GEOLOGY OF THE LAS FLORES AND DRY CANYON QUADRANGLES, LOS ANGELES COUNTY, CALIFORNIA

Thesis by

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MAPS AND ILLUSTRATIONS

ABSTRACT

The Santa Monica Mountains trend in an east-west direction and in this region lie north of and parallel to the sea. The area included in this report consists of a strip of land six miles wide and ten miles long reaching from the sea northward to the west end of San Fernando Valley. It is, then, a section six miles wide directly across the axis, and in the center of the Santa Monica Mountains in southern California.

The rocks are highly faulted, the faulting increasing in intensity toward the sea. The older sediments are on the south side of the range, the younger on the north. A fairly complete section is present from upper Cretaceous to upper Miocene in age.

The Cretaceous Chico and Eocene Martinez formations have not been separately mapped. They are represented by a maximum possible thickness of about 6000 feet of conglomerates, sandstones and shales, the thickness probably being far less than that figure. A few limestone reefs are present, particularly in the Martinez. In both the Chico and Martinez beds conglomerates of well rounded cobbles are very characteristic and serve, generally, to identify immediately the age of the sediments containing them.

About 4000 feet of Sespe beds, mostly continental in origin, are present. The strata consist of a coarse, arkosic sand containing scattered pebbles, the entire body being usually a pink or pinkish purple color. The age may be

anywhere from upper Eocene to lower Miocene but it is thought that at least the upper part of the section present is Vaqueros (lower Miocene) in age. No fossils were found in the formation.

The middle Miocene is represented by a thickness of Topanga beds varying in thickness from 3,630 feet to 9000 feet. In Old Topanga Canyon the strata consist of alternating beds of yellow sandstone, shale and some conglomerate. Fossils are fairly abundant and are characterized by a Turritella ocoyana fauna. To the west the beds thicken remarkably and a lower member 4000 feet thick is present. This member consists almost entirely of a coarse, massive, yellow sandstone containing a few specimens of Turritella ocoyana near its base. It is overlain by 5000 feet of sandstones, shales and conglomerates, much the same lithologically as the beds in Old Topanga Canyon. Intrusions of a black basalt occurred in middle Topanga time. The basalt appears to have been nearly all intrusive and was accompanied by considerable minor faulting.

The Topanga formation is overlain with marked unconformity by siliceous and punky shales of Modelo (upper Miocene) age. The shales grade very rapidly laterally into sandstone lenses, some of them of considerable size. Both pre-Modelo and post-Modelo folding has occurred. No beds younger than Modelo in age are found in the area. As the Modelo was the last formation to be deposited it is now being rapidly eroded and the thickness of Modelo beds exposed is exceedingly variable. At no place in the area does it exceed 3000 feet.

Faults are numerous and, in general, form two systems, one east-west, the other north-south in direction. The two largest faults in the area are the Topanga (east-west) and the Las Flores (north-south) faults. The latter has the largest displacement of any fault in the area, namely 2000 feet.

Several large folds have been developed with their axes trending in a north-northwest direction. Some of the folding occurred in pre-Modelo time but most of it occurred after Modelo deposition, the original folds being further steepened, the axes of folding remaining the same.

INTRODUCTION

The fifty square miles mapped comprise most of the Las Flores and Dry Canyon quadrangles in the Western Santa Monica Mountains. The two quadrangles include a strip six miles wide and eight to ten miles long reaching from the sea to the western end of the San Fernando Valley. The area is directly west of and adjacent to the area mapped and described by H. W. Hoots in the U. S. Geol. Survey Prof. Paper 165-C[1]. This paper is, in a sense, a continuation to the west of the work of Dr. Hoots although a great deal of the field mapping was done before Prof. Paper 165-C was available. The writer has made a very definite attempt not to duplicate any of the work of Dr. Hoots. This paper, therefore, is not entirely complete within itself but should be accompanied by parts of Prof. Paper 165-C. For example, although lists of fossil species will be included in this paper the collection and identification of fossils has not been nearly so detailed as would have been the case if good fossil lists from the adjacent region had not been available. Instead of duplicating work already done more extensive [redacted] and detailed mapping and stratigraphic study was pursued, much of it in hitherto unexplored territory.

A definite attempt has been made by the writer to make

(1) Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains Los Angeles County, California: U. S. Geol. Survey Prof. Paper 165-C, 1931.

this paper as short and concise as possible. Only new material is presented and most of it appears on the maps and structure sections.

PREVIOUS GEOLOGICAL INVESTIGATIONS

H. W. Hoots in Prof. Paper 165-C gives an excellent and exhaustive bibliography of previous work in the Santa Monica Mountains. In preparing this report the only publication on the area of any value whatsoever was Dr. W. S. W. Kew's U. S. Geol. Survey Bull. 753[1] and that covered only the northern third of the area.

C. A. Waring's paper[2] on the Martinez and Chico is chiefly a faunal study and the mapping was done on too rough a scale to be any assistance in the preparation of this paper. Most of the work apparently was done by a Stanford University geology party of which Waring was a member.

(1) Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California: U. S. Geol. Survey Bull. 753, 1924.

(2) Waring, C. A., Stratigraphic and faunal relations of the Martinez to the Chico and the Tejon of southern California: California Acad. Sci. Proc., 4th ser., vol. 7, No. 4, pp. 53-57, fig. 3, 1917.

FIELD WORK AND ACKNOWLEDGMENTS

This report represents the results of something over three months work in the field and about two months of office and laboratory work. A great deal more detailed mapping should be done, particularly in the southern third of the area. It is quite possible that further detailed mapping of individual beds would allow a separation of the Martinez from the Chico beds. Both the Chico-Martinez and the Sespe in the southern area are generally rather inaccessible and mapping of individual beds would require the expenditure of considerable time but the problem is of sufficient interest to warrant it, in the writer's opinion. It seems highly probable, also, that Vaqueros beds are not missing. The writer believes that further detailed work would show that either the uppermost "Sespe", or a thin fringe of lowermost "Topanga" in the extreme southwest corner of the area, would contain a _Turritella inezana_ fauna.

The writer wishes to gratefully acknowledge the assistance and supervision given him by Dr. W. S. W. Kew who has generously given a considerable amount of time to discussion, criticisms and suggestions of the mapping methods of the writer and the results obtained from the field. Mr. W. P. Popenoe has greatly assisted in identification of macro-fossils.

GEOGRAPHY

The Santa Monica Mountains trend in an east-west direction, the crest of the mountains lying about two miles from the sea with Saddle Peak as the highest point in the area - 2808 feet above sea level. Topanga Creek on the east and Malibu Creek on the west border the area as they flow south to the sea. Midway between them is Las Flores Canyon, nearly as large as the other two; between the large canyons are smaller ones including Tuna, Pena, and Carbon canyons. All contain streams running nearly directly south into the sea. Probably all these canyons have been carved consequent of uplift, with the exception of Las Flores Canyon which has been cut in the loose breccia and shattered zone of a large fault.

The tributaries of Malibu Creek extend up to the northernmost limits of the area, all the drainage being ultimately to the south. In the northeastern part of the area, however, the Dry Canyon drainage is north, eventually reaching the Los Angeles River. Although Topanga and Malibu creeks carry water all during the year, the northern drainage (Dry Canyon) seldom carries a stream.

Topanga Canyon contains the only road across the Santa Monica Mountains in this region. A road up Tuna Canyon joins the Topanga Canyon road about four miles from the sea.

In general the area is accessible over its northernmost two-thirds and rather inaccessible over the southern one-third. The latter region has considerably greater relief than the former and, because it receives more moisture from fogs, is more densely covered with chaparral.

GENERAL GEOLOGY

Stratigraphy

The oldest rocks in the area are of Chico age. Whether or not they lie on Santa Monica Slate of Triassic (?) age is unknown as erosion has not yet exposed their base. The Cretaceous rocks are overlain with apparent conformity by rocks of lower Eocene (Martinez) age. Upper Eocene rocks are lacking, the Martinez beds being overlain by beds of unknown age, tentatively considered to be Sespe (probably Oligocene or lower Miocene in age). The middle Miocene is well represented by nearly 10,000 feet of rocks of Topanga age. Between Topanga (lower middle Miocene) and Modelo (upper Miocene) time was a period of unknown duration in which no beds were deposited and widespread erosion occurred. No beds younger than Miocene are present in the area (excepting Quaternary alluvium).

It is seen, then, that the area was under water most of the time from late Cretaceous to the end of Miocene time.

Upper Cretaceous and Eocene Rocks

Chico and Martinez formations

The Chico and Martinez formations in the Las Flores quadrangle have not been separately mapped as a dense growth of brush and apparently very complex minor faulting has made such a separation nearly impossible. As one approaches the coast the intensity of faulting appears to increase, the three miles next to the sea being very badly broken up.

The Chico-Martinez is characterized mainly by thick sections of conglomerate containing very well rounded pebbles, the conglomerate being interstratified between massive beds of yellow sandstone, with some shale and quite a little limestone.

The conglomerate is compact and solid, well stratified and may be identified from a considerable distance by the rounded pebbles which stand out very resistant to erosion. The pebbles are very similar to many beach cobbles. They average 3 to 6 inches in diameter, are beautifully rounded and polished and consist of granite, porphyry, basalt and especially quartzite, all being very hard and compact. The matrix is a micaceous sandstone, sometimes with the greenish-brown tinge that Hoots mentions as so common in the eastern part of the range. It should be noted that the cobblestone conglomerate is not characteristic of the Chico alone but is found in abundance in the Martinez formation also.

The sandstone is quite massive, generally yellow or gray and occassionally weathers to a brilliant orange or red color particularly in the region between Little Flores and Tuna canyons. The yellow or gray sandstones often contain poorly preserved fossils most of which are unidentifiable.

A little gray shale is present and several limestone reefs may be traced over a considerable extent. The limestone is often filled with shell fragments, usually pieces of oyster shell.

If beds are not repeated by faulting, about 6000 feet of Chico-Martinez beds are present. Presumably all the strata are of marine origin and were probably deposited near a land mass of considerable relief, much greater, for example, than the present Santa Monica Mountains.

A section about 750 feet thick was measured in Tuna Canyon, east of the area included in this report but not included by Hoots in Prof. Paper 165-C.

Measured Chico-Martinez section in Tuna Canyon beginning at bottom of syncline about one-half mile south of big turn at upper end of Tuna Canyon:

Coarse yellow to white sandstone	50 feet
Black basalt intrusion	20 "
Fine yellow shaly sandstone weathered black	30 "
Fault	
Very hard, well cemented conglomerate of quartzite, granite, porphyry and basalt, cobbles up to one foot diameter, averageing 4-6 inches	300 "
Fault	
Intrusions of black basalt	10 "
Coarse white sandstone	15 "
Black basalt intrusion	20 "
Coarse, very massive, white sandstone	300 "
Large fault	
Strata dip south	
Total thickness measured	745 feet

The above description may give an idea as to the nature of some of the Chico-Martinez near Topanga Canyon.

The following fossil species were found in the Martinez formation at fossil locality f252:

Cucullea ? sp.

Cucullea or Glycymeris sp.

Modiolos sp.

"Tellina" sp.

Pholadomya nasuta Gabb

Venericardia pilsbryi Stewart cf. V. planicosta

Venericardia ? cf. planicosta

Oligocene and Lower Miocene Rocks

Sespe Formation

The rocks in this area mapped as Sespe formation are separated from the underlying and overlying beds purely on a basis of lithology. They consist almost entirely of a coarse, massive, arkosic sandstone of a bright purplish red color. There is little conglomerate and practically no shale present. Much of the sandstone, however, contains boulders scattered through it.

At this point the writer wants to make it clearly understood that the name Sespe is used as the name of a lithologic unit lying between the Martinez and Topanga formations, unfossiliferous, arkosic and poorly sorted as though of continental origin and may have any age from Eocene to lower Miocene inclusive. No definite correlation is attempted with the red Sespe formation at its type locality some 15 miles north of the red beds in this area. The name Sespe has been applied to beds of widely different age, from Eocene to lower Miocene, and the name is here used in that sense. The upper part or all of the Sespe in this area may prove to be Vaqueros in age if fossils are found.

Both the lower and upper contacts of the Sespe have been examined in a number of localities and no angular unconformity has yet been observed. North of the Saddle Peak road red Sespe sandstone underlies quite conformably coarse, yellow Topanga sandstone. At this locality there is a 15 foot stratum of peculiarly colored fine gray sandstone between the Sespe and the Topanga; it is characteristic of neither formation.

In Carbon Canyon the basal Sespe consists of 90 feet of coarse, white, arkosic sandstone with a few strata containing pebbles up to 6 inches in diameter. No real basal conglomerate is present. The grains average about 2-3 mm. in diameter. The pebbles are granites and quartzites and are mostly distinctly pink in color. The color effect produced by the sandstone is of a very light purple. The Sespe rests on 40 feet of medium-grained yellow sandstone which rests on conglomerate, presumably of Martinez age. The contact was drawn largely by change in color, the change being perfectly definite in nearly all cases and no difficulty was encountered in mapping on that basis. The attitude of the rock was measured in several places on both sides of the contact and the results compared. It was very difficult, however, to measure accurately the attitude of the Sespe as the beds are extremely massive and bedding planes are very crude. No nonconformity could be shown to exist. The Sespe section in this vicinity was estimated very roughly from a distance. Accurate measurement of thickness was impossible due to the extreme relief and abundance of dense brush. The roughly measured section is given:

Bright yellow and orange sandstones; probably Topanga
or Vaqueros in age but highly inaccessible .... 100 feet
Bright red sandstone and some conglomerate .... 100 "

Yellow-white sandstones containing pebbles	125 feet
Alternately yellow and pink sandstones containing pebbles	75 "
White sandstone with many thin conglomerate strata	200 "
Bright red sandstone with strata containing pebbles averaging 2-3 inches in diameter	130 "
Coarse, white, arkosic sandstone with a few strata containing pebbles up to 6 inches diameter	90 "
((Sespe and Chico-Martinez contact))	
Medium-grained, yellow sandstone	40 "
Conglomerate of rounded pebbles	. . .
Total thickness measured	820 feet

It should be noted that the Sespe grades along its strike from red into white and into some yellow sandstones.

The Sespe anticline exposed in the central part of the area consists mainly of red beds but about a tenth of the total thickness, occurring near the middle of the section exposed, is white.

The strip of Sespe downfaulted along the coast is considerably faulted in an east-west direction. In a few places a rather acid lava may be seen intruding the beds as thin dikes, also in an east-west direction. Mr. V. C. Kelley found broken rock fragments containing <u>Turritella inezana</u> lying on the beach south of these Sespe beds. It is not certain that the fragments were derived from the

Sespe cliffs directly north. If that were their source the so-called Sespe is at least in part Vacueros, a result that is not at all surprising. A Vaqueros (lower Miocene) age, however, has not yet been proved.

The Sespe strata are quite variable in thickness; it is believed that the maximum thickness of any one section of Sespe in the area is about 4200 feet.

Dr. W. S. W. Kew has very kindly furnished the writer with some generalized data on the Sespe formation from a well drilled in the Topanga anticline. A part of the data is here included to show the lithologic character of the Sespe section. Figures indicate the number of feet below the surface of the ground.

155 Pinkish gray sandstone and clay.

205 Gray to purplish very fine silty sand with scattered coarse grains.

260 Light gray loosely consolidated sand.

380 Light pinkish gray clay and fine sand.

700 Hard green compact metamorphosed rock which may be scratched by a thumb nail. Thin section shows scattered angular quartz grains in a greatly altered green matrix.

740 Sample similar to above.

800 Light gray unconsolidated sand.

850 Light gray silty sandstone with scattered pebbles.

890 Light gray sand with a few fragments of a green shale.

910 Massive tough green shale composed of a matrix of soft green material and fine angular quartz grains.

1000 Light gray fine sand containing fragments of a green shale.

1070 Gray fine sand containing pebbles of a purplish gray shale and a fine grained greenish shale.

1100 Light gray silty gravel containing subangular pebbles up to ½ inch diameter and scattered fragments of a light green material, probably chlorite.

1140 Light gray very coarse sand.

1155 Light gray sand.

((Contact with Martinez-Chico.))

1175 Light gray sand containing fragments of a rock containing a light green soft mineral, probably chlorite, and also fragments and grains of a dark gray shale.

1190 Light gray fine silty sand containing scattered grains of several minerals.

1200 Light gray sand containing angular to subangular fragments of a dark gray shale.

Sample 1175 is the first sample in which dark gray shale fragments were noted.

Miocene Rocks

Topanga Formation (Middle Miocene)

The Topanga formation was defined by W. S. W. Kew in 1923[1] as the name proposed to include the rocks lying below the Modelo formation and above the Vaqueros formation and containing the <u>Turritella</u> <u>ocoyana</u> fauna. The strata are essentially sandstones. Formerly included in the Vaqueros formation (now restricted to the <u>Turritella</u> <u>inezana</u> fauna). Unconformably overlies true Vaqueros formation and in Topanga Canyon is overlain with marked unconformity by the Modelo formation. ((The preceding paragraph was taken from Wilmarth[2].))

The Topanga formation in this area is characterized by several very significant features. First, it must be noted that the Topanga beds rest without observed nonconformity on Sespe red beds and are overlain with extreme nonconformity by the Modelo formation. An excellent starting-

(1) Kew, W. S. W., Geologic formations of a part of southern California and their correlation: Am. Assoc. Petroleum Geologists, Bull., vol. 7, no. 4, pp. 411 - 420, July-August, 1923.

(2) Wilmarth, M. Grace, Names and definitions of the geologic units of california: U. S. Geol. Survey Bull. 826, p. 91, 1931.

point for the study of the Topanga formation is the section between the Modelo and Sespe formations exposed in Old Topanga Canyon. Here a section was measured and the following data were collected:

Topanga Section Exposed on Old Topanga Canyon Road.

Brown and white Modelo shales	
Soft brown sandstone, probably Modelo. Angular quartz grains, some feldspar	100 feet
(Contact between Modelo and Topanga Sandstones.)	
Alternating brown and yellow sandstone with blue-gray and brown shale	25 "
Massive yellow sandstone. Mostly subangular quartz grains varying greatly in size	90 "
Blue-gray and soft yellow shales with a few thin beds of sandstone	20 "
Alternating massive brown sandstones and conglomerates. Boulders vary in size from 1 cm. up to 10 cms., are well rounded to subangular and consist largely of granites, granite gneisses and some dark, hard extrusives	40 "
Coarse, massive, yellow and gray sandstones including a few strata of conglomerate and shales, the latter being very thin-bedded, soft and bluish gray	80 "
Alternating beds of sandstone (up to 4 feet thick) and shale (generally less than 8 inches thick)	60 "

Poorly exposed section of yellow sandstones with some interbedded shales, about	350 feet
About equal amounts of bright yellow sandstone and gray shale. Contains a one foot stratum of very coarse sandstone (grains angular and up to 1 cm. diameter)	60 "
A very hard stratum of coarse sandstone	2 "
Yellow sandstone and a little gray and brown shale	40 "
Poorly exposed section of yellow sandstone and gray and brown shale	200 "
Coarse (up to 1 cm. diameter) yellow sandstone with a few beds of conglomerate with very well rounded boulders up to 4 inches diameter ...	45 "
Thick sandstone strata showing much crossbedding alternating with very thin shale strata	30 "
Poorly exposed section of coarse sandstones and fine gray shales	150 "
Mostly thin soft yellow and gray shales with some sandstones; standing nearly vertical	60 "
About equal amounts of yellow sandstone (strata averaging 3 feet in thickness) and shales. Shale boulders noted in the sandstone; standing practically vertical	175 "
Poorly exposed section consisting of about two-thirds gray and yellow shale and one-third yellow sandstone in beds up to 3 feet	

thick	500 feet
Alternately yellow-brown sandstones and gray shales (about two-thirds of total) ..	80 "
Blue sandstone, medium grained	2 "
Alternately yellow sandstone and gray shale	30 "
Badly warped and folded section caused by basalt intrusion beginning 40 feet to east of road cut and reaching a maximum of 200 feet in thickness. Mostly sandstone, some shale. This is along the strike of the highly fossiliferous f139 and is also highly fossiliferous	40 "
Highly fossiliferous, massive, medium grained yellow sandstone	120 feet
Alternately sandstone and gray and yellow shale. The sandstone is thin-bedded, up to 2 feet thick	90 "
Massive yellow sandstone interstratified with a few thin (about 2 feet) strata of yellow shale, yellow and blue shale, and a few thin beds of sandstone	70 "
Highly contorted section of equal amounts of sandstone and shale and containing a 3 foot bed of intruded basalt which is badly shattered and weathers in concentric shells	50 "
Contorted and generally overturned shale with some yellow sandstone intercalated. Possibly a fault cuts the middle of the section	120 "

Massive yellow sandstones with a few strata of shale	25 feet
Blue and yellow shales with a few strata (up to 2 feet thick) of yellow sandstone	90 "
Very hard black intrusive basalt	15 "
Yellow and gray shales	25 "
Massive yellow sandstone and a few thin beds of shale	150 "
Soft gray and yellow shales	90 "
Massive yellow sandstone	25 "
Green basalt weathering concentrically to black and red on surface	15 "
Bright yellow and also white massive sandstones, and a few shales	250 "
Blue clay	3 "
Coarse, massive, yellow sandstone	8 "
Blue clay	10 "
Very coarse massive yellow sandstone cut by 30 foot basalt dike at right angles to bedding	15 "
Bright purple intruded basalt mixed with gray sandstone	4 "
Yellow to gray sandstone	4 "
Bright purple intruded basalt mixed with sandstone	6 "
Alternately coarse yellow sandstone and conglomerate with a few beds (up to 3 feet thick) of blue clay	20 "

Blue sandstone .... 10 feet

Black, red and green basalt decomposing to a bright yellow clay .... 70 "

Alternately bright yellow sandstone and conglomerate (with well-rounded boulders averaging up to about 4 inches diameter). A few thin intrusions of basalt. The sandstone contains many large pectens .... 200 "

Coarse, purplish red, soft, arkosic, Sespe sandstone. 3,630 feet total

This section is characterized (first) by the presence of considerable shale and some conglomerate (between thin-bedded sandstone strata) and (second) by a great deal of basaltic lava intrusion.. Most of the lava is intruded as sills although some irregular dike masses are present. If the sills and strata are traced westward around the north nose of the Sespe anticline a very definite change in the lithologic character of the Topanga beds is noticed. They become decidedly more massive; the shale practically disappears, and beds of conglomerate become rare. At Calabasas Peak the beds have little lithologic similarity to the Old Topanga Canyon strata although they represent the same horizon.

South and west of Stunt's ranch approximately 4000 feet of Topanga sandstone are found, representing approximately the same horizons as those in Old Topanga Canyon. The strata, however, are extremely massive, thickly bedded and resistant to erosion. They stand up in great cliffs. erosion having removed the softer shale members. It should be noted that the Turritella ocoyana fauna was found at localities 277 and 280 in the south-west corner of the area not more than 700 feet from the base of the "Topanga" section. There is, then, little doubt that this 4000 feet of massive sandstone is Topanga in age.

South and north of Stokes Canyon are approximately 5000 feet of beds of Topanga age, bounded on the south by a large intrusion of basaltic lava and on north by Modelo shale. The strata consist of alternate beds of yellow sandstone and gray or brown shale with a few beds of conglomerate. Lithologically the beds are very similar to those in Old Topanga Canyon. Stratigraphically they are younger in age than the Old Topanga Canyon section. The combined thickness of the Stunt's Ranch and the Stokes Canyon series is estimated to be about 9,600 feet; that is, the maximum thickness of rocks of Topanga age exposed in this area is 9,600 feet. The lower boundary of this section is the Sespe red beds near Saddle Peak; the upper boundary is the Modelo shale 1½ miles north of Stokes Canyon. It will immediately be seen that there is a wide difference between this figure and that given for the Topanga section in Old Topanga Canyon, a section also bounded below by Sespe red beds and above by Modelo shale, a section only 3,670 feet in thickness. The discrepancy is explained as having two causes. The forst is a thickening of the Topanga strata to the west, a condition possibly resulting from an advance or withdrawal of the sea from the west. The second cause is greater post-Topanga and pre-Modelo erosion to the east than to the west. Hoots says that in the area to the east of Topanga Canyon the basalt intrusion occurred nearly all in middle Topanga time. It seems highly probably, therefore, that most or all of the beds north of Stokes Canyon, as they contain no basalt, are post basalt-intrusion. In Old Topanga Canyon, however, no post basalt-intrusion beds are present, a fact explained either by a sea withdrawing to the west or by greater erosion to the east than to the west. The latter explanation would postulate probably more elevation on the east side than on the west - again suggesting a sea advancing from the west.

The Topanga beds north of Tuna Canyon are extremely faulted and shattered. Dozens of small faults were noted but not mapped. Measurements of rock attitudes in this area mean very little as they generally are true only for one small block. It is believed that most of the faulting and shattering of the rock was directly connected with basalt intrusion. It was often difficult to determine whether or not basalt contacts occurred along true faults as in nearly every case a small displacement seemed to result from a basalt intrusion.

Fossils were found to be fairly abundant in the thin-bedded sandstone intercalated with shale. The more massive strata also contained fossils at occasional intervals. No attempt was made to make an exhaustive paleontologic study of the formation as very good collections have already been made and described by Dr. W. P. Woodring in Hoots' Eastern Santa Monica Mountains report. Fossils were collected, generally with the hope of zoning the Topanga formation but it was not found to be essential or possible to do so in the time allowed. A fossil list is included and an accurate description of fossil localities is given later in this paper

Fossils from the Topanga formation of the Las Flores and Dry Canyon quadrangles

	1	1Y	1Z	1A	1B	1C
Gastropods:						
1. Bruclarkia barkeriana Cooper				x		
2. Calyptraea costellata Conrad						
3. Calyptraea sp.	x					
4. "Cerithium" sp.						
5. Neverita cf. andersoni (Clark)						
6. Neverita sp.						
7. Tegula ? sp.	x					
8. Tritonalia edmondi (Arnold) ?	x					
9. Tritonia topangensis Arnold	x					
10. Tritonia topangensis Arnold ?						
11. Turritella ocoyana Conrad			x		x	x
12. Turritella inezana Conrad ?	x					
Lamellibranchs:						
13. Cardium schencki Wiedey	x					
14. Cardium ? cf. schencki Wiedey						
15. Chione temblorensis Anderson ?	x					
16. Clementia conradiana (Anderson)	x			x		x
17. Clementia conradiana (Anderson) ?						
18. Clementia ? sp.						x
19. Diplodonta ? sp.	x					
20. Dosinia sp.						
21. Glycymeris sp.						
22. Macoma cf. nasuta Conrad	x			x	x	
23. Macoma ? sp.				x		
24. Miltha sanctaecrucis (Arnold)						x

	1D	1E	1F	5	16	20	47	51	138	139	166	174	277	307
1.														
2.			x			x				x				x
3.										x				
4.										x				
5.	x		x			x			x		x		x	
6.							x							
7.														
8.														
9.														
10.										x				
11.		x				x			x	x	x		x	
12.														
13.														
14.						x								
15.														
16.		x							x					
17.											x			
18.														
19.										x				
20.										x				
21.										x				
22.						x			x					
23.										x			x	
24.					x	x								

	1	1Y	1Z	1A	1B	1C
25. Miltha sanctaecrucis (Arnold) ?						
26. Modiolus sp.						
27. Mytilus expansus Arnold	x					
28. Ostrea titan Conrad		x				
29. Ostrea sp.						
30. "Pecten" nevadanus Conrad						
31. "Pecten" nevadanus Conrad ?						
32. "Pecten" raymondi brionanus Trask						
33. "Pecten" raymondi brionanus Trask ?						
34. Phacoides richthofeni (Gabb)	x					
35. Saxidomus ? sp.						
36. Solen sp.	x					
37. Tellina ? sp.						
38. Zirfaea dentatus (Gabb)					x	

Remarks:

All turritellas of the Turritella ocoyana group (e.g. Turritella temblorensis Wiedey and others) have simply been classified as Turritella ocoyana because there appear to be present specimens representing intermediate stages between all forms.

The specimen of Turritella inezana ? perhaps has been reworked from lower Miocene beds.

As far as the writer knows this is the first reported discovery of Zirfaea dentatus in the Santa Monica Mountains.

	1D	1E	1F	5	16	20	47	51	138	139	166	174	277	307
25.										x		x		
26.						x								
27.						x				x				
28.						x			x					
29.				x							x		x	
30.					x	x		x						
31.											x			
32.							x							
33.					x							x		
34.														
35.										x				
36.						x				x				
37.										x				
38.														

Middle Miocene Basalt

All the basalt in this region apparently has been intruded or extruded during middle Topanga time. The lava body reaches great dimensions to the west of the area and has intruded the rocks of the Las Flores quadrangle from the west, penetrating the strata in two long arms each connected with at least one large fault. South of Stokes Canyon the basalt contact is well exposed and is clearly not a fault contact. The basalt here is probably intrusive as there are no lava boulders in the overlying rocks nor is there other evidence pointing to the contrary. In Lark Canyon tongues of lava have intruded massive Topanga sandstones and faulting has followed. In general, however, the more massive beds south and west of Stunts ranch have not been affected by minor intrusive bodies.

The basalt in Old Topanga Canyon seems to be almost entirely intrusive. Some has paralled the bedding planes and upon being mapped shows readily the anticlinal structure present. Several irregular dike-like masses are present, some of them consisting of the hardest and most resistant rock in the region. The lava is mostly a reddish black basalt sometimes showing pillow structure; a great many amygdules of calcite and zeolites are present, particularly near the Topanga Post Office.

The black basalt in the vicinity of Crater Camp is mostly very soft, decomposes easily and characteristically weathers in small concentric masses of one to five inches diameter.

The basalt in the upper part of Dry Canyon is very similar to that at Crater Camp, being very black, soft, friable, and little resistant to erosion. It is believed to be intrusive; the relation of the large Crater Camp mass to it, however, is difficult to determine due to faulting complications. The upper Dry Canyon lavas and those just north of Cold Creek are believed to be greatly faulted but faults were not traceable through them.

The black basalt north of Stunts Ranch weathers to a reddish black clay that supports a heavy vegetation, particularly of scrub oak.

Modelo Formation (Upper Miocene)

Distribution and general character.

The"Modelo" of this report consists of upper Miocene shales and sandstones resting nonconformably on the Topanga formation and overlain only by Quaternary alluvium. The nonconformity represents a period of intense folding as well as uplift and erosion. The Modelo formation of this report is of marine origin throughout and is composed of two members which appear to be conformable and to grade into each other. H. W. Hoots, in the eastern part of his Santa Monica Mountains area, experienced no difficulty in mapping separately the upper and lower members, but farther to the west he encountered great difficulty as sandstone and shale beds alternated near the contact with no characteristic beds above and below. In the Dry Canyon quadrangle the writer has found no characteristic and important difference between the lower and upper members near their contact. It was thought wise, however, to continue mapping the horizon considered by Hoots to represent the contact farther east. It must be kept in mind that the contact is not clear and distinct as it might appear from the map but merely represents a difficultly traceable horizon which may have some significance farther east. The upper and lower members of the Modelo formation, however, do have general characteristic differences and each member will be treated separately.

Lower member.

The lower member consists largely of shale with a few sandstone lenses, one of them very large. In Dry Canyon at the base of the Modelo formation a very hard, platy, white shale occurs. It is very resistant to erosion and a great cliff marks the Modelo-Topanga contact for several miles. It is in Dry Canyon that a zone of the foraminiferal species Valvulinaria californica is found - the first real basis for definitely locating the Santa Monica Mountains Modelo with reference to the Modelo and Temblor at their type localities. The occurrence of Valvulinaria californica just above the Modelo-Topanga contact would definitely place the Dry Canyon Modelo a very short distance above the "Button Bed" which Anderson, by use of macrofossils, defined[1] as the top of the Temblor. Between the Valvulinaria californica zone and the Button Bed lie only the "siliceous shales" which Cushman considers as marking the top of the Temblor, from a foraminiferal viewpoint.

The lower Modelo shows a decided amount of lateral gradation, even from shale into medium-grained sandstone. Near the mouth of Dry Canyon is a very large lens of sandstone. Its occurrence can hardly be explained except to assume that it was deposited in a deep trough on the otherwise fairly regular sea floor. The sudden lensing-out of the sandstone is very remarkable but seems to be

(1) Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: Cal. Ac. Sc., Pr. (3) G. 2: 155-248, (1905).

rather characteristic of both the lower and upper Modelo.

The shale varies a great deal in composition and appearance. Some is very hard, cherty and finely banded. Some is soft, thin-bedded brown shale associated with a little sandstone.

It should be noted that on the areal geology map in some places what is mapped as uppermost Topanga may be lowermost Modelo shale and sandstone. The Topanga beds are so badly folded that sudden changes in attitude are not always safe criteria for mapping the contact. At some places the contact was drawn at the base of the shale although it was suspected that a thin fringe of sandstone was also Modelo in age.

No attempt was made to measure carefully a section of Modelo, as Hoots has already made such a measurement nearby in well-exposed road cuts. The thickness of lower Modelo in the area is very variable but probably does not exceed 2000 feet.

Upper member.

The upper member of the Modelo formation is composed mostly of soft, punky, white, diatomaceous shale. Sandstone lenses are almost as pronounced as in the case of the lower member. The shale is well bedded and the laminae are very distinct in some cases; in others the laminae are not distinct and results of wave action can be seen

The thickness of the upper Modelo is exceedingly variable, in many places being dependent on recent erosion. It probably does not exceed 1000 feet.

Quaternary Rocks

Quaternary alluvium.

All the "Quaternary alluvium" mapped is non-marine, none of it consisting of marine terraces. In the stream channels it varies from coarse gravels and pebbles as in Topanga Canyon to fine gravel and soil as in Las Virgines Canyon. Generally, however, this stream alluvium is remarkably fine and not uncommonly supports crops.

In San Fernando Valley the alluvium is distributed very smoothly although crossbedding is common and the gravel, sand and silt is poorly sorted. None of the alluvium has become compacted and hardened to any considerable extent, most of it being easily eroded by streams.

Fossil Localities

The following list describes in detail all fossil localities mapped in the area. The localities will also be found marked in green on the areal map.

1. Along road north of Topanga Park. The section at this locality is as follows:

Unfossiliferous brown conglomerate .... 75 feet
Unfossiliferous yellow sandstone (partially
obscured) ....100 "
(1F) Thin bed of sandstone .... 2 "
Unfossiliferous coarse massive sandstone .... 20 "
(1E) Massive yellow sandstone .... 2 "
Unfossiliferous massive sandstone .... 15 "
(1D) Thin-bedded sandstones ....15 "
Minor fault (Very little displacement).
(1C) Light-colored massive sandstone .... 6 "
Unfossiliferous light-colored shattered sandstone 10 "
(1B) Highly shattered sandstone .... 15 "
Unfossiliferous shattered sandstone .... 5 "
(1A) Yellow sandstone partially leached white .... 10 "
(1Z) Yellow sandstone (Turritella zone) .... 3 "
(1Y) Yellow sandstone (oyster zone) .... 3 "

Total 281 feet

Beds dip about 33° S and strike N17°E.

5. South of Topanga Park. Yellow conglomerate and sandstone highly slickensided. Dips 25°E and strikes due N.
16. On ridge overlooking Montgomery ranch in Old Topanga Canyon. Within 200 feet of Sespe-Topanga contact. Conglomerates and sandstones.
20. One mile west of Carrapata-Topanga Canyon branch. Yellow sandstone indurated to the west.
26. One-half mile south of Calabasas Highlands. Coarse sandstone stratum containing fossils for 300 feet along ridge. No samples taken.
27. North of Calabasas Peak. Entire stratum mapped is a hard, highly fossiliferous sandstone, yellow to white in color.
47. North of Stokes Canyon. Pecten Horizon in yellow sandstone; 75 feet below contact with hard, platy, white Modelo shale.
51. In Dark Canyon. Float. Probably from south side of Dark Canyon.
72. One-half mile south of Mohn Springs. At highest point on knoll is 4 square feet of yellow sandstone containing 9 ribs, 3 to 6 inches long, and vertebrae, of a marine vertebrate indentified by Mr. E. L. Furlong as seal remains.
138. One-half mile south of Calabasas Highlands. Fossils in yellow sandstone stratum.
139. One-half mile south of Calabasas Highlands. Yellow sandstone (containing fossils) and shale. A great many more specimens present than were collected.

166. One-half mile northeast of Topanga Park, along trail. Attitude of strata undeterminable.

174. One-half mile south of Calabasas Peak. Many fossils, especially pectens, along ridge for 200 feet.

196. Three-fourths mile WSW of Garrapata-Topanga Canyon branch. Yellow Topanga sandstone. Oysters, _Turritella ocoyana_, small pectens and unidentified gastropods. No specimens taken. In road cut south of road.

252. On upper Las Flores Canyon road. Fossiliferous 15-foot stratum of yellow sandstone overlain by conglomerates containing very well-rounded cobbles.

277. South of Dark Canyon. Dozens of _Turritella ocoyana_ specimens, also oysters and other fossils.

280. South of Dark Canyon. Dozens of _Turritella ocoyana_ specimens in sandstone.

291. Between Carbon and Las Flores Canyons. Yellow sandstones overlain several hundred feet above by cobble conglomerates. Fossils are on trail north of road.

334. Highly fossiliferous limestone stratum about three-fourths of a mile northeast of Las Flores Canyon mouth. Fossils appear to consist entirely of small oysters of about 2 cm. diameter.

355. About one-half mile northeast of Las Flores Canyon mouth. All along trail for 200 feet are limestone beds, highly fossiliferous but very hard. Almost impossible to get out any complete fossils. Many small oysters present.

Structure

Post-Topanga and Pre-Modelo Deformation.

One of the greatest periods of deformation in this area followed deposition of the Topanga sediments. Not only uplift but a great deal of folding occurred. In Topanga Canyon particularly may be noticed the extreme folding of the Topanga and older formations and the relatively unfolded Modelo shales. Uplift and erosion is apparent from the decided difference of attitude of Modelo and Topanga beds on either side of their contact. Folding, uplift and erosion all occurred after the beds of Topanga age were deposited and presumably before any Modelo beds were laid down. The amount of erosion is indeterminable but in general appears to lessen towards the west. It will be noted that anticlinal and synclinal axes in general are not continuous from Modelo to older beds, at least a part of the folding having occurred before deposition of the Modelo.

Post-Modelo Deformation

The Modelo beds have been folded into anticlines and synclines. It will be noticed, however, that the folds are generally quite shallow and, although usually not directly traceable down into older beds without change of attitude of fold axes, may broadly be traced into the older formations. It is, then, apparent that post-Modelo folding followed fairly closely the directions of pre-Modelo folding but was not so intense. Uplift, however, was great, the present mountain range being the result of a large uplift presumably in Quaternary time.

Folding.

The region north of the Topanga fault is rather uniformly folded, the anticlinal and synclinal axes all running about NNW. The folds are fairly broad and smooth. They dip rather steeply to the north, especially in beds older than the Modelo. The post-Modelo folding has exaggerated the previous folding but was not so intense as the previous folding.

The regularity and direction of the folding has been considerably broken by basalt intrusion but the same axes may be seen to continue on either side of the intruding basalt.

Besides the broad, northwestward-trending folds there are many minor deformations with no consistent orientation. This is particularly true of the Topanga formation which seems to have been unusually weak and easily folded in its upper or thin-bedded part. It is possible that all these irregular and intense local folds may be explained as being caused by local basalt intrusions. Faulting, minor folding and basalt intrusion all seem to be intimately related in the Topanga formation. The Sespe formation, on the other hand, being more massive and thick-bedded, seems to have faulted where the Topanga both faulted and folded and the former strata have generally quite successfully resisted basalt intrusion.

Faulting.

Faulting has been widespread and intense throughout most of the area. Many minor faults are directly connected with basalt intrusion. The larger faults have assumed a very definite pattern, being mostly confined to east-west and north-south directions. In general, intensity of faulting has increased to the south and presumably is very great off-shore to the south of the area. There are far too many faults to be all described in this paper but it is considered advisable to describe the more important ones, beginning at the north end of the area and progressing southward.

The northernmost fault system is that in upper Stokes Canyon paralleling upper Dry Canyon. Here, if one is to judge from the drag produced in beds in upper Stokes Canyon and north of the upper Dry Canyon lava field, there has been a progressively upward movement of the area to the east of each fault relative to the west side. The overturned bed in Stokes Canyon appears to have been dragged up from about 40° to approximately vertical.

The "Topanga Fault" appears to be an extension of the Topanga fault mapped by Hoots so is given the same name. The movement, however, has been up on the north side relative to the south - just opposite to the movement given by Hoots east of Topanga Canyon. It seems highly probable that the Topanga fault is directly connected with the upper Stokes Canyon fault. In this case a block of about 10 square miles in area has been raised with respect to its south and west border. Presumably the same block extends east of Topanga Canyon and is also bounded on the east by the Topanga fault. The entire block, then, has been tilted up to the west and down to the east. The displacement along the western extent of the Topanga fault was probably several hundred feet.

The area roughly bounded by the Topanga fault on the north, the Las Flores fault on the west and Tuna Canyon on the south has been exceedingly broken up by minor faults and intruded lavas. Two small faults are shown between Fernwood and the Carrapata-Topanga Canyon branch. The east fault dips 88°S and strikes N65°W. The west fault dips 68°N and strikes N7°E. Half a mile east of the Las Flores fault several minor faults were noted striking west and dipping about 45°S. As one proceeds south from these faults the number of small slips is seen to increase. Through all this region the measured dips mean very little as they are true only for individual blocks. The fault contacting the Topanga and Chico-Martinez sandstones is accompanied by many small fractures. On this fault the south block rose relative to the north

The Dark Canyon fault is of considerable importance but is not traceable to the northwest through the lava. The north side appears to have risen with respect to the south. The displacement was probably about 800 to 1000 feet (rough estimate).

The Las Flores fault is named from Las Flores Canyon which contains it through most of its extent. It is a large fault marked by a zone of great shattering and a long, very straight valley. The movement is thought to have been nearly all vertical, the west side having risen with respect to the east. The displacement was approximately 2000 feet. The dips measured in Las Flores Canyon are of little value due to the intense shattering of the rock.

Faulting increases towards the sea. The red Sespe beds bordering the sea stand practically vertical and are bounded on the north by a fault, the movement on which has been up on the north side relative to the south. Centrally located in these Sespe beds a fault is mapped. The dip of the fault is 35°S and the strike is N35°W. The fault zone is intruded by a band of bright green acidic lava about 3 feet in width which may have caused the fracture.

At the mouth of Las Flores Canyon is a small area containing beds of unknown age bounded by faults. The beds consist of a dark gray shale with pure white limy sandstone strata intercalated. In places the shale is highly contorted between uncontorted sandstone strata. No foraminifera or macrofossils were found in the beds and no correlation is made with any similar strata in the area.

The fault nearest to Big Rock, on the coast, is rather flat-lying and dips south. In general, the Sespe along the coast is highly faulted, especially parallel to the coast.

Physiography

The writer has had the pleasure of studying the coast along the border of the Santa Monica Mountains with Professor William Morris Davis who has already presented two papers(1)(2) on the physiography of that coast. Dr. Davis distinguishes three platforms, the earliest or Malibu platform being exposed at only a few localities, the second or Dume platform probably being below sea level along the western part of the coast but rising to nearly 300 feet above sea level at its easternmost known locality about three miles north of the city of Santa Monica, the third or Monic platform existing as the present sea floor.

The writer believes that remnants of the Dume platform exist just east of the mouth of Las Flores Canyon and also slightly west of the mouth of Piedra Gorda Canyon. The elevation at each locality is very nearly 275 feet above sea level. It is not known whether the 800 foot level west of upper Piedra Gorda Canyon can or cannot be considered as an earlier platform, perhaps to be correlated with the Malibu platform.

In general the profile of the Santa Monica Mountains in this area is rather subdued as may be observed by a

(1) Davis, W. M., Putnam, W. C. and Richards, G. L. Abstract. G. S. A. Meeting at Berkeley, Calif., 1930.

(2) Davis, W. M., The shorelines of the Santa Monica Mountains, California: Abstract. G. S. A. 13 annual meeting; at Calif. Institute of Technology, 1931.

study of the structure section profiles. It is rather a striking observation to notice that although the amount of faulting has been very great the displacement seldom if ever is reflected by the topography to any great extent. It seems probably that a good deal of major faulting occurred in the Quaternary period. Erosion, however, has already largely obliterated the surface indication of such faulting.

It is believed that many of the ridge tops in the area are remnants of an earlier physiographic surface, probably produced in folded Miocene rocks. The surface may have been of early Pleistocene age and presumably has advanced to an old age stage in its physiographic cycle.

Geologic History

As there are no rocks in the area older than Cretaceous there is no record of pre-Cretaceous history. It is thought probable, however, that the rocks of Chico age rest on Santa Monica Slates of Triassic (?) age or possibly upon a granitic base.

During upper Cretaceous and lower Eocene time 6000 or less feet of conglomerates, sandstones and shales were deposited. The thicknessof the conglomerates and the size of the pebbles indicates the presence of an adjacent land mass of considerable relief, presumably greater than the present Santa Monica Mountains. This mountain range probably was uplifted in Cretaceous time. Its location is not known but must have been close to the area in which the sediments were deposited. As far as is known all the Chico and Martinez sediments were deposited in the sea.

Sometime between lower Eocene and lower Miocene time there was a great disturbance resulting in a period of no deposition of unknown duration and causing a very marked change in the character of the sediments when deposition again began.

During Oligocene and probably lower Miocene time about 4000 feet of pebbly arkosic sandstones were deposited, probably mostly by fresh water. The arkosic nature of the beds indicates a nearby origin.

At the end of lower Miocene time there was another very sudden and very pronounced change in the character of the sediments being deposited. An invasion by the sea caused the deposition of nearly 10,000 feet of middle Miocene (Topanga) sediments, all of marine origin. During the middle of this period of Topanga deposition there were great basalt intrusions centering a few miles west of the area. A good deal of minor faulting accompanied the intrusion.

At the end of Topanga (middle Miocene) time there occurred the most intense diastrophism so far experienced in the Tertiary history of the area. Folds with northwest-trending axes were developed, uplift occurred and an erosional period of unknown length followed. This is the only large nonconformity in the area and is a feature widespread throughout the entire Santa Monica Mountains.

Deposition again began in Modelo (upper Miocene) time resulting in the accumulation of several thousand feet of siliceous shales containing lenses of sandstone. At the end of Modelo time uplift occurred and as far as is known the region was above sea level until the present time.

Diastrophism producing the present Santa Monica Mountains may have occurred in late Pliocene, Pleistocene or Recent time. There are no post-Modelo beds in the area so it is not known when the uplift occurred; perhaps it is still going on.

The history of the region shows that there was marine deposition from middle Cretaceous to middle Eocene time, continental deposition during part of Oligocene and lower Miocene time, marine deposition until the end of the Miocene with the exception of an erosional interval at the end of middle Miocene time.

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