) as a division of the Fernando Group. He described it as

> "Two thousand feet of unlithified sand, gravel, and clay; stratified, water-worn, and water deposited. It is an alluvial deposit, a river progressively sinking."

Kew used the name both in 1923 (9, pp. 419-420) and in 1924 (8, p. 81) to include upper Pliocene as well as lower

Pleistocene. Several authors used the Saugus as lower Pleistocene in 1933 (12, pp. 5, 49, 58, and 61). The Saugus is now considered to be lower Pleistocene by the United States Geological Survey.

Lithology and thickness

A nearly complete Saugus section is exposed along Garfield Avenue just south of the power house. The formation is composed of a series of interbedded conglomerates, sandstones, and shales. For mapping, the formation was divided into five units. From the top down they are as follows:

Saugus section along Garfield Avenue [7]

		Thickness
5.	Brown fine-grained, sub-rounded conglomerate	500
4.	Buff siltstone, fairly well bedded, in part shaly	200
3.	Well rounded buff conglomerate in sandstone and siltstone, with mollusk casts	20
2.	Buff, well bedded siltstone	531
1.	Sandy conglomerate with shale cobbles and thin siltstone beds (pl. III, A and B)	264
	Total	1515 feet

The thicknesses of the top three units were scaled from the map; the lower ones were paced along the road cut. Lensing of several beds can be observed (pl. III, C) even on the small surface of the road cut. Some of the thin siltstone beds in the lowest conglomerate unit apparently increase in thickness eastward into mappable units.

7. For detailed section see Appendix III.

The Saugus beds exposed on the flanks of the Montebello anticline are probably low in the basal unit. At foraminifera locality no. 38 the section is as follows:

Saugus beds in Montebello Hills

----- Covered by terrace deposits -----	Thickness
Yellow to buff medium grained conglomerate with irregular sand beds.	20+
Buff siltstone with a few bedding planes.	25
Poorly sorted buff conglomerate, average size 1½ inch, typical Saugus lithology.	20
----- Disconformity with Pico siltstone -----	
Total	65+ feet

The NE-SW trending conglomerate band at the east end of the Montebello Hills is a cross-bedded mixture of sand and sandy conglomerate (pl. IV, A) whose bedding appears to dip at about right angles to the trend of the bed as a whole. The Pico siltstone was probably irregularly eroded and was then overlapped by cross-bedded Saugus conglomerates.

The petrology of the conglomerates is described on page 39.

<u>Relations to adjacent formations</u>

The Saugus lies with angular unconformity upon the Pico siltstone. The surface of unconformity is uneven, showing the conglomerate to be deposited upon a moderate topography.

The top of the Saugus formation is not exposed. Soon after its deposition the Saugus was folded, truncated by erosion, and covered unconformably by nearly flat lying upper Pleistocene terrace deposits. The unconformity between the Saugus and terrace conglomerates is exposed at several localities.

Age and correlation

The name Saugus is used in this paper because it denotes lower Pleistocene age and has no temperature significance or zonal limitations as do names such as Las Posas, Timm's Point, and San Pedro. The position of the Saugus unconformably above the uppermost Pliocene strongly suggests that it was deposited in the Pleistocene. As its folded structure is also unconformably overlain by nearly flat lying upper Pleistocene gravels, the Saugus formation may be dated with reasonable certainty as lower Pleistocene.

Fossils are of negligible value in determining the age. Foraminifera sample no. 28 has a very poor fauna, identified as probably upper Pliocene or Pleistocene; and no. 38 had a few sponge spicules usually indicative of Miocene age. The two megafossil localities contained only internal casts and were not studied.

Terrace Gravels

Lithology and thickness

The terrace gravels are composed of irregular beds of poorly consolidated, sub-angular, sandy conglomerate (pl. III, D; pl. IV, B, C, and D). Bedding planes are present but are of short lateral extent. The color is usually reddish brown. The petrology is given on page 39.

As the terrace material was deposited around and over a low topography to a nearly uniform elevation, its thickness varies accordingly. The maximum observed thickness, estimated at 140 feet, is exposed at the junction of Garvey Avenue and Repetto canyon.

Origin

The terrace conglomerates have many characters of a non-marine deposit: sand lenses, discontinuous bedding, poor sorting, abundant matrix, and sub-angular particles. The absence of beds of fine sand, siltstone, or shale suggests deposition on a large alluvial fan or river bottom. The source of the material was shown by Edwards (2) to be the San Gabriel mountains.

The process of deposition seems to be that coarse gravel was washed down rapidly from the San Gabriel Mountains as the result of a renewed uplift and was deposited upon the nearby mature topography of the Los Angeles basin area. Low hills were partly buried and the stream valleys which had cut through the hills were filled to a uniform level. The result was a line of disconnected low hills protruding above a flat gravel floor.

Comparison of Saugus and terrace conglomerates

One of the first problems encountered by the writer in the field was to distinguish between Saugus conglomerates and the terrace gravels. The steep dips of the Saugus conglomerate and the nearly flat dips of the upper Pleistocene conglomerate appeared to be the only means of separating the two formations. Where exposures were poor and the conglomerate beds had to be traced through a mantle covering, these features could not be determined. Even at good exposures, dips were sometimes not visible, and along the Mesa Drive lowlands, both formations had nearly flat dips.

Edwards (2, p. 798) reported that the two conglomerates could be distinguished by the petrography of their pebbles. He found that the terrace conglomerate material came from the San Gabriel mountains and contained pink granite and a distinctive light colored diorite, spotted with clusters of dark minerals. The source of the Saugus was reported by Edwards to be mainly from the Perris region, near Riverside, California, in which white granite is abundant.

Only two localities in this area were studied by Edwards. In order to determine how constant the petrologic differences are between the Saugus and terrace conglomerates, the writer collected pebble samples of both formations from twenty-nine exposures throughout the area. The tabulated data derived from this material is given in plate VII. The locations were classed from their field relations as terrace, probable terrace, probable Saugus, and Saugus. The samples were washed and screened through two mesh sizes, a half-inch and a quarter-inch. The large and small pebble sizes were studied separately. The average number of pebbles for each sample was 150 large and 450 small.

A petrologic grouping of the pebbles was needed that could be readily recognized in the field. Fine petrographic distinctions would be of little practical use. Considerable experimenting led to the following classification which contains easily recognized but critical characters.

Pebble classification

Pink granite - granite, aplite, and pegmatite which contain pink orthoclase.

White granite - any acid, granular, igneous rock, white or yellow, which has very few dark minerals and no pink orthoclase.

Diorite - granular igneous rocks with noticeable amounts of dark minerals.

"Dappled" diorite - named by Edwards (2, p. 790); a white granular gneissic diorite with disc-like clusters of hornblende and biotite.

Banded gneiss - other noticeably banded gneissic rocks.

Felsite - extrusive igneous rocks other than dacite, porphyritic or not. Might include cherty shale.

Dacite porphyry - dark green extrusive rock with white phenocrysts, often gneissic, and very distinctive.

Blue schist - schistose rock of blue-grey color.

Hornblende schist - green hornblende schist.

Mica schist - biotite or muscovite schist.

Quartzite - quartz or quartzite.

Miscellaneous - epidote, shale, siltstone, bryozoa, and unclassifiable rocks.

The large and small pebble sizes of each sample were separated into the above types and percentages were figured for each size. No uniform or significant variations in the lithology of the two sizes was found except that the dappled diorite was less abundant in the smaller size. This decrease is to be expected because many small fragments of dappled diorite which are too small to have a hornblende disc were probably classified either as diorite or white granite. As this difference in classification is not large enough to justify a separate tabulation of each size, the results are based upon the total number of pebbles at each locality, even though the dappled diorite percentages will be a trifle low.

Edwards' chart (2, p. 805) shows that some San Gabriel material contributed to the Saugus formation, and that the Perris block contributed nothing to the terrace deposits. Even though the terrace material was derived entirely from the San Gabriel mountains, some contamination from the Saugus is to be expected where the terrace conglomerates were deposited directly upon Saugus conglomerate. Therefore, the pure or type terrace conglomerate is found overlying siltstone or deposited north of Saugus conglomerate outcrops. These pure terrace localities are summarized on the chart in the "sub" average of the "certain terrace" field classification. An undoubtedly contaminated terrace sample is no. 22, for it was collected only one foot above Saugus conglomerate. Samples 24, 19, 16, and 25 probably contain re-worked Saugus material.

Differences in petrology may be expected between the conglomerates at the west of the area and those six miles away at the east because of mixing, weathering of the constituents, sorting, and local differences in source. Any variation as a result of east-west position is checked by grouping the localities into three zones: Garfield Avenue and west, Garfield Avenue east to the edge of the quadrangle, and east into the El Monte Quadrangle. Both the terrace and Saugus samples in the western zone proved to be more typical of their formations than those in the middle and east, probably because of less contamination.

Important differences were found in the petrology of the terrace and Saugus conglomerates. Much more abundant in the terrace are the pebble types of pink granite, diorite, and dappled diorite; while white granite, felsite, dacite porphyry, and blue schist are more abundant in the Saugus. The white granite and diorite pebbles are of little practical use in distinguishing the two formations because the difference in their frequency of occurrence is not pronounced. The types characteristic of the terrace are pink granite and dappled diorite. Common in the Saugus but very rare in the terrace gravels are dacite porphyry, blue schist, and, to a less extent, felsite. By observing the presence or absence of these five types a quick differentiation between the two conglomerates is possible. In areas where Saugus conglomerates underlie terrace gravel, contamination sometimes makes a distinction difficult (samples 16, 25, and 22). At such places other lithologic features which identify the terrace, such as angularity and general color, are also mixed, leaving only the type of bedding and structural attitude as useful diagnostic characters.

Dr. Hamptom Smith suggested that local weathering might hasten the alteration of white orthoclase to pink, causing the abundance of pink granite at some localities. Dr. Ian Campbell confirmed the possibility of such an alteration. The tabulated data also show the possible effects of weathering. Terrace sample number 22 was taken only a foot above the Saugus sample number 21, with an unconformity between. Terrace samples 25 and 24 are likewise separated by an unconformity. The percent of pink granite in the two samples of each locality are very similar, suggesting uniform alteration as the cause. However, the amount of felsite, dacite porphyry, and blue schist are also similar, indicating much contamination rather than equal alteration.

The high percent of pink granite in Saugus sample number 21 is probably the result of alteration, for its position near an old erosion surface gave it a previous period of surface weathering. As the amount of pink granite in the sample is changed only five percent, it is not a serious source of error. The small amount of pink granite and dappled diorite in the other certain Saugus samples may afford an indication of how much San Gabriel material was added to the Perris mountain conglomerate.

The excellent agreement between the physical or structural classification of the samples in the field and their content of pink granite indicates that weathering in place is of little importance. All the samples were taken from some sort of excavation and had no apparent topographic anomalies that might affect the rate of weathering. Assuming that loose consolidation of the terrace gravels permits greater weathering and, hence, more rapid alteration to pink granite, the pink color would still be a diagnostic property of the terrace formation and could be used in this separation. This assumption, however, is not justified because of Edwards' determination of the San Gabriels as the original source of the terrace material, including the pink granite.

The pebble comparisons show that petrology can be used to distinguish the Saugus conglomerates of this area from the terrace conglomerate. The method was used in the field mapping and gave reliable results except at a few places where the terrace is essentially a basal conglomerate derived from the Saugus formation.

GEOLOGIC STRUCTURE

Three east-west folds dominate the structure of the area: an anticline in the Montebello Hills, a syncline along Mesa Drive, and an anticline in East Los Angeles.

Montebello anticline

The Montebello anticline, the structural trap from which oil produced in the old and new Montebello fields, is a faulted fold whose outcrop surface is two miles long and a mile wide. The sediments exposed near the axis of the anticline are Pico siltstone; outcrops of Saugus conglomerate are found on the limbs. The trace of the anticlinal axis is convex northward and its two ends plunge slightly to the east and west respectively. The south limb dips steeply; but the exposed part of the north limb has a shallow dip.

An east-west trending normal fault, with about 700 feet stratigraphic displacement, nearly parallels the axis of the anticline. It cuts off a north-south fault near the west end of the anticline. Both faults are part of the boundary separating Saugus conglomerate from Pico siltstone. A good exposure of the east-west fault in a road cut shows a sharp, smooth contact dipping 70° degrees to the north. The eastward extension of the fault into Pico siltstone cannot be definitely located.

The north-south fault is covered by soil mantle and cannot be accurately traced. It apparently displaces the basal Saugus conglomerate bed about 100 feet vertically.

Several small patches of terrace gravels are found on the top and sides of the Montebello anticline. As only one period of terrace deposition is apparent throughout the Repetto and Montebello Hills, these terrace patches are presumed to be remnants of a single deposit. One patch of terrace gravel lies at elevation 575 along the anticlinal axis. Other terrace caps are scattered down the south limb of the anticline, and a band of terrace material at elevation 350 dips off the hill along its south edge.

The writer believes that the west end, if not the entire Montebello anticline, was completely covered by a level terrace surface in late Pleistocene time and that this surface has since been folded, forming a ridge 300 to 600 feet high. The present topography of the Montebello Hills is a modification of that folded surface. Confirmation of the folding is given by attitudes taken in the terrace gravels along the south slopes. At one locality terrace gravels dip twenty-one degrees south and, at another, the gravels dip twenty-three degrees south in the same direction. (pl. IV, C).

The unconformity at the base of the Saugus produces unusual structural features at both ends of the anticline. The Saugus conglomerate beds trend northward diagonally across the strike of the underlying Pico siltstone beds. The basal Saugus conglomerate beds were probably deposited upon a post-Pico erosion surface similar to the present hills. The contact of the overlapping conglomerates curved around the contours of the hill. In addition to the overlap the beds were cross-bedded from the southeast. The subsequent post-Saugus and post-terrace periods of folding have produced the discordant trend of the Saugus conglomerate beds.

The structural development of the anticline has been a complex one. According to Atwill (1, chart, p. 1124) the structural history began with broad folding in upper Miocene time, followed by a period of erosion. After the deposition of the remaining Miocene and the Pliocene sediments, another period of folding, uplift, and erosion left a low hill of Pico siltstone. Saugus conglomerates were deposited around and over this hill. Then a major post-Saugus disturbance produced most of the folding in the anticline which is now exposed. A subsequent relaxation of stress after compression allowed the high central part of the anticline to drop seven hundred feet along the axis. Again erosion nearly or completely leveled the topography, and it was covered by a large alluvial fan derived from the San Gabriel mountains. The last stage in the development of the anticline was post-Pleistocene compression and folding which raised the terrace surface to a somewhat higher topographic position than the present hills. Erosion has stripped off most of the terrace gravels and exposed the older formations.

A peculiarity of the field not to be expected from the surface structure is that the axial plane dips southward. This condition is shown by Atwill (1, p. 1124) and was described by officials at the Montebello field offices of the Standard Oil Company of California and Kern County Oil Company. In the same anticlinal structure the south and west Montebello fields are producing from deeper horizons than those of the old field farther north. As interpreted from the surface geology, the axial plane should dip northward, away from the steeply dipping south limb of the anticline. The probable explanation of the problem lies in the east-west fault along the anticlinal axis. Apparently flat-lying beds have been faulted down on the north flank displacing the steep dips of the anticline's north limb (see Plate X). The post-Pleistocene folding may have still further complicated the structure.

No surface indications of the south and west Montebello fields (1) were found. There is a possibility, however, that the fault along the anticline marks the north limits of production in both the new and old fields. The fault cannot, however, be traced to the east or west of the shown limits.

Other folds

Most of the folding on the syncline along Mesa Drive probably took place during the mid-Pleistocene disturbance. As it is poorly exposed, and correlation of the conglomerates across its axis is questionable, the structural history cannot be more accurately determined. The abrupt change of dip along the axis suggests faulting. The topography of the line of hills along Third Street is also suggestive of post-Pleistocene faulting, but confirming evidence for faulting at either locality is lacking.

The presence of an anticline south of Monterey Park is doubtful. The axis, if present, cannot be accurately located, and what might be the north limb is poorly exposed. The only locality where a definite north dip may be seen is on the next road cut west of Garfield Avenue. The basal Saugus conglomerate bed appears to swing north around the east end of the fold as is to be expected around a plunging anticline, but the structure is not clearly shown.

The east closure of the East Los Angeles anticline is shown in the Puente formation just inside the Los Angeles City limits. The sequence of upper shale, middle sandstone, and lower shale can be traced around the plunging axis. A thin conglomerate bed about 300 feet above the base of the upper shale member is also found at three localities around the fold in the same approximate stratigraphic position. Although the entire Pliocene and Saugus series trends as though it might also close around this anticlinal structure, definite evidence for it cannot be found within this mapped area. Minor faulting is probably more common than is indicated by the single example shown in Plate V, A, located in the sandstone of the north flank. Incompetent folding and attenuation of beds is suggested by considerable overturning and variation in dips in the Puente formation.

Some of the nearly vertical Puente beds on the south limb of the anticline have the same strike but dip in opposite directions. The probability that the beds were overturned was confirmed by a close lithologic inspection. At the conglomerate lentil just west of section AB in the upper Puente shale member, several coarse sandstone and conglomerate layers showed a gradation from a very coarse grain size on top to a fine grained sand and even shale at the bottom. Since in normal deposition the grain size in a given stratum is coarse at the bottom and finer at the top, strata with the reverse gradation may be considered as probably overturned. At several localities in the middle Puente sandstone the inverted order of variation in grain size confirmed the belief that all the north dipping Puente beds south of the anticlinal axis are overturned.

Faults

Very few important faults are found in the area. At many localities a fracture surface may be seen in a road cut (pl. V, A), but it cannot be traced. Some of these breaks may be of more importance than shown on the map, but in the absence of more stratigraphic evidence they cannot be so indicated. There are at least two and possibly three periods of faulting. A reverse fault along the Puente-Repetto contact is dated as post-Repetto and pre-terrace, the normal fault in the Montebello anticline is mid-Pleistocene, and the fault at the southwest of the area is post-terrace.

A reverse fault between the Puente and Repetto formations may be seen on a new road cut at foraminifera locality no. 49. It is possible that the fault may form the entire Puente-Repetto contact, as shown on a sketch map of the Los Angeles basin prepared by Hoots and Kew (12, p. 28), but the writer could not trace the fault in either direction from its outcrop. The contact dips fifty degrees south, and the fault is shown by local drag to have a reverse movement. Massive siltstone on the south has been thrust up against poorly bedded diatomaceous shale. The fault probably represents only a minor adjustment along the contact. It could not cause the steep and overturned dips in the vicinity. If considerable drag were produced near the fault, the steep dips of the adjacent beds should be decreased, rather than increased to nearly vertical. The unusually steep dips along the contact are probably the contortions of incompetent shale beds against which competent siltstone has been thrust. The amount of displacement on the fault cannot be determined.

Faulting in the southwestern part of the area raised the terrace formation 150 feet vertically to its present level. A reverse movement along a north-dipping plane is assigned to the fault because of considerable drag in the nearby terrace conglomerate and the overturning of the conglomerate fossil bed (pl. II, D) on the east side of Repetto canyon. Normal faulting could not cause the overturning. This reverse faulting is probably the result of the same compressional forces which produced the post-terrace folding on the Montebello anticline.

The post-terrace fault 1200 feet up Repetto canyon has a reverse movement and an 81 degree south dip. The local displacement of terrace gravel is about twelve feet vertically.

The two faults in the Montebello anticline are definitely of mid-Pleistocene age, for they cut Saugus conglomerates, and the terrace gravels near the fault and on both sides of it are not displaced.

Unconformities

The older of the two major unconformities in the area lies between the Pico and Saugus. The Pico siltstone beds dip as much as twenty degrees steeper than the Saugus conglomerates. The pre-Saugus surface was an irregular topography (pl. V, B and C), which was possibly similar to the low hills now present. The Saugus conglomerate overlaps the Pico northward.

The later major unconformity lies below the terrace formation. The terrace deposits were deposited upon an irregular erosion surface from which around 8000 feet of sediments had been removed since the beginning of the post-Saugus disturbance. This is the thickness of the section which had to be removed from the East Los Angeles anticline in order to expose the lower Puente shale. Only the low portions of much of the resulting topography were covered by gravels. Uplift and degradation left remnants of the terrace deposit in all stages of preservation throughout the area.

Significance of present topography

The flat-topped remnants of the terrace surface make a datum plane showing the nature and amount of post-Pleistocene deformation. At the south end of Repetto canyon (pl. V, D) the terrace surface lies at elevation 460, just 150 feet above the canyon and valley floors. The terrace surface slants northward to elevation 450 at Garvey Avenue and to elevation 425 at the north of the area where it grades gently into the valley alluvium. At Atlantic Boulevard (pl. VI, A, B, and C) the same northward slope of the terrace is found, from elevation 400 at the south end of the hills to 375 at the north. In both localities the surface on the east side of the canyon is slightly lower than that on the west. The deformation in the Repetto Hills may be interpreted as uplift along the south edge, causing tilting to the north and east. The new streams began cutting on the low, or east, side of the tilted surface, causing a greater removal of the terrace along the east side of the canyon. As the Repetto canyon area was lifted higher than the Atlantic canyon area, erosion was more vigorous and the canyon walls contain fewer terrace remains.

Remnants of the terrace surface on the Montebello Hills are good evidence for post-Pleistocene folding (see page 46). The surface slants off on the north and south (pl. VI, D) and terrace patches occur high on the hills. The steep cliffs around the east end of the hills may have been formed by faulting, but stream erosion of the post-terrace anticline could bring about the same result.

The steep-walled wind-gap of Coyote pass is certainly not a result of recent headward erosion, for it has so small a drainage area that no stream channel is present, and the seasonal rainfall is absorbed by the alluvium. The canyon must have been cut by streams during the erosion cycle which followed the early part of the mid-Pleistocene disturbance and preceded the major uplift of the San Gabriels. Mr. H. S. Hill of the Pasadena Junior College tobd the writer that he has drilled holes twenty-seven feet deep into the alluvium in the bottom of the gap without finding gravel. Quite possibly the valley drained a small inclosed basin in the vicinity of the Midwick Country Club. When uplift of the San Gabriels took place, the terrace gravels were deposited around the hills but perhaps could not get into the Midwick basin. When the stream in the gap lost its head because of its relative subsidence, the canyon and basin filled up with alluvium. The northeastward tilting of the block in post-Pleistocene time caused the drainage north of the gap to be captured by the Atlantic Boulevard stream.

The thin terrace deposits along Miller Avenue indicate a similar history for that canyon. The terrace is composed entirely of Puente shale blocks and flakes mixed with Repetto siltstone. Recent drainage in that canyon, however, has sufficed to cut into and expose this local terrace material.

GEOLOGIC HISTORY

A summary of the geologic history is given below. No definite evidence of igneous activity could be found.

Sedimentation	Activity	Result
Upper Miocene (Puente)		Lower shale, middle sandstone and upper shale. Partly diatomaceous.
Lower Pliocene (Repetto)		Thick, massive siltstone. Deep water deposition.
Upper Pliocene (Lower Pico)		Massive siltstone. Warm water megafossils.
	Post-lower Pico uplift.	Non-deposition. Possibly some erosion.
(Middle Pico)		Hiatus.
Uppermost Pliocene (Upper Pico)		Siltstone. Some thin conglomerate and sandstone beds with cold water megafossils.
	Post-Pliocene major uplift and folding.	Positive area near present hills. Eroded to irregular topography.
Lower Pleistocene (Saugus)		Alternate conglomerates (some non-marine) and siltstone.
	Early part of mid-Pleistocene disturbance. Folding, faulting, and uplift.	Major folds and faults of area. Followed by long erosion period.
Upper Pleistocene (terrace)		Alluvial fans from San Gabriel Mts. covered Montebello Hills and filled low areas in Repetto Hills.
	Uplift with folding and faulting.	Montebello Hills gently folded. Repetto Hills tipped to northeast. Erosion produced present topography.

ECONOMIC CONSIDERATIONS

Petroleum possibilities

The Montebello Hills are being thoroughly exploited for oil, and well logs have been extensively used to determine the underground structure. Recommendations based on the surface geology alone, therefore, are worthless. However, the possible westward continuation of the Montebello fault should be considered in the interpretation of well logs at the west end of the new Montebello field.

The anticline south of Monterey Park is small, ill-defined, and has no definite closure. The remains of two abandoned wildcat wells may be seen in the vicinity, one along the east extension of the anticlinal axis and the other 2500 feet south of the axis on hill 627. Not enough attitudes are available to plot the position of the axis at depth, but a better drilling locality appears to be somewhere near the intersection of the axis and Garfield Avenue. The favorable sequence of lower Puente shale as source, middle sandstone as reservoir, and upper shale as cap rock for oil should occur at a reasonable depth. The top of the sandstone should be found at a depth of about 4800 feet, and the irregular conglomerate bed near the base of the upper Puente shale might be found about 300 feet higher.

The East Los Angeles anticline appears to be the eastern closure of a large structure favorable for oil accumulation. If the anticline were not within the Los Angeles City limits, where drilling for oil is prohibited, its westward extension certainly should be investigated. The entire Repetto to Saugus series may possibly extend around the axis to the east and north.

The area should be considered as favorable for exploration even though the strata exposed along the axis of the anticline are older than the common oil producing zones in the Los Angeles basin. Drilling into the earlier Miocene, Oligocene, and even Eocene sediments to determine their possible oil content has been made easy by the erosional stripping from the anticline of at least 8,000 feet of Miocene, Pliocene, and Pleistocene sediments. The possibility must be considered, however, that the Puente lies upon the basement complex as it has been shown to do in parts of the Puente Hills and the Santa Monica mountains.

The owners of the rock quarry west of the mouth of Repetto canyon leased their area to an oil company at one time, and a well was located about 1500 feet up the canyon as shown on the map. The writer found no evidence of a favorable oil structure in the vicinity.

Non-metaliferous deposits

Four gravel quarries are in active operation in the area, two working the terrace deposits and two using Saugus conglomerates. Generally, only the unscreened gravel is sold, for too much fine sand and clay is present for use as a concrete aggregate. Plenty of material for other quarries may be found at convenient localities.

A large brick factory at the south end of Coyote pass uses Pico siltstone for raw material. According to workmen at the north end of Coyote pass, the Repetto siltstone there will soon be used to manufacture a light-weight concrete aggregate. The siltstone is converted by heat into a frothy siliceous pellet the size of a small pebble. It makes a light-weight concrete which is supposed to be strong and resistant to shock.

Appendix I

Foraminifera determinations
by H. L. Driver

Sample number	Nature of fauna	Age	Remarks
2	Fair	Low in Repetto	
3	Fair	Low in Repetto	
4	Fair	Repetto	
5	Fair	Upper Repetto	
6	Good	Lower Pico	A little below #10 stratigraphically
8	Fair	Upper Pico	
10	Good	Lower Pico	Similar to sample #6
11	Good	Definitely lower Pico	
12	Good	Lower Pico	
13	Good	Lower Pico or Repetto	
14	Good	Upper Repetto	
16	Excellent	Repetto	
17	Good	Repetto or Puente?	Within 50 feet of contact
24	Good	Upper Pico	
25	Limonite casts	Probably lower Pico	
26	Poor	Post-Miocene	
27	Good	Upper Pico	
28	Very poor	Probably U. Pliocene of Pleistocene	
31	Fair	Upper Pico	
32	Poor	Possible U. Pico	Definite range is post-Miocene
33	Fair	Upper Pico	
35	Fair	Upper Pico	
36	Good	Upper Pico	
37	Poor	Post-Miocene	(Determined as upper Pico by Texas Company)
38	No forams	?	Contains a few fine sponge spicules
39	Excellent	Upper Pico	
41	Excellent	Lowermost Repetto	
42	Good	Repetto	Close to #45
43	Limonite casts	Repetto	
44	Good	Upper Pico	
45	Good	Repetto	Older than #52
46	Few forams	Upper Miocene	
47	Good	Low in Repetto	
48	Good	Repetto	
49	No forams	Upper Miocene	Sponge spicules and radiolaria indicative of upper Miocene
51	Poor	Could be Miocene or Pliocene	
52	Good	Top of Repetto	
55	Poor	Probably upper Pico	
56	Good	Upper Pico	
57	Good	Repetto	
58	Forams rare	Upper Miocene	Also sponge spicules present
60	Forams rare	Upper Miocene	Also sponge spicules present

Appendix II

Detailed field description of exposures in measured Puente section

Stratigraphic distance from Puente-Repetto contact scaled from areal map

Feet from top of Puente	Dip taken at exposure o=overturned	Description
At fault contact with Repetto	66S	Very fine grained diatomaceous shale. Laminations 1 to 2 mm, alternating white and light gray with small white discs.
20?	39S	Fine buff well bedded siltstone, 3" beds.
50	36S	Yellow-white finely bedded, brown stained shale, partly diatomaceous, crushed appearance.
80	Near 42S	Buff, well bedded, silty, with one-foot concretion bed.
100	o81N	White diatomaceous shale, flaky, 1mm to 1cm banding.
150	42S	Brownish gray with purple tinge, with many white discs, 2" bedded, diatomaceous shale. At foraminifera locality 58.
200	70S	Light yellow gray silty shale, 2" laminations.
300	27S	Buff to gray with white discs, ½" bedded, diatomaceous shale.
350	70S	Yellow-gray well bedded 1" layers of silty shale with a 3" band of concretions. Along Fremont Avenue.
400	48S	Light gray, ½" laminations of coarse to fine grained shale. Some sandy.
500	52S	Buff to gray, ½" bedded, sandy to diatomaceous shale. Pecten found.
550	53S	White and yellow ½" bedded fine grained shale.
650	63S	Yellow-gray, ½ to 2" bedded shale, a few 2" coarse sandstone beds. Slightly contorted.
700	56S	Gray shale with brown streaks, some sandy, probably diatomaceous, laminations ¼ to 1".
1000	83S	Buff to gray, sandy, ½" bedded shale.
1200	o81N	Yellowish, poorly bedded shale. Looks like siltstone.

Appendix II (cont.)

Feet from top of Puente	Dip taken at exposure o=overturned	Description
1450	o80N	White, probably diatomaceous, coarse, to fine bedded shale. Yellow 20' higher in section.
1500	o80N	Gray to brown, ½" bedding, silty to diatomaceous shale.
1950	o72N	Buff to yellow sandy conglomerate layers up to 2', cross-bedded, maximum pebble size 3", average ½", pebbles almost all white granitic, well rounded. Definitely overturned, coarser pebbles on top grading to sand at bottom. White to yellow shale bands between conglomerate. Zone is 15' thick.
2250	o35N	White diatomaceous shale with white discs 3mm in diameter.
2290	------ Contact	between upper shale and middle sandstone -----
2300	o43N	White and light yellow, fine grained, friable sandstone beds up to 6' thick, of quartz and biotite. 80% sandstone, 20% white laminated shale beds. Excellent overturning evidence in variation of grain size in sandstone layers.
2350	74S	White friable medium grained sandstone with 20% shale.
2500	o68N	Yellow massive coarse to medium grained friable sandstone. A few sandy shale beds (10%). Fractured and apparently contorted.
2700	o76N	Buff fine and coarse, friable sandstone (70%) and shale. Good overturn evidence.
3100	88S	Buff fine to medium grained sandstone with 30% of white shale bands.
3200	87S	Buff, massive, friable, medium grained sandstone with 5% of 6" shale bands.
3350	------ Contact	between middle sandstone and lower shale -----
3450	70S	White diatomaceous shale, ½" beds.
3500	17E &26E	White, partly diatomaceous shale, ½" beds, on north flank of anticline.

Appendix III

Saugus section along Garfield Avenue

Thickness	Description	Note: Dashed lines separate mapped units.

Upper Pleistocene terrace and alluvium.

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500 Brown to light gray fine sub-rounded massive conglomerate, average size ¼", maximum 2", moderately hard, containing much coarse sand. Poorly exposed. Pebble sample #4.

---

200 Buff siltstone fairly well bedded, some shaly portions.

---

20 Buff conglomerate beds in sandstone and siltstone, well rounded, poorly sorted, average size 1".

(Thicknesses above computed from distances scaled on areal map)
(Thicknesses below were paced or estimated on road cut)

---

350 Buff siltstone, well bedded with bands from 1" to 15' thick. Fault 278 feet from top. Dip nearly along bedding plane.

4 Yellow cross-bedded sandstone lensing upward, with 6" conglomerate layer at base. Shale cobbles rare. (See pl. III, C)

177 Buff well bedded siltstone with a few concretions.

---

25 Buff sandy conglomerate, more sandy above, sub-rounded. Overlaps on siltstone at base.

25 Buff bedded siltstone with a few granitic pebbles five feet from top. Siltstone block 3' in diameter at base.

174 Yellow to gray series of gradational sandstone, pea gravel, and well rounded conglomerate with some silt pebbles and cobbles. Indefinite boundaries prevent making a careful description. Pebble sample #8 at top. #7 is 15' lower.

2 Brown conglomerate bed with large sandy siltstone blocks of 1' ave. size making up 70% of volume. Coarse gravel in matrix.

12 Buff siltstone with some pebbles and siltstone fragments.

5 Brown conglomerate bed with a sandy base containing a shale boulder. Upper part is coarse conglomerate with an irregular base as though a series of conglomerate mud-inclosed balls were buried in the sand (pl. III, A & B). Pebble sample #6.

11 Nearly white sandy shale with a 1' white pea gravel lens.

10 Yellow well sorted pea gravel size conglomerate. Pebble sample #5.

Pico siltstone.

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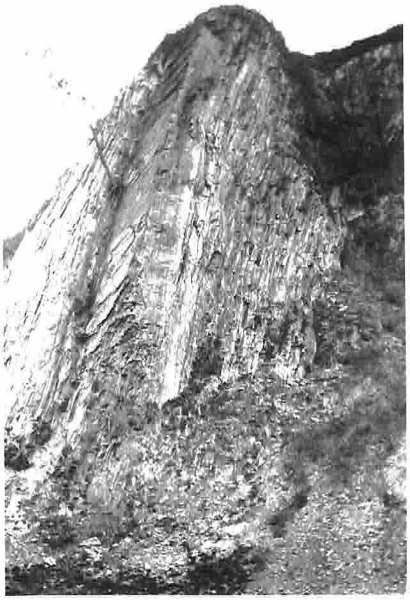
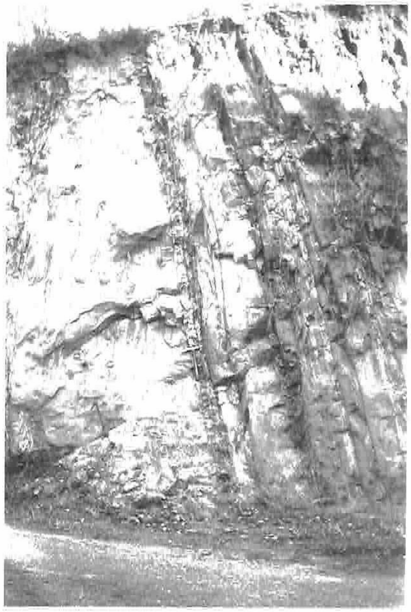
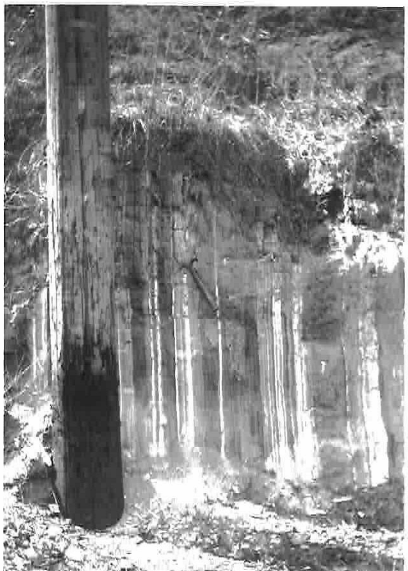
Plate I



A. Diatomaceous shale near base of upper Puente shale member. On north flank of anticline at 77 N dip .1 mile NW of Valley Blvd.



B. Middle Puente sandstone with shale stringers. Located .1 mile south of anticline axis and .1 mile west of Valley Blvd.

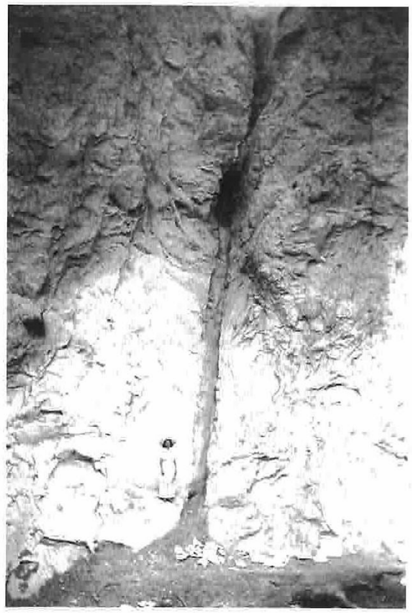


C. Middle Puente sandstone with white shale bands. Beds are overturned. On section AB at 88 N dip .1 mile south of anticlinal axis.

D. Local crushing at the contact of middle Puente sandstone with upper Puente shale. Located on the north flank of anticline where contact crosses Valley Blvd.

Plate II

A. The 3½-foot bed of coarse sandstone with a few pebbles 92 feet below top of Repetto formation. Located .1 mile west of Atlantic Boulevard.



B. Coarse brown sandstone bed 18 inches thick, at Repetto-Pico contact. Located .3 mile up Repetto Canyon.

C. Fossiliferous sandy conglomerate bed on fractured siltstone. Marks top of lower Pico. Located 30 feet south of fault, .2 mile up Repetto Canyon.

D. Overturned calcareous sandy fossil bed in upper Pico member. East side of Repetto Canyon at its mouth.

Plate III

A. and B. Shale, sandstone, and conglomerate bed 21 feet up from the base of the lower Saugus conglomerate unit. Shale slab visible in sandstone. Conglomerate pockets extend down into sandstone. At south end of Garfield Avenue pass in front of power house.

C. Sandstone lens in lower Saugus shale unit. Horizontal striations visible one foot above hammer. At south end of Garfield Avenue pass 70 feet north of minor fault.

D. Terrace gravels filling fault crack in upper Pico siltstone. Located .2 mile due south of Montebello oil field offices.

Plate IV

A. Cross-bedded sandstone in lowest Saugus conglomerate bed. In rock quarry .3 mile west of eastern tip of Montebello Hills.

B. Sandy terrace gravels dipping 20 degrees south. Where Eastern Avenue leaves south slope of Repetto Hills.

C. Contact between Saugus siltstone and terrace gravels on S side of Montebello anticline. Terrace dips 23 degrees south. Just within the Alhambra Quad. sheet .2 mile north of Avenida de la Merced.

D. Flat lying terrace gravels on top of Montebello Hills. At intersection of anticline axis and section EF.

Plate V

A. Faulting and drag in middle Puente sandstone. On north flank of East Los Angeles anticline.

B. Irregular contact of Pico-Saugus unconformity. In quarry .2 mile east of Garfield Ave.

C. Angular unconformity between Pico siltstone and Saugus conglomerate. In Sycamore Canyon quarry just north of the Edison power line.

D. Terrace surface looking S along Repetto Canyon. Picture taken from terrace at Garvey Avenue and Repetto Canyon.

Plate VI

A. Terrace surface on both sides of Atlantic Avenue Canyon. At intersection of Atlantic Avenue and Edison power line.

B. Terrace surface looking S toward Edison power line along Atlantic Avenue Canyon. Same surface shown in A.

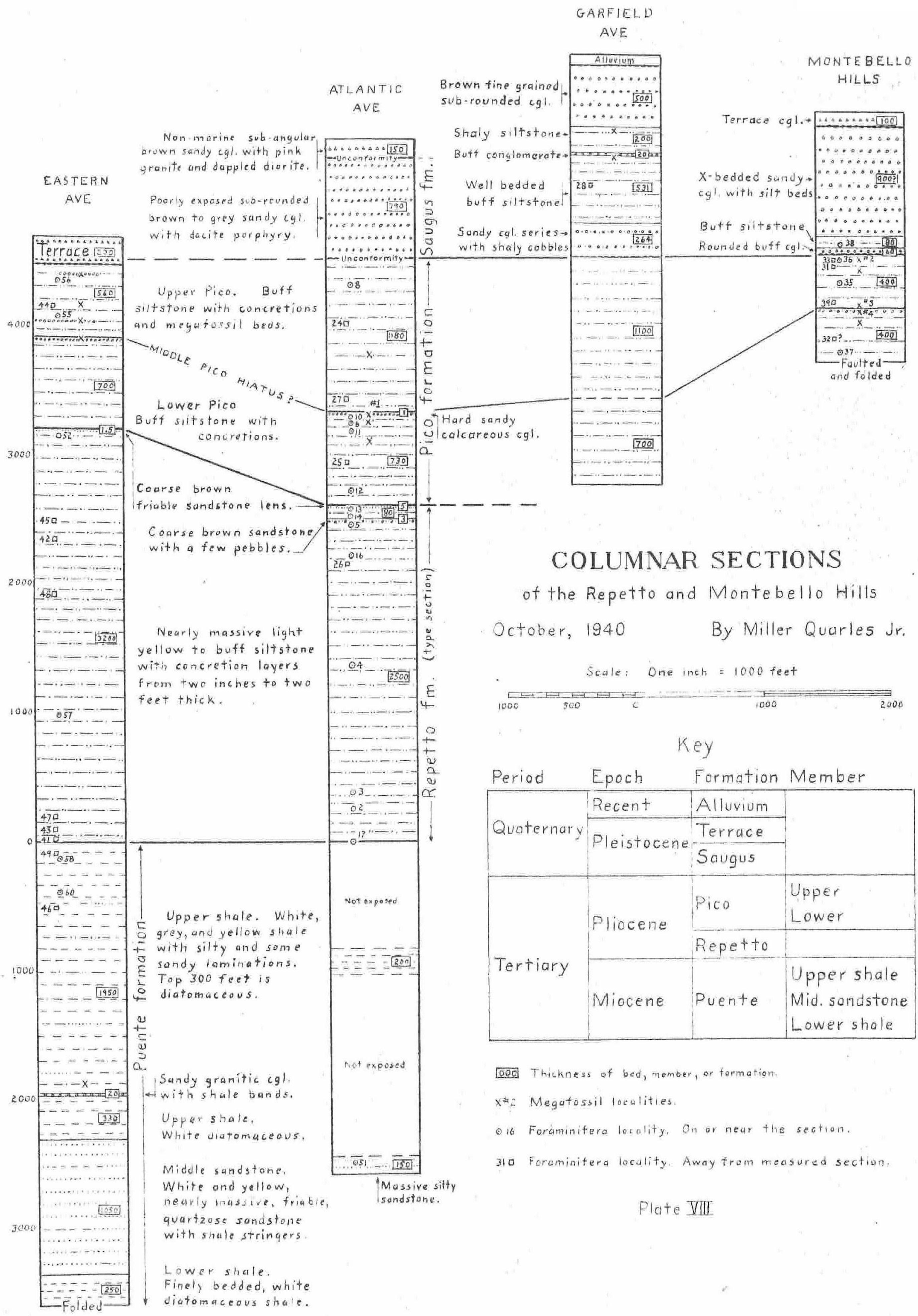
C. Another view of terrace surface near south end of Atlantic Avenue Canyon.

D. Sloping terrace surface at west end of Montebello Hills. Looking SE towards new Montebello oil field from Saugus conglomerate hill below double Edison power line.

Plate VII
Petrologic comparison of Terrace and Saugus conglomerates

Field classification	Sample number	East-west position*	Total pebbles	Pink granite	White granite	Diorite	Dappled diorite	Banded gneiss	Felsite	Dacite porphyry	Blue schist	Hornblende schist	Mica schist	Quartzite	Miscellaneous	Approximate location
				Pebble classification												
Certain terrace	1	W	680	20	43	25	4.4	1.9	2.1	0	0	.3	.6	1.9	1.3	Atlantic Boulevard
	2	W	550	19	56	17	6	.7	.4	0	0	.7	.2	.5	.2	Atlantic Boulevard
	3	W	584	21	29	39	7	1.2	1.[illegible]	0	0	.3	0	.7	.9	Atlantic Boulevard
	13	M	622	20	40	22	9	4.3	2.4	0	0	.2	1.4	.8	.3	Garvey Drive
	23	M	650	47	21	22	1.5	2.8	1.4	.3	0	1.4	2.3	.5	.2	Beverly Boulevard
	27	W	653	28	45	16	2.6	4.1	.5	0	0	.5	.2	2.0	.8	S. end Repetto Canyon
	28	W	732	25	49	12	8	3.0	1.0	.3	0	.1	0	1.5	.1	Garvey Ave & P.E. Ry.
	29	W	533	36	43	11	5	4.1	.4	0	0	0	0	1.3	0	Garvey Ave & P.E. Ry.
	Sub Ave.			27	41	20	5.4	2.8	1.2	.1	0	.4	.5	1.1	.4	
	24	M	535	26	19	7	.6	16	19	8	1.7	.9	.7	1.3	0	Above #25, Mesa Drive
	22	E	758	9	32	16	1.7	14	13	7	5.4	1.2	.9	1.3	0	Over #21 SE oil field
	Average			25	38	19	4.7	5.2	4.1	1.6	.5	.5	.6	1.2	.3	
Probable terrace	15	E	461	46	23	20	2.2	5.9	2.8	.8	0	0	.4	1.3	.4	N. Mesa Dr., in gulch
	19	E	443	24	36	10	.2	9	14	2.7	1.1	.5	0	2.9	0	Mouth Sycamore Canyon
	16	E	506	14	24	18	1.0	11	17	10	.8	.4	1.4	2.4	.[illegible]	Potrero School gulch
	25	M	719	17	24	5	.6	19	19	10	3.1	.6	1.0	1.1	.3	Below #24, Mesa Drive
	Average			25	27	13	1.0	11	13	5.7	1.3	.4	.7	1.9	.2	
Probable Saugus	18	E	668	8	47	[illegible]	.3	10	15	9	[illegible]	0	.4	1.6	.1	Sycamore Quarry
	20	E	660	10	59	12	.3	7	7	1.5	2.3	.5	0	.9	0	East end of area
	26	M	672	7	55	6	0	7	.8	5.0	.4	0	.1	3.0	0	Mesa Dr. near middle
	14	M	630	.5	59	8	.2	4.6	10	4.4	.6	.2	.5	2.4	.2	Garvey Dr. & New Ave.
	Average			6	55	9	.2	7	15	4.5	.9	.2	.3	2.0	.1	
Certain Saugus	4	W	496	.8	65	6	.2	3.4	14	4.6	0	.2	0	5	0	SW of Garfield Avenue
	6	W	946	.2	61	13	0	6	9	9	.1	0	0	2.0	0	Garfield cut 10' ab 5
	5	W	613	.7	51	11	0	6	15	12	.2	.5	0	2.8	.3	Garfield cut at base
	7	W	471	0	60	17	.4	7	6	8	.2	0	0	2.3	0	Garfield cut below #8
	8	W	578	.5	66	12	.3	5	8	3.1	0	0	0	4.3	0	Garfield cut at top
	9	M	318	.6	66	2.8	.6	4.4	11	7	.6	.3	0	4.7	1.3	Monterey Pk reservoir
	10	M	696	2.3	64	8	.4	7	7	9	.1	0	.1	2.4	0	Monterey Pk S. of #14
	11	M	510	8	54	6	0	6	13	9	.2	.2	.8	3.5	.4	S. extension New Ave.
	12	M	520	3.5	65	2.9	.2	8	11	4.6	.8	.8	0	2.5	.8	500 feet S. of #11
	17	E	548	3.1	54	8	.4	10	12	8	.9	1.2	0	2.0	0	SE of Potrero School
	21	E	446	7	55	3.8	.2	9	15	7	2.2	.2	0	1.1	0	Below 22 SE oil field
	Average			2.4	60	8	.2	6	11	7	.5	.3	.1	3.0	.3	

* W = Garfield Avenue and west.
M = East of Garfield Avenue to edge of Quadrangle.
E = El Monte Quadrangle.



COLUMNAR SECTIONS

of the Repetto and Montebello Hills

October, 1940 By Miller Quarles Jr.

Scale: One inch = 1000 feet

1000 500 0 1000 2000

Key

Period	Epoch	Formation	Member
Quaternary	Recent	Alluvium	
	Pleistocene	Terrace	
		Saugus	
Tertiary	Pliocene	Pico	Upper Lower
		Repetto	
	Miocene	Puente	Upper shale Mid. sandstone Lower shale

[000] Thickness of bed, member, or formation.

X#2 Megafossil localities.

⊙16 Foraminifera locality. On or near the section.

31□ Foraminifera locality. Away from measured section.

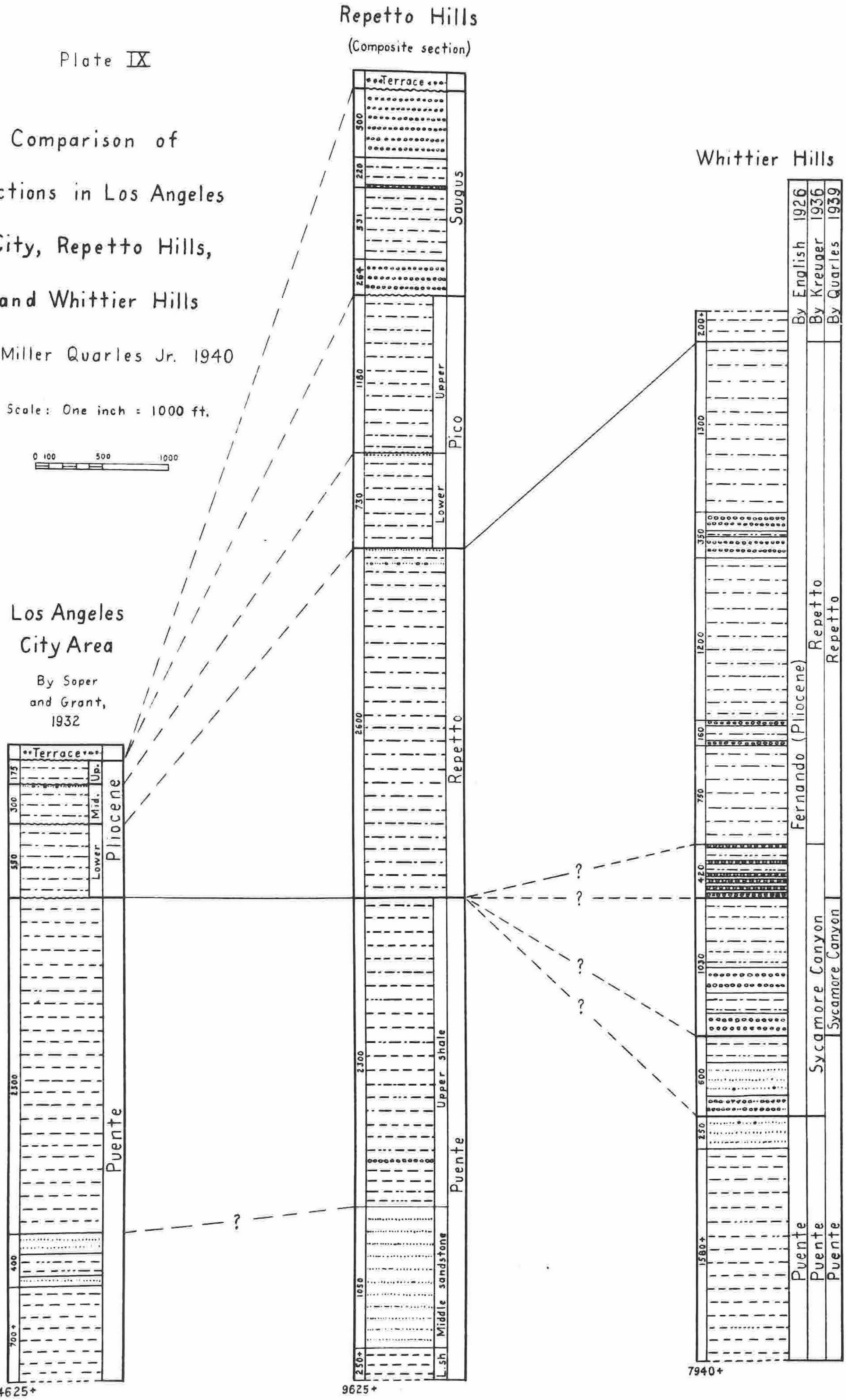
Plate VIII

Plate IX

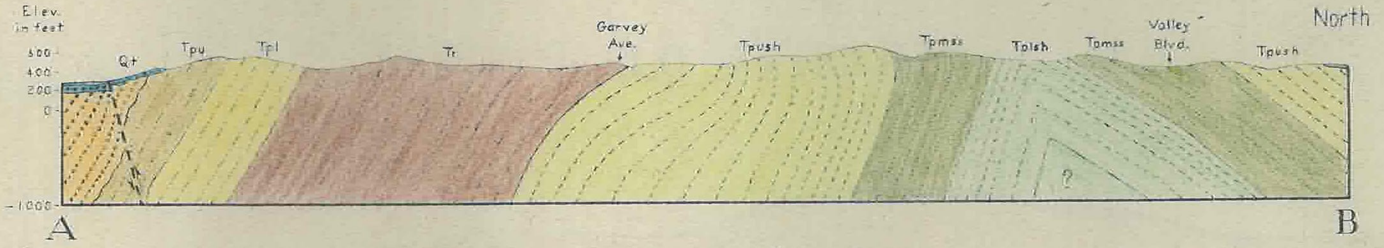
Comparison of sections in Los Angeles City, Repetto Hills, and Whittier Hills

By Miller Quarles Jr. 1940

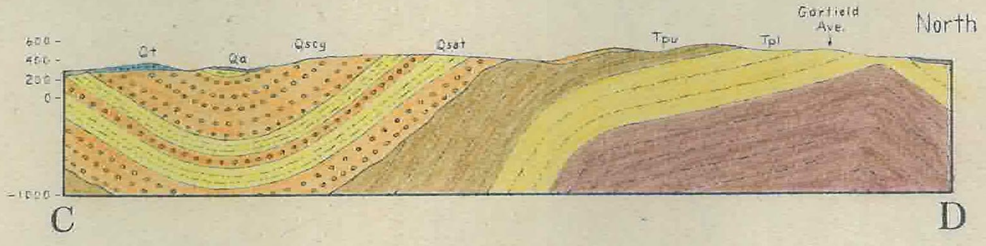
Scale: One inch = 1000 ft.



N-S SECTIONS ACROSS REPETTO HILLS



At west end of area near Eastern Avenue



South of Monterey Park near Garfield Avenue

Plate XI

For legend see map

Vertical and horizontal scales equal 0 1000 2000 3000 4000 5000 ft.

By Miller Quarles Jr. 1940

N-S SECTION ACROSS

MONTEBELLO ANTICLINE

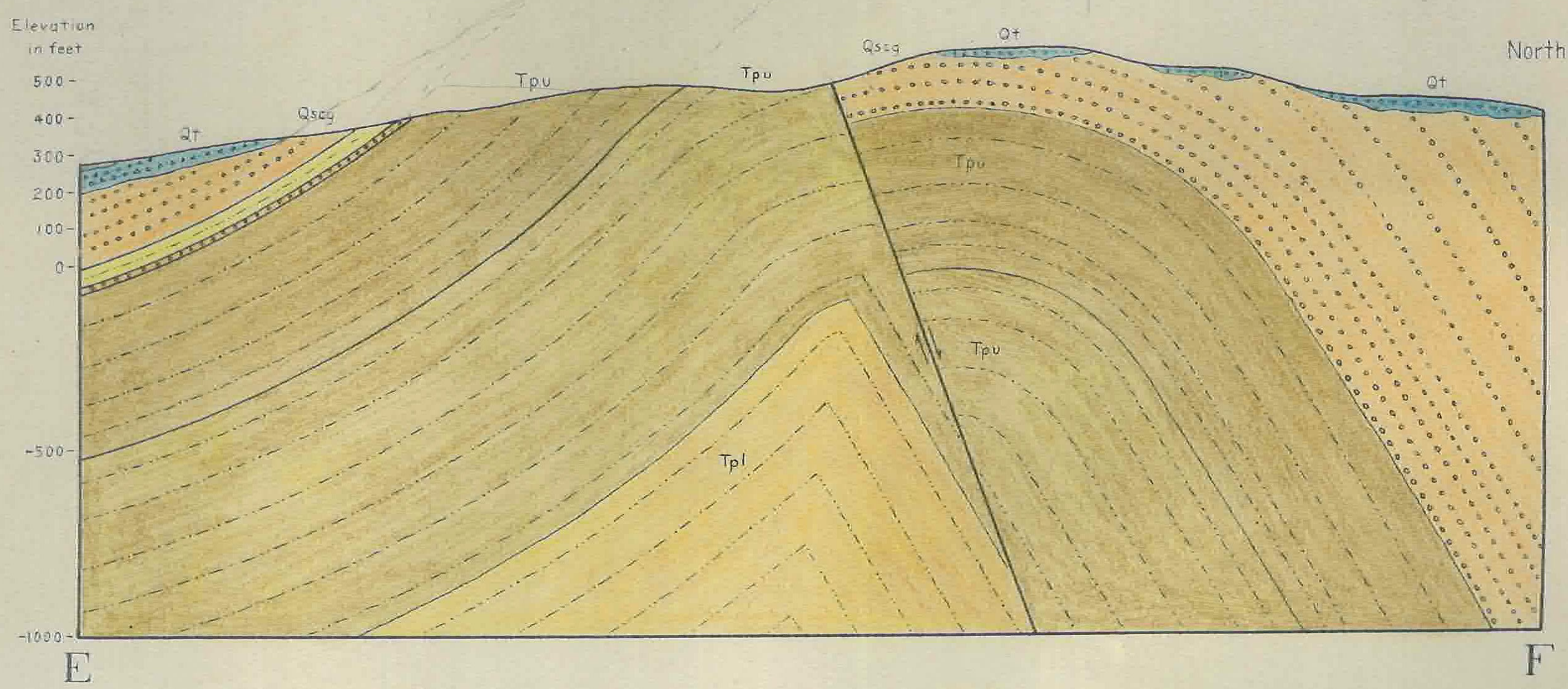


Plate X

· For legend see map ·

Vertical and horizontal scales equal - Four times size on areal map

0 100 500 1000 1500 Ft

By Miller Quarles Jr. 1940