GEOLOGY OF A PORTION OF THE SOUTHEAST QUARTER OF THE TEJON QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA,

by

Thomas Clements

E.M. 1922

THESIS

Submitted in Partial Fulfillment of the Requirements

for

The Degree of Master of Science

in

Geology

in the

Graduate Division

of the

California Institute of Technology, Pasadena, California.

1929.

T A B L E O F C O N T E N T S

LIST OF ILLUSTRATIONS

S U M M A R Y

In this area of some thirty-eight square miles in the southeast corner of the Tejon Quadrangle, are exposed igneous, metamorphic and sedimentary rocks. The metamorphics are mainly schists derived from former sediments, and Pre-Jurassic in age. The sedimentary rocks occupy the principal part of the area and represent deposition in Martinez, Sespe, Mint Canyon, Modelo, Saugus and Quaternary times. The igneous rock is an isolated remnant of acidic lava probably of Miocene age.

Three prominent faults are found in and immediately adjacent to the area; the San Francisquito, partly overthrust, partly normal in character; the Bee Canyon Fault, normal; and the fault just north of the area, which is also normal. Some folding occurs, probably related to the faulting.

Perhaps the two most important facts brought out by the study are the apparently lateral and upward grading of non-marine Mint Canyon sediments into marine Modelo, and the overthrust nature of the San Francisquito Fault in the canyon of the same name.

INTRODUCTION

The Tejon Quadrangle is one of the few areas in Southern California upon the geology of which very little has been published. Hershey (1, 2) in 1902 issued two short papers in which he described certain of the formations occurring in this region. A survey of the literature has disclosed nothing further until 1928, when the failure of the St. Francis Dam focused the attention of the world upon the southeast corner of the quadrangle, and drew forth a considerable number of papers touching in a superficial way upon one of its many complex features. While the present paper covers but a small portion of the quadrangle, it is offered as preliminary to a report to be issued later covering atleast the southeast quarter, and possibly the entire southern half of the quadrangle.

Note: Numbers enclosed in parentheses refer to papers listed under corresponding numbers in bibliography at end of paper.

ACKNOWLEDGEMENTS

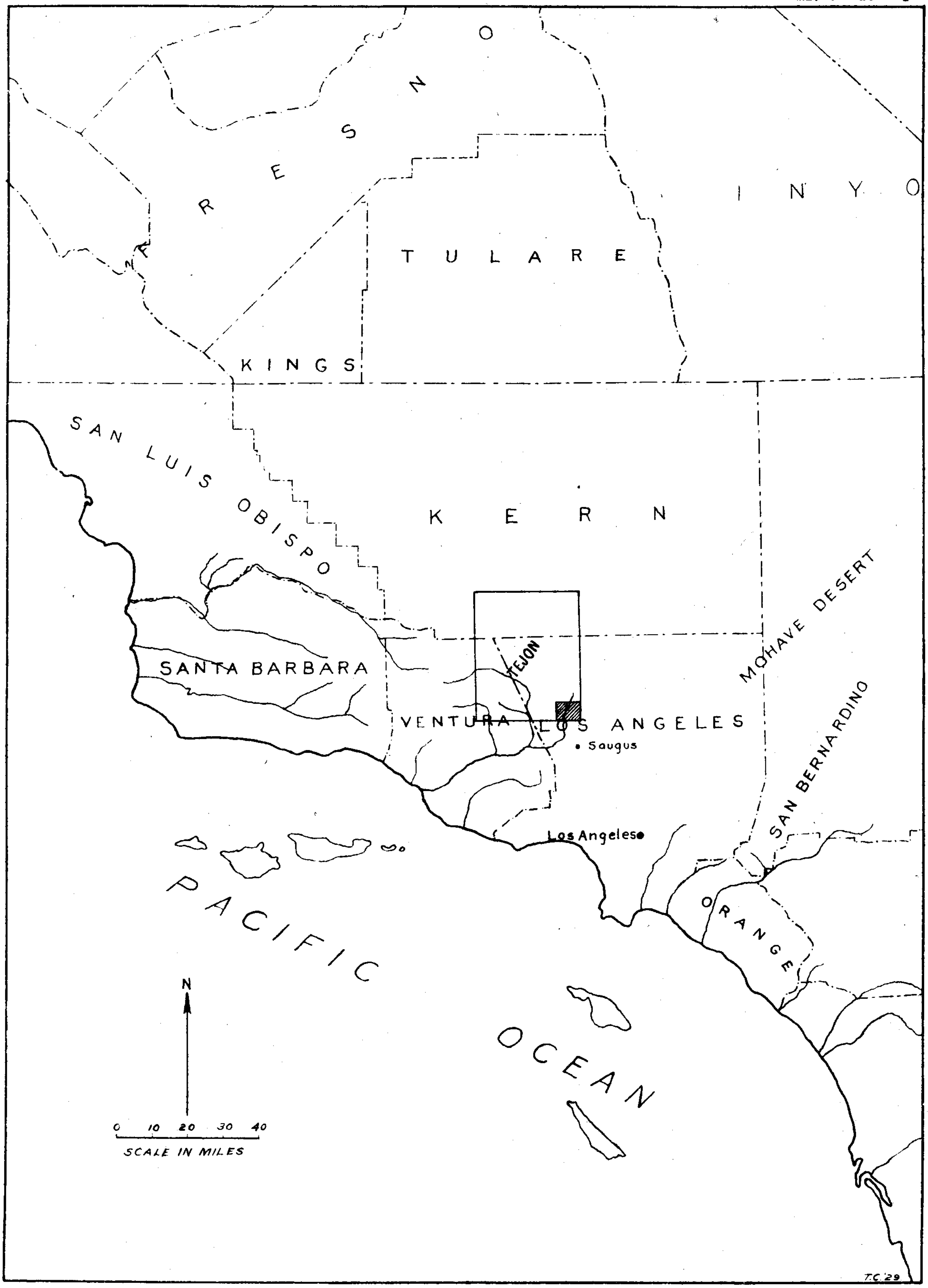
The writer wishes to express his appreciation of the assistance extended him by Dr. J. P. Buwalda and other members of the faculty of the Division of Geology and Paleontology of the California Institute of Technology. He desires to thank Mr. W. W. Stabler of the Globe Petroleum Corporation for having made available to him the logs of two of the wells in the district, as well as reports on geology and core samples. He is particularly indebted to Lydia Brooks Clements, without whose help it would have been impossible to complete this work.

GEOGRAPHY

The Tejon Quadrangle lies between 118 degrees 30 minutes and 119 degrees west longitude, and 34 degrees 30 minutes and 35 degrees north latitude, and includes portions of Los Angeles, Ventura and Kern Counties, California. (See Plate I.) The area discussed in this paper comprises some thirty-eight square miles in the extreme southeastern corner of the Tejon Quadrangle, and may be more particularly described as being portions of Townships 5 and 6 North, of Ranges 16 and 17 West, San Bernardino Base and Meridian, all within Los Angeles County. The district is about forty-five miles in a north-northwesterly direction from the City of Los Angeles, and is reached by way of the Inland Route to San Francisco, branching off either at Saugus, where one may take the road into San Francisquito Canyon, or just north of Castaic Post Office, taking the Elizabeth Lake Canyon road. These are both dirt roads, usually well kept up, and there are in addition, rather poor roads into Haskell, Charlie and Castaic Canyons. Several cleared trails make accessible most of the area between these canyons.

There are few people in the region. Most of them are concentrated in San Francisquito Canyon near Power House Number 2, of the Bureau of Power and Water of Los Angeles City, rebuilt on the site of the former power house which

PLATE I



Map of a portion of California showing location of area discussed.

was destroyed in the St. Francis flood. The remaining inhabitants are on scattered ranches and farms in the various canyons. The nearest settlements are Castaic Post Office, just south of the quadrangle on the so-called Ridge Route, and Saugus, at the junction of the Ridge Route and the Mint Canyon road.

The relief is moderate. The point of least elevation is to be found in Castaic Canyon just north of Castaic Post Office, where the altitude is approximately 1150 feet, while the highest points are in the northern portion, where the elevations reach something over 3600 feet. Red Mountain, which is just north of the area covered in this report, and is between San Francisquito and Elizabeth Lake Canyons, is 4007 feet high.

The topography is generally rough. The canyons are deep and steep-sided, and in a few places typical bad-land topography is developed. There are, however, some few small areas of almost level ground, such as Drinkwater Flat, and the terraces bordering Castaic and Elizabeth Lake Canyons, as well as the floor of Castaic Canyon itself. These level areas are covered with terrace material or alluvium, and will be discussed later under physiography.

The drainage is practically all in a southerly direction, and ultimately reaches the Santa Clara River, which flows westerly to the sea. With the exception of Elizabeth Lake Creek, the streams are intermittent, and the canyons contain water only during the winter months. Elizabeth Lake Canyon, however, draining as it does Hughes Lake and the lake from which it takes its name, and receiving the drainage as well from a considerable area of comparatively high-lying land, boasts a stream the year around.

CLIMATE AND VEGETATION

The climate is semi-arid, as might be expected from the fact that the Mohave Desert lies but fifteen or twenty miles to the northeast, while moderately high mountains to the south and west rob the ocean breezes of the major part of their moisture before the upper Santa Clara valley is reached. The mean annual rainfall as recorded at Newhall, ten miles to the south, over a period of thirty-eight years, is 17.54 inches, with a minimum yearly rainfall of 4.35 inches in 1877, and a maximum of 44.20 inches in 1884. Most of the rain comes during the winter months, and may all be received in three or four storms, or it may be well distributed over the months from December to April.

The mean annual temperature at the same recording station and for an equal number of years was 61.5 degrees Fahrenheit. The lowest temperature recorded during a period of twenty-two years was 10 degrees above zero, and the highest was 113 degrees. It is never too cold for field work, but biting winds added to the low temperatures may make it very disagreeable in December and January, and snow has been known to fall as late as in April. In full Summer the sun usually beats down from an unbroken sky, although on the ridges a breeze may temper its rays somewhat.

Fall and Spring are the best seasons for the carrying on of field studies.

The vegetation is varied, and in places is indicative of the nature of the underlying formations. For instance, on the soil derived from the Pelona Schists, there grows a low shrub that in the Fall turns a reddish brown, while shale is usually indicated by a growth of sage or of wild oats. In more open canyons grow many cottonwoods and oaks, the former being replaced, as the canyons grow narrower and more rugged, by sycamores. A few pines are scattered over the slopes of the higher hills in the northern portion of the area.

Most of the hills are covered with a dense growth of chaparral, consisting chiefly of chamise, sumac, manzanita and madroña, with some so-called California holly and lilac. This growth is in places almost impenetrable, and greatly hinders geologic work, both by masking contacts, and making the following of contacts extremely difficult. In the Spring months there is a profusion of wild flowers, especially when the rains are more or less evenly distributed through the season. California poppies are not plentiful, but their lack is balanced by the masses of prickly phlox, which give to whole hillsides their pink to lavender tinge, while brodiaea, escobitas, lupine and suncups are common. The following list of shrubs and flowers observed in the area was prepared by Lydia Brooks Clements:

Lily Family (Liliaceae)

Our Lord's Candle - Yucca whipplei, Torr.
Brodiaea, California Hyacinth - Brodiaea capitata Benth.
Golden Stars - Bloomeria aurea Kellog
Mariposa Tulip, Mariposa Lily - Calochortus catalinae, Wats.
Golden Tulips - Calochortus oculatus, Dougl.

Buckwheat Family (Polygonaceae)

Turkish Rugging - Chorizanthe staticoides, Benth.
Wild Buckwheat - Eriogonum fasciculatum, Benth.

Four O'Clock Family (Nyctaginaceae)

California Four O'Clock - Mirabilis californica, Gray

Purslane Family (Portulacaceae)

Red Maids - Calandrinia caulescens (Hook) Gray
Miners' Lettuc - Montia perfoliata, Howell

Crowfoot Family (Ranunculaceae)

Blue Larkspur - Delphinium parryi, Gray
Wild Clematis - Clematus lasiantha, Nutt

Poppy Family (Papaveraceae)

Prickly Poppy - Argemone platyceras, Link and O.
Tree Poppy - Dendromecon rigidum, Benth.
California Poppy - Eschscholtzia californica, Cham.

Mustard Family (Cruciferae)

Wild Mustard - Brassica nigra, Koch

Stonecrop Family (Crassulaceae)

Hen and Chickens (Cotyledon pulverulenta, Benth. and H.

Saxifrage Family (Saxifragaceae)

Wild Gooseberry - Ribes speciosum, Pursh.
Yellow Wild Currant - Ribes tenuiflorum, Lindl.

Rose Family (Rosaceae)

Islay, Wild Cherry - Prunus ilicifolia, Walp.
Chamise, Greasewood - Adenostoma fasciulatum, Hook and A.
California Holly, Toyon - Heteromeles arbutifolia, Roemer
California Wild Rose - Rosa californica, Cham. and S.
Mountain Mahogany - Cerocarpus betuloides, Nutt

Pea Family (Leguminosae)

Canyon Lupine - Lupinus cytisoides, Ag.
Deerweed - Hosackia glabra, Torr.
Rattleweed, Loco weed - Astragalus leucopsis, Torr.

Geranium Family (Geraniaceae)

Filaree - Erodium cicutarium, L'Her.

Spurge Family (Euphorbiaceae)

Golondrina, Rattlesnake Weed - Euphorbia albomarginata T. and G.

Sumac Family (Anacardiaceae)

Sumac, Mangla - Rhus laurina, Nutt.

Buckthorn Family (Rhamnaceae)

California Lilac - Ceonothus thyrisiflorus, Esch.

~~Mallow Family (Malvastrum fasciculatum, Nutt~~

Cactus Family (Cactaceae)

Cholla - Opuntia bernardina, Engelm.
Nopal, Prickly Pear - Opuntia linderheimeri, Engelm.

Evening Primrose Family (Onagraceae)

Clarkia - Clarkia elegans, Dougl.

Heath Family (Ericaceae)

Madrono - Arbutus menziesii, Pursh.
Manzanita - Arctostaphylos manzanita, Parry

Primrose Family (Primulaceae)

Shooting Star - Dodocatheon clevelandi, Greene

Phlox Family (Polemoniaceae)

Prickly Phlox - Gilia californica, Benth.

Waterleaf Family (Hydrophyllaceae)

Baby Blue-Eyes - Nemophila insignis, Dougl.
Whispering Bells - Emmenanthe penduliflora, Benth.
Wild Heliotrope - Phacelia distans, Benth.
Pansy Phacelia - Phacelia parryi, Torr.

Waterleaf Family (Hydrophyllaceae) continued.

Wild Canterbury Bell - Phacelia whitlavia, Gray
Yerba Santa - Eriodictyon glutinosum, Benth.

Borage Family (Boraginaceae)

Fiddle Neck - Amsinckia spectabilis, F. & M.
Popcorn Flower - Plagiobothrys nothofulus, Gray.

Mint Family (Labiatae)

Romero - Trichostema lanatum, Benth.
Black Sage, Black Ball Sage - Ramona stachyoides
Button Sage, White Ball Sage - Ramona nivea
White Sage - Ramona polystachya
Horehound - Marrubium vulgare, L.
Thistle Sage - Salvia carduacea, Benth.
Chia - Salvia columbariae, Benth.

Nightshade Family (Solanaceae)

Toluache - Datura meteloides, D.C.
Black Nightshade - Solanum nigrum, L.
Violet Nightshade - Solanum xanti, Gray
Tree Tobacco - Nicotiana glauca, Graham

Figwort Family (Scrophulariaceae)

Indian Paint Brush - Castilleia folialose, H & A.
Owl's Clover, Escobita - Orthocarpus purpurascens, Benth.
Butter and Eggs - Orthocarpus erianthus, Benth.
Stickey Monkey Flower - Mimulus glutinosus, Wendl.
Scarlet Bugler - Penstemon centranthifolius, Benth.
Scarlet Honeysuckle - Penstemon cordifolius, Benth.

Honeysuckle Family (Caprifoliaceae)

Elder - Sambucus glauca, Nutt.
Big Root,-Chilicothe - Echinocystis fabacea, Naudin

Sunflower Family (Compositae)

Tidy-Tips - Layia platyglossa, Gray
White Daisy - Layia glandulosa, H. & A.
Rabbit Brush - Chrysothamnus nauseosus, (Pursh) Britt.
Guatamote, Mule Fat - Baccharis viminea, D. C.
Tarweed - Hemizonia luzulaefolia, D. C.
Pincushion - Chaenactis glabriuscla, D. C.
Desert Sage Brush - Artemisia tridentata, Nutt.

Sunflower Family (Compositae) continued.

Brass Buttons - Cotula coronopifolia, L.
Eriophyllum, Golden Yarrow - Eriophyllum confertiflorum (D. C.) Gray.
Star Thistle - Centaurea metitensis, L.

Mallow Family (Malvaceae)

Bush Mallow - Malvastrum fasciculatum, Nutt.

Table Showing Formations Present in Area Covered, With Calculated Thicknesses.

System	Series	Formation	Thickness
Quaternary	Recent	Alluvium	80 feet
	Pleistocene	Terrace Deposits	200 "
Tertiary	Pliocene	Saugus	250 " (?)
		Pico	(absent)
	Miocene	Modelo	6,000 "
		Mint Canyon	3,500 "
		Topanga	(absent)
		Vaqueros	(absent)
	Oligocene (?)	Sespe	7,000 "
	Eocene	Tejon	(absent)
		Meganos	(absent)
		Martinez	10,000 "
Cretaceous	Upper Cretaceous	Chico	(absent)
Jurassic		Intrusive Granodiorite	(north of area)
Pre-Jurassic		Pelona Schist Series	7,000 "

FIGURE 1.

STRATIGRAPHY

The greater portion of the area under discussion is underlain by sedimentary rocks; certain formations are marine and others continental in origin. They range in age from early Tertiary, or possibly Cretaceous, to Recent. Metamorphic rocks occupy some five square miles in the extreme eastern part of the district, while the igneous rocks are represented by a few isolated occurrences of acidic lava. However, less than a mile to the north of the territory mapped, the sedimentary beds are in contact with an igneous mass of very considerable size which has been considered as part of a batholith, probably contemporaneous or continuous with the intrusive bodies of the Sierra Nevada.

PELONA SCHIST SERIES

In 1902, Hershey described the metamorphic rocks making up the mass of Sierra Pelona (1), and gave to them the name of Pelona Schist Series. The metamorphic rocks occurring in the area here under discussion correspond closely to his description, and since they can be traced in an unbroken belt directly into the schists of Sierra Pelona, the writer proposes to use Hershey's designation and shall so hereafter refer to them.

The Pelona Schist Series in the southeastern portion of the Tejon Quadrangle is continuous with the metamorphic series mapped by Kew (3) to the south, and by Nickell(5) and by Hill (3) to the east. It was upon rocks of this series that the

A. - Looking east-southeast across San Francisquito Canyon near eastern boundary Tejon Quadrangle. Rocks are Pelona Schists and show landslide topography. Recent slide shown occurred in 1927 before withdrawal of lake.

B. - Basal conglomerate of Mint Canyon formation resting upon eroded surface of Pelona Schists. Latter show weathering below contact. Ancient bedding of schists and minor cross-fault clearly visible. View taken immediately below Power House No. 2, in San Francisquito Canyon. Direction somewhat west of south.

east abutment of the ill-fated St. Francis Dam rested, and varying descriptions of the nature of the rocks at the site are to be found in the many papers pertaining to the dam's failure. Ransome and Louderback (4, 8) and Willis (7) have described them as ordinary mica schists, the latter ascribing their origin to the metamorphism of sedimentary beds, while Hill quotes Tolman as considering them to be derived from granite. As one follows San Francisquito Canyon down stream and notes the distinct bedding still preserved, there can be little doubt that most of the series was derived from sediments composed chiefly of interbedded sandstone and shale, in some instances altered almost to quartzite and slate. That most of the metamorphism resulted from forces acting at right angles to the bedding planes is evident from the fact that the planes of schistosity parallel these, and it may be inferred from this that the sediments were buried to great depths, and for a long period of time, apparently with little tilting or folding. A later application of forces from directions other than vertical is evidenced by the intense folding and crumpling to be seen in many places, this being especially noticeable in the exposures a few hundred yards down stream from the former dam-site. Innumerable faults also cross the beds in every direction. A mass of highly contorted gneiss of probable granitic derivation appears in a branch of Haskell Canyon, and there are evidences of small intrusive dikes cutting across the bedding planes . A great number of quartz veins occurs in this series of schists, and these veins are doubtless the source of the little placer gold that has been found in the lower canyons.

Hershey believed the Pelona Schist Series to be the correlative of certain schists of northern California, and Pre-Cambrian in age (1). Other writers have contented themselves with calling them simply Pre-Jurassic, indicating that they were older than the intrusion of the great batholiths, presumably in Jurassic time, but committing themselves no further. The fact that the beds show evidence of long and deep burial favors the age assigned by Hershey, and yet the succession and nature of the beds, so much like what is to be found in the Tertiary formations and indicative of similar conditions of deposition, might be considered to imply a stability that could not conceivably have existed from Pre-Cambrian to present. This is a question, however, that can be settled only by intensive field study of the series itself, and therefore, the writer will follow the example of other recent authors and call the Pelona Schist Series simply Pre-Jurassic.

No attempt has been made to work out structure in the series, and but little time has been devoted to a search for evidence of the presence of former life. The fact that limestone lenses are found in the Sierra Pelona region gives cause for some hope that fossils may be found, and the excellent exposures now to be seen on the clean-swept sides of San Francisquito Canyon offer an inducement to structural studies.

Granodiorite.

While the batholithic mass of granodiorite mentioned before does not outcrop within the limits of the area mapped, its proximity immediately to the north demands that some notice be taken of it in this paper. This intrusive body begins a few hundred yards north of the northern boundary of the area and extends northerly to the Mohave Desert, broken, however, by the great San Andreas Rift, which passes through it in a general north-westerly direction. Hershey (1) considered the intrusion to be continuous with as well as contemporaneous with the batholith of the Tehachapi Mountains and of the Mohave Desert, and therefore, to have been intruded during the interval between the deposition of the latest fossiliferous Jurassic sediments and the earliest positively identified Cretaceous.

The batholith is in fault contact with the sediments to the south, and although Nickell (5) has considered this fault to be an overthrust, with the sediments riding over the granodiorite, Hill (9) has called it a normal fault with the sediments on the downthrown block. The latter is the more logical conclusion, and in it the writer concurs, from the evidence to be seen in Elizabeth Lake Canyon. Here the fault plane, which is well exposed, strikes in a direction N 70 E, and dips in a southeasterly direction at an angle of 53 degrees, in other words, under the sediments. The igneous rock has been rendered gneissic at this point, and the sediments, consisting of sandstone and shale are badly broken and slicken-sided. It is true that at one locality a reversal of dip was observed in the sedimentary beds, causing them to dip into the fault plane, but if this is the effect of drag rather than folding, it would seem more logical to consider it as due to some slight reversal of movement along the fault instead of being evidence of overthrusting.

TERTIARY SYSTEM

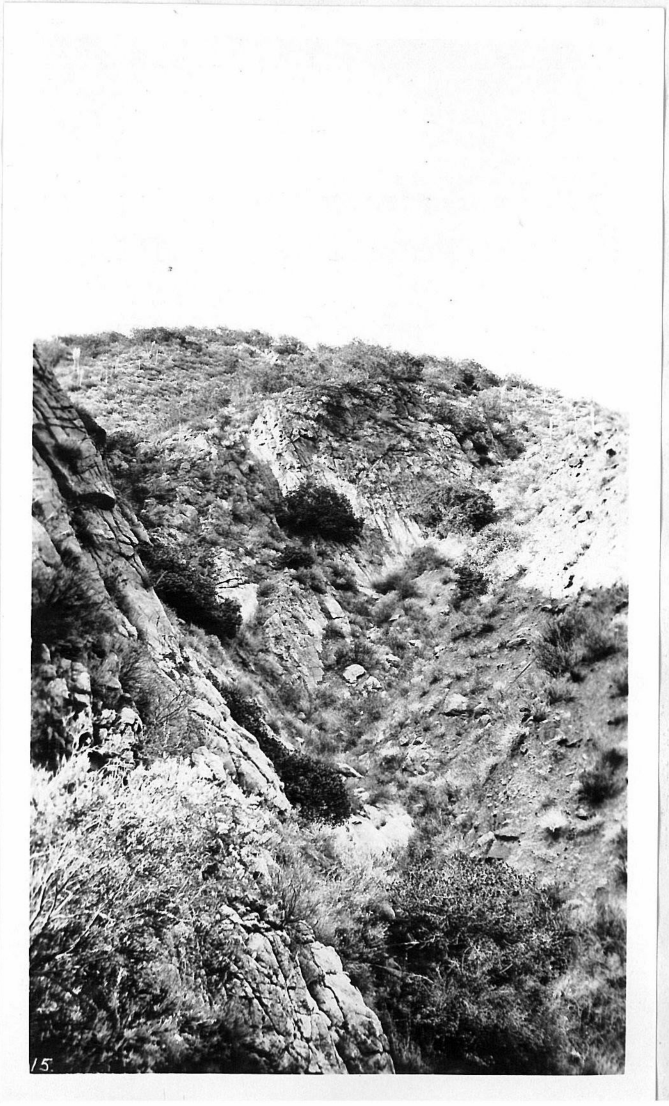
Eocene Series.

Martinez (?) Formation.

Extending across the northern portion of the area in a belt varying from one-half to two miles wide, is a series of marine sediments of doubtful age, but which, for reasons to be brought out later, have been assigned tentatively to the Martinez epoch of the Eocene period. This series is about ten thousand feet thick, and is composed principally of gray to buff sandstones with some interbedded shales, and with conglomerates becoming more important west of Elizabeth Lake Canyon. The rocks are well indurated, and weather out into prominent ridges, forming the highest lying land to be found in the area covered by the present paper. How far west these rocks extend is unknown, but they have been traced easterly by both Nickell (5) and Hill (9) to Boquet Canyon where they pinch out at the intersection of the Clearwater and San Francisquito faults.

The sandstones are made up of angular to sub-angular

A. - View looking 75 degrees west of south along fault contact between Martinez to the right and Sespe to the left (Bee Canyon Fault). Near eastern boundary Tejon Quadrangle.



B. - Basal Conglomerate Mint Canyon (right) resting upon Martinez sandstones with unconformable contact. Large bush just above line of shadow is on contact plane. Looking northeast in westerly branch of Elizabeth Lake Canyon.

quartz grains, well sorted, and held together by a siliceous cement, associated with which, however, is a considerable amount of calcite. Biotite is very common in some beds, and arkose is developed, at least locally. The average grain is fine to medium, although coarser beds are common, and lenses of rounded and polished pebbles up to an inch or two in diameter are occasionally seen. The individual beds vary from a few inches to several feet in thickness, and the bedding is well defined.

Separating many of the sandstone strata are thin beds of sandy shale, and in addition there are at least two shale beds of around one hundred feet or more in thickness. In the eastern part of the region, where only one of these latter beds has been observed, the shale is rather light colored and sandy, and contains numerous ferruginous concretions. As exposed in some of the northerly trending branches of Castaic Canyon the shale is black and carbonaceous, and devoid of concretions. The sandy, ferruginous shale is brittle and breaks readily into small fragments, while the black shale is hard and comparatively resistant to shattering.

The conglomerates may best be observed in Elizabeth Lake Canyon and in those canyons cutting through the series farther west. They occur in beds up to one hundred feet in thickness, and are composed of rounded pebbles generally from one to six inches in diameter, although great rounded cobbles of a foot or two are not at all infrequent. The pebbles are principally igneous, some being undoubtedly derived from the batholith to the north, while others are of a purplish basic lava of unknown origin. Where the series has been observed in Castaic Canyon a few miles to the northwest of this area, the conglomerates have displaced the sandstones to a large degree, and individual beds attain thicknesses of some hundreds of feet.

In general the dips are steep, this being especially true between San Francisquito and Elizabeth Lake Canyons, where 90-degree dips occur, and 70 and 80 degrees is common. West of Elizabeth Lake Canyon the dips are more gentle, and in the extreme western portion 20 degrees is probably the average. While some tight folds are evidenced by a reversal of dips near the contact with the Sespe to the south, these folds are not traceable for any great distance. As has been mentioned above, the series is in fault contact with the batholith to the north, and the fault is a normal one, on which, however, some movement in a reverse direction may have taken place. To the south the formation is in contact with rocks of three different ages, those between San Francisquito and Elizabeth Lake Canyons being Sespe, while west of the latter canyon the rocks are Mint Canyon and Modelo. The Martinez-Sespe contact, although regarded by Nickell as depositional (5), is here considered as a fault, the attitude of which is practically vertical. The Mint Canyon formation rests upon the Martinez with an unconformable depositional contact, and this may be traced westward into the unconformable depositional contact of Modelo with Martinez.

As noted above, the age of this thick deposit of sediments is doubtful. Nickell, who first described the rocks (5, p.9), designated them as Martinez, but called attention to the fact that they might well be Cretaceous. Hill described them also (9, p. 121) and called them simply Eocene, basing his designation upon work done by Gale, which work, however, has not been available to the writer. Neither determination was based upon fossil evidence, so far as is known, and it is believed that the present writing is the first record of the finding of invertebrates in the series. These invertebrates were found by the writer in one of the branches of Castaic Canyon, and consist of fragments of a Natica, and the section of three whorls of a Turritella. While the latter is specifically indeterminable, it at least shows clearly that it is not T. chicoensis, but is more probably an Eocene form. The fossils found are not important, but they point to the positive presence of invertebrate forms in the sediments, and arouse the hope that an adequate assemblage may eventually be found. Lithologically, the series corresponds to the descriptions of the Tejon as well as the Martinez, and it may be that later work will show that the rocks are of more than one period of deposition. For the present, however, the writer will consider them Martinez.

OLIGOCENE SERIES.

Sespe Formation.

In about the center of the area in a north and south direction, and extending narrowing arms from San Francisquito Canyon to Elizabeth Lake Canyon, is a formation whose age is more doubtful than that of the Martinez just discussed, but which, from its lithology, has been correlated with the Sespe. The formation is of continental origin, and varies in composition from fine shales through muddy sands to a coarse conglomerate, the total thickness being calculated as close to seven thousand feet. The color is typically red, although the fine sands and coarsest conglomerate take on grayish and yellowish hues. Bordering as it does on San Francisquito Canyon, it formed the west abutment of the St. Francis Dam, and underlay the principal part of the reservoir. Like the Pelona Schist Series, it received due attention from the many investigating committees appointed to determine the causes of the failure of the dam, and certainly its weakness when wet was a contributing cause.

Conglomerate makes up the main mass of the formation, occupying all but a band some half-mile wide on the northerly margin, and forming the bold outcrops that can be seen on the ridge separating San Francisquito and Charlie Canyons, and on

A. - Looking a little east of north on west side of San Francisquito Canyon a short distance below former dam. Sharp fold in Sespe with dip into schists.

B. - Looking southwest down San Francisquito Canyon, a half-mile below former dam. Sespe above to right, thrust over Mint Canyon, in center, whose depositional contact with schists below is concealed by detritus left by flood.

the west side of Charlie Canyon. This conglomerate, which attains the almost unbelievable thickness of nearly five thousand feet, is worthy of special attention. Where exposed at the dam-site it is made up of well rounded pebbles, often sheared, and held together in a matrix of oxidized ferruginous clay and angular sand. As brought out in the aforementioned investigations, the matrix proved quite hard when dry, but slumped to a mud when immersed in water.

As the formation is followed southerly, the pebbles become larger and more angular, and the proportion of pebbles to matrix becomes increasingly greater until finally the rock has, to all appearances, become a solid mass of granodiorite or granite in place. Here the matrix is arkosic, and the quartzite,slate and sandstone pebbles conspicuous at the dam, have given away entirely to granodiorite and granite, the weathered surface being exactly what would be expected were the underlying rocks purely igneous. However, close scrutiny will in most places disclose a few slightly water-worn boulders, or a rough bedding that is distinct from the structures to be seen in an igneous rock. There are places in both San Francisquito and Charlie Canyons where neither of these distinguishing features can be seen, and it seems that the rock should be classed as igneous. The writer, however, has come to the conclusion that these represent nothing more than extremely large blocks of the igneous rock which have become included in the conglomerate, and has therefore designated the whole as sedimentary.

The sandstones and shales occupy an area of comparatively low lying country bordering the conglomerates on the north, and have been calculated to have a thickness of about two thousand feet. In general the color is dark red, but as the northern margin is approached there is a sudden change to a yellowish gray, without, however, a change in either lithology or structure. The bedding is distinct, and the individual beds are usually thin, varying from a few inches to three or four feet, and alternating between sandstone and shale. The sandstone is very fine grained as a rule, and is composed of sub-angular to sub-rounded quartz particles, largely intermixed with clay, which in the red beds is highly ferruginous. The cementing material is largely calcareous in both red and yellow beds. The shales are thin and made up of a finely divided calcareous clay. Some lenses of gravelly conglomerate are occasionally found in the sandstones.

The structure of the Sespe formation is not simple. Bounded on all sides by faults, one of which is an overthrust, the beds have been subjected to tremendous stresses resulting in folding and shearing. Extremely sharp folds are found in the sandstones and shales, and the eastern margin of the conglomerate shows brecciation to a high degree. The beds of the main mass of the conglomerate exhibit a rather uniform southerly dip, and it may be that an east-west fault separates them from the tightly folded, finer grained members to the north. Innumerable minor faults cross the series in all directions, and in the sandstones and shales these fractures have been filled with gypsum.

The age and origin of this formation presents a very interesting problem. Since it is in fault contact with all surrounding formations, little information of a specific nature is to be gained from these relationships, and this, coupled to its utter lack of fossil material makes correlation impossible on any other than a lithologic basis. The characteristic red color of the beds and their lithologic similarity to Kew's description of the type Sespe (3, p. 31), as well as to the descriptions of various other occurrences of Sespe referred to by Reed (10) have led the author to assign this formation to it.

That the beds are of continental origin, there can be little doubt, but, as pointed out by Reed (10) in regard to other similar deposits, the well-developed bedding in the finer sediments indicates deposition in strong currents of water, and he suggests that they may be deltaic in origin. However, no cross-bedding, such as might be expected in delta deposits has been observed, and for this reason they are believed to be of playa origin. There can be but one explanation of the massive conglomerate, and this is that it represents detritus accumulating at the foot of an abrupt and rising fault scarp. From the fact that the coarseness increases as the beds are followed southward, it appears that the upraised block lay to the south, and it may be supposed that the existing fault between Sespe and Mint Canyon formations marks the site of the older fault. If this is the case, there must have been a reversal in the direction of movement, for the northerly block is now the upraised one.

Hill (9, p. 128) quotes from the report made by himself, Tolman and Murphy on their investigation of the St. Francis Dam failure, in regard to the nature of the pebbles in the conglomerate near the dam-site. Of fifty pebbles broken, 52% were considered to have been derived from the metamorphic series and consisted of granite, slate, quartzite, vein quartz and rhyolite; 40% were of a dense sandstone cemented with calcite, and 8% were too much altered to permit identification. From this it would appear that at the time of deposition the Pelona Schist area was comparatively high lying land, and if it is considered that the sandstone pebbles were derived from the Eocene to the north, with which they correspond, then it, too, lay high. The heavy conglomerate apparently overlies the fine grained members, but may grade laterally into them; this view is favored by the fact that the tight folding has caused no duplication of the conglomerate. If this is the case, then the series may have had its origin in a basin, of which the southerly boundary was a fault scarp actively rising during part of the period.

From this scarp spread out an apron of extraordinarily coarse material, growing gradually finer with distance, until in the lowest part of the basin, the finer materials were deposited in a playa lake. This would imply an arid climate, which Reed (10) considers was not the case during Sespe time, but which the apparent utter lack of organic life seems to substantiate. The relationship of these beds to other similar beds to the southeast has not been worked out, but probably they were originally continuous.

MIOCENE SERIES.

Mint Canyon Formation.

The Mint Canyon formation is, like the Sespe, also of continental origin, and outcrops in this area in a diagonally trending belt running from the southeast corner, where it is most extensively developed, to a point about two miles northwest of Elizabeth Lake Canyon, where its place is taken by marine Miocene. First noticed by Hershey (2, p - 356) in the Tick Canyon region to the east of this area, and described by him as the Mellenia series, it was later mapped and more fully described by Kew (3, p - 52) who first applied its present name. The beds here described are the northward extension of those mapped by Kew, and correspond closely to his description.

The formation may be divided into three parts, the first to be considered being the basal conglomerate, well exposed in San Francisquito Canyon and in a branch of Elizabeth Lake Canyon. In the first mentioned locality, it is from a few feet to something over a hundred feet thick, and is composed almost entirely of bluish-gray, sub-angular fragments derived from the under-lying schists. Since this was completely masked by soil and vegetation before the scouring caused by the St. Francis flood, it is conceivable that this same basal conglomerate extends eastward along the contact with the schists, although nowhere else exposed. West of Elizabeth Lake Canyon the basal

A. - Limestone lense in Mint Canyon formation not far above basal conglomerate. Note minor faults. Lake in foreground is result of St. Francis flood. View taken in northerly direction short distance above Power House No. 2.

B. - Looking southerly down San Francisquito Canyon from schist-Mint Canyon contact. Mint Canyon sandstones in foreground show characteristic poor bedding.

conglomerate is made up of boulders of Eocene sandstone in a reddish matrix of muddy sand quite similar to the Sespe.

Overlying the basal conglomerate as exposed in San Francisquito Canyon are approximately five hundred feet of alternating beds of red and gray gravelly sands, poorly sorted as to size of pebbles, and the pebbles themselves generally angular. The gray sands are ordinarily the finer and are characterized by a very large amount of mica, evidently derived from the neighboring Pelona Schists, while the red beds contain a much greater proportion of quartz sand, although the nature of the included pebbles also indicates schist derivation. These beds are considered by the writer to be of playa origin, the grayish, somewhat better sorted beds having been deposited in periods of more plentiful rainfall, while the red beds represent arid periods when the material accumulated with insufficient water for sorting and slowly enough for the ferrous iron to oxidize. A lense of hard white limestone occurs at one locality.

The upper portion of the formation, and the one of greatest areal extent, is made up almost entirely of heavy bedded, poorly sorted sandstone, generally of a yellow color, and composed chiefly of angular quartz grains rather lightly bound by a calcareous cement. The bedding is not always clearly defined, and cross bedding is frequent. Lenses of conglomerate with boulders up to a foot or two in diameter occur at irregular intervals in the sandstone, and are highly characteristic of this portion of the formation. The boulders are angular to subrounded and are composed of gneiss, schist, granite, quartzite and a hard yellow sandstone.

While the Mint Canyon formation has been subjected to some gentle northeast-southwest folding, the more prominent structural feature appears to have been faulting. These faults, of both large and small displacement, may be observed on almost any exposure, and seem to be without system in strike and direction of movement. Especially to be noted are those occurring in San Francisquito Canyon in the vicinity of the contact with the Pelona Schist Series, where the red beds, faulted into the yellow rocks make a striking contrast. No attempt has been made to map these faults.

The relations of the Mint Canyon to other formations with which it is in contact are extremely interesting. Kew (3) in the area immediately adjacent to the south, considered the contact with the schists to be a normal fault. In the mapping of this contact north and east, the writer was struck by the low angle of the contact plane as evidenced by the irregularity of its trace, and by the finding of outcrops of schist completely surrounded by Mint Canyon. It was not, however, until the water released by the collapse of the St. Francis Dam had swept clean the contact in San Francisquito Canyon that the relationship became entirely clear. Then it was revealed that a definite basal conglomerate existed between sandstones and schists; that the schists in many places showed weathering below this conglomerate; and that the contact was indeed an unconformable depositional one. That the old surface upon which the Mint Canyon was deposited was not a smooth one is shown by the presence of ancient canyons now filled with conglomerate, and by protrusions of schist through the sediments. These latter were probably small hills drowned in the detritus from the main mass of the schists, much as today similar hills are being drowned in the great fans in the Death Valley region.

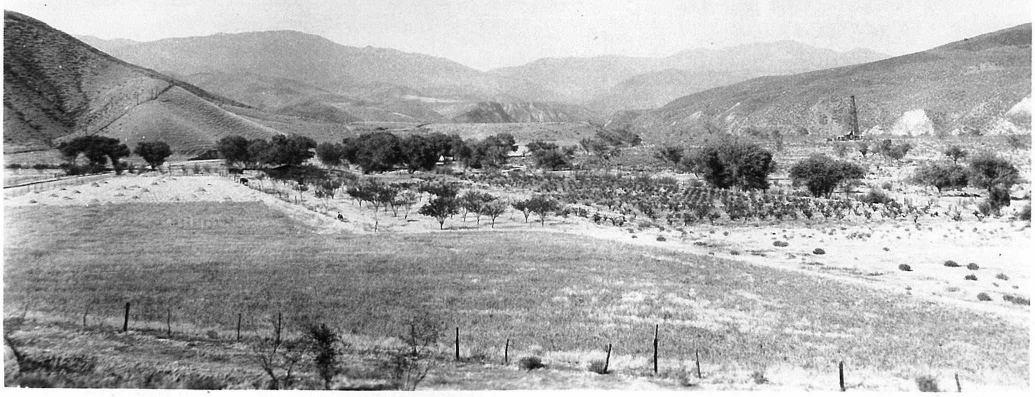
The relationship of Mint Canyon to Sespe in San Francisquito Canyon was also made clear by the scouring action of the flood waters. Here the contact is now clearly revealed as an overthrust fault, the Sespe riding over the younger sediments. The contact can be traced across the ridge between San Francisquito and Charlie Canyons, although whether or not it is still an overthrust cannot be determined because of the dense brush and lack of good exposures. Where first well exposed in Charlie Canyon, however, it has become simply a normal fault, and continues as such until Elizabeth Lake Canyon is reached. The contact from there westerly is with Martinez sandstone, and is once more depositional, the basal conglomerate containing Martinez boulders. About two miles beyond Elizabeth Lake Canyon the basal conglomerate becomes marine, and the Mint Canyon formation is found to have graded laterally into the Modelo.

The upper contact is with marine sandstone and shale of Modelo (Upper Miocene) age, and while Kew (3, p - 52) showed this to be unconformable in the region to the south, the writer finds so little difference in dip and strike of the formations in this area as to lead him to believe them to be conformable here. So extensively fractured are the beds in the eastern part by the faulting before referred to, that true determinations of dip and strike are difficult to obtain. However, since the Mint Canyon grades laterally into marine beds, it would not be surprising to find it also grading upward into marine strata.

A rather large vertebrate fauna has been taken from the Mint Canyon formation, and on the basis of his study of this material, Maxson (6) has determined the age to correspond closely to that of the Barstow of the Great Basin Province, or to the Cierbo of the Pacific Coast Marine Province. Many fragments of bone have come from the red beds exposed in this quadrangle, but so far the only specimens of diagnostic value have been an upper molar 1 or 2 of a *Merychippus* and a fragment of a *Merycodus* horn core. The horse form was determined by Maxson as *Merychippus californicus* Merriam, but as pointed out by Dr. Stock, the post-fossette of the tooth is open posteriorly, a condition not duplicated in any one of some hundred or more specimens of *M. californicus* from the type locality. Therefore, this may prove to be a new species or sub-species. Even should it be found to be within the limits of variation of the species, the fact remains that the form is much more primitive than any other horse forms so far collected from the section, and leads to the belief that a stratigraphic break may exist within the formation, a belief that is somewhat strengthened by the abrupt change in lithology between red beds and yellow sands. It is believed that a thorough and systematic search over the exposures in San Francisquito Canyon may yield more vertebrate material that will throw further light upon this question.

Modelo Formation.

Practically the entire southwestern portion of the area mapped is occupied by a great section of marine sandstones and



A. - Facing due north in Elizabeth Lake Canyon. Modelo in foreground; high ridge to left in background is Martinez, and most distant ridge Jurassic intrusives. W. W. Stabler's Jenkins Well No. 1 may be seen to right.

B. - Horizontal Pleistocene terrace material resting with marked unconformity upon Modelo sandstones and shales. Looking southwest near junction of Castaic and Elizabeth Canyons.

shales which are the northwesterly extension of certain beds mapped by Kew, and called by him Modelo (?), (3, p - 67). These beds are moderately folded in the region east of Elizabeth Lake Canyon, and west of this canyon they occupy a rather gently dipping homocline, along the strike of which, Castaic Creek has cut its channel. Aside from the above mentioned description by Kew, there seem to be no other published reports on the formation.

The lowermost member of the formation is a basal conglomerate, which, however, is present only in the extreme western portion of the area, and as mentioned before, is apparently the marine equivalent of the basal member of the land-laid Mint Canyon. This varies in thickness from a few feet up to about one hundred feet, and is a hard, well-cemented mass made up of boulders of the underlying Eocene, with a great many shells of oysters and pectens of large size distributed through it. The cementing material is largely calcareous.

Overlying the basal conglomerate is a shale member whose thickness has been calculated to be in the neighborhood of a thousand feet. This apparently grades laterally into the Mint Canyon formation to the east, and upward into buff and brown sandstones. Another bed of shale of possibly half the thickness of the first occurs a few hundred feet higher in the section. The lower member is a finely laminated, fairly hard, gray to white siliceous shale, which weathers more readily than the overlying sandstones, and whose presence is marked by a growth of sage or of grass. An examination of several samples of this shale by Mr. K. Lohman of the California Institute of Technology has revealed no diatoms, although a report by Goudkoff on samples taken from the Jenkins Well No. 1, of Mr. W. W. Stabler (quoted by permission of the latter) shows their presence in a core from the depth of 3121 feet, well within the member. At any rate they do not appear to be plentiful, and there are no exposures of the typical diatomaceous shale. The upper shale member is brown in color, contains occasional beds of hard, nodular sandstone, and a great deal of gypsum.

The balance of the formation is made up of interbedded sandstones and shales, the latter being much like the last mentioned shale above. The sandstones vary from thin-bedded hard finely conglomeratic beds to thick strata of fine grained angular sandstone, similar in lithology to the upper member of the Mint Canyon formation. However, the sorting is good and the bedding quite distinct, and the lenses of angular conglomerate so characteristic of the Mint Canyon are absent. The cementing material is usually wholly siliceous, but is sometimes partly calcareous.

While fossil invertebrates occur rather plentifully in the Modelo as far as number of individuals is concerned, the number of species secured is not large, and the material is so poorly preserved as to make identification difficult. _Ostrea titan_ is the most conspicuous species present, and may be gathered in any quantity in certain localities, individuals as large as eight or ten inches in length being found. The second most prominent genus is _Pecten_, of which the species _crassicardo_ is common. This is especially plentiful in the basal conglomerate, where it reaches a breadth of eight inches.

The faunal list from the Modelo of this area at present stands as follows:

<u>Gastropoda.</u>

Conus sp.

"*Fusinus*" cf. *fabulator* Homland

Olivella sp.

Tegula varistriata Homland

"*Trophon*" cf. *ponderosum* Gabb

Turritella sp.

<u>Pelecypoda.</u>

Ostrea titan Conrad

Ostrea titan corrugata Homland

Pecten crassicardo Conrad

Pecten cf. *estrellanus* Conrad

<u>Pisces.</u>

Shark teeth

<u>Vertebrata.</u>

Camel form

An echinoid of the genus *Astrodapsis* has been found in the Modelo of Haskell Canyon, south of this area, but has not as yet been encountered in these beds. Woodring, in his paper on the Modelo of the Santa Monica Mountains (12) refers to the assemblage taken from the Haskell Canyon locality, but simply says that it compares in size with that of the Santa Monica Mountains Modelo, without referring to its probable age. However, in a verbal communication to the author, he states that he believes the beds will be found to be comparable in age with those of the Modelo of the type locality as restricted by Hudson and Craig (11, p - 517), in other words, to the Briones and Cierbo.

Since no fauna has been recorded from the now restricted type Modelo, correlation is rather difficult. Lithologically, the beds here described are similar to at least a part of Kew's type Modelo (3, p - 55) and evidently take in more than the restricted Modelo. If Clark and Trask are correct in their restriction of <u>Ostrea titan</u> to Upper San Pablo, as stated by Hudson and Craig (11, p - 516), then the beds here recorded must represent Upper San Pablo (Santa Margarita) as well as Briones and Cierbo. If the lower beds are the correlatives of the Mint Canyon, then the lower age limit may be Topanga, or possibly even Vaqueros. No definite conclusions can be reached until work of a more detailed nature has been done upon the formation, with the object in view of attempting to find either a stratigraphic or paleontologic break. Therefore, for the present the writer records the formation simply as Modelo.

The fragments of land-vertebrate remains found in the marine beds are interesting, especially since they seem to be scattered rather plentifully throughout the lower portion of the formation. While nothing of diagnostic value has been found, most of the material is undoubtedly camel. This points to the probable deposition of the strata at no great distance from the shore, and lends strength to the theory of the existence of a wide, low-lying, partially drowned valley, in which marine Modelo was being deposited below the strand line, while non-marine Mint Canyon was being deposited above.

<u>TERTIARY AND QUATERNARY SYSTEMS.</u>

<u>Upper Pliocene and Lower Pleistocene.</u>

<u>Saugus Formation.</u>

The Saugus formation, of Upper Pliocene and Lower Pleistocene age (3, p - 31), while occupying a large area in the region to the south mapped by Kew, is represented here by but one projecting finger which is of such slight importance as to receive little more than passing mention in this paper. The area covered by Saugus is a few hundred square yards in extent, lying just east of Castaic Creek below its junction with Elizabeth Lake Canyon. There are no good exposures of the formation where seen in this area, and for this reason its boundaries and attitude are doubtful. However, where exposed just south in Charlie Canyon, the beds show a strike of approximately 20 degrees west of north, and dip 36 degrees southwesterly, thus lying unconformably upon the Modelo.

This exposure shows the formation to be made up of poorly sorted and poorly bedded sandstone with lenses of conglomerate strongly suggestive of the Mint Canyon; doubtless the modes of formation of the two were similar. Their assignment to Saugus age is based entirely upon their continuity with beds determined as such by Kew. In showing these beds upon the attached map (Plate X), the legend shows the Saugus simply as Pleistocene, but it must be remembered that the Saugus also includes Tertiary, as indicated by the symbol "Ts".

Pleistocene Terraces.

In travelling up almost any of the canyons in this region, one is struck by the fact that almost every ridge, where cut by erosion, shows a capping of flat lying terrace material. When examined at close hand it is seen that as a rule this is made up of a heterogeneous jumble of angular to sub-angular boulders and gravel, wholly uncemented, but containing a considerable amount of reddish clay and sand, and varying in thickness from a few feet up to two hundred feet. East of Charlie Canyon the main constituents are schist, gneiss, slate, quartzite and quartz, and are evidently derived from the Pelona Schist Series. West of this line granitic detritus is the principal component. In but three localities was enough of the terrace material present to make mapping practicable.

The first of these localities is on the comparatively flat ridge between Haskell and Dry Canyons. The material here is all derived from the schists to the north, and evidently represents alluvial fan material swept out over the Pleistocene valley of the Santa Clara River. A good section of this is exposed on the Dry Canyon side of the ridge near Tower No. 47 of the Los Angeles power line, and other remnants of fans of comparable age are visible in Haskell Canyon.

In Castaic and Elizabeth Lake Canyons the material forming the terraces differs from the above, and in the former named canyon there are two generations of terraces represented. The older of these is composed of partially sorted gravel of granitic derivation, and was presumably deposited as a river flood plain, since it shows fairly distinct bedding. The beds are horizontal and overlie the Modelo with a marked unconformity which is well shown in Plate VI, B. The deposit is about one hundred feet thick and extends along Castaic Creek for a half-mile from a point just above the junction of Castaic Creek and Elizabeth Lake Canyons. Overlying the older terrace is another hundred feet of younger terrace material, quite distinct from the first both in lithology and

and in its lack of bedding. The detritus making up this upper terrace deposit is derived from sandstone and granitic rock and is also probably of fluviatile origin. The third occurrence of mappable size is to be found in Elizabeth Lake Canyon about a mile above its junction with Castaic Creek, and is apparently identical in lithology and age with that last described. There also occur small remnants of a terrace that may be still older than either of the above mentioned, exposed in the most westerly branches of Castaic Canyon shown on the map. These beds, too, are horizontal and unconformably overlie strata of Modelo age.

Alluvium.

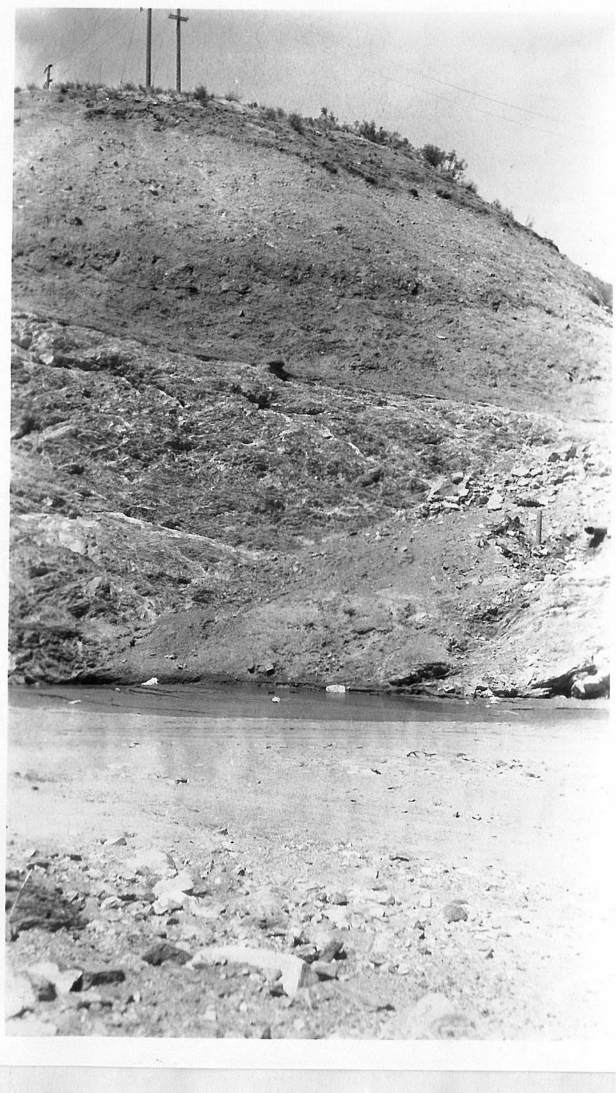
Alluvium is found in all the more important canyons, and as shown by the log of the Stabler well in Castaic Canyon, reaches a thickness of eighty feet or more. It is composed of detritus from all the rocks exposed in the various drainage basins of the streams, and may be roughly bedded. In some places it shows slight dissection.

Tertiary Igneous Rocks.

The Tertiary igneous rocks of the area consist only of the remnants of an acidic lava capping two of the highest points on the ridge between San Francisquito and Charlie Canyons. These lie wholly within the region of Sespe rocks, being cut off to the south by the fault between the latter and the Mint Canyon beds.

This lava is thoroughly brecciated, and solutions percolating along the fractures have altered it to a high degree. Where still unaltered the rock presents a dense, almost

A. - (left) View of San Francisquito Fault at dam-site. Fault trace is to be seen just above shadow of standing portion of dam, where upper group of men is standing. Darker colored Sespe above thrust up on lighter colored schists below. Looking a little south of west.



B. - (right) Looking northerly across San Francisquito Canyon, just below dam-site. San Francisquito Fault cuts through middle of picture. Red Sespe above, Pelona Schists below. Cut just above fault is former road.

cherty appearance. A few scattered quartz phenocrysts have led to the lava's being classified as a rhyolite by the writer.

That the rock is younger than the Sespe is evident from the fact that it was extruded upon a surface cut upon beds of that age. The upper limit of its age is not easily determined, but it may be concluded that it was probably contemporaneous with other extrusions in Southern California which have been definitely placed in Miocene time, and this age is here tentatively assigned to it.

Structure.

Structurally, the area is rather complex. Faulting is the dominant structural feature, as might be expected in a region so little removed from the great master fault of California, the San Andreas, and yet folding is by no means absent. However, it is believed that most of the folds represent structures of minor importance and are definitely related to the same stresses that have caused the faulting.

Probably the most interesting fault, and the one that has caused the most discussion recently, is that which has been designated as the San Francisquito Fault. This fault, following as it does in part down San Francisquito Canyon, passed under the St. Francis Dam and indirectly was partially responsible for the dam's collapse. Nickell (5, p - 19) called it a normal fault. Willis (7) regarded it not as a fault at all, but as an unconformable depositional contact; while Ransome at first simply suggested the possibility of its being an overthrust (4, p - 13), and later said that probably it was an overthrust (3, p - 556). The writer is now in a position to present data tending to show its overthrust nature.

Where the fault first appears in the northeastern part of the area, along the bottom of San Francisquito Canyon, all relations between Sespe on the one hand and the Pelona Schists on the other are concealed. From here to the dam-site the trace of the fault is quite straight, and where exposed at the latter locality, the fault-plane has a strike of about 55 degrees east of north, and dips 42 degrees northwesterly. That the contact is here a fault is evidenced by the gouge, although Willis considered this to be weathered schist under a deposit of land-laid beds. The low angle of the fault-plane suggests that it may be an overthrust, and the dipping of Sespe beds into the schists as seen a short distance southeast of the dam-site is also suggestive.

A little more than a half-mile below the site, where the fault again is visible, it is seen that the contact is no longer between Sespe and schists, but between Sespe and another series of land-laid beds which can be traced directly into characteristic Mint Canyon, the former over-riding the latter. The contact between Mint Canyon and schists at this point is depositional, and considerable weathering is shown by the metamorphics below the contact, while between the Mint Canyon and Sespe a layer of unmistakeable gouge appears. The position of Sespe above younger Mint Canyon beds admits of no other explanation than that of overthrusting.

The overthrust can then be followed in a general southerly direction, not however, along the lowest part of the canyon, and it finally swings off to the southeast about a half-mile

A. - A closer view of contact shown in Plate IV, B. Looking south thirty degrees west along San Francisquito Fault. Sespe to the right is thrust over Mint Canyon to the left. Light colored material at contact is gouge.

B. - Massive conglomerate of Sespe age to the right overthrust upon Mint Canyon to the left. View taken in northwesterly direction, about a mile below Power House No. 2.

below Power House No. 2. The exact nature of the fault after it leaves the environs of the canyon is obscure, as has been pointed out previously, but where clearly seen again in Charlie Canyon it is undoubtedly a normal fault, and so continues until it meets another fault a few hundred feet east of Elizabeth Lake Canyon.

The last mentioned fault, curiously enough, is a branch of the one just described, and forms the northern boundary of the Sespe formation, separating it from the Martinez. This also is a normal fault, and while its strike varies from slightly south of east to almost northeast, its attitude is practically vertical throughout its course. From the fact that it runs directly into Bee Canyon a short distance east of the area mapped it is suggested that it hereafter be designated as the Bee Canyon Fault.

Just north of the wide belt of Martinez rocks, and outside the area here shown is a third large fault, upon which the principal movement, as pointed out earlier, has been normal, or upward on the northern block. The whole presents an interesting problem, and one not easy of solution. The Sespe appears as a roughly triangular area, bounded on all sides by faults, with upward movement on the southeasterly and southwesterly sides and a downward movement on the northerly side. The only explanation offered by the writer at present is that stresses set up by the gradual uplift of the block of crystalline rocks to the north may have been transmitted by the quite competent Martinez beds, causing a squeezing of the Sespe against the schist block to the southeast. This squeezing apparently brought about a rotation of the Sespe block, resulting in a relative downward movement of the northern part, and an upward movement on the other two legs of the triangle, being made manifest in overthrusting on the one side and normal faulting on the other two sides. It is difficult to say what may have been the magnitude of the movement, but if we consider the thickness of the Mint Canyon as 3500 feet, the net uplift must have been at least equal to this amount.

In addition to the main faults just discussed, all the formations are crossed in almost every direction by innumerable small faults, both normal and reverse. It is probable that a careful mapping of these would show uniformity in one or more directions, but time has not permitted doing this.

Most of the folds are to be found in the Modelo formation between San Francisquito and Elizabeth Lake Canyons, as may be seen from the map, (Plate X). Of these the best developed anticline can be traced definitely from a point west of Castaic Creek to Bitter Creek and may extend along the ridge between the latter and Charlie Canyon. This has been named the Castaic Anticline, and it was upon this structure that W. W. Stabler's Jenkins Well No. 1 was drilled to a depth of 3404 feet with only a trace of oil and gas. Two previous wells were also drilled upon the Castaic Anticline to unknown depths and are now flowing water with occasional gas bubbles and a little oil.

Another short anticline which was also unsuccessfully drilled appears a quarter of a mile north of the Castaic Anticline, and synclines have been traced just east of Charlie Canyon and San Francisquito Canyon. The Modelo beds west of Elizabeth Lake Canyon have been tilted in a general southwesterly direction, and constitute the Castaic Homocline, of which the average dip is about twenty degrees. No explanation is offered at present as to its origin or interpretation, since too little of it is exposed in this area for adequate study.

As has been mentioned before, a tightly folded syncline occurs along the northerly margin of the Sespe and can be traced for some little distance, as shown on the map, accompanied for a part of the way by a similarly tightly folded anticline. Some folding also occurs in the Eocene beds. In the majority of cases the folds show a general northeast-southwest trend, approaching that of the principal faults, and suggesting some relationship between them.

Physiography.

Of considerable interest from a physiographic point of view is the appearance of an old land surface cut upon the metamorphic rocks. As one follows Dry Canyon, or any of the northerly trending branches of Haskell Canyon, upstream, there is a sudden very marked break, where the stream bed changes from a steep sided, deeply incised canyon to a low-gradient course with banks sloping gently down to the channel, and one finds himself in rolling country. The hills are rounded and the local relief is low, while considerable areas of almost flat land occur. The whole area has a gentle slope in a westerly direction, and has undoubtedly been tilted by a comparatively late movement.

That this surface is older than the Pleistocene terraces is apparent from the fact that detritus on the latter shows evidence of having been derived from areas possessing a relief

A. - Ancient valley of Elizabeth Lake Creek. View taken in a general northerly direction from old terrace about two hundred feet above present level of creek.

B. - Looking southwest from same point as in A. Shows well developed terrace bordering Castaic Canyon, and apparently formerly continuous with that upon which camera is set up. Pleistocene topography evidently was rather subdued.

comparable with that which exists today, and also from the fact that they do not exhibit the tilting seen in the old surface. Yet, neither does the tilting compare with the dips to be found in the Saugus beds of Lower Pleistocene age, and therefore the surface may be considered as being a relic of about middle Pleistocene time.

The cycle had apparently reached very late maturity or early old age when interrupted by a general uplift with tilting to the west. When the new cycle was initiated active erosion again commenced and fans of coarse material spread out over adjacent lower-lying land. This was followed by still further uplift, this time without tilting, and not only did the erosive agencies attack the old surface still more vigorously, but they began to dissect the more recently formed fans as well. At the present time the stage of the cycle may be considered to be middle to late youth, since many remnants of the former surface still persist, and relief has by no means reached a maximum.

On the northwesterly slopes of the mass of schist, overlooking San Francisquito Canyon, are certain shoulders that first impressed the writer as being cut terraces. This view was also taken by Hickell (5) and by Hill (9), but Willis pointed out that they were probably due to landsliding (7). This would explain the observed discrepancies in the elevations of some of the shoulders, and the lack of similar features in other parts of the metamorphic mass. To strengthen the argument, one may observe a large section near the eastern border of the quadrangle which slid down some months before the dam failed. This dropped vertically about fifteen feet, taking nearly two hundred feet of the road with it, and now exhibits a form comparable to that of the so-called terraces.

It is quite possible that the land surface out upon the schists extended over the whole area, and a marked flatness on the summits of many of the higher ridges seems to bear this out. The comparative softness of the sedimentary beds would explain the small extent of the remnants left upon them. San Francisquito Canyon has been cut in many places altogether within the schist body, when its stream might have been expected to follow the more easily eroded contact plane, and may therefore be considered an antecedent stream, since we have postulated uplift in the discussion above.

The terrace deposits represent a later period when at least a temporary base-level had been reached by the drainage courses and a momentary stability attained. That Elizabeth Lake Canyon was then a wide flat valley can be seen in the view shown in Plate IX, A, which was taken from the terrace some two hundred feet above the present stream. Further uplift brought about renewed down-cutting which is still actively in progress.

Economic Geology.

Little of economic importance has been found in the region. Small amounts of placer gold have been taken from San Francisquito, Haskell and Dry Canyons, and some work is being done at the present in the last named. This probably had its origin in quartz veins in the metamorphic rocks, as before mentioned. A small deposit of clay resembling bentonite has been prospected in Charlis Canyon, but is not being worked. Gypsum occurs in considerable quantities in the Sespe and some exploration work has been done, but the prospect is now abandoned. A little flagstone is being produced in San Francisquito Canyon.

In the opinion of the writer, the Modelo formation is present in the area in sufficient thickness to serve both as a source and a reservoir for oil. However, the structures so far observed appear to be merely superficial folds which probably die out at no great depth, or are open in a northeasterly direction, and therefore have failed to collect oil in any quantity. It is concluded from these facts that oil in commercial amounts will not be found in the area studied.

B I B L I O G R A P H Y

1. Hershey, O. H., "Some Crystalline Rocks of Southern California", The American Geologist, Vol. 29, No. 5, pp. 273 - 290. (1902).
2. Hershey, O. H., "Some Tertiary Formations of Southern California", The American Geologist, Vol. 29, No. 6, pp. 349 - 372. (1902).
3. Kew, W. S. W., "Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California", U. S. G. S. Bulletin No. 753, (1924).
4. Ransome, F. L. and Louderback, G. D. "Report of the Commission Appointed by Governor C. C. Young to Investigate the Causes Leading to the Failure of the St. Francis Dam." (1928).
5. 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).
6. Maxson, J. H., "A Tertiary Mammalian Fauna from the Mint Canyon Formation, Southern California", on file, Library, California Institute of Technology, (1928).
7. 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).
8. Ransome, F. L., "Geology of the St. Francis Dam-site", Economic Geology, Vol. 23, No. 5, pp. 553-563. (1928).
9. 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).
10. Reed, R. D., "Sespe Formation,California", Bulletin of the American Association of Petroleum Geologists, Vol. 13, No. 5, pp. 489 - 507. (1929).
11. Hudson, F. S. and Craig, E. K., "Geologic Age of the Modelo Formation, California," Bulletin of the American Association of Petroleum Geologists, Vol. 13, No. 5, pp. 509-518, (1929).
12. Woodring, W. P., "Age of the Modelo Formation of the Santa Monica Mountains, California", Bulletin of the Geological Society of America, (awaiting publication).