THE GEOLOGY OF THE SOUTHEASTERN PORTION OF THE TEJON QUADRANGLE, CALIFORNIA

A Thesis By

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SUMMARY

Rocks in the southeasterly portion of the Tejon Quadrangle include pre-Cambrian (?), Paleozoic (?), Jurassic granitic rocks, and a thick series of Cenozoic sediments. All epochs of the two periods of the Cenozoic are represented.

Lower Eocene (Martinez) marine beds are overlain unconformably by middle Eocene (Domengine) rocks, also marine. Oligocene land-laid beds occur in three isolated patches. A full series of Miocene rocks is present, from Vaqueros through Temblor to Modelo. These are all marine and in addition there is the Mint Canyon formation as the landward equivalent of a portion of the Modelo. An unconformity occurs at the base of the Temblor. Pliocene is represented in the southerly part of the area by marine Pico beds and in the north by the Ridge Route formation, largely lacustrine. These are both unconformable with the underlying Miocene rocks and the former are overlain, also unconformably, by land-laid Pleistocene (Saugus). Upper Pleistocene terraces border some of the streams, while Recent alluvium extends well up the larger stream channels.

Deformation has been brought about by static load, intrusion and dynamic compressive forces. The last named have broken the area into three blocks separated by major faults and faulted within themselves. A large syncline has developed in the central block and an upwarp occurs athwart the trend of other structures. The westerly block is complicated by a large overturn.

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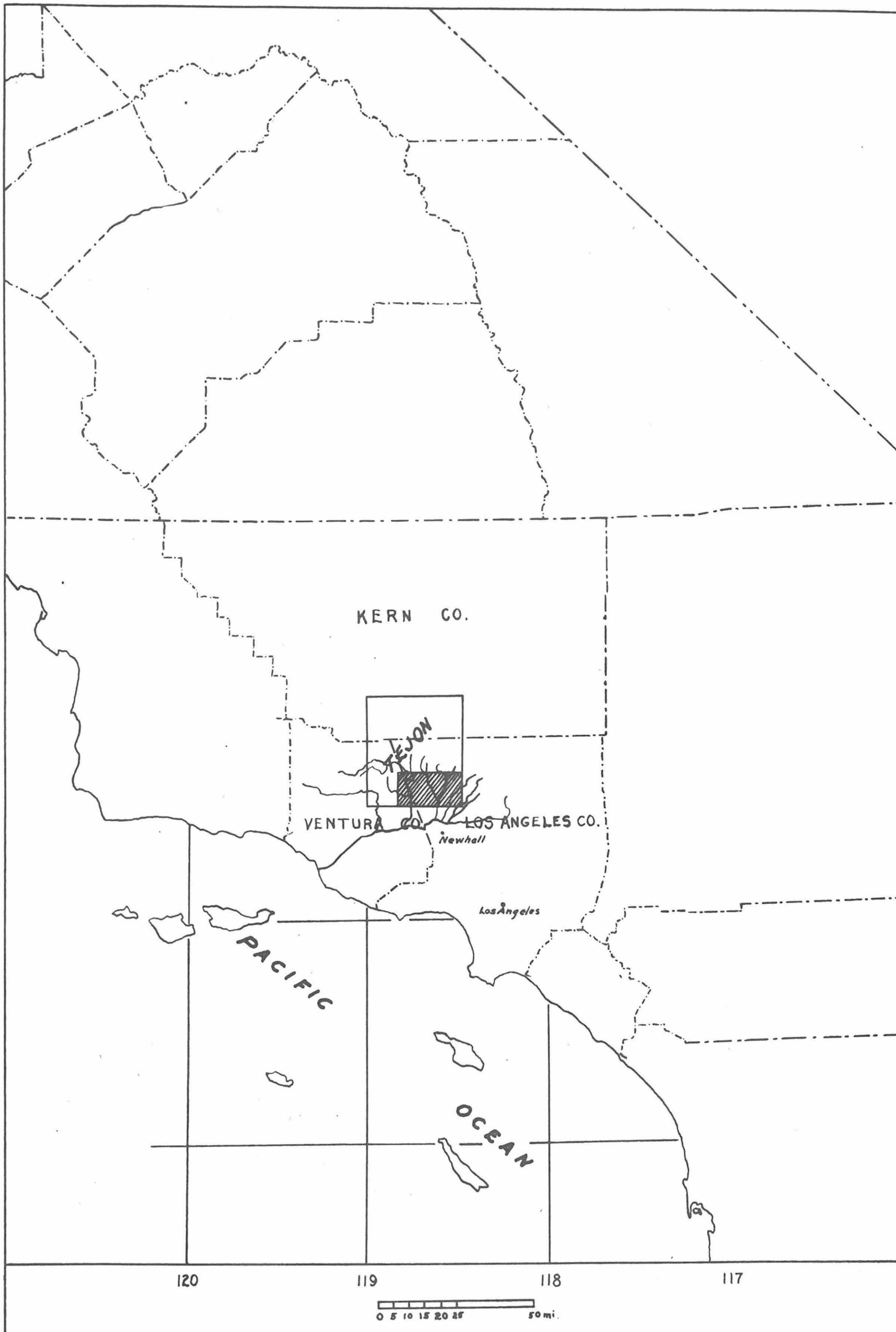
INTRODUCTION

Location and size of area

The Tejon Quadrangle, which lies between latitude 34 degrees 30 minutes and 35 degrees north, and 118 degrees 30 minutes and 119 degrees west longitude, occupies a strategic position geologically in California. Its northerly portion is largely taken up with a granitic mass that is a southward extension of the Sierra Nevada Range, while the southerly part is stratigraphically and structurally related to the Coast Ranges. Thus, in this quadrangle there is a coming together of two separate and distinct provinces. The first mentioned region has been in part touched upon by H. W. Hoots,[1] and is being mapped in detail by J. P. Buwalda and students of the California Institute of Technology. The writer has been engaged in mapping the southerly portion and presents herewith the results of his work in the southeasterly one-fifth.

The area described in this report is rectangular in shape and comprises approximately two hundred square miles. Its east and south boundaries coincide with those of the quadrangle,

[1] Hoots, H. W., Geology and oil resources along the southern border of San Joaquin Valley, California. U.S.G.S. Bull. 812-D, 1930.



Outline map showing location of area.

and it extends west almost to the 118 degree 50 minute meridian and north almost to the 34 degree 40 minute parallel. Excepting for a few square miles in its western portion which are in Ventura County, it lies within the limits of Los Angeles County. (Plate I).

Previous work.

The first references to geologic features of the Tejon Quadrangle appearing in the literature are those made by J. D. Whitney[1] in regard to the metamorphic rocks of San Francisquito Canyon. Watts[2] included the southwesterly corner of the quadrangle in his early map of a part of Ventura County, but did not extend his work as far eastward as the present author's western boundary. Hershey[3] in 1902 mapped and described certain rocks that occur in the region and referred to some of them again in 1912, but from then until 1928 nothing further seems to have been published. The breaking of the St. Francis Dam in 1928 drew attention again to San Francisquito Canyon in the southeast corner of the quadrangle

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1 Whitney, J. D., Geological survey of California; Geology, vol. 1, 1865.

also, The auriferous gravels of the Sierra Nevada of California, Harvard Coll. Mus. C. Z., Mem. 6, no. 1, 1880.

2 Watts, W. L., Oil and gas yielding formations of Los Angeles, Ventura and Santa Barbara Counties, Calif. State Min. Bur., Bull. 11, 1897.

3 Hershey, O. H., The Quaternary of southern California, Univ. Calif. Pub. in Geol., vol. 3, no.1, pp.1-30, 1902.

also, Some crystalline rocks of southern California, Am. Geol., vo. 29, pp. 273-290, 1902.

also, Some Tertiary formations of southern California, Am. Geol., vol. 29, pp. 349-372, 1902.

also, The Belt and Pelona series, Am. Jour. Sci., 4th series, vol. 34, pp. 263-273, 1912.

and called forth a great many papers dealing with the geologic features immediately concerned.[1] A short paper by the author covering about thirty-eight square miles in this corner and written in 1929 is on file in the library of the California Institute of Technology. It is also known that several of the oil companies have carried on limited studies within the region, but to date none of their reports has been published and only one, by H. R. Johnson and Van Court Warren, has been available to the writer.

Method of field work.

Field work was started in October, 1926, but due to the limited time then at the disposal of the writer, progressed slowly until 1929. The entire summer of that year was spent in the field, as have been the summers of succeeding years, in addition to which such week-ends and holidays as have been available have been put to use.

Mapping was done with the aid of a Brunton compass, and data were recorded upon an enlargement of one of the United States Geological Survey's topographic maps. The original map is on the scale of 1 to 125,000, and this enlarged four times gave a scale of approximately one inch to one-half mile. While the topography is rather generalized in some places, making accurate recording difficult, on the whole the map was found to be satisfactory. The new large scale topographic maps now being made by the Survey with the coöperation of Los Angeles County, unfortunately will be too

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[1] A partial list, including the more important papers appears in the bibliography.

late to benefit the author. Airplane maps of the western extremity of the area greatly aided in mapping some of the complexities of the Piru district.

Acknowledgments.

The writer wishes to express his appreciation of the inspiration and help given him by Dr. J. P. Buwalda and other members of the staff of the Division of Geology and Paleontology of the California Institute of Technology, under whose direction the work was done. He is particularly indebted to Dr. W. S. W. Kew of the Standard Oil Company of California for many visits in the field and for much excellent advice, and he also is indebted to the Standard Oil Company for assistance during the field season of 1929. Mr. Herschel Driver of the same company made several determinations of foraminifera from the area. Thanks are due to Mr. W. W. Stabler of Los Angeles and Castaic for well logs and reports on the Castaic district. The following members of the field geology class of the University of Southern California accompanied the writer in the field at different times: F. A. Douglass, Jr., E. M. Fitzgerald, J. N. Huber, J. F. Mason, L. B. Riggins, Jr., G. K. Robertson and F. D. Spencer. Without the constant encouragement and coöperation of Lydia Brooks Clements the task could not have been completed.

GEOGRAPHY

Accessibility.

The south boundary of the Tejon Quadrangle is about forty-five miles north of the city of Los Angeles, and the portion of the quadrangle herein described is most easily reached by the inland route to San Francisco, commonly called the Ridge Route (U.S.Highway No. 99). This cuts the area into two almost equal parts and is the only paved road in the region. A well-built dirt road branches from the Ridge Route and extends about ten miles up Elizabeth Lake Canyon, while fair roads are found in Piru, Castaic, Charlie and San Francisquito Canyons. The new road which will extend up Violin Canyon, through Oak Flat and thence into upper Piru Canyon, roughly paralleling the Ridge Route, is under construction at the time of writing but has not progressed sufficiently to be of much service to the writer. A few trails kept up indifferently well connect some of the prominent peaks with the roads, but most of the area can be reached only on foot and by dint of hard work. R. T. Hill[1] has rightly included part of it in his "Piru Wilderness" and the westerly portion is included in what Kew[2] has called "one of the roughest and most inaccessible regions in California".

Relief.

The relief of the area is not excessive. The point of lowest elevation is in the canyon of Piru Creek, and is just over 1100 feet above sea level, while the highest point is in the northwest corner of the area mapped where an unnamed peak attains an altitude of over 5100 feet. This gives a maximum relief of over 4000 feet, the average difference in elevation being probably not over 2000 feet. There is a general increase in altitude and

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1 Hill, R.T., Southern California geology and Los Angeles earthquakes, South. Calif. Acad. Sci., Los Angeles, 1928.

2 Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, U.S.G.S. Bull. 753, pp. 4-5, 1924.

ruggedness from south to north, particularly noticeable in crossing the area by way of the Ridge Route, and there is a similar but less marked increase from east to west. Altitudes in the southern one-third are generally under 3000 feet above sea level; those of the northern one-third approach or slightly exceed 5000 feet.

Topography and drainage.

Topographically the region is exceedingly rugged, with surprisingly few areas flat enough to lend themselves to culture of any sort. The canyons are generally steep-walled with at times almost knife-edged interfluves, and some of the streams flow between sheer walls four and five hundred feet high. This is especially true of Piru and Agua Blanca creeks, whose courses offer a wild grandeur known to but few people in southern California. Bad lands are developed locally, particularly in continental deposits, and landslide topography is very common.

Drainage is all in a general southward direction to the Santa Clara River, which in turn flows to the west and empties into the Pacific Ocean just south of Ventura. The series of ridges along which U. S. Highway No. 99 is built forms a natural divide between the eastern and western portions of the area, the former being drained principally by Castaic and Elizabeth Lake Creeks and their tributaries, the latter chiefly by the Piru system. In the extreme southeast corner the intermittent streams in San Francisquito and Dry Canyons flow directly into the Santa Clara River, while Palomas and Violin Canyons which are west of the Ridge Route drain into Castaic Creek rather than into the Piru.

Climate and vegetation.

Situated as it is in the southern Coast Ranges of California, this area shares the same semi-arid climate enjoyed by southern California as a whole. The nearest government recording station is at Newhall, ten miles to the south, and statistics from there may be taken as being fairly representative of the region in general. The mean annual rainfall over a period of thirty-eight years was 17.54 inches, and minimum for any year having been in 1877 with 4.85 inches and the maximum 44.20 inches in 1884. As a rule most of the rain comes from December to April, which period therefore constitutes the principal growing season, although rarely showers fall during the summer. As a consequence of the low rainfall most of the streams are intermittent, Piru Creek and Elizabeth Lake Creek being the only two to maintain running streams throughout the year. Even these become dry in places during the hottest part of the summer, but where bedrock comes to the surface a small flow generally may be found. Agua Blanca Canyon contains water here and there most of the time and near permanent springs occur in several of the smaller canyons. What appears to be a permanent spring marks the trace of a major fault in Fish Canyon, Warm Spring marking the same fault in Elizabeth Lake Canyon.

The mean annual temperature as recorded at Newhall for thirty-eight years was 61.5 degrees Fahrenheit, with a low of 10 degrees above zero and a high of 113 degrees above. The writer has recorded temperatures of 120 degrees Fahrenheit in the sun during August, and it is probable that even higher temperatures are reached. The humidity, on the other hand, is low, and such temperatures are not unbearable, although not particularly comfortable. Nights are generally cool even during the hottest part of the year. Snow is frequent in the higher regions during the wet season, and has been known to fall as late as in April. The best seasons for field work are fall and late spring, the latter being more desirable because of the presence of potable water in the major canyons at that time. During the summer no dependence can be placed upon the possibility of finding water and the extreme heat makes it imperative that the geologist carry an adequate supply.

The vegetation is a direct response to the environment, and is similar to that found throughout southern California west of the desert. Except where recently burned over chaparral mantles the hillsides, being usually more dense on the north slopes than on the south, due to the greater exposure to the direct rays of the sun on the latter. This chaparral cover consists chiefly of chamise (Adenostoma fasciculatum), several species of the sumac family, manzanita (Arctostaphylos manzanita), madrona (Arbutus menziesii) and some of the so-called California holly (Heteromeles arbutifolia) and lilac (Ceonothus thrysiflorus). The growth becomes so heavy in places as to be almost impenetrable and is a considerably hindrance to mapping, covering contacts and making climbing difficult and slow. Larger trees are plentiful in the canyons, oaks and cottonwoods being the most common, and a few conifers occur on the higher ridges.

There is a very noticeable difference in the assemblages of canyon trees on the two sides of the Ridge Route. On the eastern side sycamores are the common accompaniment of the oaks and cottonwoods, with only a few alders and no walnuts, while to the west sycamores are only moderately plentiful, alders are very common and black walnuts grow in profusion in certain localities. These latter are principally the southern California black walnut, although a few of the middle California variety are also found. It is believed that the last-named were brought in by the early Indians, traces of whose habitations have been found by the writer in Piru Canyon.

Vegetation is also influenced to a certain extent by the nature of the underlying rocks. The chaparral is thickest on soil derived from sandstone or conglomerate; shale usually supports a heavy growth of sage; the conifers are found on granitic rocks or arkosic sandstones. A crushed zone along a fault may also be marked by sage, while land-slides are frequently marked by grass or wild oats. As pointed out by Kew[1] the black walnuts seem to favor soil produced by the weathering of Modelo shales, although by no means limited exclusively to this.

It is interesting to note that in spite of the apparent barrenness of the district as a whole as viewed in passing through, more than eighty species of plants have been recorded during the period of research. A partial list of these is included in the previously mentioned paper on file in the library of the California Institute of Technology, and therefore will not be repeated.

The fauna by no means equals the flora either in numbers of species or of individuals. This is due primarily to the burning off of so much of the vegetation and to hunting and trapping. Among the carnivores observed are coyotes, foxes, bob cats, raccoons

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1 Ibid., p. 6

and skunks; the ungulates are represented by deer; while the rodents include rabbits and squirrels. Reptilian life flourishes as far as lizards are concerned, although snakes are rare. Birds are very plentiful in the trees along the canyons, and the author was fortunate enough to see in one day both a golden eagle and a California condor. The latter is now a very rare bird indeed and will doubtless be altogether extinct within a few years.

Culture.

The hand of man is not greatly in evidence in the southerly part of the Tejon Quadrangle. There are no towns in the area, the nearest settlement being at Castaic Post Office, about one-half mile south of the southerly boundary, along the Ridge Route. The town of Piru is nine miles south of the area at the confluence of Piru Creek and the Santa Clara River. Service stations and homesteaders' shacks are scattered along the Ridge Route; a small colony of employees clusters around the City of Los Angeles power house in San Francisquito Canyon and farms are found in the latter, in Elizabeth Lake Canyon, Castaic Canyon, Charlie Canyon and along Piru Creek. A few houses are located in Oak Flat, and the General Petroleum Company maintains a pumping station west of the Ridge Route in Liebre Gulch. The chief industry, if it may be called such in this case, is cattle raising. Desultory prospecting is carried on in San Francisquito and Dry Canyons.

STRATIGRAPNY

General.

Igneous, sedimentary and metamorphic rocks ranging in age from possible pre-Cambrian to Recent occur in the southerly part of the Tejon Quadrangle. The first are chiefly granitic in character, and for reasons to brought out later, are considered to be Jurassic in age. In places they are so intimately intermingled with metamorphic rocks that no attempt was made to separate them, and indeed, so frequently do they in themselves show gneissic structure that such separation is impossible. However, it has been possible in the westerly part of the area to draw a fairly accurate contact between the two, and rather general lines have been drawn in the northeasterly portion. A small amount of highly weathered acidic lava occurs on the ridge west of San Francisquito Canyon and is considered to be of Miocene age.

The metamorphic rocks are of doubtful age and of several kinds. Micaceous schists occur east of San Francisquito Canyon, gneiss, quartzite and marble in the northern part of the area, and gneiss west of the Ridge Route. The rocks are here given various ages.

The sedimentary rocks are wide spread in occurrence and underly most of the area. Conglomerate, sandstone and shale, marine and non-marine are present. The sediments as a whole have a thickness of several thousand feet and include Martinez (Lower Eocene or Paleocene), Domengine (Middle Eocene), Sespe (Oligocene), Vaqueros (Lower Miocene), Temblor (Middle Miocene), Modelo (Upper

Miocene), Mint Canyon (Upper Miocene), Pico (Pliocene), Saugus (Lower Pleistocene), terrace gravels (Upper Pleistocene), and alluvium (Recent). Some of the beds are highly fossiliferous and allow an exact age determination to be made; the age of others is based upon lithology and stratigraphic relationships.

The area is roughly divided into two sections by a northwesterly trending fault, here named the Palomas Canyon fault, extending up Palomas Canyon, thence along an unnamed canyon west of Oak Flat and across Piru Creek. The areas on the two sides of this fault are somewhat different stratigraphically and for this reason the exposures of formations of approximately the same age outcropping in the two areas will be treated separately.

Metamorphic rocks.

It is unfortunate that the impelling motive behind so much of the geologic work done in California has been strictly economic and for that reason certain formations neglected. This applies particularly to the great thicknesses of metamorphic and granitic rocks, which being non-petroliferous, generally are lumped simply as "pre-Cretaceous basement complex" and passed over. While in the limited region mapped by the author it is not possible to work out the history of southern California prior to the Cretaceous, yet it has been found practicable to separate certain marked petrologic types, and to attempt generalized correlation. It will be noted that the ~~lads~~ leads of Oscar H. Hershey have been followed in this to a certain extent.

Pelona Schist Series (pre-Cambrian ?)

The Pelona Schists occupy a triangular shaped tract of about three and one-half square miles in the southeast corner

Group	System	Series	Formation	
Cenozoic	Quaternary	Recent	alluvium	0 to 100'
		Pleistocene	terrace	200' to 300'
			Saugus	850'+ land-laid
	Tertiary	Pliocene	Ridge Route	600'+ lacustrine
			Pico	6,000'± marine
		Miocene	Modelo	5,000' to 7,900' marine
			Mint Canyon	3,500'± land-laid
			Temblor	700'+ marine and 100'± acid lava
			Vaqueros	2,400' marine
		Oligocene	Sespe	1,200 to 6,600 land-laid
		Eocene	Tejon	absent
			Domengine	7,500'± marine
			Meganos	absent
			Martinez	4,100' to 10,000' marine
Mesozoic	Cretaceous		Chico	absent
	Jurassic			intrusive granite, granodiorite, etc.
	Triassic			absent
Paleozoic(?)				marble, quartzite and gneiss, thickness unknown
Pre-Cambrian(?)			Pelona Schists	mica schist, etc., thickness unknown

Correlation chart.

of the Tejon Quadrangle. They form the easterly and at times both walls of San Francisquito Canyon from a point outside the area mapped to within a mile and a half of its south boundary, where they are overlapped by later rocks. The contact with the latter swings to the southeast and crosses into San Fernando Quadrangle, its extension there having been mapped by Kew.[1]

These rocks were first noted by J. D. Whitney in traveling along the old stage road between San Francisco and Los Angeles, which road reportedly led through San Francisquito Canyon. He called them Cretaceous in his early report, basing his opinion on general analogy, but in a later paper called them "... Miocene rocks turned upon edge and so much metamorphosed as to be converted into mica slate".[2] No reason was given for assigning them to the Miocene, nor was any cognizance taken of his own earlier designation. Becker[3] mentioned them in 1885, but referred to Whitney's brief descriptions, hot having seen them himself. Thus they were the object of no serious study until in 1902 when

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[1] Ibid., pl. I.

[2] Whitney, J. D., Geological Survey of California; Geology, vol. 1, p. 196, 1865.

and, The auriferous gravels of the Sierra Nevada of California, Harvard Coll. Mus. C. Z., Mem. 6, no. 1, p. 19, 1880.

[3] Becker, G. F., Notes on the stratigraphy of California, U.S.G.S. Bull. 19, p. 10, 1885.

Hershey[1] mapped them and described their occurrence in the vicinity of Sierra Pelona, a few miles east of, but directly connected with the outcrop herein described. It was Hershey who first applied the name Pelona Schists, and since this name is in accordance with the rules of nomenclature of the United States Geological Survey, being both geographic and petrologic, it is used in the present work.

The Pelona Schist series is made up principally of rather coarse, granular mica schists, varying locally, but on the whole rather uniform. They are well exposed in the north fork of Haskell Canyon, in Dry Canyon, and particularly in San Francisquito Canyon, where the flood waters from the breaking St. Francis Dam swept them clean.

The color varies from a light yellowish through gray and green to black, the latter being the prevailing hue of fresh material removed from the tunnels driven in connection with the construction of the Los Angeles aqueduct. An area of coarsely foliated grayish gneiss occurs in a branch of Haskell Canyon, and in both Dry and San Francisquito Canyons there are gradations from a true mica schist into a coarsely crystalline variety that approaches an impure quartzite. As the site of the former St. Francis Dam is neared, the schists become more finely fissile,

1 Hershey, O. H., The Quaternary of southern California, Unic. Calif. Pub. in Geol., vol. 3, no. 1, Pl. I, 1902.

also, Some crystalline rocks of southern California, Am. Geol., vol. 29, pp. 274-277, 1902.

and in places are almost slates in texture. There are also occasional isolated occurrences of actinolite schist in San Francisquito Canyon, and a few small talc veins were observed in branches of Haskell Canyon. The series is cut by a great many quartz-filled fissures, ranging in thickness from a fraction of an inch to several feet, and it is doubtless from these that has come such gold as has been found in the region.

Examination of representative specimens shows the major minerals of the schist to be quartz and muscovite, the latter largely of the sericite variety. A few cleavage fragments of feldspar were observed in the less highly sheared rock, suggesting that the original sandstone was in part, at least, arkosic. Biotite is fairly abundant as are also small flecks of what probably is magnetite. These two femic minerals usually are altered with consequent staining of the rock due to production of secondary iron oxide. Some chlorite is present.

The origin of the schists has been the subject of some discussion. Hershey[1] believed them to be in part derived from sedimentary beds, and in this he is supported by Nickell[2].

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[1] Ibid., p. 275.

[2] Nickell, F.A., The geology of the southwestern part of Elizabeth Lake Quadrangle between San Francisquito and Boquet Canyons, p. 6, on file, Library, California Institute of Technology, 1928.

Willis[1] also considered them to have been former sediments, but Tolman is quoted by Hill[2] as believing the material at the St. Francis damsite to be a metamorphosed granitic rock. It is the writer's opinion that within the limits of his own area, the schists are the result of regional metamorphism of sedimentary deposits. This is not so clear at the damsite, where intense shearing along the San Francisquito fault has to a certain degree obliterated the traces of former bedding, but downstream the bedding becomes quite distinct. (Plate III). The rocks appear to have been largely alternating sandstones and shales, with perhaps some conglomerate in the Haskell Canyon region, and becoming increasingly finer grained to the north. The mass of heavy gneiss mentioned above is interpreted as possibly having been an intrusive rock of granitic composition.

The uniformity of the degree of metamorphism possessed by the series as a whole, and the lack of evidence of intrusive bodies of a size sufficient to account for the changes, lead the writer to believe the schists to be the result of regional rather than contact metamorphism. The "fruchtschiefer" of the Santa Monica Mountains, exposed about the margins of the intrusive

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[1] Willis, Bailey, Report on the geology of the St. Francis damsite, Los Angeles County, California, Western Construction News, vol. 3, no. 12, pp. 409-413, 1928.

[2] Hill, R.T., Geology of reser voir sites, Part II of a report of the Board of Consulting Engineers to the Board of Water and Power Commissioners of the City of Los Angeles, p. 118, 1928.

Pelona Schists overlain by basal conglomerate of Mint Canyon formation in San Francisquito Canyon. Note distinctly bedded character of schists.

granite,[1] has no correlative here. The planes of flow cleavage developed by the diastrophic processes are parallel to the original bedding planes, thus strengthening this view and also giving evidence of static rather than dynamic metamorphism. It is true that such parallelism might be developed by the latter acting at right angles to bedding planes already practically vertical, but the comparatively low angle of dip, twenty to sixty degrees, is against such an interpretation.

The schists are broken by many faults and have been folded along a northeast-southwest axis. In San Francisquito Canyon from a short distance above the power house to the border of the quadrangle the rock is sheared and contorted, due to stresses set up within the mass by the forces causing the faulting along the margin. Because of the shearing the schist is much weakened throughout this zone, which, in connection with the fact that the planes of schistosity here are practically parallel to the east wall of the canyon, made it an extremely poor foundation for the east wing of the St. Francis Dam. This is shown by the numerous landslides that took place both before and after the removal of the water from the reservoir.

The age of the Pelona Schists is questionable. As noted previously, Whitney at different times called them both Cretaceous and Miocene, neither of which designation need be seriously considered in the light of present knowledge. All

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[1] Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California, U.S.G.S., Prof. Pap. 165-C, pp. 88-89 and Pl. 18-B, 1931.

other writers, with the exception of Hershey, have cautiously called them simply pre-Cretaceous. Hershey[1] believed the series to be the correlatives of the Abrams Schists of northern California, with which they seem to correspond lithologically, and Diller apparently agrees with him in calling the latter pre-Cambrian[2]. Again, he compares them with schists in the Randsberg Quadrangle and states that he believes the Pelona series to be "the youngest important Archean series"[3]. Whether they are Archean or Proterozoic the writer cannot say, but he does believe them to be older than Cambrian.

The oldest known Cambrian rocks on the North American continent are in the Inyo Mountains of California [4], about two hundred miles north and east of the Tejon Quadrangle. These rocks are fossiliferous, and while having undergone some changes in their long history, they are not highly metamorphosed.. It seems reasonable to believe that regional metamorphism sufficient to have produced the Pelona Schists, would have brought about similar effects in rocks as close as the Cambrian beds,

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1 Hershey, O. H., Some crystalline rocks of southern California, Am. Geol., vol. 29, p. 277, 1902.

2 Wilmarth, M. G., Names and definitions of the geologic units of California, U.S.G.S. Bull. 826, p. 1, 1931.

3 Hershey, O.H., The Belt and Pelona series, AM. Jour. Sci., 4th series, vol. 34, p. 273, 1912.

4 Knopf, A., and Kirk, E., A Geologic reconnaissance of the Inyo Range and the eastern slope of the southern Sierra Nevada, California, U.S.G.S., Prof. Pap. 110, 1918.

had they been present at the time. Neither can the rocks be compared lithologically with the Cambrian or the immediately underlying beds of the Inyo Range, since nowhere in the Pelona series are found calcareous beds comparable to those in the former.

It is the writer's opinion, therefore, that the Pelona Schists represent sediments derived during pre-Cambrian time from highlands adjacent to what Schuchert[1] has designated as the Sonoric trough or geosyncline. Sedimentation apparently continued after the Killarney Revolution, possibly throughout the Paleozoic, thus giving rise to a great thickness of quite or almost flat-lying sediments of sufficient weight to bring about the static metamorphism of the underlying formations.

Gneiss, Quartzite and Marble (Paleozoic ?)

Two areas of gneiss are exposed in the territory mapped, one lying to the east and the other to the west of the Ridge Route. In most respects the two bodies are similar, but in a few particulars they differ slightly, as will be brought out in their respective descriptions.

The gneiss lying east of the Ridge Route is a dark grayish rock made up essentially of quartz, feldspar and mica, and so intimately intermingled with quartzite and marble that it is necessary to consider the three as a unit. Together with closely associated granitic rock it occupies approximately thirty square miles in the northeastern portion of the area. Ex-

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[1] Schuchert, C., Outlines of historical geology, John Wiley and Sons, Inc., New York., Pl. I, 1931.

cellent exposures of all three types of rock may be seen in Fish Canyon, and the gneiss alone is well exposed in Elizabeth Lake Canyon.

The gneiss is coarsely foliated and often shows much contortion. The marble is a white, finely granular rock made up principally of small, sometimes secondarily twinned calcite crystals, with occasional light green serpentinous streaks through it, and occurring as a fairly well-defined bed west of Fish Canyon. It has been faulted out to the east, although appearing again farther upstream. The quartzite is massive and so highly fractured that the original bedding is indistinguishable. It is brown in color and composed of practically pure quartz.

To the south this group of metamorphic rocks is faulted against Tertiary sediments, but to the west the contact with the latter is of a normal depositional nature, showing the true original relationship. Elsewhere the mass is in contact with granitic rocks which are unquestionably intrusive. The line of demarcation between the true secondary gneiss and primary gneiss within the igneous rock is by no means well-defined, and boundaries indicated upon the map (Plate XXXI) are very general.

As in the case of the Pelona Schists, the origin and age of this body of gneiss and its associated marble and quartzite are problematical, but that it was in part originally sedimentary is obvious. Metamorphosed limestone and sandstone containing Paleozoic fossils occur in the eastern part of California and in many places are known to have been intruded by both Paleozoic and later granitic rocks.[1] Based upon the slender evidence of similarity in lithology, the writer would call the rocks here described Paleozoic sediments intruded and metamorphosed by later Paleozoic or possibly Triassic granites, and the whole again intruded by the late Jurassic granodiorite. The gneiss then would represent the earlier intrusive. This is entirely out of agreement with Hershey, who suggested that the gneiss was the oldest exposed rock in California.[2] However, Hershey apparently was unaware of the close relationship existing between the gneiss and the marble and quartzite, which to the writer appears to be highly significant.

The gneiss lying to the west of the Ridge Route occurs as a long narrow sliver extending diagonally across the area in a general northwest-southeast direction from near the south line to beyond the westerly border. (Plate IV) It is well exposed in Palomas Canyon, Canton Canyon and along Piru Creek, although in none of these is it easily accessible. In places its width diminishes to a few hundreds of feet, and nowhere is it much more than a half-mile wide. Its northeastern boundary is the well marked Palomas Canyon fault, which has

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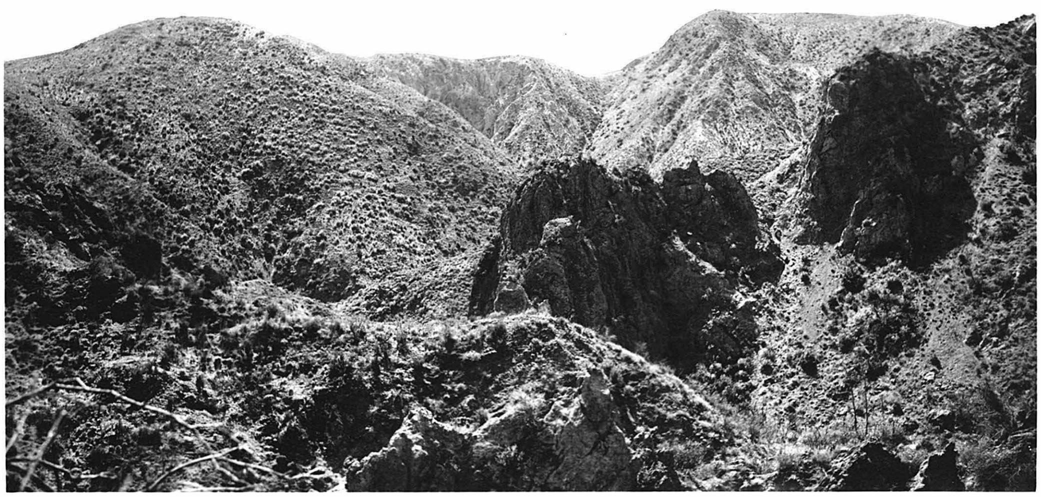
[1] Knopf, A., and Kirk, E. A geologic reconnaisance of the Inyo Range and the eastern slope of the southern Sierra Nevada, California, U.S.G.S. Prof. Pap. 110, 1918.

[2] Hershey, O.H., Some crystalline rocks of southern California, Am. Geol., vol. 29, p. 279, 1902.



Outcrop of gneiss in upper Canton Canyon. Granite in background.

brought the lower conglomeratic member of the Modelo into juxtaposition with it, and to the southeast it is in contact with granodiorite and sediments of Miocene and Pliocene age. The contact with the former is probably intrusive, the gneiss possibly representing a roof pendant or the margin of the country rock into which the igneous mass was intruded, although the rather straight line of demarcation between the two is suggestive of faulting. The sediments rest upon the gneiss with a depositional contact.

This gneiss in general is a coarsely banded, dark grayish rock composed of feldspar, quartz and mica, and similar to that first described. The marked difference in color between it and the Modelo on the one hand, and the much lighter granodiorite on the other, makes its boundaries easily traceable in the field. Its principal distinction is found in the great abundance of orthoclase, particularly in upper Canton Canyon. This is a bright flesh-pink, and occurs as porphyritic crystals and rounded grains in the quartz-feldspar bands. Nothing similar to this was noted in the occurrence of gneiss to the east, although Hershey describes a corresponding facies in the gneisses south of the Pelona Schists and also in the area south of Fraser Mountain, with which this body of gneiss probably connects.[1] He considered this facies to be a metamorphosed conglomerate, but to the writer it seems more logical

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1 Ibid., p. 279.

to call it a former porphyritic granite whose phenocrysts have not been entirely obliterated by the processes to which it has been subjected.

As in the case of the first described body of gneiss, it is impossible to set exact age limits. The fact that it is intruded by granodiorite no younger than late Jurassic, sets that as the upper limit. No marble or quartzite has been encountered in connection with this western gaeiss, but an occasional piece of marble float encountered int he bed of Piru Creek suggests that there may be a still undiscovered remnant. On the basis of these pieces of evidence, the author correlates this gneiss with that lying east of the Ridge Route, agreeing with Hershey thus far, but disagreeing with him again in calling it a metamorphosed intrusive rock of Paleozoic or possibly early Mesozioc age.

Plutonic Rocks (Jurassic)

Granitic intrusive rocks occupy roughly about thirty square miles in the region under consideration, those in the northeastern porition being a part of the Liebre-Sawmill Mountain mass, while those in the west presumably continue westerly to connect with a granitic body noted by C.L.Gazin[1] in the Mt. Pinos Quadrangle. As previously mentioned, both are intrusive into the older metamorphic rocks and both are faulted against younger Tertiary sediments.

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1 Personal communication.

The larger of these two bodies is the easterly one, which occupies the northeast corner of the area. This is very well exposed in Elizabeth Lake Canyon, Fish Canyon and in some of the unnamed tributaries of the latter and of Castaic Creek, and its northerly extension may be seen along the Ridge Route near Sandberg. The rock is very fresh as a rule, with but little soil cover, and deeply cut as it is by the above mentioned streams, it gives rise to the very rugged topography found in this part of the area. Where it is not in intrusive contact with metamorphic rocks along its southeasterly boundary, it is in fault or depositional contact with sedimentary rocks of Tertiary age.

The corresponding rocks lying west of the Ridge Route occur in a belt one to three miles wide extending from a point just southeast of Canton Canyon to the western margin of the district. Their area is approximately twelve square miles. Excellent exposures exist in the above mentioned canyon and in that of Piru Creek, both of which are cut to depths of well over a thousand feet through the solid granitic rock, forming narrows which are impassable in the case of the former and nearly so in the latter. This is part of the "Piru Wilderness" of Hill, spoken of earlier in the paper. As in the case of the first described body, these rocks are intrusive into the gneisses on the northeast and faulted against early Tertiary rocks to the southwest.

Several petrologic types are included in these intrusive rocks. Predominant among these is a coarse, granular, light gray rock made up principally of quartz, plagioclase and subordinate orthoclase, with biotite and some hornblende as ferromagnesian constituents. This is a typical granodiorite, and such a name may be safely applied to the rocks as a whole, Several more basic varieties appear, grading down into a very dark gray rock composed of hornblende, biotite and plagioclase, with only subordinate quartz, and a true granite occurs in Canton Canyon near the contact with the gneiss. A dark gray quartz diorite was found close to the corresponding contact in Fish Canyon, and near here also was found as float a porphyritic granite with phenocrysts of orthoclase almost an inch long. The latter was nowhere observed in place, and may have been many miles from its source. Another interesting rock type particularly plentiful as float in the vicinity of Whitaker Peak is anorthosite. This is coarsely crystalline, and is composed almost entirely of plagioclase, with small amounts of olivine and biotite. It is very fresh in appearance and occurs as boulders up to a foot or two in diameter, being found in most of the conglomerates in the vicinity up to and including the unconsolidated terrace gravel and coarse alluvium of the Quaternary. Diligent search through the section as exposed in Canton Canyon failed to reveal the source, and the possibility suggests itself that the anorthosite may have been present as a border facies of the granodiorite now entirely removed by erosion.

A few dikes were noted, both within the main intrusive bodies and in the gneiss. One of these is a small pegmatite made up largely of a beautiful flesh-pink orthoclase and some quartz, cutting the granodiorite in Canton Canyon. Another is an aplite, found intruding the gneiss in Elizabeth Lake Canyon. This is a fine grained, sugary rock composed of quartz, orthoclase and plagioclase with a few scattering flakes of biotite. The finding of this unsheared aplite in the gneiss throws some doubt upon the origin of the latter. It is true that the gneiss must be of an earlier date than the aplite, but it is also true that of the complementary dikes, aplite, being acid and therefore more viscuous than the melanocratic dikes, is less likely to travel far. In other words, it seldom passes beyond the limits of the solidified magma of which it is an end product.[1] Thus there is the possibility that the gneiss in the narrows of Elizabeth Lake Canyon may be primary and part of the intrusive, movement during cooling having brought about the ~~the~~ banded texture, with the aplite cutting through shortly afterwards. While this is a possibility, the extreme contortion seen in the gneiss is accepted by the writer as an indication of its secondary nature, and the occurrence of the aplite is therefore taken as an exception to the above rule rather than as a proof of the primary origin of the gneiss.

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[1] Pirsson, L.V., and Knopf, A., Rocks and rock minerals, John Wiley and Sons, Inc., New York, p. 220, 1926.

The granodiorite on weathering gives rise to a light yellowish mantle of disintegrated rock that supports some conifers and a chaparral cover a trifle less dense than that covering the later sediments. The yellowish color generally is visible in patches and gives some clue to the nature of the underlying rock even at some little distance. This is not a reliable criterion for mapping as becomes apparent when one realizes that some of the Tertiary arkosic sandstones give an almost identical soil.

The age of the granodiorite and associated intrusives is a question that cannot be settled, excepting within wide limits, on the basis of such evidence as is present in the area here concerned. It simply can be stated that they are older than earliest Tertiary, since rocks known definitely to be Paleocene are not only not metamorphosed by contact, but also contain pebbles derived from the former. Since the rocks into which the granodiorite is intruded are of indeterminate age, no strict lower limit can be set.

However, both occurrences of the intrusives can be traced without great difficulty into wide-spreading masses of igneous rock that form connections between the Tehachapi Mountains on the north and the San Gabriel-Sierra Madre Mountains on the south. Then they are seen to be not isolated outcrops, but part of the great batholith, covered at times it is true, extending at least from the northern extremity of the Sierra Nevada to Lower California. This makes the local problem one with the problem of the granodiorites of the Sierra Nevada, the intrusion of which now seems to be generally accepted as having taken place at the end of the Jurassic period.[1]

Cenozoic Group.

Tertiary System.

Eocene Series.

Martinez Formation (Lower Eocene or Paleocene).

The oldest unmetamorphosed sedimentary rocks so far known in the southern part of the Tejon Quadrangle are lower-most Tertiary or Paleocene. Hershey[2] mapped what he believed to be Knoxville (Lower Cretaceous) in the Piru Creek region and based his estimate of the age of the Alamo Mountain granites upon their relation to the supposed Knoxville beds, but the author has referred these to Upper Miocene. Apparently either no Cretaceous sea extended over this area, or Cretaceous strata that may have been deposited were eroded away prior to the deposition of the Martinez. Where the base of the latter is exposed, the underlying rocks are found to be crystalline, with no intervening sedimentary beds.

When the term "Martinez" was first applied to strata

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[1]Fairbanks, H.W., The pre-Cretaceous rocks of the California Coast Ranges, Am. Geol., vol. 11, p. 79, 1893.

Hershey, O.H., Some crystalline rocks of southern California, Am. Geol., vol. 29, p. 284, 1902.

Willis, Bailey, The California orogenic period, Science, new series, vol. 63, p. 484, 1926.

also, textbooks of geology by Grabau, Schuchert, Chamberlin & Salisbury, etc.

[2]Hershey, O.H., The Quaternary of southern California, Univ. Calif. Pub. in Geol., vol. 3, no. 1, Pl. I, 1902.

in Contra Costa County, California, these were thought to be of small areal extent and Cretaceous in age, possibly being but a subdivision of the Chico.[1] Stanton[2] later recognized that part of the beds therein included were Eocene and quite distinct from the Chico, and called them lower Tejon. Martinez beds now have been recognised in many parts of the state, and carrying as they do a very distinctive, though by no means profuse fauna, may be readily recognized when fossils are found. They constitute the lowermost strata of the Eocene, and probably should be given the rank of a separate series, the Paleocene. However, in accordance with the definition of the Martinez adopted by the United States Geological Survey[3] the writer will consider them here as a formation only, representint the lower Eocene.

The Martinez formation in the Tejon Quadrangle is represented by a thick series of marine sediments extending from the eastern boundary in a general northwesterly direction to a point on Salt Creek, where it is overlapped by younger beds. The length of this exposure is twelve miles, and the

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1 Gabb, W.M., California Geological Survey, Paleontology, vol. 2, p. xiii, 1869.

2 Stanton, T.W., Seventeenth Annual Report, U.S.G.S., Part I, p. 1028, 1896.

3 Wilmarth, M.G., Names and definitions of the geological units of California, U.S.G.S., Bull. 826, p. 46, 1931.

width varies from a few hundred feet to three miles, giving an areal extend of between twenty-five and thirty square miles. It extends to the east for another five or six miles into the Elizabeth Lake Quadrangle, where it has been mapped by Nickell[1] and Hill[2]. Another series of beds outcropping in the Piru district has been tentatively assigned to the Martinez and will be described separately.

The Martinez is composed of conglomerate, sandstone and shale, well indurated, and showing marked lateral gradation. Its thickness as shown in Fish Canyon is a little over four thousand feet, repetition of beds by folding giving the impression that it is considerably thicker. This is a minimum figure, since an unknown amount is missing in the lower portion and the top is hidden beneath the base of the upper Miocene. The thickness exposed in Elizabeth Lake Canyon, after making allowance for repetition due to folding, is about five thousand feet, which likewise is a low estimate. It is probable that the original thickness of Martinez strata deposited in this region was in the neighborhood of ten thousand feet.

The conglomerate comprising the lowermost part of the Martinez is its most striking feature, and although vary-

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1 Nickell, F.A., The geology of the southwestern part of Elizabeth Lake Quadrangle between San Francisquito and Boquet Canyons, on file, Library, California Institute of Technology, 1928.

2 Hill, R.T., Geology of reservoir sites, Part II of a report of the Board of Consulting Engineers to the Board of Water and Power Commissioners of the City of Los Angeles, 1928.

ing in thickness from place to place, reaching as it does the rather astonishing total of approximately seventeen hundred feet in Fish Canyon, it is very constant as to lithology. This conglomerate and the hard sandstone interbedded with conglomerate constituting most of the balance of the formation are quite resistant to erosion, giving rise to the bold ridges and deeply incised canyons making up the rugged scenery visible on the east side of the Ridge Route.

The best exposures of the Martinez beds are in Elizabeth Lake Canyon and in Fish Canyon, although they may be observed also in the canyons of Castaic, Salt and San Francisquito Creeks and tributaries. Wherever cut by streams the conglomerate stands in almost vertical walls, and frequently the canyons are practically impassible because of huge blocks fallen from the sides.

The Martinez in the eastern extremity of the quadrangle consists largely of a well bedded, well sorted, hard, gray to buff sandstone with some interbedded shale, all steeply tilted, with dips ranging from sixty-five to ninety degrees. Red Mountain (not to be confused with Red Rock Mountain) in this part of the area is composed entirely of Martinez. (Plate V) The yellow color of the sandstones is in striking contrast to the red of the landlaid formation adjoining on the south.

Progressing westerly, the sandstone is to some extent replaced laterally by conglomerate, which in Elizabeth Lake Canyon has become quite prominent in the northerly part of the sec-

Martinez sandstones in background separated from soft Sespe in foreground by Bee Canyon fault. San Francisquito Canyon.

tion. Shale is present near the south margin of the formation in the last named canyon, and like the conglomerate, becomes more prominent as followed to the west. Conglomerate and sandstone bedded with conglomerate make up a large proportion of the rocks in the Fish Canyon section, with the shale attaining a thickness of close to one hundred and fifty feet. Conglomerate and shale predominate in Castaic Canyon. A rather unusual quartzite breccia occurs in the vicinity of Red Rock Mountain in upper Castaic drainage, where the heavy basal conglomerate consisting principally of quartzite boulders has been crushed along two small faults and has been recemented later by silica.

The Martinez is in contact with various formations. Along most of its northern margin it is faulted down against granodiorite and gneiss, although the outlier north of the Clearwater fault shows very clearly the original relationship between sediments and metamorphics. Here the underlying rocks are principally quartzite and granodiorite, while above is the ummistakable basal conglomerate of the Martinez composed of partially rounded boulders of the same materials. A fossil locality in a branch of Fish Canyon, immediately above the contact, yielded characteristic Martinez invertebrates. This outlier, which has been displaced something like two and one-half miles horizontally along the Clearwater fault, is in turn overlapped on the west with a depositional contact by rocks of probable Oligocene age.

On the south between San Francisquito and Elizabeth Lake Canyons the Martinez is bordered also by probable Oligocene, from which it is separated by the Bee Canyon fault. The contact when followed west becomes depositional, with Mint Canyon beds resting unconformably upon the Martinez for the first mile or two west of Elizabeth Lake Canyon. Beyond this the overlying beds are Modelo.

Lithologically, the conglomerate is the most interesting member of the formation since by a study of it it is possible to learn much about the original land mass from which it was derived. The basal part, exposed particularly well on the west side of Fish Canyon in section 1, Township 6 North, Range 17 West and again in section 7, Township 6 North, Range 16 West, is approximately one hundred feet thick and is composed almost entirely of quartzite boulders up to several feet in diameter. These are of various shapes, with rounded corners and the surfaces frequently polished. The matrix is made up of smaller and more nearly rounded material of the same nature and the cement is silica. The basal portion varies in other localities according to the lithology of the underlying rocks.

Above the basal section comes that part of the conglomerate that may be said to be the characteristic feature of the Martinez as a whole. (Plate VI) This is up to seventeen hundred feet in thickness, although with some interbedding of sandstone, and is extremely uniform throughout. The phenoclasts range in size from an inch to two feet or more in diameter, are well rounded, and consist of granodiorite, gneiss, quartz-

Typical Martinez conglomerate. Elizabeth Lake Canyon.

ite and several types of extrusive rocks. The latter are in greatest abundance and are principally grayish, purplish and reddish rhyolite porphries, with some basalt, giving a striking variegated coloring to the rock mass, particularly where water-worn. A rough census of rock types within the conglomerate in Fish Canyon gives: granodiorite 6 per cent., gneiss 12 per cent., quartzite 30 per cent., extrusives 52 per cent. The matrix in which these boulders are set is principally quartz sand and the whole is bonded with a siliceous cement. The rock is so well indurated that fractures frequently pass through matrix and boulder alike.

The sandstone of the Martinez is largely arkosic, showing a direct derivation from granodiorite and gneiss. It is a well indurated rock varying in texture from a fine to a medium grain, with clasts subangular to subrounded. Quartz is the principal constituent, but both biotite and feldspar generally are present in large quantities and are very fresh. This is particularly true of the latter, which in some specimens exhibits the glassy appearance of that found in newly exposed igneous rocks, making it possible to distinguish between plagioclase and orthoclase with ease. Where exposed on the surface, the biotite usually weathers to a rusty yellow or brown. Silica is the predominant cement, although some calcite is present locally.

The material is well stratified, with individual beds varying from a few inches to several feet in thickness.

Fine partings of shale frequently occur between strata. Sorting is good, although isolated conglomerate lenses occur, the clasts as a rule being not over pebble size (4 to 64 milimeters)[1]. These are well rounded and at times highly polished. As already indicated, the proportion of conglomerate in the sandstone increases materially towards the west. Ripple marked sandstone occurs in Elizabeth Lake Canyon, and has been found useful in ascertaining that the beds are in their normal position and not overturned as they sometimes appear to be where so steeply dipping.

The prevailing color of the sandstone is gray, ranging from a dark gray where fresh biotite is unusually abundant to a buff or yellowish gray where oxidation has changed the iron of the biotite to limonite. As previously mentioned, the sandstone of Red Mountain between San Francisquito and Elizabeth Lake Canyons, is almost yellow, the name of the mountain being of uncertain derivation.

The shale in the eastern part of the region is light colored and sandy, at times being hardly more than a thin bedded, argillaceous sandstone. Numerous ferruginous concretions characterize this shale, which is present in a band from one hundred to two hundred feet thick. The shale farther west is

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[1] Wentworth, C.K., A scale of grade and class terms for clastic sediments, Jour. Geol., vol. 30, pp. 377-392, 1922.

of a dark carbonaceous type, although it too is arenaceous in part. This variety is well exposed in Castaic Canyon just north of the junction of Fish Canyon, and also in various of the northerly trending tributaries of the former. Being much softer than the other members of the formation it is subject to slumping in the canyons with over-steepened walls, and is marked by a somewhat more subdued topography.

The inferences as to origin to be drawn from the sediments of the Martinez are interesting indeed. First, the great water-worn blocks included in the basal portion indicate that the Laramide revolution which brought to a close the Mesozoic era, caused a general uplift along the coast, so that Martinez seas washed an abrupt and rugged coast line. The immense thickness of the overlying finer conglomerate gives evidence of a land of high relief,[1] supplying material in large quantities for a considerable period of time. Since the clasts large and small are complex mineralogically, that is, made up of aggregates of minerals or of single minerals complex in themselves, it may be inferred that the land was subject to mechanical erosion to a much greater extent than to chemical weathering, and therefore that there was not a particularly heavy mantle of vegetation. The corollary of this is that the climate was probably arid, lack of oxidized iron products in the Martinez precluding its being only semi-arid. The presence of the very fresh feldspars in the sandstone strengthens this belief.

Further, it is assumed from the preponderance of

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1 Twenhofel, W.H., and others, Treatise on sedimentation, p. 96, The Williams and Wilkins Co., Baltimore, 1926.

rhyolite boulders that the surface of the land was largely composed of lavas in the early part of the epoch, doubtless either the correlatives of the lavas extruded in the Sierra Nevada region concommitantly with the granitic intrusions, or those thrown out later during the Cretaceous period. For reasons to be brought out in the discussion of the geological history of the area, the latter seems the more probable. That these, however, had been deeply cut into by erosion prior to the deposition of the Martinez sediments is manifest from the presence of granodiorite in the lower part of the conglomerate, and it is inconceivable that the thousands of feet of material overlying the granitic rocks at the time of their intrusion should be so quickly cut through without there having been some assistance during the preceding period. The final removal of the lava covering and the erosion of the metamorphic and granitic rocks over a wide area is indicated by the sandstones. The region must have been reduced to maturity at least by this time, and possibly an old age stage is indicated by the shales.

The high degree of rounding attained by most of the boulders and pebbles might be taken to mean long transportation by rivers, thus vitiating the evidence above advanced in support of the idea of a land mass in topographic youth close to the shore. However, the size of the boulders, as well as the above-cited mineral complexity are against long stream transportation. Most of the boulders are of a size that could only be carried by turbulent streams of youthful gradient; probably largely intermittent, in view of the postulated aridity of the region. The rounding and polishing may be considered the work of ocean currents and waves, which with so abrupt and rugged a coast line doubtless were sufficiently strong to churn and grind the rocks about for some time before final deposition.

The age of this great area of sediments was until recently very much in doubt. Hershey did not describe them, but on his reconnaisance map[1] shows part of them as Cretaceous and part as questionable Tejon (upper Eocene). Nickell[2] in describing their occurrence in the southwestern part of the Elizabeth Lake Quadrangle called them tentatively Martinez, basing his designation upon lithology only, and pointing out that they might be Cretaceous. Hill[3] named the same occurrence simply Eocene, referring to work of Hoyt S. Gale, which, however, has not come to the attention of the present writer and which apparently was not based upon fossil evidence. The latter found the first fossils known to have come from the formation, fragments of a <u>Natica</u> and of a <u>Turritella</u> from a branch

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1 Hershey, O.H., The Quaternary of southern California, Univ. Calif. Pub. in Geol., vol. 3, no. 1, Pl. I, 1902.

2 Nickell, F.A., The geology of the southwestern part of the Elizabeth Lake Quadrangle between San Francisquito and Boquet Canyons, on file, Library, California Institute of Technology, p. 9, 1928.

3 Hill, R.T., Geology of reservoir sites, Part II of a report of the Board of Consulting Engineers to the Board of Water and Power Commissioners of the City of Los Angeles, p. 121, 1928.

of Castaic Creek.[1] These were specifically indeterminate, but resembled Eocene forms and their finding spurred the search for further material.

The search was rewarded in the summer of 1930 by the discovery of a locality in Elizabeth Lake Canyon yielding excellent specimens of both *Turritella pachecoensis* and *T. infragranulata*. These are species of definite characteristics and limited range, fixing the age of the formation as Martinez, or lowermost Eocene (Paleocene). Other localities have since been found by the writer, and a small but diagnostic fauna collected. The first public announcement of the definite age of these beds was made in a brief paper given before the Cordilleran Section of the Geological Society of America in 1931.[2]

A faunal list follows:

Mollusca

Gastropoda

Turritella infragranulata Gabb

Turritella pachecoensis Stanton

Polinices cf. *hornii* Gabb

Sycum sp.

Natica sp.

Pelecypoda

Glycimeris major Stanton

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1 Clements, T., Geology of a portion of the southeast quarter of the Tejon Quadrangle, Los Angeles County, California, p. 19, on file, Library, California Institute of Technology, 1929.

2 Clements, T., Extent of the Paleocene sea in the southerly part of the Tejon Quadrangle, California.

Venericardia venturensis Waring

Scaphapoda

Dentalium cooperi Gabb

Martinez (?) of Piru Creek.

There occurs in the western portion of the area a series of conglomerate and shale that for reasons to be brought out later is correlated tentatively with the Martinez east of the Ridge Route. These rocks are exposed along Piru Creek from the upstream end of what is known locally as the Little Narrows, for a distance of something over two miles (three or more along the stream), the conglomerate forming the lower end of the Big Narrows. The canyon is more or less open where the formation is shale, but where cut in the conglomerate the creek runs through a gorge with sheer walls up to five hundred feet in height. The rocks extend east of the creek for about a mile and west for an unknown distance beyond the area mapped. Cobblestone Mountain is six miles to the north and west of the exposures in Piru Canyon, and the name of the mountain coupled with the known trend of the formation suggests that it may be made up of the same conglomerate. The areal extent within the limits of the map is roughly four square miles.

The conglomerate, as in the case of the Martinez east of the Ridge Route, is the striking feature of the formation. This is an extremely hard rock slightly exceeding three thousand feet in thickness, and containing a few intercalated beds of buff sandstone. It consists of rounded and polished pebbles of rhyolite porphyry, basalt porphyry, gneiss and granodiorite, with, if anything, a preponderance of the first named in pink and red colors. The matrix is composed of angular quartz grains, and the cement is silica. Where polished by the waters of Piru Creek, the great walls of conglomerate are impressively beautiful. The rock as a whole is the exact analogue of the conglomerate of the known Martinez, and is the first reason for assigning a similar age to the formation.

The overlying shale is blue to black in color, finely laminated, well indurated, and remarkably constant in lithology throughout. Where exposed in the bed of Piru Creek it stands out in hard, sharp little ridges. It in part contains ferruginous concretions, and is then apt to be a rusty brown. It is brittle and breaks into tiny fragments that eventually weather to a blue to brown soil, supporting a somewhat more dense growth of chaparral than do some of the later shales.

Dips are fairly uniform in both conglomerate and shale, ranging from fifty to seventy-five degrees in a southerly direction. This indicates a thickness for the whole formation of ten thousand feet, the shales making up approximately seven thousand feet of the total. This seems a very high figure, and suggests the possibility of duplication of beds as a result of folding. No evidence of such folding is visible in Piru Canyon, although exposures are excellent. It seems probable that thickening of the shale has taken place as a result of some of the diastrophic movements to which it has been subjected during its long history.

This conglomerate-shale series is in fault contact with granodiorite on its north and easterly margins. Here, as in the eastern exposure of Martinez beds, the igneous rock is on the upthrow side, the fault being of the reverse type. This is shown particularly well on the west side of Piru Canyon some little distance above the stream. To the south the series is overlain unconformably by rocks of Domengine age (middle Eocene).

As previously stated, these rocks have been tentatively assigned to the Martinez. The similarity in lithology is a very strong piece of evidence, in view of the lithologic uniformity of the known Martinez. One thoroughly familiar with the latter would without hesitation pronounce the two to be the same. The stratigraphic position of the Piru Canyon exposure is further evidence upon which its probable age is based. The rocks overlying it to the south contain Domengine fossils, which leaves only the Meganos unaccounted for in the particular section under discussion. Since the United States Geological Survey accepts the Domengine as simply a part of the Meganos[1], it would seem that if the latter were present it would hardly be separated from the former by so marked an unconformity as exists in Piru Canyon between the formation in question and the Domengine. There still remains the possibility that the rocks are Cretaceous. While there is no absolute proof to

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1 Wilmarth, M.G. Names and definitions of the geological units of California, U.S.G.S. Bull. 826, p. 47, 1931.

the contrary, neither is there any indication that they are Cretaceous; such evidence as there is pointing rather to their being Martinez. The writer therefore feels justified in so designating them.

Domengine Formation (Mpper Middle Eocene)

No Eocene rocks other than the Martinez are exposed east of the Ridge Route. Whether they were not deposited or have since been eroded away it is difficult to state, but the next younger overlying rocks are land-laid deposits of probable Oligocene age. West of the Ridge Route, however, later Eocene time is represented by Domengine beds. As previously indicated, the Domengine is accepted by the United States Geological Survey simply as a part of the Meganos, but it will be treated here as of formation rank with the reservation in mind that the interval between Meganos and Domengine probably was much shorter than either that between Martinez and Meganos, or that between Domengine and Tejon. Indeed, it seems possible that the Domengine may represent deposition during a part at least of the time interval indicated elsewhere by the unconformity between Meganos and Tejon.

The Domengine formation is exposed in a belt varying from a few hundred yards wide to two miles or more in width, extending from a quarter of a mile east of Canton Canyon to the western margin of the area. The widest part is in the vicinity of Piru Creek north of Blue Point, and it narrows both to the east and to the west. The formation is marine in origin, and consists of conglomerate, sandstone and shale.

It has been found difficult to determine the total thickness of the formation owing to rather complex folding in the southerly portion, and to the impossibility of following a section even approximately normal to the direction of strike. Considerable lateral gradation is encountered in attempting to follow out individual beds and this adds to the difficulty in arriving at an accurate figure. It is estimated that the formation has an approximate thickness of seven thousand, five hundred feet.

The best exposures of the Domengine are in Piru Canyon, which is cut through rocks of that age from the upstream end of the Little Narrows almost to Blue Point. The Little Narrows owe their existence to the conglomerate member which is exposed to good advantage only in this place. South of the narrows are sandstone and shale whose hardness is considerably less than that of the conglomerate and in consequence the canyon of the Piru here opens out to a quarter or half mile wide. The bed of Canton Creek is cut for approximately a quarter of a mile through the shale member and almost at right angles to its strike. Good exposures of the sandstone occur in Agua Blanca Canyon; in an easterly tributary of Piru Creek just south of the Little Narrows; and in another unnamed easterly tributary just north of Blue Point.

The Domengine is bordered by rocks of many types and ages. On the northeast it is faulted against granitic rocks in a manner similar to the Martinez. It overlies the latter with un unconformable depositional contact, extreme discordance in dip and strike being manifest along the margin. This is well shown in Piru Canyon, but on both sides of the latter the dense growth of brush has made the contact very difficult to follow. To the south the section has been overturned and the older Domengine rocks overlie younger lower Miocene beds from the westerly boundary of the area mapped to just east of Piru Creek. Thence east, the underlying rocks are Oligocene. This overturn, which has caused some faulting along the contact is a notable feature of this portion of the region and is discussed in more detail under the subject of structure.

The conglomerate making up the lower four hundred and fifty feet of the Domengine is at first glance somewhat similar to that of the Martinez, but on close inspection it is seen to differ to a considerable degree. It is not so well sorted and the perfection in rounding found in the lower Eocene formation is lacking. The material, however, is much the same, with the exception that the colored porphyries characterizing the Martinez are in the minority, and therefore the rock-mass as a whole is more of a dead gray in color. Granodiorite and gneiss are fairly abundant and some quartzite pebbles occur. Phenoclasts are subrounded and are up to a foot in diameter. The matrix is a coarse, angular sand, and while the cement is in part siliceous, a considerable amount of iron oxide also is present as cementing material. Occasional thick sandstone beds occur in the conglomerate, generally exhibiting a cavernous type of weathering.

The sandstone lying immediately above the conglomerate and which has an estimated thickness of about one thousand feet, is a rather thin bedded, hard, light gray rock composed of angular material similar to the matrix of the conglomerate. A short distance above Blue Point, however, the sand is massively bedded and is a yellowish to light gray arkose, in places supporting a slight growth of conifers. This is rather soft, as compared to the above mentioned beds and the topography cut in it and also in the shales is somewhat more subdued. It is locally very fossiliferous, oysters in particular being abundant. While partially cemented by silica, the cement is in part ferruginous, giving the yellowish color to the rock. Some calcite also is present. Partings of shale occur between many of the sandstone beds and there is an insensible gradation between the portion in which sandstone predominates and that in which shale is predominant.

The shale varies from a brown arenaceous type to black carbonaceous material, both with interbedded sandstone strata. The former variety is found more abundantly in the region between the Little Narrows and Blue Point; the latter occurs along the granodiorite contact and in Canton Canyon. Both have undergone considerable contortion and the beds adjacent to the granodiorite are completely overturned. Minor landslides and slumping are frequent with attendant shattering of the shale. The thickness of the shale is approximately six thousand feet.

Fossils have been found in the sandstone in Agua Blanca Canyon and on both sides of Piru Creek just north of Blue Point. They also occur in sandstone interbedded with the shale and in the shale itself in Canton Canyon. Those from the first mentioned locality are fragmentary, and offer only negative evidence as to age, but a fairly large number of specimens has been collected from the other two places. Oysters are perhaps the most abundant, occurring in the heavy sandstones for a half or three-quarters of a mile on either side of Piru Creek; some gastropods are associated with them. Excellently preserved molluscs of several genera are easily obtainable in Canton Canyon. The large foraminifer Discocyclina clarki is visible to the naked eye in the dark shales of the latter locality, and was determined as to genus and species by Mr. Herschel Driver of the Standard Oil Company.

The age as evidenced by the fossil mollusca is Domengine, or upper middle Eocene. While the type locality of the above mentioned foraminifer appears to be in the Meganos below the Demengine contact,[1] Mr. Driver considers the assemblage of foraminifera as a whole also to indicate Domengine age.[2] It is

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1 Schenck, H.G., Discocyclina in California, Trans. San Diego Soc. Nat. Hist., vol. 5, no. 14, p. 220, 1929.

2 Personal communication.

true that the conglomerate and lower sandstone beds have as yet yielded no identifiable fossils, and it may be that these strata represent the Meganos, the stratigraphic break between Meganos and Domengine not having been recognized by the writer. Until definite proof of this is brought to light it seems necessary to include the whole in the Domengine.

A faunal list is appended.

Protozoa

Discocyclina clarki (Cushman)

Mollusca

Gastropoda

Turritella aplini Hanna

Amaurellina clarki Stewart

Natica hannibali Dickerson

Conus remondii Gabb

Neverita sp.

Pelecypoda

Ostrea idriaensis Gabb

Scaphapoda

Dentalium sp.

The origin of these sediments is not greatly different from that of the Martinez. They appear to have been derived from a land mass lying to the north, the surface rocks of which were principally granitic and metamorphic. The presence of boulders of porphyritic lava in the conglomerate might lead to the inference that some of the Jurassic or Cretaceous lavas still mantled the uplands, but it seems more likely that these are reworked material derived from the underlying Martinez. The unconformity at the base of the Domengine indicates a period of diastrophism during which the older beds were elevated, tilted and exposed to erosion to some extent. It is probable that the conglomerate, extensive as it is, was cut into to furnish detritus for the later conglomerate before again becoming submerged. The lower degree of perfection in rounding as seen in the phenoclasts of the Domengine is possibly due to there having been produced a secondary angularity by the breaking of once rounded pebbles. This may have been brought about in weathering or in transportation.

Oligocene Series.

Sespe Formation.

Rocks of Oligocene age are the next younger series after the Domengine known to outcrop in the southerly part of the Tejon Quadrangle. Upper Eocene (Tejon) rocks have not been recognized. It is quite possible that the latter were never deposited here, but in view of the fact that the type locality of the formation is in the northern part of the quadrangle and extensive beds of this age are known to exist to the south and west,[1] it seems probable that they were deposited and have been removed by subsequent erosion.

Three isolated outcrops of rocks have been assigned to the Sespe formation. These are all continental in origin and because of certain common characteristics logically should be considered together. It is possible that none of these belongs to the Sespe. However, for the reasons brought out below, the writer believes that he is justified in classifying them as such, and hopes that eventually fossil evidence will be forthcoming to definitely prove their age. It is also recognized by the writer that the Sespe is not universally accepted as belonging to the Oligocene epoch, but this, too, will be discussed below.

These strata are as a whole rather poorly sorted conglomerates, sandstones and mudstones, of varied composition and usually somewhat highly colored. Red is the most prominent color, although yellows, browns, grays, pinks, greens and purples are all common. Outcrops are found in the eastern portion of the area, between San Francisquito and Elizabeth Lake Canyons; in the north along Castaic and Salt Creeks, and in the west in the vicinity of Canton Canyon. Each of these areas will be described in detail after which will be presented certain general-

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[1] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S., Bull. 753, p. 26 and Pl. I, 1924.

izations derived from a consideration of them all.

The Sespe of the San Francisquito Creek Region occupies a roughly triangular shaped area of about five square miles, bordered on the north by rocks of Martinez age, on the east along San Francisquito Canyon by the Pelona Schists and upper Miocene beds, and on the southwest by the upper Miocene. As already stated, the beds are considered to be of continental origin and consist of a massive conglomerate member and a series of interbedded calcareous shales and muddy sandstones. These rocks formed the foundation for the west abutment of the St. Francis Dam, and their weakness was at least a contributing factor in the failure of the dam. The many papers called forth at the time dealt briefly with the formation; a more detailed description is included in a previously mentioned paper of the present writer.[1]

Excellent exposures of the Sespe are found in San Francisquito Canyon from the eastern margin of the quadrangle to below Power House Number 2 of the Department of Water and Power, City of Los Angeles. Downstream from the former damsite the rock has been stripped of its soil covering by the flood, while above, the spreading waters of the previously existing lake killed all vegetation, leaving the rocks well exposed. Good outcrops also may be seen in the upper part of

[1] Clements, T., Geology of a portion of the southeast quarter of the Tejon Quadrangle, Los Angeles County, California, pp. 20-25. on file, Library, California Institute of Technology, 1929.

Charlie Canyon on the ridge between the latter and San Francisquito Canyon, and along the trail connecting Elizabeth Lake Canyon and San Francisquito Canyon.

The apparent lower portion of the Sespe as here exposed is made up of a series of alternating sandstones and shales occupying a strip of about one-half to one mile in width across entire northern margin. The sandstones are fine grained and consist of subangular particles of quartz, rather plentifully mixed with a ferruginous clay and the whole cemented with more or less calcareous matter. The shales or siltstones are composed of a finely divided calcareous and ferruginous silt. The bedding is well defined, individual beds ranging from an inch or two to three or four feet in thickness, and the sorting is fairly good. Occasional lenses of conglomerate occur and the whole series is impregnated with gypsum, which locally makes up rather large masses. The prevailing color is a dull red, although near the northerly contact the beds are a yellowish gray. The strata are ~~are~~ highly tilted and tight folds occur throughout the series. The total thickness is about two thousand feet. The belt is marked by an area of comparatively low relief, showing that these beds are less resistant to weathering than the harder beds to the north and south.

The southerly part is occupied by conglomerate which comprises the main part of the Sespe in this locality. This is remarkable for its thickness, which is twenty-five hundred to five thousand feet, and for the size of some of the boulders it contains. Where exposed at the damsite it is composed of fairly well rounded pebbles of granitic and metamorphic rocks with nearly an equal number derived from sandstone, ranging from a few inches up to a foot in diameter and all set in a matrix of angular quartz and ferruginous clay. The cementing material seems to be largely the clay, since while the rock is hard when dry, it rapidly disintegrates when immersed in water. This is true to some extent of the sandstones as well, since they, too, showed excessive slumping around the margin of the lake both before and after the withdrawal of the water.

Progressing southerly, the clasts in the conglomerate become larger and more angular (Plate VII) and in greater proportion igneous, until the point is reached where the rock appears to be diorite and granodiorite in place. This is seen particularly well a short distance below the power house in San Francisquito Canyon and also across the ridge in Charlie Canyon. Careful search will reveal faint bedding planes, and more significant still, slightly water-worn boulders. A similar occurrence is reported by Kew[1] in beds that probably are the correlatives of these in the Fernando Quadrangle.

At the damsite the color is predominantly red from iron oxide, which is so abundant close to the contact with the

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[1] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, p. 38, 1924.

Sespe conglomerate on ridge between San Francisquito and Charlie Canyons.

schists as to have coated the contained pebbles with a shining red film of hematite, similar to the so-called "desert varnish". Since this concentration of hematite in the zone immediately above the San Francisquito fault is the result of deposition by ground water moving parallel to the impervious seam of gouge along the fault, it is obvious that the "desert varnish" is of no significance in the interpretation of the origin of the formation. Along the ridge opposite the power house, the massive beds of conglomerate are alternating red and gray, and at the southern extremity, the formation is the gray of granitic rock.

The age of these sediments must remain problematical until such time as fossils are found. Bounded on all sides as they are by faults, their true stratigraphic position is difficult to determine. On the north they are separated from the Martinez by the Bee Canyon fault, while on the southeast and southwest they are separated from schists and later landlaid sediments by the above-mentioned San Francisquito fault. Lithology gives the only clue to the age. Since the conglomerate contains a large percentage of sandstone boulders that are of undoubted Martinez derivation, it must be at least younger than lower Eocene. The sandstones and shales compare favorably in lithology with type Sespe on Sespe Creek, and the formation as a whole closely resembles that described by Kew[1] in Boquet Canyon and tentatively assigned by him to the Sespe.

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[1] Ibid., pp. 38-39.

For these reasons the writer assigns this occurrence also to the Sespe.

The sediments are without question continental in origin, the sandstones and siltstones being in part fluviatile and in part possibly playa deposits. The conglomerate is of the alluvial fan type or fanglomerate of Lawson, and evidently was formed much as the fans are forming in the Mohave Desert region today, at the mouths of and within the canyons cut in the abrupt faulted face of an actively rising mountain. It would be difficult otherwise to account for a conglomerate of this thickness and character. Since coarseness increases towards the south, the mountain from which part of the boulders of the conglomerate were derived must then have stood to the south in the position now occupied by Miocene beds. If such were the case, a reversal of movement has occurred along the fault forming the southerly boundary of this area of Sespe, since the last movement indicated has been upward on the northern side.

An apparent anomaly occurs in that the extremely coarse material of the formation is on top and the fine grained material below. This may be accounted for in several ways. First, the series may be overturned, the mechanics of which, however, are not at all clear. It is possible, too, that the conglomerate is folded into a series of overturned isoclinal folds corresponding to the tight folding in the thin bedded sandstones and shales, lateral gradation accounting for the

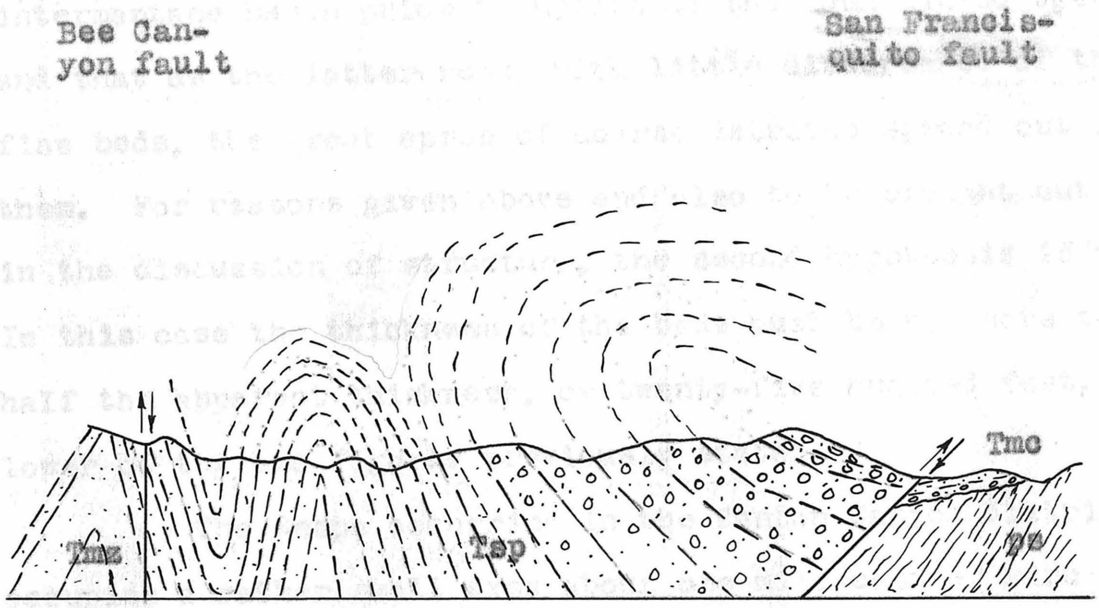
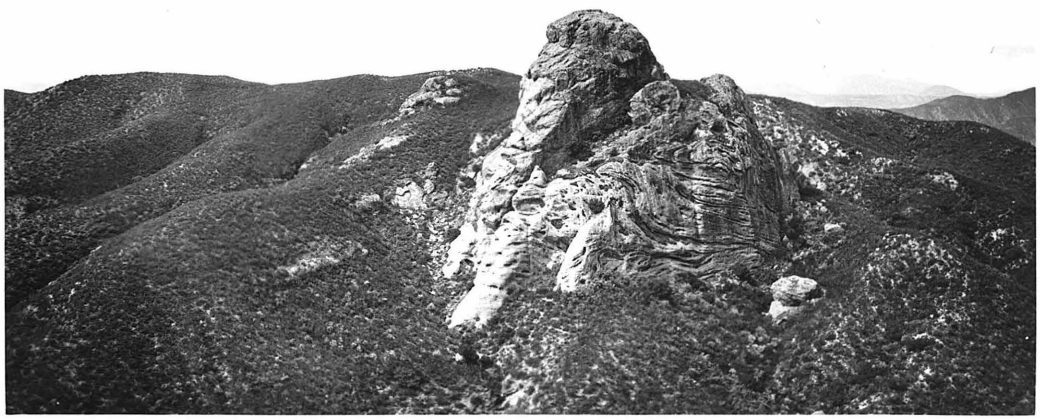


Figure 1. Section through Sespe of San Francisquito Canyon showing hypothetical tight, overturned folds.

differences in lithology of supposed continuous beds. Again it is not clear how such massive beds as those of the conglomerate might be isoclinally folded, while the weaker beds apparently are folded to a lesser degree, and yet extreme contortion in a monumental crag of conglomerate in Charlie Canyon suggests that such may have occurred. (Plate VIII). The third possibility is that the fine beds were laid down in an intermontane basin prior to uplift of the mountain to the south and that as the latter rose, with little disturbance of the fine beds, the great apron of coarse detritus spread out over them. For reasons given above and also to be brought out later in the discussion of structure, the second hypothesis is favored. In this case the thickness of the beds must be not more than half the apparent thickness, or twenty-five hundred feet, the lower of the two figures previously stated.

The Sespe occurring in the Canton Canyon district occupies a rather small area about one mile east of Piru Creek and two miles north of the south boundary of the Tejon Quadrangle, lying in the northeast quarter of Township 5 North, Range 18 West. Its total areal extent is approximately two square miles. The beds are land-laid sandstones and shales with a few scattering lenses of conglomerate, not particularly well sorted and with the bedding frequently indistinct. Folding makes the series appear much thicker than actually is the case; the true thickness as calculated from the section in Canton Canyon is twelve hundred feet.



Extreme contortion in coarse Sespe sandstone and conglomerate. West side of Charlie Canyon.

The best exposures are found in the canyon just mentioned, which intersects the formation about two miles from its junction with Piru Creek and again a mile farther upstream. At the latter locality the stream cuts almost at right angles to the strike of the beds and a good section is exposed. Tributaries on both sides of Canton Canyon have deeply incised the soft sediments and also offer excellent opportunities for observation. Small scale bad-land topography is developed locally. A long narrow finger of the Sespe cresses the ridge into the Piru drainage, and may be seen in the easterly trending branch canyon just north of Blue Point.

The most persistent petrologic type is a poorly sorted arkosic sandstone. This is of varying colors, red, white, yellow, brown and green, of which the first two are probably predominant, although all are common. The clasts are angular, of a large range in size, and are derived from the older rocks of the region, igneous, metamorphic and sedimentary. The bedding is massive and not always sufficiently well defined to allow the taking of dip and strike. Occasional lenses of conglomerate occur, and isolated boulders so frequently are found in the sandstone that their occurrence might be said to be characteristic of the formation. The shale is principally an arenaceous type, little different from the sandstones excepting in thickness of beds, and observed chiefly as a parting between the heavier strata. Clay and iron oxides are the cementing materials, the beds on the whole being rather loosely cohering.

The stratigraphic position of the Sespe of this locality is clear if it is kept in mind that the section is in places overturned. Thus west of the ridge separating Canton and Piru Canyons, the red beds underlie rocks containing Domengine fossils and overlie beds of definitely known lower Miocene age. Again along the northerly margin in Canton Canyon the land-laid beds underlie marine sandstones containing a Domengine fauna. The southerly contact in this latter locality is in its normal position, however, as are also the contacts where exposed near the sharp bend in Canton Creek. On the east the three formations are overlain by later Miocene strata. In all cases observed, the contacts are definitely unconformable, a discordance in dips or in both dips and strikes accompanying a distinct break in lithology. There is also minor faulting between the Sespe and lower Miocene, although the indications are that this has taken place along the original contact plane.

The age as determined by stratigraphic position is between upper middle Eocene and lower Miocene. It might, therefore, be either upper Eocene or Oligocene. The former, wherever exposed in southern California, is a marine formation of definite characteristics, and in no way similar to this series of beds. On the other hand, the Oligocene or at least the Sespe is very similar lithologically, judging from the personal observations of the writer and from comparisons with published accounts.[1]

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[1] Reed, R.D., Sespe formation, California, A.A.P.G. Bull., vol. 13, pp. 489-507, 1929.

The series, therefore, is considered to be the correlative of the Sespe formation and Oligocene in age.

The origin of these sediments is more or less obvious. They very apparently are detrital material derived from an older land mass composed of granitic and metamorphic rocks and with Eocene sedimentary rocks also exposed. While such sorting and bedding as are present are the result of deposition in or by water, this deposition certainly was not in a marine environment, judging from the lack of perfection in the results produced, and from the utter lack of evidence of marine life. The opinion of the writer is that they are the result of stream deposition either on a broad alluvial apron, on a floodplain, or possibly as suggested by Reed,[1] on a delta. The nature of the material suggests the first.

The supposed Sespe beds in the northern part of the region under discussion are found in the upper Castaic Creek district, extending from the base of Red Rock Mountain west to Salt Creek and northerly beyond the confines of the area. These are a series of well bedded and fairly well indurated sandstones and sandy shales, in part definitely land-laid, but in part having the appearance of being marine in origin. Their thickness is in excess of sixty-five hundred feet.

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1 Ibid.

The occurrence is difficult of access, the only road penetrating the district being a private one constructed recently by the Southern California Telephone Company. This is of single width with excessively steep grades, few turn-outs, and closed with a locked gate just above the junction of Castaic and Fish Canyons. The rocks are well exposed along the road as well as in both the north and west forks of Castaic Canyon. The best exposure of the basal beds is in one of the northerly branches of the latter, just above its confluence with Bear Canyon and almost at the northern extremity of the area.

The basal beds just mentioned are coarse, red sandstones, grading upward without change in dip or strike into white sandstones. The latter type is the characteristic rock of the foundation as a whole, although the color varies from white to a buff. The sand is coarse grained and composed of rather angular frggments of quartz and feldspar cemented with silica. The material is well sorted and well bedded and very hard, giving a wavernous effect on weathering. The dips average around thirty-five degrees in a general westerly direction and broad dip slopes characterize the exposures east of Castaic Canyon. Red and green beds are intercalated with the white higher in the section, and since they are thin bedded they give the impression of being shales. Examination with the hand lens, however, shows them to be composed of very fine quartz grains interlayered with an extremely large amount of biotite and muscovite and a little green chlorite. A rough estimate would put the percentage of mica at nearly fifty per cent. Considerable clay is present, acting as a binder for the other materials. Hard when dry, it is readily crumbled when wet, much as in the case of the Sespe of San Francisquito Canyon.

This series lies with an unconformable depositional contact upon Martinez beds to the east and is faulted against similar beds to the southwest. The logical explanation of its position in this latter case is that horizontal movement has taken place along this fault (the Clearwater fault), displacing the Sespe beds at least two and a half miles. Minor faulting has also broken the easterly contact to some extent. To the north and west the formation is overlapped by land-laid and lacustrine strata of probable upper Pliocene age, and apparently for a short distance by upper Miocene beds.

No fossils have been found in this formation and from the stratigraphic position it is only possible to say that it is younger than lower Eocene and probably older than upper Miocene. It therefore again is necessary to base an estimate of age upon lithology. Red beds occur in the Coast Ranges not only in the Sespe, but in the upper Miocene and lower Pleistocene as well. Compared with known deposits of the last two occurring in the area, it is seen that these beds are very much harder and show better sorting, lacking the occasional lenses of very coarse conglomerate and the isolated boulders that are characteristic of the later formations. On the other hand, the lithology is in many respects similar to that of known Sespe, and on this basis the beds are correlated with the other two exposures of Sespe in the area.

From the nature of the sediments it is apparent that the material was derived from the weathering of an area whose surface rocks were quartzitic and either granitic or gneissic. The presence of one or the other of the last two is indicated by the great abundance of mica and by the chlorite, while the quartzite is suggested by the large quantity of clean quartz, although the latter might have been supplied by the granite or gneiss. Rocks of all three types are very abundant in the immediate vicinity in the metamorphic and igneous complex and in the basal part of the Martinez. The material therefore need not have been transported far. That water was actively engaged in the process of deposition is shown by the good sorting and well developed bedding in some of the strata, although that these were marine waters it is difficult to say. Lack of marine fossils is but negative evidence and carries no great weight. However, the presence of the muddy and highly colored beds suggests that the environment could hardly have been more than deltaic, and may possibly have been that of a river flood plain.

General discussion of the Sespe question.

The fact that three widely separated areas of not altogether similar rocks have been here assigned to the Sespe is not simply a convenient catch-all for rocks whose age cannot be determined, but which actually may belong to any post-Jurassic series. It is possible that this is true, but on the other hand it is possible to conceive of a period of time when different types of material were being received in separate basins of deposition, with perhaps only one constant over limited areas, and that the climate. Even the climatic conditions might vary within certain limits, since there is no evidence pointing to absolute contemporaneity of the deposits. The present epoch is an example of such a period of time. Deposits forming in Death Valley are not exactly the same as those forming in Panamint Valley, which in turn differ from those sediments being laid down in Owens Valley or in any of the other closely associated intermontane basins. Even within the individual basins differences exist; the sands of the northern end of Death Valley are contemporary with the dry mud of the Mesquite Wells district. Meanwhile, not many miles away the Mohave River is spreading detritus of an entirely different nature over its flood plain.

Similarly, it is not difficult for the writer to conceive of the Sespe as a time of emergence, with active erosion in the highlands and many basins of deposition receiving sediments. The description by Thompson of the material forming the great alluvial plain of the Upper Mohave Valley[1] is applicable to the Sespe of San Francisquito Creek, at least lithologically, and equivalents likewise might be found for the other deposits. The rocks are found in scattered areas probably because they were originally deposited in separated basins; it is unnecessary to consider them as ever having been continuous.

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1 Thompson, D.G., The Mohave Desert region, California, U.S.G.S. Water Supply Paper 578, pp. 390-391, 1929.

In comparing Sespe beds with present day sediments of the Mohave Desert region, the writer is not suggesting similar climatic conditions. Red coloration in sediments is not an indication of extreme aridity, although it has been frequently cited as such in the literature of geology. An examination of logs of wells in the Mohave Desert shows that red is a very rare color indeed, blues, yellows and grays being the most prominent[1]. However, red coloration is predominant in the Sespe, and from this it is inferred that the climate was semi-arid, or at least one such that long, hot, dry periods alternated with the more humid seasons[2]. This is not greatly out of accordance with the views of Reed[3] as a result of his studies of the physical characteristics of the Sespe, nor with

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1 Ibid.

2 Twenhofel, W.H., and others, Treatise on sedimentation, p. 547, The Williams and Wilkins Co., Baltimore, 1926.

3 Reed, R.D., Sespe formation, California, A.A.P.G. Bull. vol. 13, p. 506, 1929.

those of Stock[1] from his/review of the mammalian remains from the South Mountain area.

Due to the absence of fossils in the Sespe of the portion of the Tejon Quadrangle under discussion, its position in the geologic time scale can only be inferred from its stratigraphic relationships as disclosed in Canton Canyon. It seems to be generally accepted from studies in other localities that Sespe is at least younger than Eocene[2]. Stock[3] considered the beds to be lower Miocene, and believed the transition between land-laid and marine deposits to have taken place within the Miocene. This may appear to be the case in the South Mountain region where the Sespe is conformably overlain by lower Miocene marine sediments, but in Canton Canyon there is an angular unconformity and a marked lithologic break between Sespe and Vaqueros (lower Miocene). There is indicated then, a period of diastrophism between the two with subsequent submergence, and it seems logical to place the beginning of lower Miocene time at the top of this unconformity. The Sespe, therefore, falls naturally into the Oligocene.

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1 Stock, C.A., Oreodonts from the Sespe deposits of South Mountain, Ventura County, California, Pub. No. 404, Carnegie Institution of Wash., p. 37, 1930.

2 Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, p. 37, 1924.

3 Op. cit., p. 36.

Miocene Series.

General.

The Miocene, as revealed by a study of the rocks of that age exposed in the southerly part of the Tejon Quadrangle, was an epoch marked by wide transgression of the sea following the Oligocene emergence, although the character of the rocks indicates that these were shallow, epeiric seas, landlocked to a certain extent. A profound disturbance occurred either at the beginning or sometime during middle Miocene time, followed during upper Miocene by the greatest submergence recorded in this part of the quadrangle. Land-laid deposits somewhat similar in character to the Sespe are also known to have formed during the upper Miocene. Most of the rocks are fossiliferous and permit exact age determination.

Vaqueros Formation (Lower Miocene).

The Vaqueros Formation, named for its occurrence on Los Vaqueros Creek in Monterey County, is now known from many localities in southern California. It is marine in origin, and characterized by the Turritella inezana fauna, it is accepted by the United States Geological Survey as the basal part of the Miocene.[1] Kew[2] found it to be conformable below with the Sespe and above with the Modelo in the Santa Clara Valley, but

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[1] Wilmarch, M.G., Names and definitions of the geologic units of California, U.S.G.S. Bull. 826, p. 94, 1931.

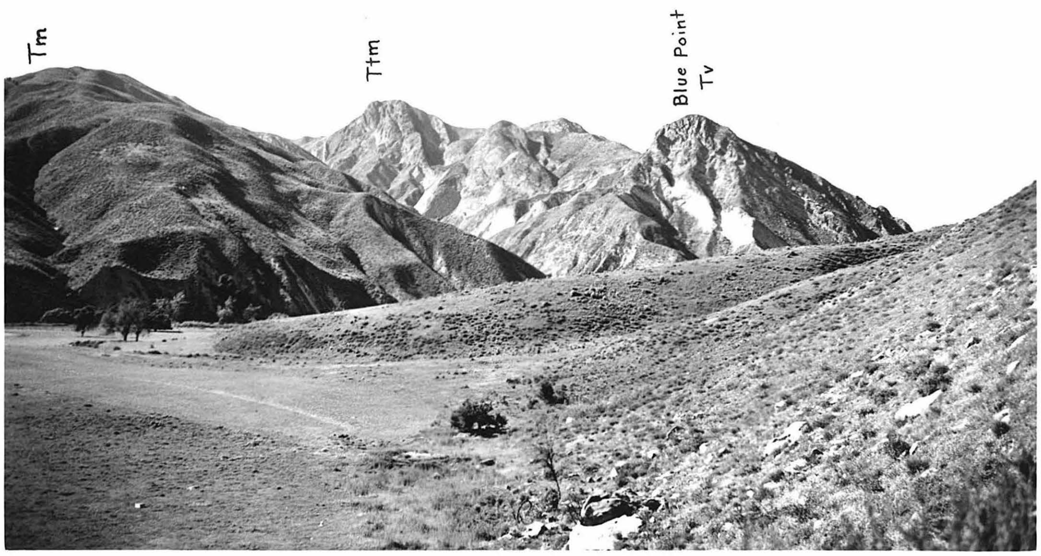
[2] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull 753, p. 41, 1924.

in the Tejon Quadrangle it is conformable with neither.

Rocks of Vaqueros age are found only in the western part of the area, extending in a narrow belt seldom as much as a mile wide from a short distance east of Canton Canyon in a westerly direction beyond the margin of the territory mapped. The formation is composed of marine sandstones and shales with a basal section made up of a very coarse conglomerate. The sandstones are extremely fossiliferous. The total thickness of the formation is forty-three hundred feet.

The best exposures are in Piru Canyon, which is cut for almost a mile across the strike of the beds in the vicinity of Blue Point, laying bare the complete section. The basal portion is exposed again in Canton Canyon and along Agua Blanca Creek. The series is completely overturned from Piru Canyon west, (Plate IX) so that the basal beds are resting above the sandstones and shales. The axis of overturn is visible a short distance south of Blue Point on the east side of the stream (Plate XXV).

The basal portion of the Vaqueros as exposed in Piru Canyon is a series of massive conglomerates grading upward into coarse red and green sandstones with occasional beds of white sand. Boulders in the conglomerate are principally granodiorite, gneiss, quartzite and sandstone, subangular, and up to eighteen inches in diameter. The matrix is an unsorted mixture of smaller particles of the boulder material with angular fragments of quartz, feldspar and biotite, the last two being considerably weathered. Iron oxide (hematite) coats everything and is the only



Overturned Vaqueros lying upon Temblor and Modelo. Piru Canyon.

apparent cement, giving to the rock its red color. The red and green sandstones are well sorted and well bedded, and are separated by thin laminae of mudstone. Contortion produced at the time of the already mentioned overturning is evident on both sides of the creek. The thickness of the basal portion in Piru Canyon is about nine hundred feet, although just to the east where the thickest section of Vaqueros is exposed it reaches twelve hundred feet.

The conglomerate and overlying sandstones are very well indurated and form the bold ridge of which Blue Point is a part, causing the canyon of Piru Creek to narrow to gorge-like proportions for a short distance. An almost spheroidal weathering has developed in the sandstones in this gorge, somewhat resembling pillow structure in lava, and this, coupled with the deep red color and evident superior hardness, gives to the casual observer the impression that the rock is igneous.

The basal section in Canton Canyon is almost entirely conglomeratic, giving strong evidence of lateral gradation in the formation. The conglomerate is very much coarser than in Piru Canyon, (Plate X) the phenoclasts ranging from pebble size to boulders three feet in diameter, and many of them show a higher degree of rounding. Hematite is present in smaller quantity, and silica forms part of the cementing material. The color is a dark yellowish brown rather than red. A few strata of hard brown sandstone occur between the massive conglomerate beds and make it possible to determine the attitude of the series, which here is steeply tilted, but not overturned. The

Vaqueros basal conglomerate. Canton Canyon.

most northerly exposure in the canyon is a massive sedimentary breccia with only a hint of stratification. Wherever cut through the conglomerate, Canton Canyon, like Piru Canyon, is gorge-like.

The basal beds along Agua Blanca Creek as a rule show less conglomerate than the other exposures, being in large part a deep maroon sandstone with only occasional lenses of well rounded pebbles. At Devil's Gateway, however, heavy beds of conglomerate are again present. These are gray in color, composed of subrounded pebbles of gneiss and granitic rocks cemented by silica in a matrix of subangular quartz sand. The conglomerate is interbedded with sandstone similar in composition to the matrix of the former. The Gateway, which is a narrow cut a few tens of feet in width, with sheer walls three or four hundred feet high, owes its origin to the resistant nature of the conglomerate.

The middle section of the Vaqueros is made up of six to seven hundred feet of light colored sandstone that stands out in marked contrast to the red beds stratigraphically below. This is a massively bedded rock varying in color from white through gray to tan, and in composition ranging from a quartz sand cemented by silica, to a somewhat argillaceous sandstone in which limonite is the cementing material. The grain is very fine to medium, and the clasts are angular to subrounded. Scattering cleavage fragments of fresh, glassy feldspar occur in the coarser sand, and a veritable shell limestone is developed locally through abundance of fossils. Shale partings occur between the sandstone strata, and with an increase in the thickness of these and a thinning of the latter, the series gradually merges with the upper shale member.

Some six hundred feet of shale are exposed from the top of the sandstone to the point where later beds come in, although this figure might be increased or decreased by moving the lower contact one way or another, since from its gradational character it is necessarily arbitrary. These are soft, gray to brown mudstones, more or less sandy in places, and with frequent sandstone lenses. They are exposed to good advantage only on the east side of Piru Canyon. Their lack of hardness is in contrast to the superior hardness of the sandstone and conglomerate, and results in a low area at the top of the section which might be taken as topographic evidence of faulting.

As stated in the discussion of the older rocks, the Vaqueros lies with a depositional contact against strata of Domengine and Sespe ages. Some faulting has occurred along this contact, as could be expected in view of the overturning of the series, and slickensided surfaces, gouge and crushing may be seen in the first easterly trending branch of Piru Creek north of Blue Point, as well as in Agua Blanca Canyon. It is the opinion of the writer, however, that the faulting is of secondary importance, simply having taken place along the already existing line of deposition. The basal beds of the Vaqueros show no indications of having been cut off at the contact, while evidence that Sespe red beds were in their same relative position at the time of deposition of the Vaqueros is seen in the inclusion of the red material of the former in the basal beds of the latter.

The nature of the contact between Vaqueros and the beds adjacent to the south is not altogether clear. These beds are of middle and upper Miocene ages and it seems natural to believe that the contact should be depositional. On the other hand there are certain pieces of evidence that suggest faulting. These are seen particularly in Piru Canyon below Blue Point, where beds of the younger formation appear to butt into the older beds, a circumstance that could be explained in a depositional contact only under exceptional conditions. Again, certain of the younger beds that appear in some places seem to be missing in others, this being particularly true of the conglomerate overlying the Vaqueros east of Canton Canyon. An explanation is suggested in the known lateral variation of the beds. The series of notched ridges marking the contact may be indicative of faulting, but it also is explainable by the more rapid weathering of the soft shales comprising the upper part of the Vaqueros. In view of the stresses that must have been set up by the powerful compressive forces causing the overturning and folding of the section, it is reasonable to expect some faulting at this contact as at the lower one. It is the belief of the author that such faulting, while sufficient to bring about the anomalous relationships mentioned above, was of minor importance, and that the contact is essentially of an unconformable, depositional nature.

The Vaqueros is the most fossiliferous of all the formations found in the area described. Large collections were made by the writer from both sides of Piru Canyon, with some additions from the outcrops in Agua Blanca Canyon. Sandstones, shales and conglomerates furnished specimens. The characteristic fossil is <u>Turritella inezana</u>, of which practically all the varieties noted by Doel and Corey[1] appear. Samples of the upper shale member yielded some foraminifera which have been determined by Mr. Driver. He states[2] that the uppermost strata contain a fauna which correlates with that in the lower portion of the Las Sauces Creek section west of Ventura, which is considered to be transitional between Vaqueros and Temblor. Two samples taken stratigraphically below these beds contined a meager Vaqueros fauna, while others from still farther below were barren of foraminifera, but contained echinoid spines and ostracods. Typical Vaqueros molluscs were found in sandstone beds associated with the shales from which the last mentioned samples were taken. Most of the fossils are well preserved, although a distinct flattening of many of the <u>Turritellas</u> occurs and gives an indication of the deformative pressures to which the rocks have been subjected.

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[1] Paper in press.

[2] Personal communication.

The following fossils were collected from the Vaqueros in the vicinity of Piru Creek:

Mollusca

Gastropoda

Turritella inezana Conrad

Turritella inezana (Conrad) var. *santana* Loel and Corey

Turritella inezana (Conrad) var. *bicarinata* Loel and Corey

Turritella inezana (Conrad) var. *sespeensis* Arnold

Ficus ocoyanus (Conrad)

Solenosteira venturana Loel and Corey

Sycum sp.

Pelecypoda

Macoma nasuta Conrad

Macoma arctata (Conrad)

Ostrea vespertina (Conrad)

Arca santana Loel and Corey

Clementia pertenius (Gabb)

Panope cf. *generosa* Gould (possibly n. var.)

Pecten sp.

Echinodermata

Echinoidea

Scutella fairbanksii Pack

Arthropoda

Crustacea

Balanus sp.

The question may arise as to whether the basal conglomerate and the red and greed beds may not be the equivalents of type Sespe rather than Vaqueros, lying conformably below the strata bearing fossils characteristic of the latter. This is a possibility worthy of being considered, especially in view of the fact that in Piru Canyon the conglomerate is not fossiliferous. Too, the beds resemble the Sespe of the type locality to a marked degree, and probably are the correlatives of those described by Kew and others[1] as conformably underlying Vaqueros. The answer, it is believed, lies in the finding of a large _Macoma_ in the green beds of Blue Point and of fragmentary _Turritellas_ in the conglomerate of the Devil's Gateway, indicating marine origin; in the presence of Turritella _inezana_ in gray sands intercalated with red sands low in the section west of Devil's Gateway; and in the presence of beds that can be assigned to the Sespe, lying unconformably below the conglomerate of Piru Creek. This, it seems, is sufficient evidence for calling the basal beds Vaqueros in age.

The basal portion of the formation indicates deposition in a transgressing sea, the sediments apparently having their derivation in the highly colored continental deposits of

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[1] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, p. 41, 1924.

also, Hudson, F.S. and Craig, E.K., Geologic age of the Modelo formation, California, Bull. A.A.P.G., vol. 13, p. 512, 1929.

the preceding epoch, although that granitic and metamorphic rocks also were being eroded at the time is suggested by the type of boulders in the conglomerate. The red color is held by the writer to be of secondary origin and therefore of no significance in interpreting climatic conditions under which the sediments were deposited. The light colored sandstones were deposited later as the shore line moved farther inland, and covered with the basal beds such portions of the Sespe as had not been removed by erosion. They were probably in part derived from earlier formed sandstones either exposed to erosion above sea level or simply above the profile of equilibrium, but that granitic rocks were undergoing erosion still farther inland is indicated by the presence of the feldspars. It is possible, however, that the latter might be attributed to the breaking down of granitic and gneissic boulders known to occur in profusion in the Eocene rocks.

The abundance of fossils is indicative of comparatively quiet waters, and may be interpreted as showing the presence of an embayment, somewhat protected from strong wave action. On the other hand, the sediments may have been deposited off an open coast in currents sufficiently strong to quickly bury the shells, thus preserving them from destruction. Since Vaqueros beds mapped by Kew[1] to the southwest doubtless connect with these beds, giving a long, curving outcrop, deposition in a wide bay seems to be the logical conclusion. The shales followed the sandstones as the landmass became lower in relief and was further submerged by the sea.

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[1] Op. cit., Pl. I.

Temblor (Topanga) Formation (Middle Miocene)

Lying above the Vaqueros with a marked angular unconformity are rocks of middle Miocene age. These consist of a heavy, poorly sorted basal conglomerate of little lateral constancy, followed by a series of hard cherty shales interbedded with occasional thin sandstone layers. The thickness of the beds is indefinite, since it so far has been found impossible to satisfactorily fix their upper limit. This is die to the facts that the overlying beds of Modelo are also shales, that both formations are unfossiliferous along the contact, and that the great disturbance at the time of the Agua Blanca overturn has greatly distorted the incompetent beds. The writer believes that the contact probably comes at an apparent lithologic change between the brown cherty shales and a softer siliceous type lying above, and it is here that he has attempted to place it. It should be recognized that this is by no means an exact boundary, since it is more or less arbitrarily chosen in the first place, and in the second, poor exposures of the beds and their discontinuity even where exposures are good, make it impossible to follow for any great distance.

These beds are best exposed in the easterly branches of Canton Canyon about four miles from Piru Creek. Here they form the lower portion of the series of rocks overlying in succession the highly tilted Vaqueros, Sespe and Domengine formations, lapping up finally on the granodiorite. Other exposures of the conglomerate are above the Vaqueros conglomerate on the east side of Canton Canyon about two miles from Piru Creek; on the ridge between Canton and Piru Canyons; and west of Piru Canyon. In the first two localities the conglom erate is in normal position, but west of Canton Creek it is only by keeping in mind the overturning, with some attendant overthrust faulting, that it is possible to conceive of the conglomerate's occupying the position it frequently does. At the western extremity of the area mapped it apparently has been folded back upon its formerly overlying beds and subsequently cut through by the erosion of the channel of Aqua Blanca Creek.

The conglomerate is a massive, poorly sorted rock, varying in thickness and lithology from place to place, and at times being entirely absent. This may be due in part to faulting and in part to lateral gradation of the conglomerate into sandstones and shales. In the eastern localities it is yellow to very light gray, becoming darker gray to brown toward the west. The phenoclasts are of granite, granodiorite, anorthosite and gneiss, with some sandstone, shale and schist, and are up to four feet in diameter, although as a rule considerably smaller. All show a fair degree of rounding. Where observed on the peak west of Blue Point, the pebbles are well rounded and rather resemble Martinez. The matrix is a coarse brown or yellow arksoic sand and the cement siliceous and ferruginous. The thickness of the conglomerate varies from nothing to over four hundred feet.

More or less sandstone is interbedded with the conglomerate and is similar in composition to the matrix of the latter. Near the contact with the granodiorite east of Canton Canyon this sand is impregnated with tar.

The shales are thin, rather hard and cherty, and yellow to brown in color. Thin beds of muddy sands are present with them. The thickness of the shale member is estimated to be two or three hundred feet, although this may be much increased or decreased locally as a result of squeezing.

The true relation of the Temblor to other formations is best seen in Canton Canyon. Here the basal part unconformably overlies all older beds, the attitude of the latter being practically vertical. (Plate XI). A major disturbance is thus indicated between lower and middle Miocene time. To the west, where all beds are disturbed by the later Agua Blanca overturn, this relationship is not so clearly visible. Above the Temblor lies the Modelo or upper Miocene, which apparently is conformable. As previously stated, the exact location of the contact is doubtful, but has been taken to be where there is a change in the type of shales. It might be more logical to place it at the base of a thick sandstone stratum two or three hundred feet higher in the section.

The evidence as to the age of the Temblor is scanty but conclusive. In float found in a branch of Canton Canyon cut entirely in Sespe red beds up to the point where it intersects the base of the supposed Temblor, occurs an unmistakable <u>Turritella ocoyana</u>. The piece of float is much too large to have been carried to the location by human agency, and is similar in

Unconformity at the base of the Temblor. Canton Canyon.

every way to other large blocks of float in the same and adjoining canyons. The writer has been unable to trace the float to the fossil bearing stratum from which it came, but in lithology the matrix in which occur the fossils is similar to that of the lower part of the overlying beds, and absolutely dissimilar to the Sespe. The only conclusion possible is that the float came from the overlying beds, and since Turritella ocoyana is restricted in its distribution and is of diagnostic value, these beds must be Temblor or middle Miocene.

The sediments appear to have originated in a basin of marine deposition not greatly different from that of the Vaqueros. Following the disturbance at the end of Vaqueros time during which the older beds were highly tilted and folded but not greatly uplifted, there appears to have been rather rapid submergence, causing the deposition first of the conglomerate and sandstone followed almost immediately by the shales. Sediments that are probably the equivalents of these, although mapped as Modelo,[1] occur to the southwest between Sespe and Piru Creeks, and again suggest a large embayment similar to that of Vaqueros time.

Mint Canyon Formation (Upper Miocene)

Land laid beds corresponding in many ways to the Sespe formation are found in the southeastern portion of the Tejon Quadrangle. These are a northerly extension of beds mapped by

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1 Ibid.

Kew[1] to the south, and they extend in a rapidly narrowing band for about six miles to the northwest, another small finger projecting northeasterly along San Francisquito Canyon. Hershey first described the occurrence of the formation some miles southeast of the Tejon Quadrangle in Tick Canyon, and named it the Mellenia series[2], roughly indicating its extent on his earlier published reconnaisance map.[3] Since his name had no geographic significance, it was changed by Kew[4] to the Mint Canyon formation from the good exposures in the canyon of that name, and it is now so known.

The Mint Canyon formation comprises a series of heavy-bedded, poorly sorted conglomerates and sandstones, highly colored, and ranging in thickness from nothing to over thirty-five hundred feet. The lower portion of approximately one hundred feet is a basal conglomerate that varies in composition from place to place depending upon the nature of the underlying rocks. Above this lie about five hundred feet of red and gray coarse sandstone and fine conglomerate, followed by yellow

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1 Kew W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, Pl. 1, 1924.

2 Hershey, O.H., Some Tertiary formations of southern California, Am. Geol., vol. 29, p. 356, 1902.

3 Hershey, O.H., The Quaternary of southern California, Univ. Calif. Pub. in Geol., vol. 3, Pl. I, 1902.

4 Op. cit., p. 52.

sandstone with interbedded lenses of coarse conglomerate. The thickness is considerably greater to the southeast.

The best exposures of the formation in this quadrangle are in San Francisquito Canyon, where the rocks were swept clean by the flood of 1928. The contact between the Mint Canyon and the overlying series crosses the canyon a short distance south of the southerly boundary of the quadrangle, and the channel of the stream is cut in or near the continental beds for about three miles. The bright colors stand out in vivid contrast against the somberness of the Pelona Schists. Good exposures also occur in Dry, Haskell, Charlie and Elizabeth Lake Canyons.

The basal conglomerate of the series, with the exception of that portion west of Elizabeth Lake Canyon, was very poorly exposed until the breaking of the St. Francis Dam. It is now disclosed to excellent advantage in San Francisquito Canyon about three-quarters of a mile below the former damsite, again just below the powerhouse, and yet again where the schists leave the canyon and swing off to the east. In all these localities it is a bluish gray to rusty yellow rock made up entirely of subangular to subrounded boulders of schist up to a foot in diameter, and encased in a matrix of finer schist fragments. (See Plate III) The cementing material appears to be a fine gray silt, and oxide of iron, making a not exceptionally well consolidated rock. The exposure west of Elizabeth Lake Canyon exhibits a red to brown conglomerate consisting of boulders of Martinez sandstone of about the same size and degree of rounding, cemented in a sandy matrix by iron oxide, largelt hematite. This, too, is a comparatively soft rock, weathering more rapidly than the underlying sandstone.

The middle member of the formation is best exposed in a westerly branch of San Francisquito Canyon about a mile north of the south boundary of the quadrangle, where it attains its maximum thickness. It comprises a series of alternating red and gray sandstones, both showing derivation from the neighboring schists. While the gray beds are generally the finer in texture, both are made up of quartz, mica and fragments of schist, subangular, and cemented by silt, aided in the case of the red beds by iron oxide. The latter beds frequently approach a conglomerate texturally, and being somewhat better cemented, generally are more resistant to weathering than the gray, standing out for some time after the latter have been eroded away. Bad lands are developed here on a small scale.

A single stratum of limestone occurs in the middle member a short distance above Power House No. 2. (Plate XII) This is a firm, dense, white rock, containing as impurities scattered grains of quartz, which give the impression of its being a felsite porphyry. It has been encountered nowhere else in the area, although this may be due simply to poor exposures, since this outcrop was not particularly noticeable prior to the flood. All the beds are more or less lens-like and appear to grade laterally into beds similar to those making up the overlying member, or into marine beds, and it is probable that the limestone bed also is only a lens oflittle areal extent.

The upper portion of the Mint Canyon formation is composed of a thick series of heavy-bedded, yellow to buff sandstones, poorly sorted, and frequently exhibiting cross.bedding. The rock consists of angular quartz grains held together by a rather weak calcareous and ferruginous cement. Lénses of conglomerate are very common and may be said to be one of the characteristic features of this portion of the formation. The latter are usually made up of angular to sub-angular boulders of schist, gneiss, granodiorite, quartzite and sandstone, in a matrix similar to the main mass of the sandstone. The yellow upper member approaches three thousand feet in thickness, and is the most persistent and constant part of the formation.

The Mint Canyon, as already indicated, lies upon the Pelona Schists with a depositional contact. This was mapped by Kew[1] as a fault over the short distance it is exposed in the Camulos and Fernando Quadrangles, and was so considered at first by the writer. The basal conglomerate was everywhere concealed by the soil mantle, showing weathered schist and giving the impression of the presence of a crushed zone. A few springs along the contact strengthened the belief of a fault, although the irregularity of the contact suggested a very low angle. The exposure of the basal conglomerate in San Francisquito Canyon by the flood waters released by the breaking of the St. Francis Dam removed all question as to the nature of the contact there, and since the surface expression had everywhere been similar, there is no reason for not believing it all to be of a depositional nature.

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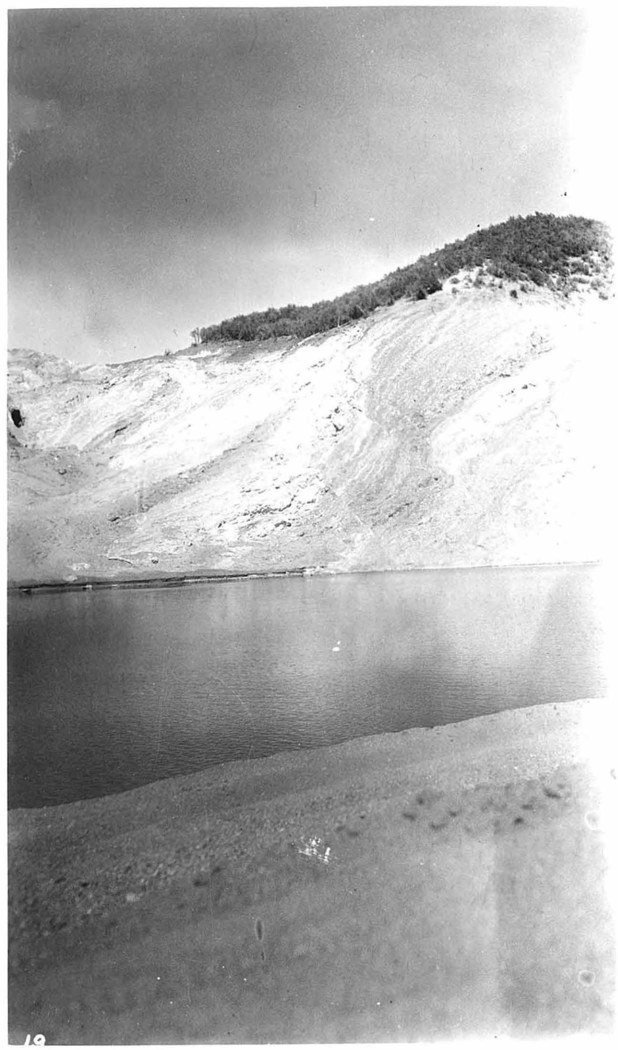
[1] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, Pl. I, 1924.



Limestone lens in Mint Canyon formation. San Francisquito Canyon.

On the other hand, the Mint Canyon is in fault relationship with the Sespe. From where the former first appears in San Francisquito Canyon to where it swings across the ridge to Charlie Canyon, this is an overthrust fault, the Sespe lying above the Mint Canyon. West of this ridge as far as Elizabeth Lake Canyon the fault is normal, or at most a reverse of high angle. From the latter canyon westward the contact is again depositional, as indicated by the conglomerate at the base with included boulders of the underlying Martinez formation. Two miles west of Elizabeth Lake Canyon this conglomerate grades laterally into the basal beds of the Modelo marine series.

The Mint Canyon formation is everywhere overlain by marine beds that have been assigned to the Modelo, or upper Miocene. Kew[1] found the two to be unconformable to the south, but where exposed in the Tejon Quadrangle the dips and strikes are so nearly the same as to lead the writer to believe them to be conformable. The indication given by the lateral gradation of the basal beds into each other is that the lower portion of the Modelo is the seaward equivalent of the Mint Canyon and it therefore would appear that there is likewise an upward gradation from the latter into the former.

Portions of the Mint Canyon formation have yielded vertebrate remains and it has been possible to determine the age with some degree of certainty. The remains are generally

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1 Ibid., p. 52.

fragmentary, the only material of diagnostic value found in the Tejon Quadrangle exposures having been an upper third molar of Merychippus and a Merycodus horn core. These were found by the writer in the middle red beds in the small area of bad-lands developed just west of San Francisquito Creek about a mile north of the quadrangle's southern boundary. They have been described by Maxson[1] in connection with his study of the Mint Canyon fauna as a whole.

Maxson has determined the age of the Mint Canyon fauna as somewhat younger than that of the Barstow and older than the Ricardo, both of the Great Basin province. The former is considered to be upper Miocene and the latter lower Pliocene. From the strategraphic position of the beds he would place them below the Cierbo of the Pacific Coast marine province, depressing them still further to allow for the time necessary for deformation and erosion before deposition of the overlying marine beds. This would make them the approximate equivalents of the Briones, although he does not so show them on his correlation chart.[2] Maxson was basing the stratigraphic position upon the belief that the overlying marine beds, supposedly of Cierbo age, were unconformable with the Mint Canyon. However, as mentioned above, in the Tejon Quadrangle no evidence of either such unconformity or

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[1] Maxson, J.H., A Tertiary mammalian fauna from the Mint Canyon formation of southern California, Pub. No. 404, Carnegie Institution of Wash., pp. 77-112, 1930.

[2] Ibid., p. 85.

erosion interval was observed by the writer, while on the other hand there is apparent lateral and upward gradation of the Mint Canyon formation into the marine beds. The Mint Canyon then is the equivalent of the lower portion of the marine series, and as such has the same general age. This, as will be brought out under the discussion of the latter, may simply be stated as upper Miocene, there being insufficient evidence of stratigraphic breaks to attempt subdivision into Briones, Cierbo and Santa Margarita. Mint Canyon, representing the lower part, might be regarded as equivalent to Briones and part of Cierbo time.

The origin of the Mint Canyon formation may be deduced from a study of its lithology, fauna and relation to other rocks. The character of the basal conglomerate indicates that it was largely deposited as alluvial fan material directly upon the rocks from which it was being derived. The inlier of Mint Canyon in the Pelona Schists adjacent to San Francisquito Canyon is interpreted as a filled canyon in the old surface, while the outliers of schist surrounded by sediments in the same region are undoubtedly former hills buried in the talus or fan material. Therefore, it appears that at the beginning of Mint Canyon time the land surface in this particular district was more or less irregular, and material derived from the schist and sandstone hills was deposited directly at their base, probably in a valley with minor branch canyons cut back into the hills. That this valley was close to the sea is evinced by the westerly gradation of the basal beds into beds similar in lithology but containing marine fossils. Moderate relief is suggested by the moderate thickness of the fanglomerate.

The middle member of the formation, made up of the red and gray beds, shows a lowering of relief and deposition of smaller fragments close to the hills, with sands farther out in the valley and shales in the sea at its mouth and westerly along the coast.

Semi-aridity may be postulated from the high coloration of some of the beds, for although this may be due in part to erosion of older red beds (Sespe), its retention by continental deposits laid down under humid conditions is unlikely. That ephemeral lakes existed locally is proven by the limestone deposit and the finding of some fresh-water fossils in deposits to the south and east[1]. Around these lakes and along such streams as flowed through and into the valley, there probably existed sufficient plant life to furnish food for the rather varied assemblage of vertebrates (horses, camels, mastodons, etc.) shown by fossils to have been present.

The upper sandstone member apparently represents deposition in a new broad valley over which the sands were spread by the main stream and such other streams as issued from the tributary valleys. Sudden floods, or brief periods of above-normal rainfall are evidenced by the occasional lenses of conglomerate. The schist hills appear to have yielded little sediment at this time and may have become almost entirely buried. The main stream, actively aggrading in its lower reaches was well

1 Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, p. 54, 1924.

along in early maturity. Considering that submergence is indicated by the gradation into the overlying marine formation, a general sinking of the landmass may be postulated which would account for the rather rapid attainment of maturity in a region of semi-aridity. It seems likelt from the resemblances between the faunas of the Mint Canyon and the Barstow beds[1], that there was easy migration between the two regions and therefore it is possible that this valley was in part receiving deposits from the present Mohave Desert region. Some part of this upper sandstone may represent delta deposits, since cross-bedding is present, although it has not been found possible in the limited exposures in this quadrangle to work out the conventional sequence.

There follows a list of the Mint Canyon fauna as a whole, taken from Maxson and Kew. Those forms occurring in the Tejon Quadrangle are starred.

Vertabrata

Testudinata

Fragments, probably of Testudo and Clemmys

Aves

Fragments only

Carnivora

Aelurodon sp.

Lagomorpha

Hypolagus? cf. apachensis Gazin

Proboscidea

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[1] Maxson, J.H., A Tertiary mammalian fauna from the Mint Canyon formation of southern California, Pub. no. 404, Carnegie Institution of Wash., p. 83, 1930.

*Trilophodon sp.

Equidae

Parahippus? (Archeohippus) near mourningi Merriam

Merychippus sumani Merriam

*Merychippus sp. (possibly californicus)

Merychippus (Protohippus) intermontanus Merriam

Protohippus sp.

Hipparion? (two species)

Hipparion? near mohavense Merriam

*Rhinocerotidae

Rhinocerotid indet.

Tagassuidae

Prosthennops? sp

*Camelidae

Miolabis californicus Maxson

Alticamelus? sp.

Antilocapridae

*Merycodus near necatus Leidy

Oreodontidae

Oreodont cf. Merychyus

Invertebrata

Gastropoda

Paludestrina imitator Pilsbry

Modelo Formation (Upper Miocene)

The problem of the Modelo is one of considerable interest in the region north of the Santa Clara River. The name was first applied by Eldridge[1] in 1907 to beds of upper Miocene age typically exposed in Modelo Canyon, Ventura County, and later was redefined by Kew[2], who excluded certain beds proven in the interim to be Vaqueros. Hudson and Craig[3] in 1929 pointed out that beds of middle and of uppermost Miocene also were included in the Modelo at the type locality, and limited Modelo to those unfossiliferous beds between, equivalent to the lower San Pablo (or Briones and Cierbo) of central California. Their conclusions will be discussed later in connection with the age of the formation described below. The United States Geological Survey[4] accepts the intention of Kew as applying the name to beds of upper Miocene age, apparently regardless of whether they are upper or lower San Pablo. It is in this sense that the term is used in this paper.

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[1] Eldridge, G.H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California, U.S.G.S. Bull. 309, p. 17, 1907.

[2] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, Califotnia, U.S.G.S. Bull. 753, pp. 55-67, 1924.

[3] Hudson, F.S. and Craig, E.K., Geologic age of the Modelo formation, California, Bull. A.A.P.G., vol. 13, pp. 509-518, 1929.

[4] Wilmarth, G.M., Names and definitions of the geologic units of California, U.S.G.S. Bull. 826, p. 49, 1931.

Marine beds of upper Miocene age occupy roughly about a fifth of the area discussed in this paper. One exposure occurs in the Piru Creek region and is the northerly extension of typical Modelo beds. The other occurrence is in the middle portion of the area where the beds are well exposed along the Ridge Route, and are traceable directly into Kew's questionable Modelo[1]. The hope was expressed by the latter that mapping north of his northern boundary might show these beds swinging around and connecting with type Modelo, but such has not been the case. It is probable that they originally were connected and that movement along the Palomas Canyon fault has brought about a separation. Their nearest approach is southwest of Oak Flat where the two exposures are a half-mile apart.

The Modelo in the Piru Creek region occupies the southwestern corner of the area mapped, reaching a narrowing arm north and east along Canton Canyon to the western body of gneiss. These beds are known to extend to the west for some miles, and as already mentioned are the northerly continuation of Kew's Modelo. The rocks are principally shales, with, however, some very thick interbedded strata of sandstone, and attain a thickness in this part of the quadrangle of approximately seventy-nine hundred feet. There is a westerly gradation into massive sandstone which in the vicinity of the Pothole has become the predominant petrologic type, standing out in great gray and white ridges with prominent dip slopes.

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1 Op. cit., pp. 67-69.

The rocks are excellently exposed in Piru Canyon from the south boundary of the quadrangle to a short distance north of the mouth of Canton Creek. (Plate XIII) Good exposures exist also in the canyon of the latter, where steep faces cut largely in the shale attain a height of several hundred feet. (Plate XIV) The sandstone is exposed to advantage at the mouth of Canton Canyon, in the abrupt rim of the Pothole, and also farther west along Agua Blanca Creek and its tributary canyons.

The shale is of several types and shows varying degrees of induration. Near its eastern extremity it is a light buff in color and is fairly dense and hard, becoming a gray, soft type in lower Canton Canyon. The latter is rather brittle and breaks up into small sized fragments of irregular shape. On the east side of Piru Canyon it is again a light buff, weathering to a rusty brown, and is locally siliceous and very hard. Where exposed to atmospheric agents of erosion small parallelopipeds are produced. This same sort of shale persists to some degree west of Piru Creek, with a dark gray platy type showing partings of ash. This last mentioned variety also is quite hard locally. Associated with the shale are strata of sandstone usually less than a foot in thickness, although occasionally beds are twenty or more feet thick. The thin beds are fine textured and composed of subrounded quartz grains with frequent flecks of biotite. The cement is in part ferruginous and in part calcareous, with perhaps some clay. This gives a rather soft rock that in the vicinity of the Agua Blanca overturn

Typical exposure of Modelo in Piru Canyon.

is as highly contorted as the shales.

When followed west the shales become more and more sandy until they pass over into true sandstones. There is likewise an upward gradation into sandstone, although shales remain prominent all through the eastern portion of the section. The sandstones range from the rather poorly compacted yellowish type characteristic of the shale member to a quite dense, hard, gray variety, becoming a striking white rock in the western extremity of the area. A sample from Devil Canyon is finely conglomeratic and made up of subangular rock particles, principally metamorphic and granitic, in a matrix of quartz with small cleavage fragments of exceptionally fresh feldspar. The cement is calcareous and ferruginous.

The Modelo overlies with no apparent difference in dip and strike the shales and conglomerate assigned by the writer to the Topanga formation. As previously indicated, fossil evidence is so infrequent as to make the contact quite indefinite and it has been arbitrarily placed at a not too clear lithologic break between shales. It therefore is possible that some Modelo has been included in Topanga or vice versa. Above, the Modelo is overlain by beds that have been referred by the writer to the Pico, or Pliocene. In Devil Canyon a very prominent basal conglomerate is present at the contact and this can be followed south and east to the southerly margin of the quadrangle. The divide between Devil and Canton Canyons is a rather flat, easterly-tilted surface with poor outcrops, and

Minor anticline in Modelo shales and sandstones.

Lower Canton Canyon.

here the contact can be followed only by noting the presence or absence of pebbles in the soil mantle. It appears that in places the basal conglomerate of the overlying formation grades laterally into soft sandstone and shale, and where this occurs the contact is quite obscure. The conglomerate reappears, however, in the cuts west of the ridge as the granite is approached and the contact again becomes traceable. The overlying beds are everywhere unconformable with the Modelo.

A few scattered fossils have been found by the writer in the western exposure of Modelo beds. The most prominent invertebrates are Ostrea titan, Pecten estrellanus and Astraea biangulata. The first is frequently accepted as a Santa Margarita (restricted, or latest upper Miocene) marker, but for reasons to be brought out under the discussion of the other body of rocks of comparable age it seems that in this region it can hardly be said to be more definite than simply upper Miocene. Both of the other forms range through all three horizons of upper Miocene. Samples of the shale on the west side of Piru Creek carry an abundant foraminiferal fauna which has been pronounced by Mr. Driver to be of Modelo age.[1] The author finds no good stratigraphic basis for subdividing these beds, and therefore accepts them as representing deposition throughout upper Miocene time.

It has been suggested by Grant and Gale[2] that because of "striking similarity of the whole sequence of lithologic and

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[1] Personal communication.

[2] Grant, U.S., IV, and Gale, H.R., Pliocene and Pleistocene mollusca of California, Mem. San Diego Acad. of Nat. Hist., vol. 1, pp. 28-29, 1931.

faunal units" to those of middle California, formational names of the latter can be applied to the Ventura basin and that "as the name Modelo does not apply to a natural unit and is not needed, it should be abandoned". Field work does not bring out this similarity. The stratigraphic break between Hudson and Craig's "Santa Margarita" and the underlying part of the "upper Modelo shale"[1] has not been observed in the Tejon Quadrangle, and so far as can be seen, there are no lithologic breaks anywhere in the section upon which to base a subdivision into Briones and Cierbo. Further, no faunas characteristic of these two formations have been found in the great thickness of sediments that would thus be assigned to them. It seems illogical to apply these names that have definite meanings elsewhere to beds that give no proof of being their equivalents. As for replacing the term "Modelo" with "Santa Margarita" in its broad sense, the prevalence of the use of the latter term in its restricted meaning points only to confusion if such a policy is adopted. It therefore seems more necessary than ever to retain the term "Modelo" for beds of upper Miocene age.

The various subdivisions of the Modelo made by previous writers, so far as they are represented in the Tejon Quadrangle are interpreted as follows:

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[1] Hudson, F.S., and Craig, E.K., Geologic age of the Modelo formation, California, Bull. A.A.P.G., vol. 13, p. 516, 1929.

Upper shale member) (Upper sandstone member)	Modelo
Middle shale member) (Lower sandstone member)	Topanga
Lower shale member)	Vaqueros

The lower shale, as previously indicated, carries a foraminiferal fauna of Vaqueros and transitional Vaqueros-Temblor age; because of its conformable sequence it is placed wholly within the Vaqueros. The lower sandstone apparently is represented by the conglomerate taken as the base of the Topanga on the faunal evidence already mentioned. The upper sandstone is believed to have been replaced laterally by the shale which is put at the base of the Modelo.

It should be noted here that in a locality in Devil Canyon a short distance above the Modelo-Pico contact, were found a few shells of _Pecten_ comparable to _estrellanus_, presumably an upper Miocene form. This might be taken to indicate an unconformity within the Modelo, placing the Miocene-Pliocene break still higher in the section. No break is known to occur between these beds and higher ones in Palomas Canyon containing an abundant Pico fauna. Further, the presence of the shells might be attributed to a reworking of Miocene material, since similar forms have been found immediately below the contact, and the material here mentioned came from a filled channel in the lower part of the Miocene. Again, _Pecten estrellanus_ is not necessarily confined to the Miocene, but according to Grant and Gale[1]

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[1] Grant, U.S., IV, and Gale, H.R., Pliocene and Pleistocene mollusca of California, Mem. San Diego Acad. of Nat. Hist., vol. 1, p. 186, 1931.

also occurs in the lower Pliocene. Thus there seems insufficient evidence for calling these overlying beds Miocene, while there are many reasons for placing the Miocene-Pliocene break at their base, as has been done.

The main body of Modelo rocks occupies the central part of the area, extending in a northwest-southeast direction for approximately twelve miles with an average width of four miles. The formation is marine in origin and consists chiefly of alternating sandstones and shales, although with a well developed conglomerate at the base. The thickness is five thousand feet.

These rocks were first mapped by Hershey[1] who apparently considered the northern portion, at least, to be Cretaceous. Their southern extension was mapped and described by Kew[2], as previously mentioned. The present writer discussed the southeastern portion of the formation in his earlier paper on the Tejon Quadrangle.[3]

This occurrence of Modelo is exposed in an almost ideal manner. The Ridge Route with its many road cuts runs through strata of this age for about fifteen miles. The new road just west of the Ridge Route shows beautiful exposures in the recently

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[1] Hershey, O.H., The Quaternary of southern California, Univ. Calif. Pub. in Geol., vol. 3, Pl. I, 1902.

[2] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, pp. 67-69, and Pl. I, 1924.

[3] Clements, T., Geology of a portion of the southeast quarter of the Tejon Quadrangle, Los Angeles County, California, pp. 29-33, on file, Library, California Institute of Technology, 1929.

completed cuts from the south boundary of the Quadrangle to Piru Creek. (Plate XV) Castaic Creek has eroded its channel for over eight miles along the strike of the beds and its tributary canyons are cut almost parallel to the direction of dip. Good exposures are also found in Charlie Canyon, Bitter Creek, Elizabeth Lake Canyon, Palomas Canyon, Violin Canyon, Oak Flat, and along the upper part of Piru Creek. Most of the region immediately adjacent to the Ridge Route has been burned over within the last few years, with the result that brush offers very little hindrance to the making of observations.

The Modelo has been folded into a long, assymetric syncline, the direction of whose axial plane is approximately the same as the trend of the formation, and there is a repetition of beds on the two sides of the axis. The basal portion differs somewhat on the opposite limbs as might be expected from the fact that the bordering rocks are quite different.

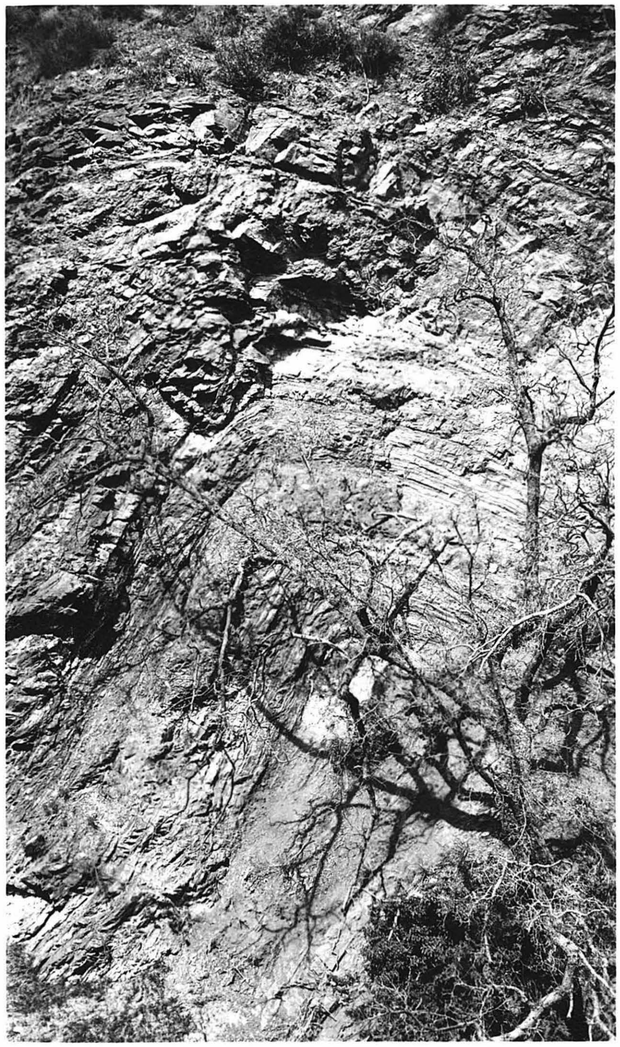
On the northeasterly margin the basal conglomerate is from a few feet to almost three hundred feet in thickness, although the latter is unusual. It is made up principally of subrounded boulders up to three feet in diameter of hard, grayish sandstone and a variegated conglomerate identical with the sandstone and conglomerate of the underlying Martinez beds. The matrix is composed of coarse to fine, subrounded particles of quartz sand and quartzite rock, cemented with silica and a small amount of ferruginous matter. Since the conglomerate is very fossiliferous in places, considerable calcite also may be present

Recumbent folds in incompetent Modelo shales and sandstones on westerly limb of Castaic syncline. New state highway south of Oak Flat.

as cement. Large oyster reefs were noted in the basal beds just west of Castaic Creek a short distance horth of its junction with Fish Canyon, and again in some of the eastern tributaries of the former. To the southeast the conglomerate merges with the basal portion of the land-laid Mint Canyon, with which it is almost identical in lithology, excepting for a greater abundance of iron oxide as c ementing material in the latter. Locally the marine conglomerate has the appearance of being of continental origin, which is interpreted as indicating the presence of small canyons along the Modelo sea coast more or less contemporaneous with the valley in which Mint Canyon deposition was taking place.

The basal conglomerate along the westerly side is of an entirely different nature, and was at first mapped as a separate formation, faulted against the Modelo. The marked accordance in strikes in the two, and the constancy of the conglomerate along its strike finally convinced the writer that the latter was simply the basal portion of the Modelo separated from the upper portion by the intraformational Violin Canyon fault. Evidences of this faulting are visible along the upper margin of the conglomerate, a part of the movement having been taken up by the slipping of the overlying incompetent shales along their bedding planes at the time of birth of the fault and syncline. The shales are frequently overturned.

This conglomerate is extremely thick, varying from twelve hundred feet to twenty-four hundred feet. A sharp fold visible in the tributary canyon of Canton Creek draining Oak Flat (See Plate XVI) may be represented by isoclinal folding in other

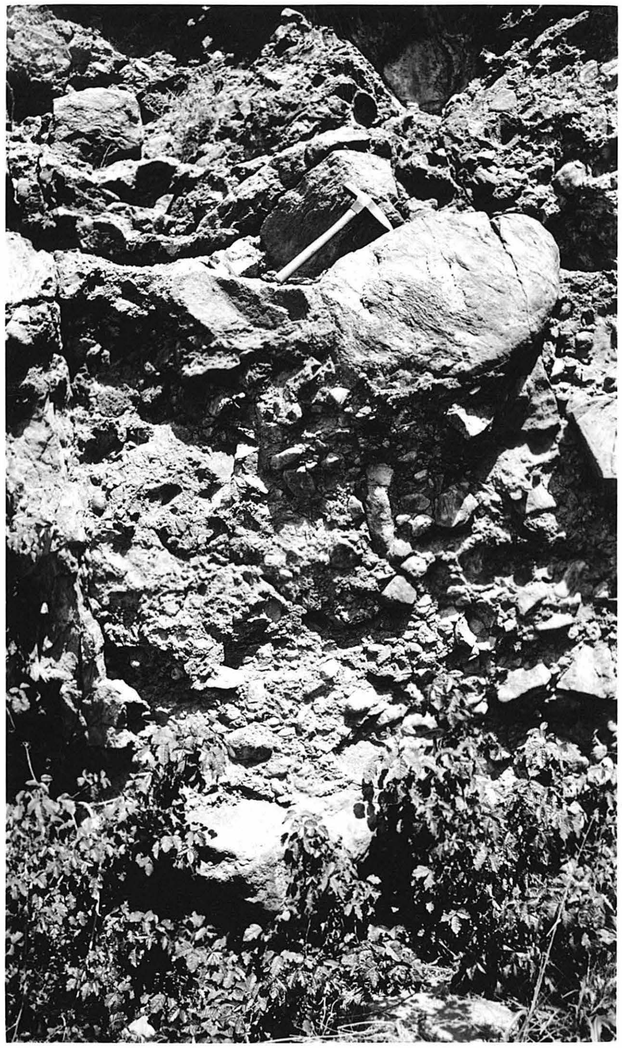


Sharp fold in sandstone member of Modelo conglomerate.
Upper Canton Canyon.

localities, thus accounting for the higher figure, but even though this is true there remains a very great thickness. The lower part of the conglomerate is extremely coarse, with boulders three and four feet in diameter, chiefly of gneiss and granitic rock. These are in a sandy matrix cemented with silica, giving a hard rock through which the streams have cut vertical-walled canyons. The upper portion of the member contains beds of hard, yellowish gray sandstone and thin shale. No sorting is visible in the conglomerate portion and the boulders are angular, making it practically a sedimentary breccia. (Plate XVII) The entire member has proven unfossiliferous excepting for an unidentifiable fragment of a mollusc found between Palomas and Violin Canyons. While this has no stratigraphic significance, it suggests a marine origin, which is not always apparent from the lithology. It is not impossible that the conglomerate is not Modelo at all but perhaps is Martinez.

Above the basal section of the Modelo in Castaic Canyon come shale beds that are up to a thousand feet in thickness. This shale is a gray to white siliceous type, well compacted, but unresistant to erosion, and it is along the strike of these beds that Castaic Creek has found it easiest to carve its channel. The shale is frequently sandy, and locally is sulphur-stained.

In the western exposures the shale member is colored brown to a light bluish gray near the south margin of the quadrangle and is of a black, carbonaceous type in the north.



Poor sorting in Modelo conglomerate. Upper Canton Canyon.

The latter breaks into fine hard particles on weathering and takes on a rusty brown hue, giving a "coffee ground" effect. In the upper part of Piru Creek the shale is almost slaty and so resistant that a minor narrows is developed. It seems probable that it was this superior hardness that led Hershey to consider the formation to be Cretaceous.

With increase of sand content the formation becomes a buff to brown sandstone with alternating shale beds, although a few hundred feet higher in the section another five hundred feet of brown shale occur. The sandstone is variable in composition. In part it is a gray to brown, coarse-grained quartz sand, very similar to the matrix of the eastern outcrop of conglomerate. The clasts are subangular to rounded, the latter predominating, and the cementing material is hydrous ferric oxide and calcium carbonate. Another type of sandstone is gray to buff in color, fine grained, and composed of well rounded qu artz grains with occasional cleavege fragments of feldspar. Fine flecks of biotite give a salt and peper effect to this variety. The cement is siliceous. Frequent thin seams of gypsum abound throughout the sandstone-shale series.

Along its easterly margin the Modelo is in contact with the Mint Canyon and Martinez formations. As brought out in previous discussion, the contact is gradational into the former, it being the opinion of the writer that the two represent contemporaneous deposition in different environments. The Modelo overlies the Martinez with an angular unconformity, there existing a considerable difference in attiitude of the beds above and below.

On the west the basal beds are faulted against gneiss excepting in the extreme southerly part where they are in contact with Pliocene beds. To the north the Modelo is overlain by continental strata that are here designated as the Ridge Route series. Because of the great similarity in lithology between the two formations the contact is rather indefinite, but has been located along the Ridge Route at its intersection of the north line of Township 6 North, or about a mile south of Reservoir Summit. A slight difference in dip and strike is apparent here as well as in Piru Canyon.

The Modelo has proven fairly fossiliferous, although the fossils seldom are very well preserved. The fauna clearly indicates upper Miocene age, but when the attempt is made to correlate with middle California subdivisions of the upper Miocene certain difficulties arise. Collections from the basal beds have yielded _Ostrea titan_ and _Turritella freyi_, which are considered to be characteristic of Santa Margarita in its restricted sense, or uppermost upper Miocene. However, some poorly preserved specimens of the echinoid _Astrodapsis_ and of certain other forms found by Woodring[1] in beds just south of the area and higher in the section have caused him to consider the containing beds as approximate equivalents of the Cierbo. He reiterated this opinion in a verbal statement to the author. There exists, therefore, the anomalous condition of Santa Margarita (restricted) guide fossils in beds stratigraphically below beds that supposedly are older than Santa Margarita, with no evidence whatsoever suggesting overturning or overthrusting.

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[1] Woodring, W.P., Age of the Modelo formation of the Santa Monica Mountains, California, 28th annual meeting, Cordilleran Section, G.S.A., Stanford University, California, 1929

These guide fossils then lose their significance so far as the part of California here under consideration is concerned, and only can be accepted with safety as indicating upper Miocene. The beds are similar lithologically to those of the western area of rocks that connects with type Modelo and the faunas are similar; therefore they are taken to be their correlatives and likewise Modelo.

The rocks of the Modelo formation are considered by the writer to have been deposited in a large bay or perhaps in a small gulf with a long, rather narrow inlet running to the northwest. The deposition represents a greater transgression of the sea than in earlier Miocene time. To the east and north the basal conglomerate indicates that the seas washed a coast line of moderate relief with at least one broad valley coming down to the shore, but on the west an abrupt, rugged coast, apparently but shortly uplifted, yielded coarse granitic and gneissic material to the not too active waves and currents. This was spread over the bottom, thickest near the shore and thinning with distance until it met with the finer detrital material washed in from the more subdued easterly coast. Thus the extremely thick deposit of coarse material on the west is replaced gradually by finer material toward the east. This would explain the great difference in thickness of the basal conglomerates on the two sides of the Modelo basin.

It is the belief of Grant and Gale[1] that the oyster-

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[1] Grant, U.S., IV, and Gale, H.R., Pliocene and Pleistocene mollusca of California, Mem. San Diego Acad. of Nat. Hist., vol. 1, p. 28, 1931.

facies fauna of the Modelo indicates that the basin was filling and giving place near its head to brackish water or mud-flat conditions, and insofar as the upper portion is concerned the writer agrees. It is difficult to conceive of the thick series of alternating sandstones and shales in the light of the conventional cycle of marine deposition, but it does seem logical to consider it as a shallow water and mud-flat deposit progressively sinking. The presence of considerable quantities of charcoal in the shale and of occasional fragments of fossilized reed add strength to this belief. During cycles (perhaps seasons) of greater rainfall the coarser sands were spread over the basin, while during the periods of low rainfall only the finer material was deposited on the flats. This is not inconsistent with the view that the Mint Canyon formation was being laid down contemporaneously on the shore under conditions of semi-aridity. The finer sands and sandy shales of the latter probably correspond in time to the shales of the Modelo, while the lenses and bands of conglomerate probably are the shoreward equivalents of the marine sandstones deposited during the rainy periods. The finding of camel remains intimately associated with the marine invertebrates of the Modelo is further evidence in support of the belief of near-shore, shallow water conditions.

The faunal list of the Modelo follows:

Mollusca

Gastropoda

<u>Turritella margaritana</u> Nomland

<u>Tegula varistriata</u> Nomland

<u>Astraea biangulata</u> (Gabb)

<u>"Fusinus" fabulator</u> Nomland

<u>Thais</u> cf. <u>ponderosum</u> (Gabb)

<u>Conus</u> sp.

<u>Olivella</u> sp.

Pelecypoda

<u>Ostrea titan</u> Conrad

<u>Ostrea titan corrugata</u> Nomland

<u>Pecten estrellanus</u> Conrad

<u>Pecten crassicardo</u> Conrad

<u>Panope generosa</u> Gould

Vertebrata

Pisces

Shark teeth, and bones of a small form

Mammalia

Skeletal fragments of camel and of probable whale

Pliocene Series.

Pico Formation (Lower, Middle and Upper Pliocene)

Marine beds of Pliocene age occur in the southern part of the Tejon Quadrangle between Palomas Canyon and Devil Canyon, extending northward almost to Canto Canyon. These beds connect to the south with strata mapped by Kew[1] as Pico. The formation consists principally of light colored, rather loosely consolidated sandstone and conglomerate with a heavy conglomerate member at the base and considerable overlying shale. The total thickness as shown here is about six thousand feet.

The lower portion of the Pliocene is best exposed in Devil Canyon which it crosses at a large angle, swinging thence along the ridge between this canyon and Canton Creek. Other good exposures of the formation exist in the northerly extending tributaries of Santa Felicia Creek whose main channel lies to the south of the area, and particularly in and along Palomas Canyon. The ridges between the various drainages show very poor exposures, since they are fairly well shrouded with soil, but the streams between have cut deeply into the beds.

The basal conglomerate can be traced from the southern boundary of the quadrangle north and west across Devil Canyon where it is lost because of lateral gradation into sandstones, as previously stated. It again becomes apparent about one and one-half miles farther along the ridge west of Devil Canyon and is traceable from there along the west side of the ridge to the

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1 Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, pl. I, 1924.

point where it comes in contact with the gneiss. Thence it can be followed southeasterly along Palomas Canyon and the original northerly extension of the latter again to the south margin of the quadrangle.

The conglomerate consists of rounded to subrounded boulders, some of which attain a foot or more in diameter, although with smaller sizes predominating. A few angular clasts are present, but the preponderance of rounded forms indicates considerable transportation. The boulders are principally of igneous origin, including anorthosite, granite, basalt porphyry and rhyolite porphyry, with some quartzite, gneiss and, locally, fragments of the underlying Modelo shale. A few pieces of vein quarts and of flint also were noted. The matrix is a coarse, angular, yellow sand with a cement largely ferruginous and calcareous, giving a comparatively soft rock. The thickness varies from about fifty to something more than one hundred feet.

The sandstone is generally conglomeratic and at times differs from the conglomerate only in the ratio of phenoclasts to matrix. It is distinguished from the sandstones of the Modelo by its yellowish white color, its coarseness and angularity, its lack of induration and by the prevalence of lenses of well rounded pebbles. It is difficult to draw a sharp line between the basal conglomerate and this sandstone, and indeed along the eastern boundary of the formation the basal beds are as often as not of this nature. The sandstone is frequently interbedded with sandy shale and grades upward into a buff to brown shale rather similar in characteristics to part of that of the Modelo. The shale occupies the central part of the area of Pliocene, accounting for the subdued topography found there.

The Pico lies unconformably upon the Modelo along its western margin, as was pointed out in the discussion of the latter. On the northeasterly side it laps up on the gneiss, excepting for about two miles in the lower end of Palomas Canyon where it is in depositional contact with the basal conglomerate of the main body of Modelo. Overlying the Pico in the south is a series of land-laid beds referred by the writer to the Saugus.

Parts of the Pico formation have proven very fossiliferous, and thus a definite age determination has been possible. The best collecting localities are just west of Palomas Canyon, a short distance north of the quadrangle boundary, where several fossil-bearing strata are exposed. The San Diego Society of Natural History locality number 253, mentioned by Grant and Gale[1] corresponds to one of these. A few scattered shells are found farther north along the ridge west of Palomas Canyon, and also in and above the basal conglomerate in Devil Canyon.

Grant and Gale in the piece of work to which reference has been made consider the fauna from locality S.D.N.H. 253 to indicate lower middle Pliocene age, although they state that

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[1]Grant, U.S., IV, and Gale, H.R., Pliocene and Pleistocene mollusca of California, Mem. San Diego Acad. of Nat. Hist., vol. 1, Diagram A, and p. 105, 1931.

it may be basal Pliocene. The specimens of Pecten estrellanus mentioned in the discussion of the Modelo as having come from a filled channel in the basal portion of the Pico might be taken as showing lowermost Pliocene, which would indicate that either the basal beds of the Devil Canyon region are older than those of Palomas Canyon, or that the whole formation is lower Pliocene. In view of the close proximity of the two localities and the fact that the basin of deposition narrows rapidly towards the north, the first conclusion seems hardly logical. It should be kept in mind that there is a third explanation, previously mentioned, that the Pecten may have come from reworked Modelo material included in the basal beds. Unfortunately, the assemblage from the Devil Canyon locality is so small that it makes generalizations hazardous. Since the above mentioned writers consider the Pico to include lower, middle and upper Pliocene[1] there can be little question as to the propriety of calling these beds Pico. Possibly the Devil Canyon beds are the equivalents of the Jacalitos (Elsmere Canyon) zone while the Palomas Canyon portion corresponds to the San Diego zone as differentiated by the same writers[2]. Perhaps both represent the Jacalitos, or perhaps both are the equivalents of the San Diego. From the evidence at hand, the present writer is inclined to favor the last, concurring therein with Grant and Gale.

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1 Ibid., p. 32

2 Ibid., p. 32

The origin of the sediments appears to have been in a relatively narrow embayment, closed to the north and spreading out in the direction of the Santa Clara Valley, which probably was at least a very large arm of the sea. Thisoccurrence marks the farthest advance in a northerly direction of the Pliocene sea in the eastern part of the Ventura basin. Current and wave action apparently were not strong in this more or less land-locked bay, since good sorting is lacking in the deposits. That relief was at least moderately high at the beginning of Pico time (or such part of Pico time as is here represented) is suggested by the considerable thickness of basal conglomerate and conglomeratic sandstone. While pebbles in the conglomerate frequently show perfect rounding, the rounding either is inherited from a previous epoch, or is the result of stream action, in view of the above postulated weak waves and currents. This leads to the further inference of at least moderate rainfall, with rather turbulent streams entering the sea. The last is to some extent corroborated by the gravel filled channel visible in Devil Canyon. The shales again are the result of lessening relief of the land-mass, since the shore line doubtless was little farther removed from the middle of the basin during their deposition than during deposition of the conglomeratic sand. It is possible that these shales represent sedimentation under tidal flat conditions brought about by the filling of the small basin. This would be one explanation to account for the failure to find upper Pliocene deposits in this vicinity.

The fauna yielded by the Pico formation follows:

Mollusca

Gastropoda

Turritella cooperi Carpenter

Cancellaria tritonidea Gabb

Neverita cf. _secta_ Gabb

Astraea sp.

Conus sp.

Thais sp.

Pelecypoda

Phacoides annulatus (Reeve)

Tresus nuttalli Conrad

Macoma inquinata Deshayes (probably n. var.)

Cardium sp.

Pecten sp.

Echinodermata

Echinoidea

Dendraster gibsii (Remond)

Ridge Route Formation (Pliocene ?).

A series of continental beds occurs in the northern part of the area, overlying with slight angular discordance the upper sandstones and shales of the Modelo. These beds have their most southerly exposure on the ridge followed by U. S. Highway No. 99, being first encountered approximately one mile south of Reservoir Summit. From this point they swing to the northeast into the upper Castaic drainage and northwest to Piru Creek, which they c ross a short distance north of the junction of Liebre Gulch with the latter. How much farther north they extend is unknown to the writer, although beds that appear to be the same may be seen along the Ridge Route for another five or six miles. Hershey[1], who first noted the presence of the series estimated that the main basin wasabout twelve miles long by seven miles wide. So far as is known to the writer, the name here used was first applied to the series by Dr. J. P. Buwalda.

The formation is well exposed in road cuts along the Ridge Route, and also in Piru Canyon, Liebre Gulch and along Salt Creek. It consists of a series of rather well bedded sandstones and shales with frequent beds of conglomerate, the thickness of the exposure in the area mapped being about six hundred feet. This, of course, is much less than its total thickness.

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[1] Hershey, O. H., Some Tertiary formations of southern California, Am. Geol., vol. 29, pp. 362-364, 1902.

see also, The Quaternary of southern California, Univ. Calif. Pub. in Geol., Pl. I, 1902.

The sandstones are buff to yellow or brown in color and occur in beds from a few inches to a few feet in thickness. The interbedded shales, which in places are little more than thin.bedded sandstones, so arenaceous do they become, are colored light grays, yellows and browns. The pebbles in the conglomeratic strata show a fair degree of rounding.

The lithology along the Ridge Route is so similar to that of the underlying marine sediments, that it is possible to determine the position of the contact between the two only by close inspection. The presence of conglomeratic layers is generally indication that one has passed from Modelo into the Ridge Route formation. In Piru Canyon the change is shown by a change in topography, since the less consolidated land-laid beds give a much softer contour to hills and valleys than the indurated shales of the Modelo immediately to the south. Even here it is difficult to locate the contact with any degree of accuracy.

The change in lithology is rather sharp in Salt Creek, where the conglomerate of the Modelo and the land-laid deposits of the Sespe give place to a yellowish, arkosic and conglomeratic sandstone at the base of the overlying beds. Heavy brush, however, makes it extremely difficult to view the contact excepting where exposed in the canyons. On the whole, therefore, the exact location of the border line between the Ridge Route series and the underlying rocks is very doubtful, and has been delineated upon the map almost entirely as a dotted line.

The age of this formation is questionable. Since it unconformably overlies all beds in contact with it in this area, it is at least younger than Modelo, or upper Miocene, which is the youngest formation exposed beneath it. The difference in attitude between the two is not great, and it might be considered that the upper beds represent deposits formed after the final silting up of the Modelo basin prior to the inauguration of the Pliocene epoch. The writer feels that small as is the difference in dips and strikes, it is sufficient to indicate deformation following deposition of the Modelo beds, which would place the formation in the Pliocene. Hershey regarded the beds as upper Pliocene[1] in age and in part, at least, the equivalents of the Saugus. The _Pecten_ he reports as apparently having come from the beds probably came from the underlying marine Modelo and has no significance as far as the Ridge Route formation is concerned. Fresh water molluscs and a horse tooth (Protohippus ?) were found in what are probably equivalent beds somewhat farther north by members of the summer field geology class of the California Institute of Technology. This material has not been seen by the writer, and no statement has been published in regard to it. Until the entire basin covered by these deposits has been mapped and definite evidence as to age produced, it seems best to call the sediments questionable Pliocene.

The Ridge Route series apparently originated in a basin formed by warping at the end of the Miocene epoch. Into

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[1] Ibid., p. 362.

this basin was swept detrital material from the surrounding highlands. The fairly good sorting indicates probable deposition in lake waters, this conclusion being further substantiated by the above mentioned fresh-water molluscs that have been taken from the beds. The later history of the basin is not decipherable from the limited exposures in the area covered by this paper, excepting that apparently at the end of the Pliocene there were diastrophic movements which deformed the lake sediments and probably destroyed the basin.

Quaternary System.

Pleistocene Series.

Saugus Formation (Lower Pleistocene)

Beds that are here referred to the Saugus formation occur in two outcrops in the extreme southern portion of the Tejon Quadrangle. While the exposures are separate in the area mapped, they connect immediately to the south, being projecting tongues of the large body of Saugus rocks mapped by Kew[1].

There has been much discussion of the meaning of the term "Saugus" and some objections to its use have been advanced. The name was first proposed by Hershey[2] for the considerable thickness of continental beds typically exposed in the vicinity of the town of Saugus. Kew[3] used the term in the same general sense, but included some marine deposits that he believed to be younger than Pico. Since then rather indiscriminate use has been made of it in applying it to both marine and non-marine beds in the Ventura basin, some of which are Pliocene and some Pleistocene. It seems to have been the intention of Hershey to use the name for continental deposits overlying the marine

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[1] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, Pl. I, 1924.

[2] Hershey, O.H., Some Tertiary formations of southern California, Am. Geol., vol. 29, pp. 360-362, 1902.

[3] Op. cit., pp. 81-89.

beds that since have been called Pico and determined as being of Pliocene age. This is the sense in which it is used in this report.

The larger of the two exposures of Saugus occurs just west of Palomas Canyon where it is found forming the crest of the divide between Castaic and Piru drainages. The other exposure is a half-mile east of Castaic Creek. Both outcrops are rather inaccessible in themselves, but their southerly continuations are easily reached from the town of Castaic.

The Saugus shows a remarkable difference in lithology between the two localities, directly traceable to variation in the underlying material. West of Palomas Canyon the Saugus is light gray to white and consists of sandstone and conglomerate very similar in character to the Pico below. The sorting is poor and the bedding so indistinct that it is difficult to make accurate dip and strike observations. The sand is a coarse quartzite type, which with increase of coarser particles becomes conglomerate. Boulders in the latter reach a foot in diameter and are principally gneiss, granite and hard, arkosic sandstone. Many of the phenoclasts show a good degree of rounding, but since they are obviously derived, in part at least, from the marine conglomerates of the Pico, this cannot be used as criteria of long transportation. The beds are poorly indurated, which in view of the steep-sided canyons and general youthful character of their topography, suggests a rather short period during which they have been exposed to erosion.

The Saugus east of the town of Castaic is very similar in lithology to the Mint Canyon formation. It consists principally of rather well indurated, yellow sandstone, with the occasional lenses of subangular boulders of metamorphic and igneous rocks characteristic of the latter. The nature of the material shows derivation in part from the underlying Miocene rocks. Stratification is so poorly defined that it has been found impossible to take the dip and strike of the beds in the limited area exposed. However, observations made a short distance south, near the mouth of Charlie Canyon show it to have a strike of about north 20 degrees west and a dip of approximately 36 degrees southwesterly. The Saugus is nonconformable with the underlying formations in both localities. Thickness as estimated for the western exposure is eight hundred and fifty feet.

The age of this series of continental rocks is doubtful. Hershey[1] called it upper Pliocene, basing its age upon the lithologic and structural resemblances to the Paso Robles and Merced formations of western California. From a comparatively large invertabrate fauna collected from marine beds mapped with the Saugus, Kew[2] concluded that the beds were upper Pliocene and Pleistocene. Grant and Gale[3] state that the

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[1] Op. cit., p. 361.

[2] Op. cit., p. 39.

[3] Grant, U.S., IV, and Gale, H.R., Pliocene and Pleistocene mollusca of California, Mem. San Diego Acad. of Nat. Hist., vol. 1, p. 34, 1931.

formation may be the non-marine equivalent of the entire Pliocene and part of the Pleistocene sedimentary cycle. It is obvious that if the marine beds be excluded from the Saugus, the fossils from those beds are no longer of use in determining its age unless they are in strata that can be traced directly into Saugus strata. The discovery of mastodon remains in the formation at a locality a short distance south of the Tejon Quadrangle has been recently reported by Dr. Chester Stock of the California Institute of Technology[1] but its significance is not as yet known.

From its unconformable attitude with regard to the underlying rocks, which are middle Pliocene in age, the Saugus as here defined must be not older than upper Pliocene. The unconformity at the base represents deformation with consequent uplift and erosion of the underlying beds, since if the Saugus represented merely the landward equivalent of upper Pliocene marine beds deposited upon middle Pliocene after simple withdrawal of the sea, there would be slight difference in attitude of the strata and there would have been little opportunity for erosion of the last deposited marine beds. This period of deformation and erosion probably marks the end of the Tertiary period in this region, and therefore the writer considers the Saugus to be lower Pleistocene in age.

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[1] Personal communication.

The close connection between the lithology of the Saugus and that of the underlying beds suggests local basins of deposition during the early part of its time of formation. It apparently is of fluviatile origin, deposited by small streams along their individual channels. Later there may have been a fusion of the local basins into one or more large ones due to a burial of intervening ridges by the accumulating deposits. The relief probably was not great at any time, but it seems likely that the Pliocene deposits were well cut into before at least temporary base level was reached and deposition commenced. Whether this change from erosion to deposition was brought about by the uplifting of some obstruction between this area and the sea or by a general lowering of the land-mass as an aftermath of the post-Tertiary-pre-Quaternary disturbance can only be conjectured. The small extent of the exposures in the Tejon Quadrangle and their very apparent local variations makes inferences as to climatic conditions of the Saugus of doubtful value.

Terraces (Upper Pleistocene).

Terraces are well developed in some of the larger canyons, and terrace material is found capping many of the ridges in the southwastern part of the area. This material is of a variable nature and shows local derivation. In all cases, it, like the Saugus, is stream deposited, showing a rude sorting and at times no bedding whatsoever. The thickness varies from a very few feet on some of the hilltops to about two hundred feet along Castaic Creek.

The terraces represent at least three periods of still-stand in the downward cutting of the streams, or in the elevation of the land-mass, which may or may not be the same thing. The oldest gravels, which stand at an elevation of around two thousand feet above sea level, are those found mantling the ridges as far west as Charlie Canyon, but of which the only occurrence of mappable size is on the ridge between Dry and Haskell Canyons. This patch is slightly over a half-mile long by a few hundred feet wide and is accessible from either of the canyons named. It is made up almost entirely of subangular boulders of schist, gneiss, quartzite and vein quartz, with the first predominating, in a matrix of red sand and clay. No cementing material other than the clay is present. Although it was found impossible to determine the dip and strike, due to lack of definite bedding, from a distance it can be seen that the gravels are approximately horizontal.

The second terrace stands approximately five hundred feet lower than the first and is especially well developed in Castaic and Elizabeth Lake Canyons, where it has been possible to map four isolated areas. One of these is exposed in the road cuts where the Ridge Route first begins to climb. Other exposures are along the road between the Ridge Route and Castaic Creek; along the west side of the latter, and about a mile upstream from the mouth of Elizabeth Lake Canyon. The material is made up of unconsolidated, medium-grained arkosic sand with a considerable quantity of coarse gravel, likewise unconsolidated. The clasts are subangular to rounded in both sand and gravel, and in the latter consist principally of granite, granodiorite, sandstone and quartzite. Irregular patches of a sandy clay are present and the upper portion of the deposit is a brown, fine-grained sandstone. The latter is regularly bedded, in contrast to the lower members which frequently show cross-bedding. The other occurrences are somewhat coarser, with a noticeable increase in size of clasts the farther upstream the deposit is located. The exposure along the Ridge Route shows a decided tilting, attributed to movement along the Palomas Canyon fault to which it is immediately adjacent. It is possible that a similar tilting exists in the other localities, although since none was observed it is believed that they retain their original more or less horizontal position.

The youngest terrace is represented by material in Castaic Canyon, lying immediately below the second terrace and very well exposed in section adjacent to the bridge that crosses the creek just above its confluence with Elizabeth Lake Canyon. (Plate XVIII) This is composed of partially sorted sand and gravel largely granitic in nature, and showing rather good bedding. No cementing material is present, with the consequence that the gravel erodes very rapidly. The beds are quite horizontal. Another small terrace a mile and one-half farther up Castaic Canyon is probably the correlative of this.

Pleistocene terrace gravels overlying Modelo sandstone and shale with angular unconformity. Junction of Castaic and Elizabeth Lake Canyons.

Numerous other occurrences of terrace material were observed, but were too small to show on the map used. One of these is in a branch of Castaic Creek in section 31, Township 6 North, Range 16 West. A second is in Piru Canyon two miles north of Agua Blanca Creek. Still smaller patches occur somewhat farther downstream in Piru Canyon and also along Canton Canyon. These vary in content with the locality, but all have the common characteristic of poor bedding and lack of consolidation.

No fossils have been found in the terrace gravels and no definite age can be assigned them. That they are younger than Saugus is indicated by the greater lithification and by the greater degree of deformation exhibited by the latter, and also by the fact that immediately south of the quadrangle and east of Castaic Creek, Saugus is overlain by the gravels. The oldest terrace, which was apparently wide spread, at least in the southeastern part of the quadrangle, is possibly the equivalent of the Timber Canyon fanglomerate of Grant and Gale[1] which would make it the possible equivalent of the marine Palos Verdes formation. This would place it fairly high in the Pleistocene, causing the time of formation of the other terraces to come still later. In the absence of evidence to the contrary it seems logical then to designate all the terrace material upper or late Pleistocene.

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[1] Op. cit., pp. 37-38.

The older terrace probably was built along the northwestern margin of the broad Pleistocene valley of the Santa Clara River. From the general accordance in level of the crests on which are found the gravels, the surface upon which they were deposited must have been comparatively flat and regular, although hills of Pelona Schists were yielding detrital material as in Mint Canyon time. Following uplift, degradation took the place of aggradation and the country was actively dissected. Apparently two halts in the uplift are recorded by the two lower terraces, although these might be explained as easily by the etching out of the barriers downstream causing the establishment of temporary baselevel at two different stages.

Alluvium (Recent).

Alluvium covers the floors of all the larger valleys at the present time and extends far up many of the canyons. This is generally an unsorted, rather coarse detritus varying widely in composition from place to place depending upon the nature of the rock adjacent to the stream channels. The larger blocks show little rounding as a rule, although this, too, is a variable characteristic. The thickness ranges from practically nothing to something under one hundred feet. A well drilled in the bed of Castaic Creek approximately a mile north of the quadrangle's south boundary logged eighty feet of alluvial fill. In some of the canyons this material is being slightly dissected. It is nowhere within the area known to be disturbed by recent faulting.

Tertiary Volcanics (Middle Miocene ?).

A few isolated outcrops of igneous extrusive matter occur along the ridge between San Francisquito and Charlie Canyons. This is apparently an acidic lava, and it now forms a capping on two of the higher peaks of the ridge, also occurring lower down on the San Francisquito side just upstream from the power house.

The rock is reddish brown in color, aphanitic and somewhat porphyritic in texture with phenocrysts of quartz. It has been brecciated and recemented by infiltration of opaline silica. Alteration of rather abundant iron minerals has in part caused the coloration by the development of iron oxides and has so clouded the other minerals as to make accurate determination under the microspope very difficult. However, principally on the basis of the quartz phenocrysts the writer has called it a rhyolite porphry.

The lava rests upon and possibly is intruded into rocks of Sespe age, being cut off by the San Francisquito fault at the contact with Mint Canyon beds. The principal post-Oligocene period of igneous activity in southern California was in middle Miocene time, and for that reason these rocks have been tentatively assigned to that age.

STRUCTURE.

General.

The southeastern part of the Tejon Quadrangle is very interesting structurally, and presents some rather complex problems. It is impossible to solve all these problems without additional extensive field work to the west and north, but observed facts are set forth and such conclusions as possible are drawn from them.

The area is divided into three major structural blocks, all of which trend in a northwest-southeast direction, roughly parallel to the general trend of the larger structures in this section of southern California. This is not surprising in consideration of the fact that what may be termed the major single structural feature of California, the great San Andreas fault, passes but a few miles to the northeast of the area.

The first of the blocks is the Red Rock Mountain block which occupies the northeastern portion of the area and is so named for its most prominent topographic feature. It is made up principally of crystalline rocks, although with a covering of sediments in the northwest, and is separated from the adjacent block to the southwest by the Clearwater fault.

The second block is here designated the Castaic block. This is covered principally with sedimentary rocks and possibly should be considered to terminate against the Pelona Schists to the southeast. However, in view of the fact that the sediments are in part resting upon the schists it seems more logical to consider the latter as part of the crystalline basement of the block. The westerly boundary is the Palomas Canyon fault.

The remaining area is included in the Piru block, whose rocks are partially crystalline and partially sedimentary in character. It is not known how far west this block extends, nor what may be considered as its western boundary. It is largely complicated by differential movement within itself, especially along the Agua Blanca overturn.

In addition to the faults mentioned there are numerous minor faults cutting all the blocks into smaller segments. There is also a major fold running parallel to the other major structures and there are many other smaller folds, some of which are directly traceable to local structural conditions. A rather prominent fold athward the general trend of the larger structural units has been brought to light by the areal mapping.

Major Faults.

Clearwater Fault.

The Clearwater fault is named for its evident connection with a canyon of that name in the Elizabeth Lake Quadrangle where it has been described by Nickell[1] and Hill[2].

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1 Nickell, F.A., The geology of the southwestern part of the Elizabeth Lake Quadrangle between San Francisquito and Boquet Canyons, on file, Library, California Institute of Technology, 1928.

2 Hill, R.T., Geology of reservoir sites, Part II of a report of the Board of Consulting Engineers to the Board of Water and Power Commissioners of the City of Los Angeles, 1928.

It enters the Tejon Quadrangle at the head of Ruby Canyon about six miles north of the quadrangle boundary, and continues diagonally across the area to the northern margin, which is intersected a mile east of the Ridge Route. Where it crosses the highway farther north it is marked by a low notch and a small anticlinal fold.

The fault is well exposed in many places, the most accessible of which is in Elizabeth Lake Canyon where cuts made in building the new road afford an excellent opportunity for study. (Plate XIX) Other good exposures are in Fish Canyon and along Castaic Creek. A rather wide crushed zone exists along the fault, particularly in the crystalline rocks. This is up to a quarter or half mile wide in some places, with the granite and gneiss shattered and slickensided throughout. A spring of warm water in Fish Canyon, and Radium Hot Springs in Warm Spring Canyon occur in this zone.

The topography shows very clearly the control exerted by the crushed zone in the series of canyons all in line wnd in the notched divides between canyons. Ruby, Warm Spring and Fish Canyons all owe their general alignment to the presence of the Clearwater fault or its branch, as does also the westerly fork of Salt Creek. The peculiar southward swing made by the fault trace in Elizabeth Canyon is attributed to a marked warping of the blocks in a direction almost at right angles to the general trend after the faulting had taken place. Later differential movement of the blocks

Slide in crushed zone along Clearwater fault. Elizabeth Lake Canyon.

is shown by more recent faulting, which has to some extent cut off this lobe of crystalline rocks and again produced an almost straight fault trace. Present stream channels, of course, are determined by this later faulting.

A study of the fault plane as exposed in various localities shows it to have a strike that varies from sixty to seventy-five degrees west of north. The former is the prevailing figure west of Castaic Creek and the latter to the east. The dip averages sixty degrees in a southwesterly direction, although locally it may be much higher and may show even a northeasterly dip.

Displacement along the fault has been of two very different natures. Vertical displacement with the northeasterly or Red Rock Mountain block relatively uplifted is indicated by the present exposure of the Martinez basal conglomerate and underlying gneiss northeast of the fault, adjacent to beds considerably higher stratigraphically. The minimum vertical movement here is calculated to be close to four thousand feet. That this faulting was of a hinge type, with greatest throw along the southeastern portion and least along the northwestern, is suggested by the fact that east of Elizabeth Lake Canyon no sediments are found on the upthrow block, basal beds of the Martinez are exposed in the Fish Canyon section, while farther west higher beds of the Martinez are found on the northeasterly side of the fault.

Horizontal displacement is shown by presence of the body of Sespe rocks lapping up on the Martinez on the northeasterly side of the fault, while being absent to the southwest. Younger overlying beds have covered all trace of the remaining portion of the Sespe to the northwest and therefore it is impossible to determine the maximum movement, but the minimum is a little over two miles. Movement was to the southeast on the Red Rock Mountain side and to the northwest on the Castaic block side. Well preserved horizontal grooves and striae on certain exposures indicate that the horizontal movement took place after the vertical displacement, and it seems probable that deposition of the Sespe intervened between the two disturbances. This is evidenced by the fact that although broken by the later faulting, the Sespe appears to have been unaffected by the vertical displacement, being not greatly eroded despite its presence on the uplifted block. The latter, however, might be the result of the hinge type of movement. Some slight vertical movement since Pliocene time is shown by the disturbance of the Ridge Route series along U. S. Highway No. 99, and this may have been coincident with the cutting off of the lobe of crystalline rocks in the Elizabeth Lake Canyon region.

The Clearwater fault evidently came into being, or awoke from dormancy, with vertical movement in post-Martinez times, and was active again following deposition of the Sespe, at which time the horizontal displacement took place. Further displacement, probably vertical in nature, occurred in post-Pliocene time. The previously mentioned warping must have occurred between the last two events, since Miocene deposits farther south are affected by the warping, while the Warm Spring Canyon branch of the Clearwater fault is not.

Palomas Canyon Fault.

The Palomas Canyon fault, named for its excellent exposure in that canyon, extends in a northwest direction from a point on the southern boundary of the quadrangle just west of Castaic Creek to approximately the northwest corner of the area mapped. A study of the topography suggests that it continues on in a northwesterly direction, and it has been mapped by Kew[1] extending southeasterly to connect with the San Gabriel fault near Saugus.

In addition to the exposure mentioned, the fault is visible in upper Canton Canyon just below Oak Flat, (See Plate XX) in Piru Canyon near the upstream end of the Big Narrows, and on various of the ridges on both sides of the canyons named. It is very prominent when crossed, showing a crushed zone that varies from a few feet to several hundred yards in width, with considerable gouge and slickensiding of surfaces. Between Canton Canyon and the south boundary of the quadrangle the wide, grayish band of crushed and leached gneiss makes the following of the contact very simple, but where it passes altogether into sedimentary rocks it becomes difficult

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[1] Personal communication.

PLATE XX.

Palomas Canyon fault. Upper Canton Canyon.

to locate accurately.

The straight trace of the fault across the map is indicative of its high angle. Where exposed in upper Canton Canyon the strike is forty degrees west of north and the dip is eighty degrees to the northeast. The plane flattens somewhat in Piru Canyon where the dip is approximately sixty degrees to the northeast, but at no time does it appear to be less than this.

Movement on this fault has been much more simple in its nature than that on the Clearwater fault. There is evidence of vertical displacement only, with the Piru block relatively upthrown, although the sharp fold in the Modelo conglomerate adjacent to the fault suggests a reversal in direction of movement. (See section A-A^{1}, Plate XXXI) The minimum amount of this uplift might be calculated as equal to the thickness of Modelo rocks that have been removed by erosion, if it be conceded that the two areas of Modelo originally were continuous across the southern part. This would make the displacement about five thousand feet. Since there is no proof that the Modelo was continuous across the granitic-gneissic mass, but on the other hand it seems evident that the fault was in existence prior to and during Modelo time, the figure given is of doubtful value.

Displacement seems to have been periodic from before upper Miocene time to Recent. From the nature of the basal conglomerate of the Modelo, it appears that the gneissic rocks stood relatively high at that time, and that Modelo seas washed a comparatively recent fault scarp. Movement between Modelo and Pico times is indicated by the higher dips in the former, and similar evidence suggests repeated movement between Pico and Saugus and again between Saugus and late Pleistocene. Tilting of young terrace material just east of the fault line tends to show post-Pleistocene activity. As already mentioned, disturbance of alluvium has not been observed.

Minor Faults.

The most interesting of all the minor faults is that which has been named the San Francisquito fault. Passing as it did under the St. Francis Dam, it was indirectly, at least, responsible for the failure of the dam, and received considerable attention in many of the papers called forth at that time.[1] It forms the boundary between the Sespe and the Pelona Schists (See Plate XXI) from the east margin of the quadrangle to about a half-mile below the former damsite, where Mint Canyon beds are interposed above the schists and become the footwall rocks. Continuing down the canyon to a short distance below Power House No. 2, the fault swings to the west across the ridge into Charlie Canyon. Thence it is traceable northwesterly to a point just east of Elizabeth Lake Canyon, where at its intersection with the Bee Canyon fault it apparently ends.

The fault can be seen to excellent advantage almost continuously from the former site of the dam to where it crosses the ridge into Charlie Canyon. Above the damsite it is

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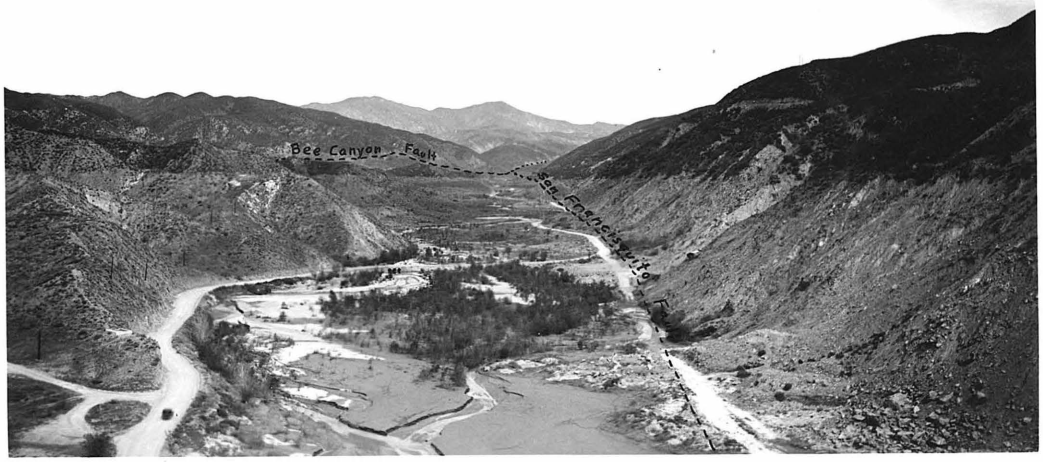
[1] See partial list in bibliography, but especially Ransome, F.L., Geology of the St. Francis Dam-site, Econ., Geol., vol. 23, pp. 553-563, 1928.



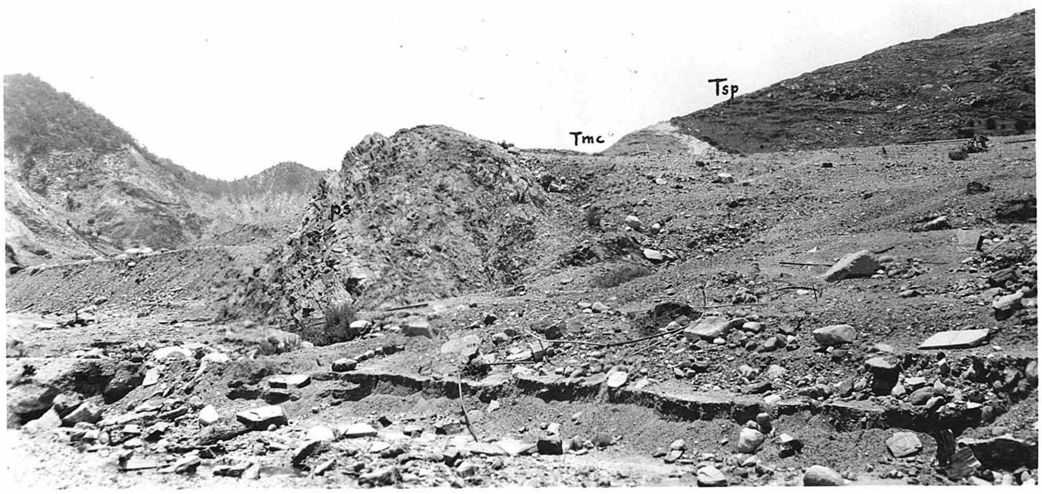
Junction of San Francisquito and Bee Canyon faults just east of Tejon Quadrangle. Foreground is in quadrangle. (Sharply cut lower limit of brush shows water level in St. Francis reservoir prior to failure of dam.)

obscured by alluvium, and below, on the ridge where it leaves the canyon, thick brush makes observations impossible. It is very well exposed again in the west fork of Charlie Canyon.

Where exposed at the damsite, the fault strikes fifty-five degrees east of north and dips at an angle of forty-four degrees to the northwest. This is a comparatively low angle and suggests a thrust, although the fact that older rocks comprise the footwall favor its being of the type usually designated as normal. Of the geologists making examinations after the dam's failure, the majority considered it to be a thrust fault, although some called it normal, and one believed it to be a depositional contact.

At the locality below the dam where Mint Canyon beds first appear, the latter rest upon the schists with a depositional contact, but above them are found older Sespe beds. The Sespe here is highly fractured and stained a deep maroon from hematite deposited by water moving along the fractured zone, and at the contact there is approximately a foot of unmistakable gouge. This is made up largely of crushed schist from the boulders in the underlying basal conglomerate of the Mint Canyon and is leached to a light gray. This superposition of Sespe on younger beds is rather conclusive evidence of overthrusting. (Plate XXII)

The only objection remaining to accepting the idea of a thrust is that the Sespe appears to dip into the schists, which could hardly be explained by other than normal faulting;



Sespe (dark colored) thrust over Mint Canyon formation along San Francisquito fault three-quarters of a mile below former St. Francis Dam. Light colored band is gouge.

that is, uplifting of the schists and depression of the Sespe. From the anomalous condition previously mentioned of the appearance of the coarsest material of the Sespe in the upper part of the formation, and from the evidence of great contortion in the heavy beds of the Sespe, the writer concludes that in part, at least, the Sespe is overturned and tightly folded. This explains not only the reversal in the normal order of sedimentation, but also the dipping of Sespe beds into the schists. There can be little doubt then that the fault is an overthrust.

The overthrust nature of the fault is maintained down the canyon, but where exposed in Charlie Canyon it has assumed the character of a normal fault, the plane dipping at an angle of about sixty-five degrees to the southwest, or under the Miocene sediments. It continues as such to its end.

The time of movement on the San Francisquito fault will be discussed in connection with that of the Bee Canyon fault, to which the former is closely related. The latter forms the Martinez-Sespe contact between San Francisquito and Elizabeth Lake Canyons, (See Plate XXIII) its name coming from its probable influence in the formation of Bee Canyon, which lies a short distance east of the Tejon Quadrangle. The break is visible at the base of the Martinez hills forming the northern rim of the basin of Sespe, and is marked by a crushed zone that at times is two to three hundred feet wide, although generally much more narrow. This is easily followed because of the absence of all vegetation excepting sage, while the unsheared

Bee Canyon fault west of San Francisquito Canyon.

rocks on either side support a heavy chaparral cover. The ridges show decided notches where crossed by the fault, and both breccia and slickensided surfaces are found.

The strike of the fault varies from seventy-five degrees east of north to northeast, with a northwesterly direction assumed over one short stretch. The attitude of the fault plane approaches the vertical, although because of slumping of the crushed material in the transverse canyons, no good section was found and no satisfactory dip observations could be made. Direction of movement on the fault appears to have been relatively upward on the north side and downward on the south side. A suggestion of recent lateral displacement is afforded in an apparent offset of not more than two hundred feet of the canyons crossing the fault line. This, however, does not appear too constant in direction, and probably is due to the streams' having eroded for short distances along the crushed zone before resuming their normal southerly direction.

The exact time of activity of the Bee Canyon and San Francisquito faults is difficult to fix. The movement on the latter, at least, was late Miocene or post-Miocene, as indicated by the fact that Mint Canyon beds are affected. The joining of the two faults and their abrupt termination near Elizabeth Lake Canyon suggests that they are closely related in time and causative forces, and therefore it is possible to date the first named as late Miocene or post-Miocene, as well. Terrace material occurring along the ridge between San Francisquito and Charlie Canyons has not been disturbed by the fault and therefore an upper time limit of upper Pleistocene is established. Reports that movement on the San Francisquito fault had caused the collapse of the St. Francis Dam are not borne out by geologic field evidence. It would have been surprising if there had not been a variance in surveys, which was the basis of the report, since the one made prior to the disaster was without doubt less accurately done than that made afterward.

It is the belief of the writer that neither the Bee Canyon fault nor the San Francisquito fault penetrates very far below the surface, the probability being that they actually meet beneath the Sespe. The latter formation, deposited as a comparatively thin film in the basin between Martinez on the one side and schists and Mint Canyon on the other, has been folded and compressed, but has acted as a unit. Thus the forces that brought about the high tilting of the Martinez and the folding of the Mint Canyon, appear also to have folded the Sespe beds, but rather than folding into and with the other formations, the last mentioned strata have been squeezed between the much more competent Martinez and schists and forced to ride up on the latter and its overlying Mint Canyon beds, at the same time being forced down on its northerly margin. It is difficult otherwise to explain the changing of the San Francisquito fault from an overthrust to a normal fault, and particularly the abrupt ending of both faults where they come together east of Elizabeth Lake Canyon. No evidence whatsoever has been found to indicate any extension of these faults west of the canyon named.

The intraformational Violin Canyon fault has been traced extending in a northwesterly direction from the south boundary of the quadrangle to Piru Creek, beyond which it has not been followed. It is clearly exposed in but few places, the best localities for observation being where it crosses the lower end of Violin Canyon and in the vicinity of Oak Flat. In other places its location has been based largely upon topographic evidence. The fault is between the heavy conglomerate of the Modelo on the west and the incompetent shales and sandstones of the same formation on the east and has been named from its obvious connection with the origin of Violin Canyon.

The attitude of the fault plane is not greatly different from that of the beds on both sides, observations giving dips of from fifty to sixty degrees in a northeasterly direction. The conglomerate shows little effect of the movement, but the weak shales have been dragged to verticality and even overturned along the fault. These beds have apparently taken up some of the movement by slippage along their bedding planes as previously suggested.

The fault is of the normal type with the slightly older basal beds on the upthrown side. However, as in the case of the Palomas Canyon fault, this fault appears to have been formed by compression, probably having come into being contemporaneously with the Castaic syncline discussed below. The amount of throw as estimated from the thickness of beds missing on the west limb of the syncline is in the neighborhood of thirty-five hundred feet.

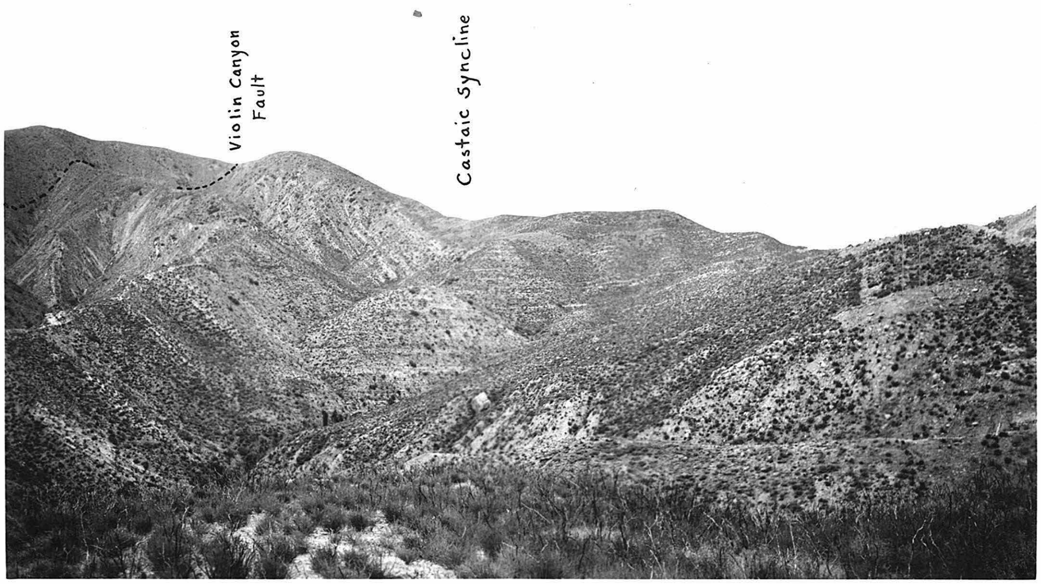
The Whitaker fault occurs on the Piru block, separating the granitic mass of which Whitaker Peak is the most prominent point from Tertiary sediments to the south and west. The fault plane is well exposed in Piru Canyon and in Canton Canyon, as well as in many of the smaller channels crossed. The plane dips steeply, varying from sixty to eighty degrees, and generally in a southerly direction, although a reversal of direction was noted in one locality. The strike of the fault also varies but is generally northwesterly.

Movement apparently has been relatively upward on the northerly side, since all sediments have been stripped from the crystalline mass. This makes the fault of the high angle reverse type with the granitic rocks riding up on the sediments. The resistant Martinez conglomerate is highly fractured adjacent to the fault, with abundant slickensides, although only a very thin seam of gouge is present. The soft Domengine shales show great contortion with some overturning of beds in the vicinity of Canton Canyon. The disturbance was later than middle Eocene in time, since middle Eocene beds are affected, and because Modelo and probably Temblor beds rest upon the granite with a depositional contact, it appears to have been pre-upper and possibly pre-middle Miocene. Closer than this it is impossible to date it at present.

A number of smaller faults has been recorded, of which one in Fish Canyon is particularly interesting. This strikes thirty degrees east of north with a slight change in direction along its northern extension, and is practically vertical. It is well marked by an alignment of topographic features, part of the north fork of Fish Canyon having been determined by its presence, while notches show where its trace crosses the ridges. Horizontal movement is indicated by the offsetting of basal beds of the Martinez along its strike, although the amount of offset is not more than two or three hundred yards. The fault is obviously post-Martinez and is also pre-Clearwater, since it is not traceable into the Martinez south of the Clearwater fault. Its offset southerly extension has not been found. Other faults of minor importance exist in Fish Canyon west of the one described; in upper Castaic Canyon, and also in the crystalline rocks of Elizabeth Lake and Canton Canyons. Many of the massive beds of sedimentary rocks are crossed by numerous insignificant faults of slight displacement.

Folds.

The major fold in the area is the Castaic syncline, (See Plate XXIV) the axis of which roughly parallels the southwesterly margin of the Castaic fault block. The Martinez and Modelo rocks dipping towards the west form the long, more gently sloping easterly limb of the assymetric fold, the westerly limb turning up abruptly against the crystalline rocks of the Piru block. Only Modelo sediments appear in this westerly limb, as has been previously brought out. The interbedded shales of the Modelo show an extreme degree of contortion,



Castaic syncline and Violin Canyon fault. Violin Canyon just south of Oak Flat.

which is readily visible in the cuts along the Ridge Route which crosses from the southwest to the northeast flank of the fold about two miles north of the south boundary of the quadrangle. Where squeezed against the hard conglomerate of the basal portion along the western side, the shales and thin sandstones have been completely overturned and faulted.

Kew, in his mapping to the south, does not show a continuation of this syncline,[1] and it seems probable that it swings around to the northeast, being manifested in the smaller syncline occurring between San Francisquito and Charlie Canyons. This is suggested by the sinuous character of the small anticline that crosses Castaic Creek a mile north of the quadrangle boundary, and from an original parallelism with the Castaic syncline, swings to the east and apparently is continued to the northeast by the anticline between Bitter Creek and Charlie Canyons.

It will be noted from an inspection of the map (Plate XXXI) that the deflection of the Castaic syncline as well as of the minor anticline is quite in line with the great southerly swing of the Clearwater fault and with the less marked but still distinct curvature of the two sedimentary contacts crossing Elizabeth Lake Canyon between. The only conclusion possible to reach from these observed facts is that a rather

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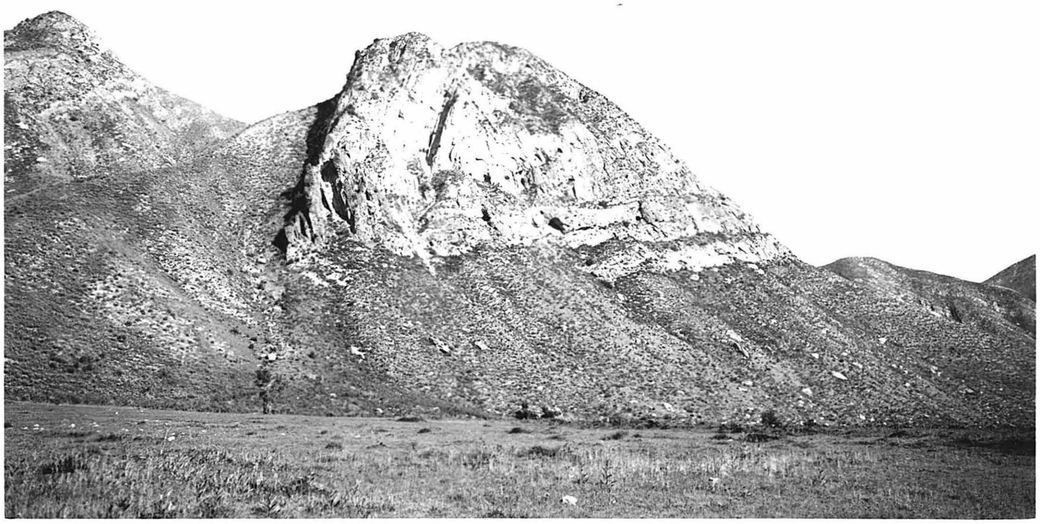
[1] Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, Pl. VIII, 1924.

large transverse upwarp has developed athwart the general structural lines, affecting not only the Castaic Block but likewise a part of the Red Rock Mountain block. This feature is of such magnitude that at no time has it been possible to see more than a hint of it in the field, although there can be no question as to its existence. The writer proposes to call it the Elizabeth Lake Canyon upwarp.

The most prominent fold in the Piru Creek region is the Agua Blanca overturn. (Plate XXV) This first becomes visible just east of Canton Canyon and extends west for an unknown distance. Complete overturning of the beds involved is not found all along the structure, but where so well exposed in Piru Canyon just south of Blue Point, the beds very distinctly are overturned to the south, and this seems to be the rule as far west as observation has been carried by the writer. Domengine, Sespe, Vaqueros, Temblor and Modelo beds are involved in the overturn. In addition to the overturning, there has been a certain amount of overthrust faulting, with Domengine and Sespe beds pushed over Vaqueros, and the latter in turn perhaps thrust over Temblor. The overturn has been rendered somewhat more complex east of Piru Creek by smaller folds whose axial planes trend at oblique angles to that of the Agua Blanca fold.

A very large number of minor folds occurs throughout the southern part of the area. These are particularly prominent in Modelo and Pico strata between Piru Creek and Palomas Canyon, and also west of the former. An attempt was made to map some of these, although they are considered of minor importance in the



Axis of Agua Blanca overturn. Piru Canyon.

interpretation of structural history since they are intimately related to the larger structures. Small, tightly appressed folds in the Sespe of the San Francisquito Creek region give some clue to the deformation to which the formation as a whole has been subjected.

Dips and strikes taken on the still visible bedding planes of the Pelona Schists give evidence of a general anticlinal structure, complicated by minor folding. That flow cleavage had developed prior to the folding and not as a consequence of the forces causing the folding is indicated by the parallelism between flow cleavage and bedding planes rather than between the cleavage and the axial plane of the fold. Jointing is well developed in the schists.

One of the minor structural features that is of more than ordinary interest in this area is landsliding. Landslides are especially prominent in the schists along the east side of San Francisquito Canyon. (Plate XXVI) Viewed from some distance, the canyon wall has the appearance of being terraced, excepting that the flat, terrace-like areas show no accordance of levels whatsoever. Furthermore, similar effects are not in evidence on the northwest side of the canyon, although the Martinez rocks are equally capable of retaining such effects. Willis first pointed out that these probably were due to landsliding[1]

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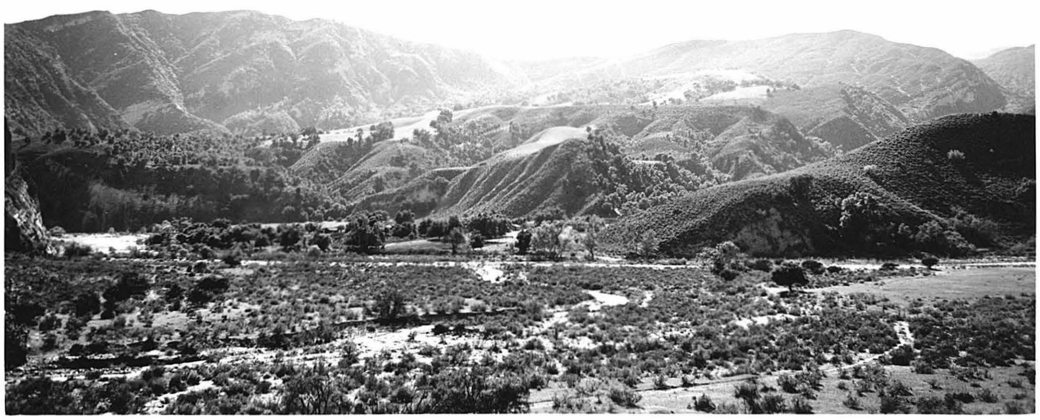
1 Willis, B., Report on the geology of the St. Francis Damsite, Los Angeles County, California, Western Construction News, vol. 3, pp. 409-413, 1928.

PLATE XXVI.

Recent landslides in Pelona Schists on easterly side of San Francisquito Canyon above former damsite. Hummocky topography due to ancient slides.

and an examination of recent landslides that have taken place both before and since the withdrawal of the lake bears out his idea. The oversteepened canyon side with the planes of flow cleavage of the schist approximately parallel to it has resulted in landslides for a very considerable period of time. Most of the older ones are entirely overgrown with brush, but the most recent show the same flat areas, slightly tilted back toward the hill, and bounded by steep, curving minor fault surfaces.

The most prominent landslide in later sediments is located west of Piru Creek and just north of the quadrangle boundary. (Plate XXVII) Here a mass of Modelo sandstone and shale of something over a square mile in area has slipped down some hundreds of feet, displaying a typical landslide topography and structure. Almost flat, grass covered surfaces are tilted back towards the hill and are bounded by rather abrupt scarps. Mapping of the structure at the base where exposed by the later cutting of Piru Creek, gives a bewildering variation in dips and strikes, showing complicated folding on a miniature scale caused by the thrust of the mass as it slid down. Other smaller landslides are common throughout this part of the area.



Large landslide in Piru Canyon opposite mouth of Canton Canyon.

Structural History.

Broadly interpreted, the structural details just described tend to show that compressive forces have been active in this region for a vast period of time. Some of these forces have been static, as in the case of the development of flow cleavage in the schists parallel to the bedding. Largely, however, the forces have been dynamic, and partially, at least, rotational in their application. This is indicated by the thrust faults and the folds, and particularly by the horizontal movement of some of the blocks in answer to shearing stresses. While it is true that tension causes normal faults, it is not necessarily true that all normal faults are caused by tension, and there is no need to interpret the Palomas Canyon fault differently from the others.

It is difficult to state at what time the forces first became active. Doubtless there was uplift at the time of the intrusion of the late Jurassic batholith, and it is possible that the anticline developed in the schists dates from this time. That there also must have been uplift at the end of the Mesozoic era has already been indicated.

The first activity of the forces that can be more closely dated than the above came after the deposition of the Martinez and prior to Sespe deposition, when the Red Rock Mountain block was uplifted and partially denuded of Martinez sediments. That the uplift was not great in amount and was possibly of the hinge type with decreasing displacement to the northwest is suggested by the still rather considerable thickness of basal Martinez lying beneath the Sespe. Horizontal movement on the Clearwater fault took place after Sespe time, but apparently before the Modelo, since deposits of the latter do not appear to have been disturbed. It is probably that uplift of the Piru block was contemporaneous with this, from the already postulated conditions of deposition of the Modelo conglomerate adjacent to the Palomas Canyon fault. Doubtless the Whitaker fault also occurred at this time. The marked unconformity at the base of the Temblor in Canton Canyon in all probability places this period of diastrophism between the Vaqueros and Temblor ages.

Another period of compression resulted in the folding of the Modelo beds in the Castaic syncline and probably also resulted in the Agua Blanca overturn, in which Modelo strata are to a considerable extent involved. It cannot be stated whether this came before or after Pico time, since the overturn dies out to the east. At least, Pico beds do not appear to have been affected.

The last great period of compression was also marked by shearing stresses. It is apparent that at this time the Castaic block was unable to yield by slipping along the bounding faults, either horizontally or vertically, as it had hitherto done, and the sediments folded into the Elizabeth Lake Canyon upwarp. The shallow basin of weak Sespe found itself between the relatively strong Martinez and the unyielding schists and was forced into tight folds and thrust over the Mint Canyon and Pelona Schists, dropping relative to the Martinez along the Bee Canyon fault. It is probably that the Canton Canyon folds, involving to some extent even the Saugus to the south, were brought into being at this time. This period apparently came after Saugus time but before the deposition of the late Pleistocene terrace gravels.

The only definitely recorded movement since the last compressive period seems to have been along the Palomas Canyon fault, causing the tilting of the terrace deposits. It is probable that the Warm Spring branch of the Clearwater fault also was formed in post-Pleistocene times, since it is not affected by the upwarp. Both of these movements may have been due to tension or relaxation following the great compressive activity.

PHYSIOGRAPHY.

The southern part of the Tejon Quadrangle may be considered to be in the state of physiographic youth. This is shown by the narrow, V-shaped valleys and in part steep walled canyons, by the presence of a few flat-topped interfluves, and by the dendritic drainage pattern. Drainage is well developed for a semi-arid region, indicating that the initial stage is well ~~passed~~ past, while the fact that the streams are still very actively downcutting and doing little lateral corrasion, shows that maturity is far in the future. The stage in the erosion cycle represented seems to be about middle youth.

Piru Creek and the streams in San Francisquito and Elizabeth Lake Canyons are out of accord with the topography of the region as a whole, since they possess decidedly meandering courses, although deeply intrenched. There can be little doubt that their courses are inherited from a previous cycle of erosion, during which time they probably meandered on comparatively flat flood plains. (Plate XXVIII) This is shown particularly by San Francisquito Creek, whose channel is in part cut in the hard schists and in part in the soft Mint Canyon sandstones, indicating that neither was exposed when the location of the channel was determined. These flood plains may have developed during a period when some obstruction had caused temporary base-leveling, but because of the fact that all three rather widely separated streams show the same features, it seems more

Remnant of old land surface bordering Castaic Canyon.

logical to conclude that the land formerly was near base level and has since been uplifted. This would make all three creeks antecedent streams, their courses having become intrenched as uplift brought about rejuvenation. In addition, Elizabeth Lake Canyon has been cut in opposition to the rising of the fold which it dissects.(Plate XXIX)

A few remnants of the old erosion surface developed by these streams and their tributaries are still extant. One of these is Drinkwater Flat, east of San Francisquito Canyon, which is cut on the Pelona Schists. Upon ascending any of the small streams draining this area, one passes suddenly from a distinctly youthful, deeply incised canyon, to an open valley of small gradient running through a rather gently rolling country. This probably antedates somewhat the highest terrace gravels, since it shows a slight easterly tilt which the latter apparently do not have. Another remnant is the small area of low relief visible on Whitaker Peak, and several other of the neighboring high ridges show rather flat tops. The tilted surface found on the ridge between Canton Canyon and Devil Canyon may represent this same surface, although now almost two thousand feet lower than that on Whitaker Peak. On the other hand, this is cut in soft sediments and possibly is very much later. Oak Flat and the Pothole owe their existence to differential erosion of comparatively recent date.

An example of an exhumed topography is found around the southerly and southwesterly margins of the Pelona Schists.

Ancient broad channel of Elizabeth Lake Creek.

The inliers of Mint Canyon basal conglomerate in the schists very evidently represent filled canyons that existed in a probable middle Miocene land surface, while the outliers of schist surrounded by Mint Canyon sediments can be nothing else than buried hills previously standing out on this same surface. The middle Miocene relief was much greater than that of the Pleistocene surface represented by Drinkwater Flat.

Two instances of stream piracy have been noted in the area. These are south of Oak Flat, and Canton Creek is acting as the beheading stream in both cases. Oak Flat originally drained down Violin Canyon into Castaic Creek, and the canyon immediately to the west of the Flat drained similarly through Palomas Canyon. Canton Canyon with shorter course and steeper gradient cut rapidly northeasterly by headward erosion and beheaded first Palomas Canyon, and finally penetrated the ridge west of Oak Flat and captured the headwaters of Violin Canyon as well. The new highway parallel to the Ridge Route enters Oak Flat through the wind gap. (Plate XXX).

The largest of the subsequent streams is Castaic Creek. It is possible that it originally also flowed on the surface developed by the three main streams, but if so, it shows no evidence of it, and the probability is that it has developed subsequent to the uplift. At present, most of its course is through the soft Modelo shales, whose strike it parallels for several miles.

Wind gap at south end of Oak Flat. New state highway passes through this gap.

HISTORICAL GEOLOGY

The first event decipherable in the long history of the region under discussion was the deposition of the clastic sediments which today are represented in changed form by the Pelona Schists. It is presumed that this took place in a pre-Cambrian sea, possibly in Schuchert's Sonoric geosyncline of the Proterozoic,[1] and sufficiently close to the shore for some fairly coarse material to have been received. Little can be inferred as to land conditions at the time excepting that from the nature and thickness of the sediments there is suggested a land of fairly high relief subjected to more or less rhythmic climatic conditions. Since metamorphism apparently was brought about by static load, deposition must have continued for a considerable period of time with progressive sinking of the trough until the lower sediments had been forced down into the anamorphic zone. Here heat and pressure brought about mineralogic and molecular changes and the schists were produced.

The Paleocoic era, believed to be represented by the gneiss, quartzite and marble, saw deposition of a different nature, in that during a part of the time the sediments laid down were not clastic, but chemical precipitates. Either the sea had become very widespread, or the land was so low in relief that it contributed little detritus to the waves, or

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1 Schuchert, C., Outlines of historical geology, John Wiley and Sons, Inc., New York, Pl. I, 1931.

perhaps both conditions existed. What part of the Paleozoic is represented, if it is indeed Paleozoic, it is impossible to say.

It is probable that the area was disturbed by the Appalachian revolution, which affected western North America to some extent, following which deposition again became active. This is not apparent from any sediments attributable to either the Triassic or Jurassic periods, but may be inferred from the fact that intrusives into the older rocks are coarse grained and must have cooled slowly under a thick cover. If the region had stood high and had been subjected to erosion during the earlier periods of the Mesozoiv, this would have been impossible.

The Jurassic peiod was ended by orogenic disturbances which first brought the Sierra Nevada and Coast Ranges into being, and concurrently with which was intruded the great Sierran batholith of granodiorite and associated rocks. This time of diastrophism is manifested in the Tejon Quadrangle by the intruded granitic rocks and the consequent metamorphism of the supposed Paleozoic sediments.

The Cretaceous is represented by sedimentary rocks some miles to the south of this area,[1] and while it is possible that similar deposition took place here, the results of which

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1 Kew, W.S.W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Bull. 753, Pl. I, 1924.

have since been eroded away, it is the growing belief of the writer that the Cretaceous sea did not extend this far north. The Paleocene rocks show derivation from a land mass dominantly of lava, but with plutonic and metamorphic rocks exposed. The great thickness of sediments overlying the latter at the time of intrusion of the Sierra Nevada batholith must have been almost entirely removed between the end of the Jurassic and the beginning of the Tertiary. If the Cretaceous had been a time of deposition, then the interval of erosion could only have been between the end of the latter and the inception of the Eocene, and there also would have been the additional sediments to be removed. Evidence in Simi Valley[1] does not indicate a profound break between upper Cretaceous and Martinez, and it therefore seems logical to conclude that the erosive interval in the Tejon Quadrangle extended throughout Cretaceous time. In this case the lavas extruded contemporaneously with the intrusion of the granodiorite must have been entirely removed, the boulders in the Martinez coming from a later effusion, apparently in later Cretaceous time. Cretaceous history thus becomes one of erosion and volcanic activity.

The sea crept back over the area during the opening part of the Eocene epoch, attacking the rugged coast of the rather high-lying, youthful land mass resulting from uplift during the Laramide revolution at the end of the Mesozoic

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[1] Ibid., p. 15.

era. This was a general advance of the sea, but it apparently did not extend to any great distance north of the region mapped. A slight disturbance caused retreat following the Martinez, subsequent to which the sea again advanced and deposited Domengine beds. It appears from the present distribution of the latter in the area that this was a less extensive invasion than the previous one, although the presence of similar beds along the southern border of the San Joaquin Valley[1] suggests that it was greater, the beds in the intervening region having been eroded away. The same reasoning may apply also to Tejon beds which are nowhere visible in the southern part of the quadrangle, although their type locality is in the northern end.

A general emergence of the land took place at the end, or possibly in the latter part of the Eocene, accompanied by the formation of the Clearwater fault, and erosion under semi-arid conditions followed. Some of the sediments formed under these circumstances failed to reach the sea, but instead were deposited in local basins where interruption of the Oligocene cycle of erosion possibly by rather rapid sinking of the land caused their burial and preservation.

The lower Miocene sea coming in from the south reworked much of the land-laid material of the preceding epoch and deposited it without great change, because, perhaps, of

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[1] Hoots, H. W., Geology and oil resources along the southern border of the San Joaquin Valley, California, U.S.G.S. Bull. 812-D, pp. 248-250 and Pl. 31, 1930.

the low effective power of waves and currents in the small, bay-like area undergoing submergence. Marked diastrophic movements drove back the encroaching waters at the end of Vaqueros time, and deformed all previously deposited sediments to a greater or lesser degree, exposing them to subsequent erosion. Horizontal displacement on the above mentioned fault probably took place at this time.

The middle Miocene waters advanced over the eroded edges of the older strata, although not quite as far as during the previous minor cycle, and deposition continued throughout the balance of Miocene time. It is quite probable that a disconformity exists between Temblor and Modelo sediments, even though it has not been found. Certainly the former sea did not extend up into the long gulf now marked by Modelo deposits, probably indicating that that basin was progressively sinking. A consequence of this progressive sinking was the simultaneous building of shore deposits represented by the Mint Canyon formation with their lateral gradation into marine sediments and their final overlapping by the same marine series. It was possibly a downdropping of the Castaic block along the Palomas Canyon fault beginning in Temblor time that brought about the submergence of the block in the upper Miocene.

Further diastrophism, with emergence of the land, followed the Miocene epoch and after erosion some slight sinking allowed the Pico sea to extend for a short distance into the area. Wide-spread uplift again took place, presaging the glacial epoch, and as in Oligocene times, interior drainage, or at least the establishment of temporary base levels, caused the sediments to collect in irregularities in the land's surface. This cycle of erosion was interrupted by diastrophic movements that brought about the transverse warping of the Castaic and Red Rock Mountain blocks and ended lower Pleistocene time.

Upper Pleistocene time was the age of terrace building, and saw the Santa Clara River and its principal tributaries aggrading their channels and spreading their flood-plain gravels wider and wider. Over these broad flood-plains the streams meandered until an interruption of some sort revived them and they resumed downcutting. Change in climatic conditions may have brought about this renewed vigor, but the evidence of the tilted erosion surface represented by Drinkwater Flat points to uplift. Various halts were made in the progressive re-elevation of the land, and during these halts the streams again widened and aggraded their channels.

The Recent epoch, represented by conditions existing today, is still not well developed. The land stands at a moderate elevation and streams are actively downcutting. Deposits are collecting in local basins as they have in times past, but if the cycle is uninterrupted these eventually will be removed and redeposited in the sea, which, although at present many miles to the west, might be expected once more to encroach upon the basin occupied so many times before. If the cycle should be interrupted, the present alluvium might be preserved similarly to that former alluvium now making up Sespe, Mint Canyon and Saugus deposits. Continued study of the Pleistocene and Recent deposits may give sufficient perspective that the two may be seen in their true relationship. It is rather difficult so to do in the light of present knowledge.

ECONOMIC GEOLOGY.

There is little of economic interest occurring in the southerly part of the Tejon Quadrangle. Gold was first discovered in California in 1841 in the vicinity of Newhall, a short distance south of the area, and doubtless had its origin in the quartz veins of the Pelona Schists. These veins are rather similar to those of the Mother Lode district of California, consisting principally of fissures filled with quartz containing a small amount of auriferous pyrite. While some of these veins attain a thickness of more than ten feet, they are very low in grade, and nowhere in the district have they been worked. There has been some accumulation of placer gold derived from the veins and this is being worked at the present time on a small scale in San Francisquito, Dry and Haskell Canyons. No figures are available as to the total amount of gold produced, but it doubtless is small.

Placer gold also has been mined in Piru Canyon between the Big and Little Narrows. This occurred principally in deposits of Pleistocene terrace gravels of small extent, and it is said that at one time approximately one hundred and fifty Chinese were working in this locality. The gold probably had its origin in veins in the gneissic rocks cut by Piru Creek a few miles to the north, although such veins are not greatly in evidence. Gold recovered from placer deposits in Santa Felicia Canyon, a short distance south of the quadrangle, probably originated in similar veins. A rather promising looking quartz vein in the Canton Canyon granitic rocks assayed only forty-two cents in gold per ton, and it is the opinion of the writer that most of the veins are of such low grade as to offer little chance of profitable mining.

Several wild-cat oil wells have been drilled in the region, but none has been productive. Those in the so-called Castaic field were drilled on minor folds on the northeasterly limb of the Castaic syncline and failed to take into consideration the major structure, the nearness of the Palomas Canyon fault, and the lack of any quantity of a suitable source rock from which the oil might have been derived. Practically all these wells were drilled in Modelo sediments, the deepest reaching something over three thousand feet. Most of them are at present flowing water with occasional bubbles of inflammable gas and small drops of oil.

The Richfield Oil Company drilled a well in the Modelo beds just west of Piru Creek, in a small canyon opposite the mouth of Canton Canyon. This well reached a depth of slightly more than twenty-eight hundred feet, and a fair pressure of wet gas was obtained. Whether or not a production test was made is unknown, but the well is capped at present. Springs a short distance up the branch canyon from the well yield both hydrogen sulphide gas and an inflammable gas. The structure is anticlinal, but is complicated by the landslide to the south of which it possibly is a part, and it is difficult to determine much as to its nature. It probably is a very minor, superficial wrinkle, brought about by the same forces that caused the Agua Blanca overturn.

Sufficient organic shale is present in the Canton Canyon region to have yielded large quantities of petroleum, but most of this is exposed on the surface and the oil doubtless in large part has escaped. It is possible that the minor folds crossing Devil and Canton Canyons may have caused the trapping of some of this oil and that wells drilled in this region may prove productive. The field, if productive at all, will never be extensive in area. Probably any really productive district will be found west of the area mapped in the Modelo rocks between Piru and Sespe Creeks.

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