GEOLOGY OF THE NORTHERN PART OF THE SANTA ANA MOUNTAINS

ORANGE COUNTY, CALIFORNIA

By

Lloyd A. Lewis

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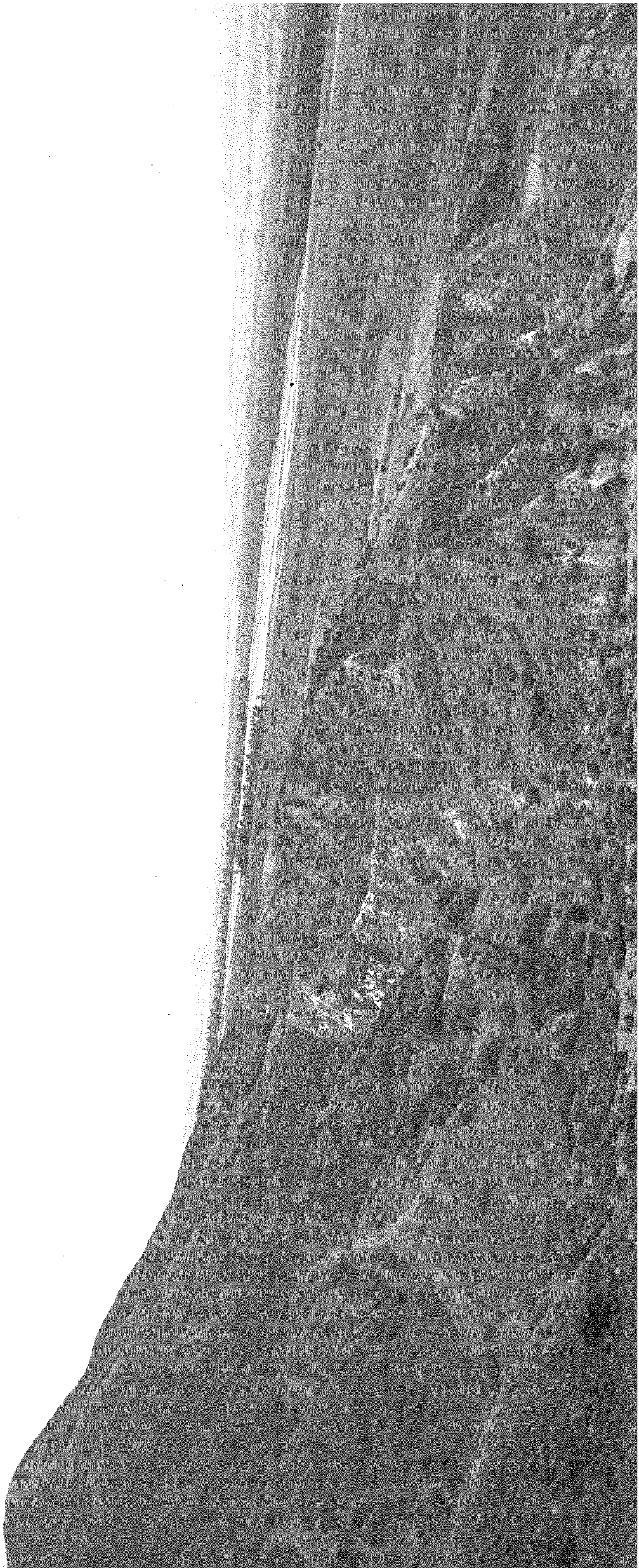
View looking northwest from Bedford Canyon along the trace of the Elsinore fault, northeast scarp, Santa Ana Mountains. Fault in the left center placing andesite against Vaqueros arkose.



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SUMMARY

The area covered includes parts of the northern end of the Santa Ana Mountains and the southeastern corner of the adjoining Puente Hills. The area is somewhat larger than 50 square miles. The work was done during the academic years of 1939-40 and 1940-41 while the author was the holder of the Standard Oil Company of California's fellowship in geology. The purpose of the mapping was to work out the stratigraphic and structural relations of the rocks exposed in this area. Most of the area on the northeast side of the Santa Ana Mountains had never been mapped before and the differentiation of the Cretaceous and lower Tertiary sediments had never been attempted.

The rocks of the northern Santa Ana Mountains range in age from pre-Triassic to Quaternary. The Triassic and pre-Triassic rocks are a complex of slates, sandstones, conglomerates and limestones which have been intruded by Jurassic acid intrusives and by andesitic extrusives of pre-Cretaceous age. The oldest un-metamorphosed rocks are upper Cretaceous in age. They lie with profound unconformity upon the Basement Complex of the Triassic and Jurassic rocks. The Tertiary rocks range in age from Eocene to upper Miocene. They consist of an alternating succession of conglomerates, sandstones, and shales with the sandstones and conglomerates predominating. Most of the Tertiary formations progressively overlap each other towards the southeast. The lithology of the entire section is so similar that it has

been, at times, very difficult to recognize the stratigraphic position of sediments bounded by faults.

Viewing the structure of the northern end of the Santa Ana Mountains as a whole, it seems to be a large asymmetrical anticline with gentle southwestward dips on the southwest side and nearly vertical, and frequently overturned, dips on the northeast side. This structure is complicated by considerable faulting. The faults, in general, trend northwest-southeast and they are generally parallel with the strike of the sediments. The area is also the scene of the junction of the Chino and Whittier faults which are two of the major faults of Southern California. Much of the area mapped lies between these two faults and this area is a mosaic of slice-blocks in which the dips of strata are always nearly vertical. As far as can be determined, the attitude of the faults is nearly vertical; come of them are reverse faults. Movement on many of the faults has been strike-slip as well as dip-slip.

INTRODUCTION

Area Covered:

The area described in this report includes parts of the northern end of the Santa Ana Mountains and the southeasternmost tip of the Puente Hills, the northwest corner of which is approximately 30 miles from the center of the city of Los Angeles in Southern California. It occupies an area of approximately 50 square miles. The area is shown on the topographic map, "Corona Quadrangle," of the United States Geological Survey. The general location is shown on the index map, Plate I. On Plate II, the Corona Quadrangle, the boundaries of the two areal geologic maps, and Maps 1 and 2, are outlined.

The region covered by Map 1 occupies a roughly rectangular block on the southwestern slope of the Santa Ana Mountains about 3 miles wide and extending west of south from Santa Ana Canyon approximately 6 miles to Santiago Canyon. Map 2 covers a two mile wide strip which parallels the northeast front of the range from Bedford Canyon northwestward 10 miles to the southeastern tip of the Puente Hills.

Purpose and Scope of the Report:

A study of this district was made possible by funds supplied by the Standard Oil Company of California Fellowship at the California Institute of Technology in Pasadena. This fellowship was held by the writer during the academic years of 1939-40 and 1940-41. This particular area was chosen because it was believed that data acquired in its study might throw considerable light on the structural and stratigraphic


OUTLINE MAP OF CALIFORNIA
SCALE
PLATE I
OREGON
NEVADA
MEXICO
PACIFIC OCEAN
DEL NORTE
CRESCENT CITY
SISKIYOU
YREKA
MODOC
ALTURAS
HUMBOLDT
EUREKA
TRINITY
WEAVERVILLE
SHASTA
REDDING
LASSEN
SUSANVILLE
TEHAMA
RED BLUFF
PLUMAS
QUINCY
GLENN
WILLOWS
BUTTE
OROVILLE
SIERRA
DOWNIEVILLE
MENDOCINO
UKIAH
LAKE
LAKEPORT
COLUSA
YUBA
MARYSVILLE
SUTTER
NEVADA
NEVADA CY
PLACER
AUBURN
EL DORADO
PLACERVILLE
YOLO
WOODLAND
SACRAMENTO
SONOMA
SANTA ROSA
NAPA
SOLANO
FAIRFIELD
AMADOR
JACKSON
ALPINE
MARKLEEVILLE
CALAVERAS
SAN ANDREAS
MONO
BRIDGEPORT
MARIN
SAN RAFAEL
CONTRA COSTA
MARTINEZ
SAN JOAQUIN
STOCKTON
TUOLUMNE
SONORA
SAN FRANCISCO
OAKLAND
ALAMEDA
MODESTO
STANISLAUS
MARIPOSA
REDWOOD CY
SAN MATEO
SAN JOSE
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
HOLLISTER
SAN BENITO
SALINAS
MONTEREY
FRESNO
INYO
INDEPENDENCE
VISALIA
TULARE
PORTERVILLE
HANFORD
KINGS
SAN LUIS OBISPO
KERN
BAKERSFIELD
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
SANTA ANA
RIVERSIDE
SAN DIEGO
IMPERIAL
EL CENTRO

problems existing in the area and because a determination of the type of deformation effecting the area would be of considerable interest to all those studying the structural history of the Southern California region.

Methods of Field Work:

The writer spent approximately seven months in the field. Since reconnaissance examination in the area on the northeast flank of the Santa Ana Mountains showed a great structural complexity with considerable faulting parallel to the strike of beds, it was apparent that the best method of attack would be to study the stratigraphy on the west flank of the range where relatively undisturbed sections of the formations are exposed. Since the Cretaceous rocks on the west flank of the range had already been carefully studied by Dr. W. P. Popenoe the writer concentrated his attention on the Tertiary formations, concerning which only the general features of the stratigraphy were available. In particular, the Martinez, Domengine and Vaqueros were studied. The first three months of the field work were spent in mapping the area shown on Map 1. The remaining four months were spent mapping the eastern area shown on Map 2.

As a base for the field mapping, aerial photographic maps prepared by the Fairchild Aerial Surveys, Inc., were used. The scale of the contact prints used in the western area is 1550 feet to the inch; the scale of those in the eastern area is 1000 feet to the inch. Photographic mosaics were used for the finished maps. Their scale is 2000 feet to the inch. The contour map, "Corona Quadrangle", prepared by the United States Geological Survey is not suitable for detailed geologic mapping because of its large contour interval and small scale. It has many topographic errors and its only use proved to be in the preparation of the profiles for the structure sections included with this report.

Acknowledgments:

The writer is indebted to Drs. Francis D. Bode and Willis P. Popenoe of the Division of Geological Sciences of the California Institute of Technology for their constructive advice, personal interest and time given both in the field and during the preparation of this report. The work was done under Dr. Bode's supervision. Dr. Popenoe gave valuable assistance in the determination of the fossils as well as a good deal of help in working out the stratigraphy and structure of the Cretaceous rocks on the western slope of the Santa Ana Mountains. Gratitude is extended to Mr. G. C. Gester and Dr. W. S. W. Kew of the Standard Oil Company of California, and to Professor J. P. Buwalda and the faculty of the Division of Geological Sciences at the California Institute of Technology for the suggestion of the problem. Dr. Kew and Professor Buwalda have offered helpful criticisms, and discussions with them of various problems encountered during the course of the work proved of great help. The friendly cooperation of several members of the Geologic Staff of the Standard Oil Company of California has been a constant encouragement; particularly, determinations made of foraminifera by Mr. W. H. Holman have been indispensable. Suggestions and information supplied by Mr. R. G. Reese have been very helpful.

Geography:

The Santa Ana Mountains form the northwestern end of the Peninsular Range. They lie in southwestern Riverside and northeastern Orange Counties in Southern California. The Santa Ana River Canyon forms the northern boundary of these mountains. The northeastern side of the Santa Ana Mountains forms an impressive scarp which rises steeply from the Elsinore Valley and its northern extension, Temescal Wash. The southwestern slopes of the range are gentle and slope to the Santa Ana coastal plain. The boundary with the Peninsular Range to the southeast is indefinite, corresponding roughly to the San Diego-Orange County line in the vicinity of the Temecula River 40 miles south of the Santa Ana River.

Topography and Drainage:

The Santa Ana Mountains in this area are higher and more rugged than the Puente Hills. Much of this higher country is reached with difficulty because of its rugged nature and heavy brush. From Sierra Peak southeast the elevation of the crest of the range rises from 3045 feet to Santiago Peak, 5680 feet above sea level. To the southwest of the crest, there is a gradual decrease in height and ruggedness and the lower hills have a topographic form somewhat similar to that of the Puente Hills.

The Santa Ana River flows throughout the year. Its source is in the San Bernardino Mountains; after crossing the San Bernardino Valley, it flows through Santa Ana River Canyon before entering the Santa Ana coastal plain.

Santiago Canyon receives the drainage from almost all of the northern part of the Santa Ana Mountains. In general, tributaries to Santiago Creek flow southwest directly down the slope of the range through deep V-canyons and join Santiago Creek near the contact between the Cretaceous and Tertiary sediments. Santiago Creek has been dammed above the mouth of Sierra Canyon and a large supply of water remains in this reservoir throughout the year.

The canyons on the northeastern side of the Santa Ana Mountains are short and deep, and they drain small areas. Water flows in these canyons only immediately after rains.

The portion of the Puente Hills studied has a relief of less than 500 feet, is well dissected, and is almost devoid of heavy brush. The canyons although narrow are usually flat-floored with steep slopes near the bottoms, and generally rounded ridges.

Vegetation:

Most of the area described in this report is covered by a substantial growth of brush particularly the areas underlain by the Basement Complex and the coarser sediments of the Cretaceous and Martinez formations. Surfaces underlain by the shales, silts and fine sandstones of the Cretaceous and Martinez are commonly covered with grass and white sage. The bottoms of many of the canyons are wooded with oak and contain occasional sycamore and bay trees.

Culture:

Most of the area mapped by the writer is too rugged and dry for cultivation. Some of the less brushy parts are fenced for grazing, particularly portions of the area on the western slope of the Santa Ana Mountains and in the Puente Hills. The alluvial fans below the northeastern front of the mountains in the vicinity of the town of Corona are the site of rich citrus orchards. Roads have been built in several of the larger canyons. The fire control roads and fire breaks built by the United States Forest Service have made the region accessible and have also provided some fresh outcrops. The highway between Corona and the Santa Ana River Canyon furnishes excellent exposures of the Martinez and Puente formations.

STRATIGRAPHY

General:

The rocks in the Northern Santa Ana Mountains range in age from pre-Triassic to Quaternary. Most of the formations thin southeastward. The Cretaceous rocks are the oldest un-metamorphosed rocks found in the region and they lie with profound unconformity upon the intruded and metamorphosed rocks of Triassic and, probably, pre-Triassic age. The basal Tertiary rocks lie with slight unconformity upon the Cretaceous and overlap these older rocks to lie on the Basement Complex at several places. Several overlaps between the various Tertiary formations are also present, but no great unconformities were found within the Tertiary section. The lighology of the entire section is so similar throughout that it has been a very difficult task at times, to recognize the stratigraphic position of sediments; particularly, those found in isolated fault blocks.

The stratigraphic sequence in the northern Santa Ana Mountains is summarized in the following table:

Age	Formation	Lithology
Quaternary		Terrace and stream gravels
Upper Miocene	Puente	Predominantly sandstone, coarse and fine grained, with some siltstone members and minor amounts of shale; 2700 feet thick in the Santa Ana Mountains, probably thicker in the Puente Hills.
Middle Miocene	Temblor	Massive buff-colored sandstone grading downward into fine shaley sands, approximate thickness - 225 feet.
Lower Miocene and Oligocene	Vaqueros-Sespe	Varicolored soft sandstones and clays interbedded with massive poorly sorted cross-bedded buff sands, stones and conglomerates - 1000-3000 feet.
Eocene	Domengine	Buff-colored sandstone and conglomerate, at least 1,000 feet thick.
Eocene	Martinez	Fine tan-colored siltstones and sandstones, 900-1500 feet thick, underlain by a non-marine member of arkosic sandstones 440-750 feet thick.
Upper Cretaceous	Williams and Ladd	Alternating conglomerate, sandstone, and shale members with a total thickness of about 4000 feet.
Jurassic to pre-Triassic	Basement Complex	A complex of Triassic, and older, slates sandstones, conglomerates and limestones together with Jurassic acid intrusives and andesitic extrusives.

Basement Complex:

A complex of metamorphosed slates, sandstones, conglomerates and limestones together with intrusives, mostly of andesitic composition, comprise the oldest rocks and the core of the northern end of the Santa Ana Mountains. Fossils of middle Triassic age have been found in part of this complex. These rocks occupy a belt which extends southeastward from Santa Ana River Canyon, broadening in that direction. The problem undertaken by the writer was not concerned with the details of this complex and its rocks are shown on the maps in one color.

UPPER CRETACEOUS:

Resting with profound unconformity upon the Basement Complex is a thick section of Upper Cretaceous rocks, the stratigraphy and paleontology of which has been extensively studied by Dr. Willis P. Popenoe of the Division of Geological Sciences of the California Institute of Technology. Most of the information concerning these rocks has been obtained from Dr. Popenoe's Ph.D. thesis and by conversations with him. Two areas of Upper Cretaceous rocks were mapped in detail by the writer: 1) the Cretaceous on the northeastern side of the Santa Ana Mountains and 2) the Cretaceous of the western flank of the Santa Ana Mountains north of the Sierra-Clay Canyon divide.

Dr. Popenoe divided the Cretaceous strata of the Santa Ana Mountains into three formations, distinguishable on a lithologic basis. In descending stratigraphic order the classification adopted by him is as follows:

Formation	Member
Williams	Pleasants Sandy shale member
	Schulz conglomerate member
Ladd	Holz shale member
	Baker conglomerate and sandstone member
Trabuco	

Trabuco Conglomerate:

In 1916, Packard described the basal part of the Cretaceous in the Santa Ana Mountains as the Trabuco formation. In Packard's area, the basal part of the Cretaceous consists of 250 to 300 feet of soft massive red boulder-conglomerates which outcrop along the west side of the Santa Ana Mountains from Black Star Canyon south to Trabuco Canyon. He thought the Trabuco to be non-marine in origin. In 1936, Popenoe described the Trabuco in greater detail. The Trabuco was not distinguished from the Baker conglomerate at the base of the Ladd formation by the present writer. On the northeast side of the Santa Ana Mountains the Baker member contains boulder beds, conglomerates, and sandstones at its base which may be the correlative of the Trabuco. These rocks lack the characteristic red color of the Trabuco on the west side of the Santa Ana Mountains, however, and they are not separated from the Baker on the map.

The Ladd Formation:

Popenoe assigned the name Ladd to the Cretaceous beds of the Santa Ana Mountains included between the top of the Trabuco conglomerate and the base of the Williams formation. The contact between the

Ladd and Trabuco formations is apparently conformable and possibly gradational. The upper contact of the Ladd formation is marked by an abrupt lithologic break and is probably a disconformity if not actually an angular unconformity. Popenoe divided the Ladd into two members on paleontologic and lithologic grounds - the Baker, which is the lower member, and the Holz Shale.

Baker Conglomerate and Sandstone Member:

Characteristically, the Baker consists of a coarse, hard and massive, grey colored conglomerate at the base which grades upward into a thick-bedded, coarse grained arkosic sandstone. The sandstone is sometimes calcareous. According to Popenoe, the contact between the Baker and the underlying Trabuco is usually sharp; although in some places it seems gradational. In Popenoe's area the Baker conglomerate is distinguished from the Trabuco by its greater consolidation and less weathered appearance. Also, the boulders in the Baker conglomerate seem to be better rounded.

Some of the rocks in the lower part of the Baker conglomerate may actually belong to the Trabuco, however the writer made no attempt to differentiate the two on his map.

In the Clay Canyon region the beds of coarse clastic material are faulted along their west boundary against Holz shale. In general, this coarse material consists of ill-sorted coarse conglomerates with occasional lenses of arkosic sandstone and boulder beds with large boulders, many three feet in diameter, a few four to five feet. These boulders are all fairly well rounded and usually are composed of diorite or granodiorite. A striking scour channel filled with large boulders can be seen in the wall of Clay Canyon a mile south of the intersection of the canyon with the Santa Ana River Canyon highway.

The Baker in the Clay Canyon region is usually buff to gray and occasionally reddish brown in color. On the south wall of Santa Ana River Canyon, just east of the mouth of Clay Canyon the Baker conglomerates are highly shattered and are oxidized to a reddish color. Moore has suggested that this coarse clastic material in the Clay Canyon region belongs stratigraphically above the Holz shale, but this is not the case. These conglomerates, sandstones and boulder beds are stratigraphically below the Holz shale and belong to the Baker. The only fossils found in these beds are marine, and, hence, should be correlated with the Baker rather than with the Trabuco conglomerate.

Conglomerates, boulder beds, and sandstones which may belong to the Trabuco formation also occur on the northeast flank of the Santa Ana Mountains. These rocks lack the characteristic red color of the Trabuco formation and are included in the Baker sandstone and conglomerate by the writer. Due to the intense faulting in the sedimentary rocks of this area, these rocks are found in irregular belts extending from Hagador Canyon northeastward to the vicinity of the Lewis orchard near the head of Fresno Wash, a distance of over 3 miles. These rocks consist of about 500 feet of massive, buff to yellow conglomerate and boulder beds which characteristically have a soft sandy matrix and poor bedding and sorting. At some places these rocks have brick red oxidized zones; at other places a few red and green sand lenses. Occasionally present are boulders several feet in diameter; one of these boulders measured 9 feet in diameter.

Beds with boulders 3 feet in diameter are rather common. The very large boulders are usually composed of light-colored diorite and granodiorite. The rock types that make up the boulders agree with the description of the Trabuco boulders. All of the boulders except the very large ones are well rounded. Although much of the material is highly decayed, this condition does not seem to be as prevalent as in the Trabuco formation on the western slope of the mountains. Polished and limonite-coated boulders are common.

The writer could find no justification for separating these beds from the Baker conglomerate. The field relations are not well exposed but it is the opinion of the writer that these beds grade both laterally and vertically into the occasionally fossiliferous sandstones and conglomerates of the Baker member. Here they appear to be a coarser phase of the lower part of the Baker.

For almost a mile northwestward from Tin Mine Canyon about 500 feet of these soft conglomerates and boulder beds rest depositionally on andesites of the Basement Complex. From the vicinity of Mabey Canyon northwestward to Fresno Wash these conglomerates, sandstones and boulder beds occur as an irregular belt adjacent to the andesite of the Basement Complex.

The Baker sandstones are limey, and lensing; richly fossiliferous reefs are abundant. Rudistid reefs are especially prominent. The following fossils were found in these beds:

Gastropods
    Acteonella oviformis Gabb

Pelecypods

Lima (Acesta) beta n. sp., Popenoe
Cucullea sp. cf. C. gravida (Gabb)
Liopistha hardingensis (Packard)
Flaventia zeta n. sp., Popenoe
Crassatella gamma n. sp., Popenoe
Trigonarca californica n. sp., Packard
Trigonocalista regina (?)
Rudistids

The above species were identified by Dr. W. P. Popenoe. They belong to the Baker conglomerate and sandstone member, or Popenoe's "acteonella oviformis zone."

Unfossiliferous conglomerates and sandstones, which are believed to belong to the same part of the Cretaceous section as the fossiliferous conglomerates and sandstones mentioned above, occupy the center of the anticline between Kroonen and Mabey Canyons. In this fold these conglomerates and sandstones closely resemble the fossiliferous Baker beds lithologically but no fossil reefs are present. Correlation of these beds with the Baker member is on a purely lithologic basis.

Southeast of Fresno Wash and immediately north of the Whittier fault zone is a series of conglomerates and sandstones conformably under the Holz shale. On the basis of their stratigraphic positions, these rocks are tentatively correlated with the Baker. However, they are covered by brush and outcrops are poor. The boulder filled soil gives almost the only indication of the rocks underneath.

Holz Shale Member:

The thick series of sandy shales overlying the Baker conglomerate in the Ladd Canyon area (see Corona quadrangle) were named the Holz Shale member by Popenoe in his description of the Ladd formation.

The Holz shale is one of the most persistent members of the Cretaceous in the entire northern Santa Ana Mountain region. The predominate rock of this member is a soft, brownish-gray, micaceous shale. The Holz shale frequently contains heavy conglomerate lenses which appear abruptly in the shale section. Thin concretionary limestones are common, and thin beds of gritty sandstone are not unusual.

The contact between the Holz shale and the underlying Baker is generally gradational. However, field relations in the writer's area show that the Holz shale transgressively overlaps the Baker to the northeast.

According to Popenoe, on the east side of Blackstar Canyon, the entire coarser clastic basal series of the Cretaceous including the Trabuco conglomerate, the Baker member and a huge conglomerate lens at the bottom of the overlying Holz shale completely lenses out. Only a few hundred yards north of Tick Canyon, the Holz shale rests directly on the Basement Complex. The writer found that just southeast of the Clay Canyon-Sierra Canyon divide the Holz shale is in contact with the Basement Complex. About at the divide, a series of boulder beds and coarse conglomerates with sandstone lenses lies with depositional contact on andesite. This relationship continues northward along the east wall of Clay Canyon to Santa Ana River Canyon where the strata are truncated by the Whittier Fault.

Holz Shale in Clay Canyon:

Just southeast of the Clay Canyon-Sierra Canyon divide the Holz shale overlaps the entire coarser clastic basal series of the Cretaceous and rests directly on andesites in the Basement Complex. Popenoe has found that this condition extends to the south to within a few hundred yards of Tick Canyon. From the Sierra Canyon-Clay Canyon divide northward the Holz shale is present in a long narrow strip faulted between the Baker conglomerate and sandstone member on the east and the Martinez on the west. In the upper reaches of Clay Canyon these relations are well shown. Here all but 100 to 200 feet of the shale is cut out by faulting. Further north, in the main part of Clay Canyon the relations are not as well exposed. However, a few shale outcrops at the base of the east wall of the canyon suggest that almost the whole of the Baker member present in the vicinity is exposed on the east wall of Clay Canyon. The fault which probably extends down the canyon cuts out the lower part of the Holz shale. On the west wall of the lower mile of the canyon the Holz shale consists of unfossiliferous alternating shale, sandstone and some conglomerate which is overlain by the Martinez formation. The following section was measured here:

Martinez Formation

Fine green sandstone and shale, occasionally minutely cross bedded	- 30 feet
Arkose, buff, chloritic, medium-grained to conglomeratic	- 30 feet
Conglomerate, matrix arkosic and containing some chlorite	- 10 feet

Cretaceous (Holz Shale)

Dark gray thinly bedded shale, silt and sandstone	- 15 feet
Brown arkosic sandstone	- 10 feet
Dark gray thinly bedded shale, silt and sandstone	- 15 feet
Brown coarse to medium-grained micaceous sandstone, shale fragments	- 20 feet
Buff conglomerate and sandstone to canyon floor	- 25 feet

A thick series of interbedded shales, conglomerates and sandstones belonging to the Holz shale member are present on the northeastern side of the Santa Ana Mountains. The largest area of this series is a long narrow irregular strip averaging about 1500 feet in width extending from Santa Ana River Canyon three and one-half miles south of east almost to Mabey Canyon. This strip is in general bounded on the north by the Martinez which lies conformably over the Holz shale. To the south of the Holz shale, and immediately under it, are the coarser clastics of the Baker conglomerate and sandstone. The Holz shale member is brought to exposure in other smaller areas by the Whittier fault as far south as Tin Mine Canyon. South of Tin Mine Canyon the shale does not outcrop. A long sliver of Holz shale marks the trace of the Whittier fault from Mabey Canyon to Tin Mine Canyon.

The Holz shales on both the northeastern and southwestern sides of the Santa Ana Mountains resemble each other lithologically. However, the section seems to be thicker on the northeastern than on the southwestern side of the Santa Ana Mountains. Both Moore and Popenoe mention a thickness of 1500 feet for the beds in the latter region. A maximum thickness of at least 1800 feet is attained by the Holz shale on the northeastern side of the Santa Ana Mountains. Possibly, in this district, it contains a larger proportion of coarser material than it does to the southwest. At any rate on the northeastern side of the Santa Ana Mountains striking variations in the lithology are characteristic. The beds are exceedingly lenticular and discontinuous.

The three sections of the Holz shale which follow serve to describe the member as it occurs on the northeastern side of the Santa Ana Mountains. The sections were scaled from the field maps.

Section a mile due west of the north end of the Lewis orchard in Fresno Wash (see Plate IV).

Paleocene Martinez chloritic arkose

Cretaceous Holz shale

Dark gray to black thin-bedded, fissile carbonaceous shale, occasionally containing a few poorly preserved but identifiable foraminifera and tiny prismatic fragments of Inoceramus shell	- 430 feet
Massive resistant coarse yellow sandstones with a few stringers of buff conglomerate and occasional lenses of medium-grained yellow sandstone with dark shale fragments	- 220 feet
Black thin-bedded fissile shale, with some thin limey concretionary lenses	- 300 feet
Yellow sandstone and conglomerate, poorly sorted and bedded and containing beds of hard gray lime-cemented sandstone and conglomerate up to about 15 feet thick; often carries subordinate thin beds of light gray thin-bedded lignitic shale or dary gray to black carbonaceous shale and sandy shale	- 900 feet
The base of the section is faulted against the basement by the Whittier fault.	
Total thickness	- 1850 feet

Section $\frac{1}{2}$ mile due east of the north end of the Lewis orchard in Fresno Wash (see Plate IV).

Paleocene Martinez chloritic arkoses

Cretaceous Holz shale

Dark, fissile, thin-bedded shale with a few lenses of yellow sandstone with shale fragments	- 160 feet
Yellow alternating sandstone and conglomerate; in general, poorly sorted and bedding shown only by the sandstone stringers; shale fragments are often present in the sandstones	- 220 feet
Dark gray to black thin-bedded alternating fine sandstone, silt and shale with a few thin beds of coarser sandstone and conglomerate	- 340 feet
Buff to yellow alternating conglomerates and sandstones with beds generally poorly marked, occasional hard limy gray beds	- 830 feet
Dark shale	- 110 feet
Conglomerate and sandstone, upper part buff, lower part mostly hard gray and well cemented with lime (not well exposed)	- 300 feet

The base of this section is faulted against the basement by the Whittier fault.

Total thickness - 1960 feet

Lower 300 feet may belong to the Baker conglomerate and sandstone.

Section about 1000 yards due east of the north end of the Lewis orchard in Fresno Wash (see Plate IV).

Paleocene Martinez basal conglomerates and chloritic arkosic sandstones

Cretaceous Holz shale

Tan weathering shale and fine sandstone	- 150 feet
Conglomerate and sandstone	- 60 feet
Tan weathering dark shale	- 40 feet

Conglomerate	- 100 feet
Light to dark gray and tan shales and sandy shales with occasional gray calcareous lenticular sandstone beds	- 550 feet
Poorly bedded yellow sandstone and conglomerate	- 520 feet
Dark gray concretionary shale interbedded with about an equal amount of hard gray lime-cemented conglomerate. The beds of shale and conglomerate are very lenticular and vary greatly in thickness. Base taken arbitrarily where shale no longer appears intercalated with the conglomerate. Conglomerate and sandstones below are included with the Baker	- 400 feet
Total thickness	- 1820 feet

Baker conglomerate and sandstone

The Holz shale is rarely fossiliferous on the northeastern side of the Santa Ana Mountains. Fossils found in the member include:

Pelecypods

Tenea inflata (Gabb)
Acila sp.
Inoceramus sp.
Trigonia sp.

Gastropods

A few poorly preserved small forms

Cephalopods

Baculites sp.
Scaphites sp.
A few poorly preserved foramenifera

Williams:

The highest formation in the Cretaceous section of the Santa Ana Mountains has been named the Williams formation by Popenoe after exposures in Williams Canyon on the west side of the Santa Ana Mountains. Popenoe divided this formation into two members: a lower, "Schulz Sandstone and Conglomerate," member, and an upper, "Pleasants Sandy Shale," member.

The Williams is overlapped to the northeast by the Martinez which, north of the Clay Canyon-Sierra Canyon divide lies directly on the Ladd. (See structure section F-G-H.) The writer was not able to determine whether the Williams was ever deposited in this region.

Schulz Sandstone and Conglomerate:

This member consists of a series of conglomerates and coarse sandstones. The constituent boulders in the conglomerates are usually of rather small size, the boulders rarely exceeding a diameter of one foot. The boulders are nearly all well-rounded and are generally quite fresh in appearance. The smaller size and the light color serve as one of the main distinctions between this and the Baker conglomerates. The member outcrops characteristically in rugged thickly brush-covered bluffs which contrast sharply with the smooth grass-covered slopes formed by the underlying Holz shale.

Pleasants Sandy Shale:

This member predominately consists of fine-grained and thin-beddedferruginous micaceous shaly sandstone intercalated with numerous thick layers of a calcareous sandstone which sometimes contains sufficient lime to be called a sandy limestone. The limy beds occasionally carry a good fossil fauna.

The Pleasants has not been everywhere distinguished on the map from the Schulz which underlies it. It is also frequently cut out of the section by faulting or by overlap of the Martinez. The Pleasants has a thickness of approximately 400 feet in the vicinity of Sierra Canyon.

Martinez:

The Martinez of the Santa Ana Mountains is composed of two types of sediments: fresh water and marine. The lower part of the formation, in most localities, is fresh water in origin; although, in places, brackish water beds are intercalated with the non-marine sediments. The upper member of the Martinez is generally a siltstone of marine origin. The base of the siltstone is nearly always marked by a persistent oyster reef; the lower member is everywhere characterized by an abundance of chlorite.

The arkosic sandstones and conglomerates of the lower member of the Martinez have a characteristic lithology which makes them the best marker beds in the entire stratigraphic section in the northern Santa Ana Mountains. The material which forms these sediments has unmistakably been derived from the underlying Cretaceous. It consists of well-rounded reworked pebbles and cobbles identical to those in the Cretaceous mixed with scarcer fragments of Cretaceous sandstone, conglomerate and shale. The shale cobbles are particularly distinctive. The cobbles range in size from one-half inch to 6 inches in diameter and probably average about three inches in size. Limonite crusted and polished pebbles are not at all rare. There seems to be universally present pebbles and cobbles of a pure white milky quartz which the writer has never observed in the Cretaceous conglomerates. These, especially, often seem to be highly polished. The matrix is, in general, arkosic and of angular grain. Often there are present large flakes of chlorite and muscovite. On weathered outcrops the conglomerate imparts an appearance totally different from the underlying Cretaceous conglomerates. It weathers to a ligh color, at times a dazzling white. The surface of the coarse grains and cobbles often have a sort of waxy luster, which is due to the decomposed mica and feldspars of the matrix. Basal Martinez conglomerates of the northeastern side of the Santa Ana Mountains have a similar character.

The arkosic sandstone member varies considerably from place to place, but it is easily recognized by its clay beds, lignitic shales, and by the presence of chlorite. The sandstones are almost always angular in grain and poorly sorted. The zone in which chlorite is abundant is in the lower part of the member, but it is found in all parts of the formation and is distinctive since it is not found in quantity in any other formation of the region. In some places the chlorite is so abundant that the beds take on the aspect of a rotted schist; in others, the sandstones contain minute cross-bedded laminae composed of this mineral. Often the flakes of chlorite are as large as a quarter of an inch in diameter and some of them still preserve their hexagonal outline.

Muscovite and biotite are also found with the chlorite but not in the quantity of the chlorite. Where the sandstones are weathered they often become brown and red in color due to the iron staining derived from the decomposition of the mica minerals. Frequently, thin beds of lignitic shales, and sandy shales are found intercalated in the arkosic member, especially in the lower half. They consist of fine, thinly laminated clayey beds which contain a considerable amount of organic material, usually in the form of tiny fragments of carbonized wood. They vary considerably in color, but are usually dark gray when fresh. Upon weathering the beds attain lighter colors, especially light gray to a light lavender tint. English mentions the presence of glauconite in this part of the Martinez but the writer at no place observed this mineral to be present.

The upper member of the Martinez in this region consists predominately of soft tan-weathering silt and thin-bedded fine sandstones which attain a maximum thickness of over 1000 feet. These sediments are in general well-sorted and undoubtedly marine in origin. There are present in this member occasional thin lenticular limy gray concretions which differ from those found in the Holz shale in that they are not as dark gray on fresh surfaces nor are they as dense. Instead of breaking with a concoidal fracture, as in the case of the Cretaceous concretions, the Martinez concretions possess a thin-bedded structure and they fracture along these planes. This part of the section is apparently not present in the east-west belt north of the reservoir formed by the Santiago Dam, however it makes up a considerable portion of the Martinez section in the other areas of outcrop north of Santiago Canyon. At the base of the upper member an oyster reef bearing Turritella pachecoensis Stanton is usually present. This reef is particularly well developed on the divide between Gypsum and Clay Canyons in the vicinity of the Claymont Mine. Here it is in places at least 25 feet thick and is composed of a hard cemented mass of shell fragments. Often it is merely a thin hard calcareous sandstone, but it is possible to trace the horizon throughout most of the region and it is an excellent marker bed.

North of the Sierra Canyon-Clay Canyon divide the upper tan siltstone and fine sandstones are faulted off out on the west. Probably a maximum of about 200 feet of this member is exposed here. The basal portion of the formation in the region just south of Santa Ana Canyon is very similar to the description given above. One irregularity is the development of about 200 feet of fissile reddish, occasionally lignitic, shale in the clay producing horizon exposed on the west wall of the upper reaches of Clay Canyon. The shales include beds of chloritic arkose up to 3 feet thick. This is the greatest development of shale in the basal part of the formation that the writer saw in the Santa Ana Mountains. The body is lenticular and grades laterally into the arkoses that are characteristic of this part of the Martinez. It is underlain by chloritic arkosic sandstones and at the base a few feet of conglomerate separates the Martinez from the Cretaceous.

The Martinez of the northeastern side of the Santa Ana Mountains is quite similar to the formation as it appears north of

Santiago Canyon which has been described on preceding pages. It occurs as an almost continuous, though considerably faulted, belt extending southeast from Santa Ana Canyon to beyond the town of Elsinore. In the entire area on the northeast side of the range which was studied by the writer, the beds invariably have a very steep dip, vertical or overturned beds being common. Faulting is very pronounced in this district and repetition of beds is found in some places. A striking example is between Tin Mine Canyon and the McKnights Mine where the oyster reef is repeated several times.

The thickness of the Martinez varies considerably and lateral variation is prominent. The lower part of the formation is present throughout the entire region from Santa Ana River Canyon to south of the town of Elsinore. The relations are not always clear in the area because of the structural complexity, lack of good exposures, and marked lateral variations of the formation. About a mile east north east of the Lewis orchard in Fresno Wash a normal succession of basal Martinez is present. Here about 750 feet of the member lies on the Holz shale and is overlain by the upper silts and fine sandstones which in turn are faulted against the Vaqueros to the north. Between this locality and Tin Mine Canyon to the southeast, a considerable thickness of Martinez basal conglomerate is exposed, especially in the fault slice immediately west of Mabey Canyon. This fault slice is composed almost entirely of steeply dipping or vertical Martinez conglomerate beds.

The upper member is well developed from Santa Ana River Canyon southeast to the vicinity of Eagle Canyon; but, to the southeast, it is not exposed. The member on the northeast side of the range is not particularly different from that in the region north of Santiago Canyon. There is present a maximum thickness of at least 1500 feet on the south wall of Santa Ana River Canyon. About a mile and a half southwest of Prado Dam there are striking thick lenticular bodies of massive conglomerate in the upper member.

In the McKnight Mine between Mabey and Tin Mine Canyons, the Martinez basal beds are highly faulted. Clay beds are intercalated in the sandstones and conglomerates. They grade downward in the section to arkosic sandstones and conglomerates of typical Martinez composition. To the east of the open pit on the south side of Kroonen Canyon there are some red shales in the section which closely resemble the argillaceous beds occurring in the lower Martinez in the Clay Canyon region. Fossiliferous gray calcareous sandstone occurs above the clays, arkoses, and shales. *Turritella pachecoensis* Stanton and many poorly preserved pelecypods, including giant venericardias and ostrea, have been found in this area.

About 1500 feet southeast of Hagador Canyon, the Martinez overlaps the Cretaceous which is not found to the southeast. From this point southeast to Bedford Canyon, which marks the southernmost boundary of the area studied by the writer, the Martinez outcrops as a long irregular narrow, occasionally cross faulted, belt paralleling the Basement Complex. On the north wall of Bedford Canyon the Martinez sandstones and conglomerates are faulted against the shales of the Puente. The beds in this long narrow fault sliver are highly crushed and are universally dipping at very steep angles to the northeast or are vertical or overturned.

Unconformities separate the Martinez from the underlying Cretaceous and the overlying Eocene and Miocene formation. Dickerson cites a locality at Coal Mine Hill (just north of Orange County Park) as showing a profound unconformity between the Martinez and the Cretaceous, indicated by great differences in dip and strike between the two formations. A careful examination by the writer casts doubt on such a great unconformity. However, near the Cretaceous contact the Martinez beds dip more steeply and there are a few small displacements present. Dips as high as 37 degrees were observed in the Martinez. Erratic strikes are also present in beds which are definitely Martinez. This all indicates that there is probably some faulting near the contact rather than a great unconformity marked by great discordances of strike and dip.

The best example of the unconformity between the Cretaceous and Martinez in the area mapped by the writer is shown on the north wall of the north fork of Sierra Canyon near its head. Just south of prominent bluffs formed by a basal conglomerate lens in the Martinez, the Pleasants sandstone may be seen underlying the Martinez. As this contact is traced eastward, the Pleasants member thins rapidly and disappears leaving the Martinez to rest upon the Schulz. Farther to the east on the divide between Clay Canyon and Sierra Canyon the Schulz member also pinches out and disappears under the Martinez which then rests directly on the Holz Shale.

Popenoe says that he found several small areas of the very basal part of the Martinez high up on the east slope of Sierra Canyon resting on the Schulz member.

There is always a pronounced break in the lithology at the contact between the Cretaceous and the Martinez. The occasional presence of a basal conglomerate whose materials are obviously reworked from the Cretaceous is good evidence of an unconformity. Moore says, concerning the relations of the Martinez to the Cretaceous in the southern Santa Ana Mountains, "The relations of the Martinez to the Cretaceous are unconformable . . . . in Silverado Canyon . . . . . the lower conglomerate of the Martinez laps over the Cretaceous shale. The thick beds of Turritella chicoensis are missing and most of the Opis zone is covered . . . . . While the angular discordance of the Martinez is rarely as great as 10 degrees there is always a distinct unconformity shown where vegetation is not too dense."

The Martinez is unconformably overlain by the Domengine and in places overlapped by the Vaqueros. These relations will be described later.

The only identifiable fossil found by the writer in the Martinez in the area studied by him was Turritella pachecoensis Stanton. This form is regarded as an unquestionable marker for the Martinez. The following faunas have been reported from the Martinez of the Santa Ana Mountains;

Moore gives the following fauna from a shale in the upper part of Sierra Canyon:

Venericardia sp.
Meretrix stantoni Dickerson
Euspira nuciformis (Gabb)
"*Fusus aratus Gabb*" Dickerson 1915
Priscoficus caudatus (Gabb)
Turritella pachecoensis Stanton

Dickerson lists the following fauna from the vicinity of Santiago Canyon (only specifically determined forms are given here):

Crassatellites unionoides	*Tellina undulifera*
Cardium cooperi	*Tellina kewi*
Glycimeris veatchi var. major	*Tellina cf. T. herndonensis*
Leda cf. L. gabbi	*Venericardia planicosta*
Meretrix dalli	*Calyptraea excentrica*
Meretrix stantoni	*Ringinella of. R. pinguis*
Modiolus ornatus	*Turritella infragranulata*
Spisula ? weaveri	*Turritella pachecoensis*

"Of these species *Turritella pachecoensis*, *Crassatellites unionoides* and *Meretrix stantoni* are distinctive Martinez species."

Sutherland reports from the non-marine horizon of the Martinez of Temescal Valley a fauna and flora which establishes their continental origin beyond all doubt. He cites brackish water pelecypods (Corbicula ?) and leaf impressions. In the overlying strata he found a meager marine fauna including a giant venericardia and *Turritella pachecoensis*.

The following sections, measured through the Martinez, are given with the belief that they will well serve the role of a detailed description of this formation in the northern part of the Santa Ana Mountains. The sections measured in Trabuco and Silverado Canyons and the section along the Santiago-Aliso canyon divide were taken from Moore. The other sections were measured by the writer.

A section in Trabuco Canyon (scaled from map):

Vaqueros

--Unconformity--

Martinez:

Alternating massively bedded sandstone members and greenish shales . .	1700'
Serrano clay	10'
Dark green chloritic sandstone, weathers red	20'
Greenish fine-bedded sandstone	80'
Lignitic shale	1'
White sandstone	20'
Lignitic shale	1'
Massively bedded coarse white sandstone	1080'
Total	2900'

Section taped off along Santiago Aliso divide:

Vaqueros conglomerate

--Unconformity--

Martinez:

Buff sandstone	63'
Greenish white sandstone	26'
Coarse buff sandstone	72'
Fine greenish sandstone	86'
Coarse pebbly sandstone	108'
Thin-bedded green sandstone	83'
White sandstone	42'
Light buff sandstone	120'
(Serrano clay near the base of this member)	
Coarse pebbly sandstone	3'
Lignitic shale	1'
Shaley sandstone	3'
Conglomerate sandstone	86'
Sandstone with large amount of chlorite	7'
Black clay shale	2'
Tan clay shale	3'
Dark green sandstone weathering red (mica and chlorite)	6'
Conglomerate	25
Total	736'

Section in Silverado Canyon (taped):

Domengine conglomerate

--Unconformity--

Martinez:

Coarse to medium-grained sandstone	240'
Shaley sandstone	62'
Coarse to medium-grained sandstone	94'
Concretionary sandstone	27'
Coarse white quartzose sandstone	153'
Fine greenish micaceous sandstone	93'
Shale and sandstone	85'
Brown sandstone	36'
White quartzose sandstone	6'
Brown sandstone	86'
Coarse buff sandstone and conglomerate	43'
Lignitic shale	2'
Coarse brown sandstone with micaceous beds and tan clay shale . . .	14'
White quartzose conglomerate	18'
Conglomerate	197'
Total	1176'

Section of the Martinez at Santiage Canyon just north of Orange County Park:

Domengine conglomerate

--Disconformity--

Martinez:

Marine upper member

Fine tan sandstone, well sorted, thin-bedded to massive, often silty, concretionary in part . . .	950'

Non marine lower member

Lignitic shale, grades laterally into light-weathering sandstone. .	10'
Gray to tan arkosic sandstone, mostly massive, medium to coarse-grained, occasional thin pebble and conglomerate stringers, often grades laterally into beds of finer grain, in general, poorly sorted. .	400'
Olive-green arkosic sandstone which is about half chlorite.	5'
Massive medium to coarse-grained tan sandstone, quartzose often cross bedded	17'
Red weathering pisolitic clay	3'
Brown to green chloritic arkose	15'
Total	1400'

--Unconformity--

Cretaceous

The following section was measured about two miles north of the Santiago Coal Mine. It should be mentioned that the area is not one of good outcrops, especially in the upper fine grained portion, and that, although the writer believes that he located the major faulting at this locality, there may be some repetition of the section by faulting. However, the lithology of the Martinez here is given as:

Marine upper member	
Tan silts and shale, thin-bedded	300'
Gray to buff weathering mostly medium-grained arkosic sandstone, contains some petrified wood	200'
Tan weathering silts, fine thin-bedded sandstones and sandy shales with occasional thin concretionary lenticular limy lenses, sometimes grades laterally into well sorted, medium-grained tan sandstone	750'
Non-marine lower member	
Fine thin-bedded light gray, buff weathering sandstone with a few thin stringers of coarse arkosic sandstone	20'
Softer tan to buff poorly sorted fine to coarse-grained micaceous sandstone, with occasional large flakes of chlorite in the fine-grained beds, also a few hard limy "cannon ball" concretions in the finer beds.	30'
Gray to buff medium-grained arkosic sandstone, occasionally cross-bedded and with coarser lenses	150'
Gray coarse arkose, thin-bedded to massive, a few thin streaks of lignitic shale.	10'
Hard brown resistant arkosic sandstone	10'
Sandy lignitic light-weathering shale with occasional iron-stained thin layers of arkose	10'
Brown, tan or buff medium-grained arkosic sandstone	30'
Softer tan arkosic sandstone	40'
Hard, resistant buff, cliff-forming arkosic sandstone	30'
Buff to tan or gray medium to coarse-grained massive arkosic sandstone	60'
Dark lignitic clay shale	10'
Heavily chloritic coarse to fine-grained brown-weathering arkose	10'
Pisolitic clay (weathers red to yellow)	3'
Heavily chloritic yellow to green arkose	10'
Red shale	5'
Medium to coarse grained olive green heavily chloritic arkosic sandstone, often has shale fragments; conglomerate at base	15'
Total	1693'

--Unconformity--

Cretaceous

Section one and one-half miles S.W. of Prado Dam:

Massive, almost structureless light buff conglomerate	(?)
Alternating lenticular beds of tan to greenish siltstone and conglomerate	320'
Massive light buff conglomerate	375'
Tan siltstones, fine to medium sandstones with a few conglomerate stringers	± 800'
Calcareous medium-grained gray sandstone, occasional ostrea fragments	3'
Medium-grained hard brown sandstone	60'
Coarse white gritty arkose, very little ferromagnesian minerals .	150'
Coarse white arkose with occasional brown to green heavily chloritic beds, lower part most chloritic . . .	60'
White to buff or reddish tinted sandstone	100'
Total	1968'

--Fault

Cretaceous Holz Shale

The following section describes the formation about two miles south of east of the preceding section:

Vaqueros-Sespe light sandstones and conglomerates
Martinez: --Fault--

Tan-weathering siltstones, dark fissile shales, and fine-grained thin-bedded sandstones	800'
Hard gray calcareous sandstone with occasional ostrea fragments	10'
Yellow to buff and gray arkosic sandstone with a few thin conglomerate and shale stringers. . . .	140'
Red-weathering chloritic arkose with a few thin clay seams	30'
Buff to gray sandstone, medium-grained for the most part	180'
Coarse gray calcareous arkose	50'
Yellow arkosic sandstone, conglomeratic	50'
Yellow to gray calcareous sandstone and arkose with some thin lignitic shale beds	130'
Yellow conglomeratic arkose	60'
Yellow sandstone and conglomerate with intercalated shaley beds	100'
Total	1550'

Domengine:

In the area covered by this report the Domengine is exposed only at three isolated localities on the western side of the Santa Ana Mountains. It is not found on the eastern side where the Vaqueros-Sespe lies directly on the Martinez. The Domengine is also absent in the Puente Hills to the north. This formation was mapped by Dickerson and English as "Tejon". Following the more detailed and later work of Moore, however, the writer assigns this formation to the Domengine.

Lithologically, this formation is composed characteristically of massive, yellow to buff, cliff-forming sandstones with intercalated thin lenses of conglomerate which is underlain by a thick basal conglomerate member.

Just north of the reservoir of the Santiago Dam in Santiago Canyon, the Domengine consists of a basal conglomerate 50 feet thick with well-rounded boulders and cobbles up to 8 inches in diameter, although the average size is about 3 inches. The sandstone has a yellow to creamy color and contains a considerable amount of quartz. The boulders in the conglomerate consist of quartzite, fine-grained light colored igneous rocks, and granite. The basal conglomerate is overlain by 500 feet of massive yellow sandstone which characteristically weathers into rugged cliffs and irregular caves. Some of the beds in the sandstone member are slightly conglomeratic and dark brown concretions are sparingly present. Characteristic fossils were found in several parts of the section.

Dickerson and English did not recognize the Domengine which lies between the Martinez and Vaqueros-Sespe just north of Orange County Park. They apparently included these beds in the Martinez. Moore mentions these beds and describes a fauna from them which he assigned to the Domengine. There is at the base, overlying the tan-weathering silts and fine sandstones of the Martinez, a thick conglomerate overlain by massive yellow to buff-weathering sandstones which are sometimes somewhat conglomeratic. Intercalated in these sandstones are a few lenses of concretionary siltstone, from which Moore collected the fossils. These strata are in turn overlain by the continental Vaqueros-Sespe beds.

In the upper and eastern part of Gypsum Canyon there is a thick section of lithologically similar beds underlying the Sespe-Vaqueros. Although this section is unfossiliferous, it undoubtedly corresponds to the Domengine beds farther south. To the north of this locality the Domengine thins and finally disappears entirely under the Vaqueros-Sespe about 2000 feet south of Santa Ana River Canyon. The Domengine sediments of the Gypsum Canyon area consist essentially of resistant buff sandstones, ill-sorted, massive, often showing cross-bedding and intercalated lenticular beds of buff conglomerate. The beds weather to characteristic rugged, cavernous prominent outcrops. The sandstones are usually pebbly and made up of angular grains of quartz and feldspar, with a good deal of biotite. The conglomerate lenses are made up of reworked cobbles predominantly of light-colored fine-grained felsites and andesites and a smaller proportion of quartzite, schist and granodiorite. These cobbles generally vary in diameter from 2 inches to 6 inches, and average about 3 inches.

In the area mapped by the writer, the top of the Domengine has been placed at the base of the lowest red clay bed characteristic of the Vaqueros-Sespe formation. The contact between these two formations seems to be gradational. Above the lowest red clay beds, characteristic of the Vaqueros-Sespe, there is a thick section of sandstones and conglomerates which should be correlated with the Domengine because, lithologically, they are identical. The upper part of the Vaqueros-Sespe is quite definitely non-marine in origin and the suggestion is that the lower part of the Vaqueros-Sespe and the upper part of the Domengine represent a gradual transition from marine to non-marine conditions. However, the Vaqueros-Sespe overlaps the Domengine, for, on the south wall of the Santa Ana River Canyon, the Vaqueros-Sespe lies directly on the Martinez, while a short distance to the south the Domengine appears and attains a considerable thickness in the upper part of Gypsum Canyon only two miles away. Whether the Vaqueros-Sespe overlaps the Domengine and the Martinez, or whether this overlap commenced in Domengine time and was continued through the time of deposition of the Vaqueros-Sespe, can not be determined for certain with the evidence available in the field. The fact, that the Vaqueros-Sespe lies on the Martinez everywhere on the northeast side of the Santa Ana Mountains and that the Domengine is absent in this area is more suggestive of an overlap between the Vaqueros-Sespe and the Domengine than it is of an overlap beginning in Domengine time, but the slight unconformity between the Domengine and the Martinez indicates that the overlap probably began with the deposition of the Domengine. In general, the Domengine is separated from the underlying Martinez by an unconformity. English says that the unconformity between the Martinez and "Tejon" is clearly seen. Moore, in describing the Domengine horizon in the vicinity of Silverado Canyon, states that there is a slight angular discordance between the basal conglomerate of the Domengine and the underlying Martinez sandstone. He gives as further evidence an irregular contact and reworked material. The conglomerate of the Domengine just north of Orange County Park seems to be unconformable upon the Martinez but the angular discordance is certainly not very appreciable. Concerning this locality Moore says, ". . . . there is fossiliferous occurrence near the old coal mine back of Irvine Park (B.M. 610 Corona Quad.). Here the Domengine occurs lying concordantly on the Martinez. It is separated by an unconformity, however, which is at the base of a thick conglomerate. In Bulletin 786 of the U. S. Geological Survey this unconformity was not recognized and the whole thickness was mapped as Martinez . . . . . The relations of the Domengine to the Martinez are clearly unconformable. There is a slight difference in the attitudes of the beds on either side of the contact. Further, the contact is an erosional one, the basal conglomerate of the Domengine being deposited on an irregular surface of the Martinez. This contact surface was taken by Dickerson to be very rough and he cites in support of this contention two sections taken a mile apart which show in one case more than a thousand feet of basal beds that are missing in the other section. Unfortunately the fact was overlooked that the thicker section was composed of both Martinez and Domengine......."

Dickerson lists the following specifically determined fossils from the formation and calls them Tejon:

Meretrix hornii	Solen parallelus
Spisula cf. S. merriami	Cadulus pusillus
Tellina longa	Bulla hornii
Tellina ovalis	Cylichna costata
Tellina cf. T. hornii	Ficopsis remondi
Cardium cf. C. brewerii	Turritella uvasana

Moore gives the following fauna from the occurrence north of Orange County Park and calls the beds Domengine:

Cardium brewerii Gabb (?)
Pitaria aequilateralis (Gabb)
Solen novacula Anderson and Hanna
Amaurellina (Euspirocrommium) clarki Stewart
Cerithium dumblei (Dickerson)
Conus remondi Gabb
Ectinochilus canalifer (Gabb)
Ficopsis remondii (Gabb)
Galeodea tuberculiformis (Hanna)
Globularia hannibali (Dickerson)
Pseudoperissolax blakei (Conrad)
Sinum obliquum (Gabb)
Scaphander costatus (Gabb)
Turritella uvasana Conrad

Vaqueros-Sespe:

The section of red and green clays, conglomerates, white arkosic sandstones, and some buff-colored sandstones which overly the Domengine or the Martinez in the northern Santa Ana Mountains has been referred to the Vaqueros-Sespe.

The section consists essentially of varicolored soft sandstones and clays interbedded with massive, poorly sorted, cross-bedded, buff sandstones and conglomerates. There is considerable evidence indicating that at least the "red beds" are continental in origin. The buff sandstones and conglomerates, though, are very similar to the beds of the Domengine which are in all probability shallow-water marine. Hence, there may have been an alternation of two types of sedimentation during the interval of time represented by these beds.

Although the writer spent considerable time searching for fossils in this formation his only reward was the discovery of a few unidentifiable fragments of bone. Professor Chester Stock informed the writer that a few poorly preserved artiodactyl bone fragments have been found in the red beds in the Santa Ana Mountains. To the south fossils characteristic of the Vaqueros formation, including *Turritella inezana*, have been found several hundred feet below the top of the red beds.

Moore emphatically disagrees that any part of this section in the Santa Ana Mountains can be assigned to the Sespe. He insists that the beds of this horizon are all marine although they are vari-colored. He cites, as evidence for this contention, the well-sorted condition of the sediments. According to him the red color of the material is due to alteration after and not before deposition of the sediments.

In the area studied by the writer there is little doubt that the beds are mostly non-marine in origin. Since there seems to be no stratigraphic or lithologic reason for recognizing more than one formation between the Domengine and Temblor the rocks were mapped as a unit and called the "Vaqueros-Sespe."

The formation varies laterally both in thickness and in composition. In general, the thickness in the area north of Santiago

Canyon is about 1000 feet. However, immediately south of the Whittier fault in Santa Ana Canyon this thickness almost doubles. Within half a mile to the south of the Whittier fault the thickness of the Vaqueros-Sespe decreases to 1000 feet from 1900 feet and the material is less coarse. The Vaqueros-Sespe section about $\frac{1}{2}$ mile south of Santa Ana Canyon is as follows:

Temblor, silty sands etc., with about 6 feet of basal conglomerate.

Vaqueros-Sespe	
Mostly red medium to coarse-grained arkosic sandstone poorly sorted, occasional thin conglomerate stringers, bedding indistinct, often cross-bedded, few beds of red and green claysand	250'
Very conglomeratic sandstone	50'
Variegated soft red, white, green purple arkosic sandstones and clays, massive, occasionally pebbly or conglomeratic, few beds of better cemented buff cross-bedded sandstone	650'
Conglomerate with few thin sandstone lenses, buff	50'
--overlap-- Total	1000'

Domengine buff sandstones and conglomerates

It has been mentioned before that the buff sandstones and conglomerates which occur in the Vaqueros-Sespe, particularly in its lower part, are very similar to the beds in the Domengine formation. The conglomerate, at the base of the section given above, seems identical to the conglomerate in the Domengine just below it. However, it grades up into the "red beds" through an alternation of the two types of material. The contact is an arbitrary one since the red clays and sandstones at the base are very lenticular and seem to grade laterally into the buff sandstones and conglomerates. The contact as shown on the map represents the general position at which the red beds appear.

Above the conglomerate is a thick section of soft interbedded arkosic sandstones and clays. The sediemnts are, in general, poorly sorted and made up of angular to subangular material. The beds range from pebbly and conglomeratic coarse sandstones, through medium-grained sandstones, to sandy clays and clay-silts. A great variety of colors are found. White, purple, red, pink, gray-green, green and light buff are the most common. Both glassy and milky quartz is abundant and decomposing feldspar grains are universally present. The predominant ferromagnesian minerals are micaceous, and they vary in amount of decomposition from black, brown and green biotite to chlorite and muscovite. In the red beds the color seems to be the result of the alteration of these minerals. In some of the lighter sediments the biotite is simply not decomposed. The pebbles and boulders are sub-angular to sub-rounded and consist essentially of acid igneous rocks with some light and dark metasediments. They are almost all hard and fresh but a few are so badly decomposed that they are now extremely friable. The bedding planes are usually very indistinct except for the color separations which are generally quite sharp. Minor angular discordance of bedding is often present. This formation has a tendency to weather into gullies with steep fluted walls which often give outcrops , a sort of "badland" topography.

Above this succession is a 50 foot zone which is much more conglomeratic. Some of the cobbles reach a diameter of one foot and the average is about 3 or 4 inches. This conglomerate is followed by a series of medium to coarse-grained brick-red arkosic sandstones which have a few conglomeratic and pebbly streaks and occasionally contain lenses of sandy clays. Some of the beds are gray-green to yellow arkosic sandstones and grits. Beds are massive and generally 10 to 30 feet thick. The Sespe-Vaqueros exposed on the south wall of Gypsum Canyon is as follows:

Temblor

--conformity--

Sespe-Vaqueros:

Red to reddish-buff medium to coarse arkosic thick-bedded sandstones	100'
Massive buff conglomerate	700'
Green-gray, to yellow, light-weathering medium to coarse-grained sandstone, occasionally conglomeratic, a few thin red claysand beds	900'
Conglomerate	200'
Total	1900'

--overlap--

Martinez silts and shales

In the preceding section, the two conglomerate lenses are light yellow to buff in color. The material is poorly sorted and only occasional thin partings of sandstone show the attitude of the strata. The cobbles are sub-round and vary in diameter from 2 inches to a foot and average about from 4 to 6 inches. They are mostly metamorphic rocks, usually light-colored gneiss, contorted chert, cross-bedded quartzite, and phyllite. Very common in this conglomerate are cobbles of purple pyroclastic andesite which were not observed in the older formations. There are also many cobbles of andesite - porphyry, rhyolite- porphyry and felsite. Occasional boulders of coarse-grained to pegmatitic garnetiferous, micaceous granodiorite and fine-grained basic igneous rocks can be found. The matrix varies from coarse sandstone to clayey silt. These thick conglomerates apparently were rapidly deposited in shallow water, possibly very near sea cliffs.

The section between the two conglomerate lenses generally consists of poorly bedded, ill-sorted light weathering sandstones with some conglomerate beds. There are only a very few thin red clay and sand beds. That this section was also rapidly deposited is suggested by the extreme lenticularity of the beds, their poor sorting and their cross-bedding.

The Vaqueros-Sespe occurs extensively on the northeastern side of the Santa Ana Mountains. However, outcrops are very poor in this area and the details of the stratigraphy are difficult to learn. In the area between Santa Ana River Canyon and Wardlow Canyon the Vaqueros-Sespe has a thickness of between 2000 and 3000 feet. It consists of soft gray-green to white arkosic sandstones and conglomerates interbedded with considerably smaller amounts of red sandy clays than on the western side of the mountains. The formation is poorly sorted and poorly bedded and contains large lenses of massive conglomerate. Along most of the southern boundary of this particular area of Sespe-Vaqueros, its contact with the underlying Martinez silts and shales is a fault. In the vicinity of Fresno Wash this contact seems to be depositional, but this interpretation is not too trustworthy due to the complicated structure and poor exposures here. At any rate, at this place the lowest part of the Sespe-Vaqueros is a body of massive yellow conglomerate which has a maximum thickness of at least 400 feet. Higher in the section is found another lens of conglomerate 1000 feet in lateral extent and about 300 feet thick. The formation is faulted against the Puente formation to the north.

To the southeast the Vaqueros-Sespe occurs as a long narrow fault slice which extends from Tin Mine Canyon to about 2000 feet south of Eagle Canyon. Here the formation is cut off by a high angle thrust fault along which the Basement Complex is thrust over the Vaqueros-Sespe.

Temblor Formation:

The Temblor (Topanga) of the Santa Ana Mountains consists mostly of sandstones and siltstones containing marine fossils of middle Miocene age. The Temblor rests conformably on the Vaqueros-Sespe; the two formations being separated on the basis of lithology and fossil content. The base of the Temblor was mapped at the top of the highest red bed in the Vaqueros-Sespe section. No fossils were found stratigraphically near this contact so that there is a good possibility that the actual contact may lie a slight distance either higher or lower in the section than the author has placed it. The contact as mapped in this report, however, is a very convenient one for field mapping.

The Temblor in the area mapped by the writer is generally composed of finer material than rocks of this age found farther to the south on the west side of the Santa Ana Mountains.

The following section, obtained from the Standard Oil Company of California, gives a good description of the Temblor in the northern part of the Santa Ana Mountains.

Puente Formation

--disconformity--

Sandstone, massive coarse gray, silty, better bedded and finer at top and middle	129' ±
Sandstone 30 ft. conglomerate, coarse at base followed by fine to medium soft and hard silty and calcareous sandstone, tan and gray, several fossiliferous reefs	150' ±
Sandstone, medium bedded, fine to medium grained, buff to buff gray; mostly silty with many fossiliferous zones in more calcareous silty parts. Most highly fossiliferous zones 15 ft.-40 ft. below overlying conglomerate . .	175'
Sandstones, massive buff and gray buff, medium to coarse, mostly firm, stringers pebbles alternating with minor soft silty darker sands, with calcareous fossiliferous zones (T. ocoyana reefs at top and in upper parts) some thin bodies, dark gray, blue mica silts in upper part. Harder massive sandstones are clean, softer interbeds and calcareous zones poorly sorted, silty. A few sandstones in the upper part are coarse, conglomerate and arkosic	300'
Massive, medium to coarse grained, buff colored sandstone with pebbly stringers grading downward into immediately underlying unit	125'
Fine sandy tan colored silt and silty sand, massive to well bedded; abundant molluscan impressions.	55'
Basal member of two 10 ft. beds of coarse sandstone and conglomerate separated by 25 ft. of soft tan colored sandy silt	45'
Total	970'

--conformity--

Vaqueros-Sespe

Only two small areas of the Temblor formation crop out in the area studied by the writer. One locality is between Gypsum Canyon and the first small canyon to the west. Only the lower part of the Temblor section is present in this area.

The following measured section serves to describe these beds:

Resistant arkosic sandstone, thin bedded in lower 5 ft. upper ten feet massive, medium fine to coarse and pebbly, weathers light buff, poorly cross bedded in part	15'
Fine grained light gray well sorted soft silty sands and silts, weathers tan to yellow, a few conglomeratic and pebbly stringers, occasional cross bedding	100'
Resistant, buff weathering quartzose sandstone, cross-bedded in part	12'
Coarse-grained soft yellow sandstone, conglomeratic, pebble stringers, contains ostrea and molluscan imprints	
--conformity--	
Vaqueros-Sespe Red Beds	10'
Total	137'

The other locality of Temblor is north of the Santa Ana River about two to two and one-half miles southwest of Prado Dam where unfossiliferous sandstones underlie the Puente beds. These sandstones, which were mapped as Temblor, are very similar to the Puente beds above. Red beds at the base of the section along the railroad, however, indicates the presence of basal Temblor. The Temblor at this locality is thinner than it is in the southwest flank of the Santa Ana Mountains. The Temblor does not occur on the eastern side of the mountains; the Vaqueros-Sespe here is overlain by the Puente.

Dickerson lists the following fossils from the "Topanga" of the Santa Ana Mountains:

Scutella norrisi	Phacoides santacrucis
Spisula cf. S. catilliformis	Calyptraea costellata
Chione temblorensis	Trophosycon cf. T. kernianum
Tellina cf. T. ocoyana	Thais vaquerosensis
Cardium cf. C. vaquerosensis	Turritella ocoyana
Venus pertenius	Pecten lompocensis
Phacoides cf. P. richthofeni	Pecten crassicardo
Cunus hayesi	

To the west of the area studied by the writer Mr. R. G. Reese of the Standard Oil Company of California found specimens of Turritella temblorensis in beds between the Santa Ana River and the Whittier fault.

Puente Formation:

The Puente is the youngest Tertiary formation exposed in the region mapped by the author. It consists of clastic sediments varying from siliceous and diatomaceous shales to heavy conglomerate beds. In general, a rock of a given degree of coarseness occupies a definite position in the stratigraphic section and is usually thick enough to be readily mappable. Because of this distribution, it is possible to divide the Puente into a number of members. The writer's divisions are quite similar to those of English and are identical with the divisions made in the Standard Oil Company of California's report of October 14, 1930 on this area. Following the Standard Oil Company, the writer has divided the Puente into three members: upper, middle, and lower Puente; and he has further divided these members into several sub-members which are distinguished on a ligholologic basis. From youngest to oldest the divisions of the Puente used in this report are as follows:

Puente

Upper Puente

Uppermost Puente sandstone
sandstone
upper shale
conglomerate
lower shale

Middle Puente

sandstone

Lower Puente

shale
sandstone

The reader is referred to the columnar sections, Plate III, for a detailed description of the members of the Puente formation.

The upper part of the Upper Puente has the greatest areal distribution and this part of the Puente section can be correlated across the Santa Ana River Canyon in the vicinity of Prado Dam. This correlation is also shown on Plate III

As was noted by English, the sediments in the Puente become coarser in texture towards the east. In addition, the field work of the writer shows that the Puente progressively overlaps all of the older formations as one goes southeast from Prado Dam at the entrance of the Santa Ana River Canyon. The Puente itself is also involved in the overlap, for, in Temescal Wash southeast of Corona and northeast of the area covered by this report, the upper shale in the Upper Puente lies directly on the Basement Complex. The writer also agrees with English that the Puente probably lies unconformably on the Temblor although the relationships at this contact, where it is exposed in the area covered by this report, are somewhat obscure.

The correlation of the upper half of the Upper Puente Section across the Santa Ana River in the vicinity of Prado Dam indicates quite definitely that there is no large fault underlying the bed of the river in this region.

Since no fossils were found in the Puente, it is difficult to establish a certain age for the whole formation. The lower part of the formation must certainly be upper Miocene in age since similar rocks occupying this stratigraphic position have been shown to have this age in adjacent areas. The finding of a *Hipparion* tooth in the Puente to the north of the area covered by the writer in the Puente Hills suggests that, perhaps part of the upper Puente in this region may be lowermost Pliocene in age.

Terrace Deposits:

The terrace deposits of this area may be divided into those formed along the stream courses within the mountains and those formed as outwash plains or fans where streams have emerged from the mountains. Deposits of the former type are small in areal extent and thickness. Those of the latter type, however, occupy considerable area especially in Temescal Wash along the northeastern scarp of the Santa Ana Mountains. Where the fan deposits have been dissected they are classed as terrace deposits, elsewhere they are part of the alluvium filling the valleys. English says, "The highest outcrops of river gravel occur toward the east end of Santa Ana Canyon. Some of them are several hundred feet above the present river level. These extend westward to the mouth of the canyon as disconnected patches of gravel lying at various heights above the river. Most of the terraces are about 200 feet above the present river level, corresponding to the present altitude of the dissected fan on the south side of the Puente Hills which in this report is called the La Habra terrace. The river terraces along Santa Ana were formed while movement on the Chino-Elsinore fault was still taking place. Since their formation, they have been uplifted relative to San Bernardino Valley the same amount that they now stand above the river level. As the Santa Ana River has not changed its level relative to the surface of San Bernardino Valley, the only discordance in level between the terraces and the valley must have been produced by faulting that took place subsequent to the deposition of the gravel that covers the terrace."

At the upper end of Santa Ana River Canyon over 200 feet above Wardlow Canyon are terraces which have been uplifted by faulting. Recent fault scarps crossing the fan of Maby Canyon and the alluvium in the Prado Dam region attest to the fact that this displacement is still going on. Similar features are present to the southeast along the northeastern front of the Santa Ana Mountains.

Valley Fill and Alluvium:

Sand and gravel, generally called valley fill, underlies the floor of the Santa Ana River Canyon, parts of Temescal Wash, and all other large canyons in the area. The San Bernardino Valley is also underlain by sand and gravel. The surface soil or alluvium is sandy near the hills and becomes finer away from the hills where the slope is not so great. The valley fill is the accumulated Quaternary outwash from the adjacent mountains.

STRUCTURE

General Features:

The Santa Ana Mountains are bounded on the northeast by the Elsinore fault, along which the range has been uplifted. The range is asymmetrical, the crest lying nearer the steeper northeast side. The core of the range is composed of igneous and metamorphic rocks. The outcrop of the Basement Complex narrows toward the north and ends at the Santa Ana River Canyon. However, to the south it widens to a broad belt. In general, the southwest flank of the Santa Ana Mountains is structurally a monocline of sedimentary rocks of Cretaceous and Tertiary age dipping to the southwest, complicated by several faults and folds.

The general structure of the area was developed during the deformation occurring in post-Pliocene time. The age of this period of deformation is definitely fixed by the fact that the Pliocene, and all older formations, are folded, whereas the younger Quaternary formations remain relatively undisturbed and rest upon the eroded and truncated edges of the older formations. There has been some rejuvination since the main post-Pliocene deformation. Evidence of these more recent movements is expressed by uplifted terraces and by scarps crossing the alluvial fans along the Chino fault near Corona.

The structure of the northern end of the Santa Ana Mountains is, on a broad scale, a large asymmetrical anticline with gentler southwestward and northwestward dips on the southwest flank and nearly vertical or overturned beds on the northeast side. This structure is complicated, however, by considerable faulting and some folding. Near Elsinore and to the south, this anticlinal structure gives way to a block-fault structure with uplift along the northeast side and tilting of the block to the southwest. This large asymmetrical anticline plunges to the north just south of the Santa Ana River Canyon, where the Cretaceous strata form an almost continuous ring around the nose of the Basement Complex. Even on the northeastern flank, where the beds are for the most part nearly vertical or overturned and are much complicated by faulting, an anticlinal pattern is expressed and the different formations occur in bands with the oldest nearest the Basement Complex and younger formations successively exposed to the northeast.

This anticlinal structure is truncated by the Whittier fault at the Santa Ana River Canyon, which cuts obliquely across the north end of the trend of the range. In the northernmost part of the Santa Ana Mountains the deformation may be attributed mainly to the upbowing of this fold with displacement on the Whittier fault playing a less important part. The Whittier fault in the Santa Ana Canyon region has been considered by E. K. Soper to be a pivot or hinge fault. West of Santa Ana Canyon, along the south side of the Whittier Hills, the upthrown side of the Whittier fault is the north side; southeast of Santa Ana Canyon, along the northeast side of the Santa Ana Mountains, however, the upthrown side of the Whittier fault is the southwest side. The direction of movement on the Whittier fault thus seems to be reversed on each side of the Santa Ana River Canyon. However, if one considers the northern end of the Santa Ana Mountains as a large asymmetrical anticline, with the elevation of the Basement Complex due in large part to upbowing and to a lesser extent by faulting, it might be possible to obtain these relations without the use of a fault.

There is little doubt, however, that the Elsinore fault, with its two northwest branches - the Whittier and Chino faults - was the controlling factor in the development of the Santa Ana Mountain block, for, as one proceeds southeast from the Santa Ana River Canyon along the northeast side of the range, the Santa Ana Mountains become more and more a fault block tilted towards the southwest.

The Elsinore fault is one of the major faults of Southern California. It extends along the northeastern side of the Santa Ana Mountains and separates the mountains from the Perris peneplain. A few miles southeast of Corona in the vicinity of Eagle Canyon, the Elsinore fault splits into two branches, the Whittier fault and the Chino fault. The former from its junction with the Chino fault curves more to the west and trends about N. 65° W. along the south side of the Puente Hills. The Chino fault continues northwestward along the east base of the Puente Hills.

The attitude of these major faults is difficult to determine but, in general, they are nearly vertical. This fact is suggested by the straightness of their traces in rugged topography. In some places these faults dip steeply to the northeast, in others, steeply to the southwest. The Chino fault can only be recognized physiographically. From Eagle Canyon northwestward, it may be traced by the alignment of scarplets crossing the fans at the base of the Hills. An especially conspicuous scarplet is present on the fan of Mabey Canyon. Northwest of this scarplet the Chino fault follows an anomalous straight canyon south of the Wardlow Ranch buildings. This canyon is peculiar in that its trend is parallel to the front of the mountains. The streams emerging from the mountains flow into this canyon instead of following the expected course directly out and away from the higher country. This canyon flows parallel to the base of the mountains for about a mile before turning to the west to enter Santa Ana River Canyon. The Chino fault is topographically expressed in the Prado Dam region. Cuts for the dam, north of the fault, reveal a thick deposit of alluvium whereas, immediately on the south, the Puente is exposed.

An exceedingly interesting fault pattern is present in the elongated triangular area between Santa Ana River Canyon and the Whittier and Chino faults. This area is rather complicated structurally. From Santa Ana Canyon southeastward to the head of Fresno Wash, the Whittier fault marks the boundary between the Basement Complex and Cretaceous conglomerates and sandstones. The Cretaceous strata are nearly vertical or overturned and trend obliquely at a very acute angle to the fault. From Fresno Wash southeast to Tin Mine Canyon, the Whittier fault is located in the sediments away from the Basement Complex. For a considerable part of this distance the Baker member of the Ladd formation rests with depositional contact upon the Basement Complex. This depositional contact in general dips steeply to the northeast. Between the Whittier fault and the Chino fault are a number of cross-faults whose pattern probably offers a suggestion as to the nature of the movement on the two major faults. These cross-faults generally trend eastward and form a sort of giant fracture-cleavage pattern between the Whittier and Chino faults. The axis of the plunging anticline in the Mabey Canyon-Kroonen Canyon region, and the axis of the plunging syncline just north of Tin Mine Canyon, follow the same trend as the faults, and, undoubtedly, they are a result of the same forces. The cross-faults are vertical or steep-reverse in character. The structure of this triangular area shows that it has been subjected to compressional forces. It further suggests that there has been a tendency toward relative horizontal movement on the Whittier and Chino faults corresponding to the displacement of the San Andreas rift. Thus the Santa Ana block tended to move north crowding against the Puente Hills on the north and the rigid block underlying San Bernardino Valley and the Perris peneplain.

Faulting west of the Basement Complex in Clay Canyon also seems to have had strike-slip components. Here tear-faults feather southward from the main northwest trending fault, suggesting a tendency for the southwest side of the main fault to move northwestward.

From Tin Mine Canyon south to Bedford Canyon, the fault separating the Basement Complex and sediments is warped and is cut by occasional cross-faults. Later faulting has occurred in the sediments parallel to and in front of this older fault between the sediments and the basement.

The Temescal Wash-Elsinore Valley depression bounds the Santa Ana Mountains along the northeast front. This trough is structurally a graben and has been described by Engel and by Sutherland. Sutherland says, "It is broken up into slices which follow the longitudinal axis of the depression, with movement observable not only between the upthrow blocks on either side but also between smaller units in the valley itself. With but a few exceptions, only the downthrow slices within the valley are topped by sediments, the mountains on either side having suffered sufficient erosion to carry away the overlying sedimentary series, thus exposing the Basement Complex."

"Structure within the valley, aside from the complex faulting, consists normally of a synclinal fold, the axis of which is parallel to the valley. At Alberhill, for instance, the clays dip 5° to 12° SW down the slope of the hill but come up on the other side of the valley."

A northwesterly-dipping monocline forms the principal structure of the western flank of the northern end of the Santa Ana Mountains. Here the sediments dip rather steeply away from the Basement Complex of the range flattening to a dip of about 15° to 25° to the northwest farther from the mountains. This monocline is, however, broken by many faults and a few folds. The faults in general trend north to northwest, although a few trend east and northeast. The faults are normal and are predominantly vertical or high angle in attitude. On each main fault the block to the east side was uplifted. The magnitude of displacement of the main faults is considerable and they may be considered to be a series of step faults rising toward the crest of the range. A shallow northwest plunging syncline is present between Gypsum and Clay Canyons. There is a northeast plunging anticline about three and a half miles east of south of the mouth of Gypsum Canyon. This fold brings to exposure Domengine conglomerates which are flanked by Vaqueros-Sespe red beds. Immediately to the southwest of this fold is a syncline whose axis runs parallel to the anticline.

GEOLOGIC HISTORY

The first known event in the geologic history of the area studied by the writer is the deposition of the sediments which now form a part of the metamorphosed complex of the Santa Ana Mountains. That these oldest rocks were once sediments can be definitely established by their present composition, for some of them are slates, quartzites and limestones. A few Triassic fossils have been found in the limestones; so the age of at least a part of the metamorphic complex is early Mesozoic in age. That a part of the complex may be older and be Paleozoic in age is suggested by the finding of a Carboniferous coral in limestones near Crestmore, California, by Dr. R. W. Webb of the University of California at Los Angeles.

The second event in the history of the area is the intrusion and consequent metamorphism of the Triassic and older sediments by the granitic and volcanic rocks which also form a part of the Basement Complex. That these plutonic and volcanic rocks are younger than Triassic seems certain. Fragments of all the igneous rocks are found in the Trabuco Conglomerate at the base of the Upper Cretaceous, the oldest unmetamorphosed sediment now found in the Santa Ana Mountains. It thus seems certain that the period of intrusion and extrusion is at least older than the Upper Cretaceous. Probably the period of igneous activity should be assigned to the Jurassic which is in accord with the age assignment of other similar intrusions in the southern California region.

During the intrusion of the igneous rocks the old sediments were metamorphosed and intensely deformed. The intrusion must have been followed by uplift and a period of erosion which was long enough and intense enough to allow the cover of sediments to be stripped away exposing the granite rocks in the center of the range.

Gradual submergence followed during which time first the non-marine Trabuco conglomerates were deposited - possibly on alluvial fans adjacent to the sea coast - and then by the increasingly deep water sediments of the upper Cretaceous. That the Cretaceous seas were probably never very deep in this region is suggested by the distribution of conglomerate members through the Cretaceous section. The Cretaceous period of deposition seems to be one of continued progressive overlap, for, while there are no marked unconformities between the Cretaceous formations, the younger Cretaceous rocks overlap the older and lie on the Basement Complex toward the east.

That the time interval between the Mesozoic and the beginning of the Tertiary was a period of at least some uplift and erosion is shown by the presence of boulders in the basal Martinez conglomerates which were derived from the Cretaceous. As discussed in the description of the Martinez, a slight angular unconformity exists between the Cretaceous and the Martinez. How great an amount of erosion took place during the time represented by this unconformity is not certain; the overlap of the Martinez on to the Basement Complex southeast of Hagador Canyon is not suggestive of any great unconformity, at least according to the mapped relations. However, the marked change in lithology which appears with the deposition of the Martinez, the presence in the Martinez conglomerates of a great deal of material derived from the Basement Complex, and the abundance of chlorite in the Martinez all suggest that the period of erosion between the Martinez and the Cretaceous was of considerable length.

During the time interval between the beginning of the deposition of the Martinez and the close of Puente deposition the area remained relatively stable. While each succeeding formation overlapped older ones to lie on the Basement Complex to the east, no great angular unconformity has been found between any of the Tertiary formations. That during most of this time the region must have been close to the shoreline is suggested by the recurrence of heavy conglomerates throughout the section. The region must have been above sea level during the time represented by the Vaqueros-Sespe since most of this formation is of continental origin. The rest of the Tertiary section, however, is marine. Parts of this time must have been periods of non-deposition, especially that between the Temblor and Puente, for, according to Kleinpell, several of his Miocene stages are absent between these two formations.

While the Pliocene is not represented in the area mapped by the writer, it is found in adjacent areas and here beds in the Pliocene are concordant with the Puente. It seems, therefore, that the present elevation of the Santa Ana Mountains must be at least post-Pliocene in age. Neither the Chino or Whittier faults can be dated closer than this.

The presence of so much conglomerate in the Tertiary section, especially on the northeast side of the Santa Ana Mountains, is suggestive of a nearby topographic high but it cannot be said whether the material forming the Tertiary sediments was derived from the area now occupied by the present Santa Ana Mountains or whether this material was stripped from the Perris block. Certainly, there seems to be no difference in the Puente on either side of the Chino fault suggesting its presence during Puente time.

Following the uplift of the Santa Ana Mountains in post-pliocene time, the mountains have been rejuvenated at least once, as is indicated by the Quaternary gravels which are now found well above present day stream beds.

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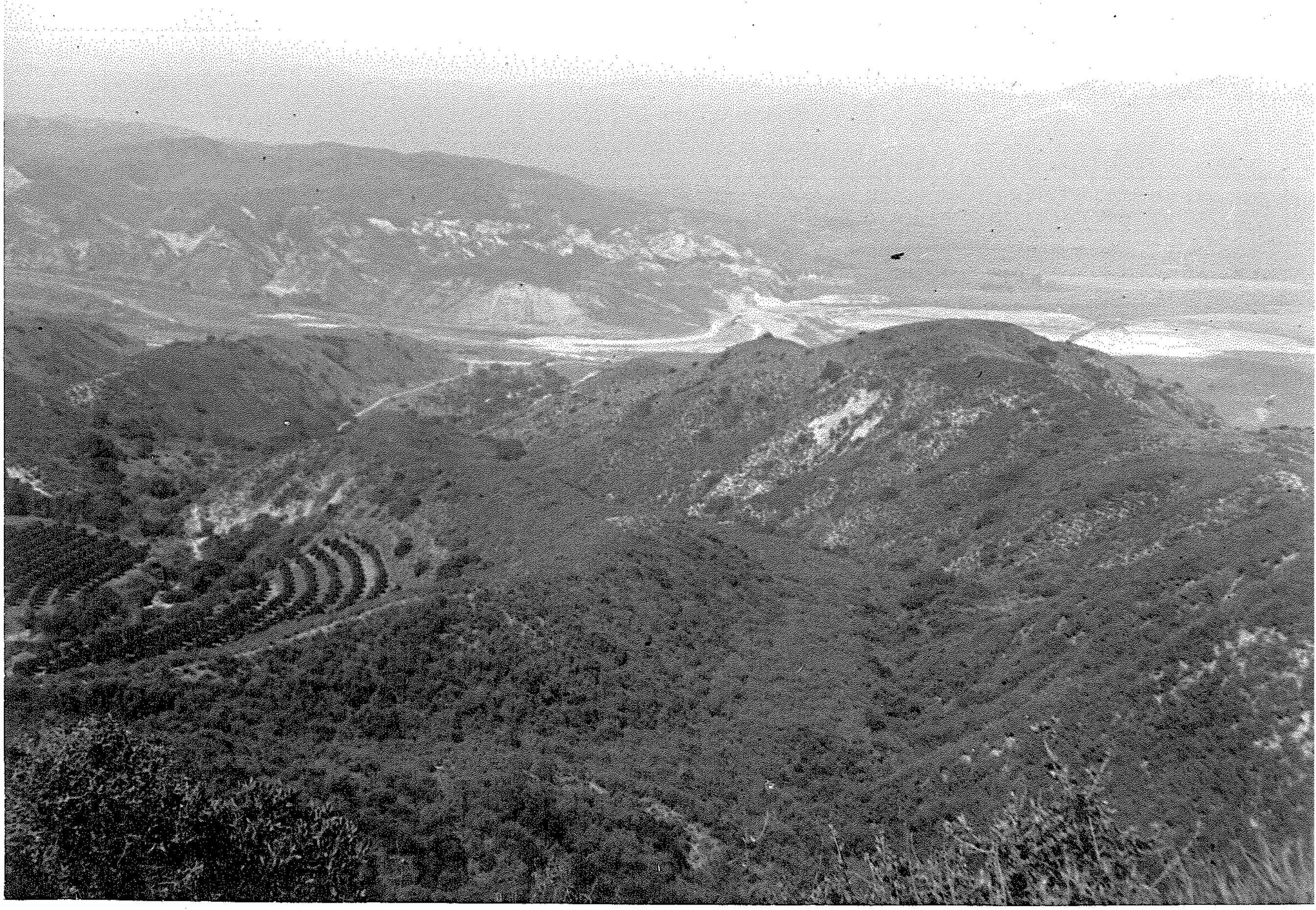
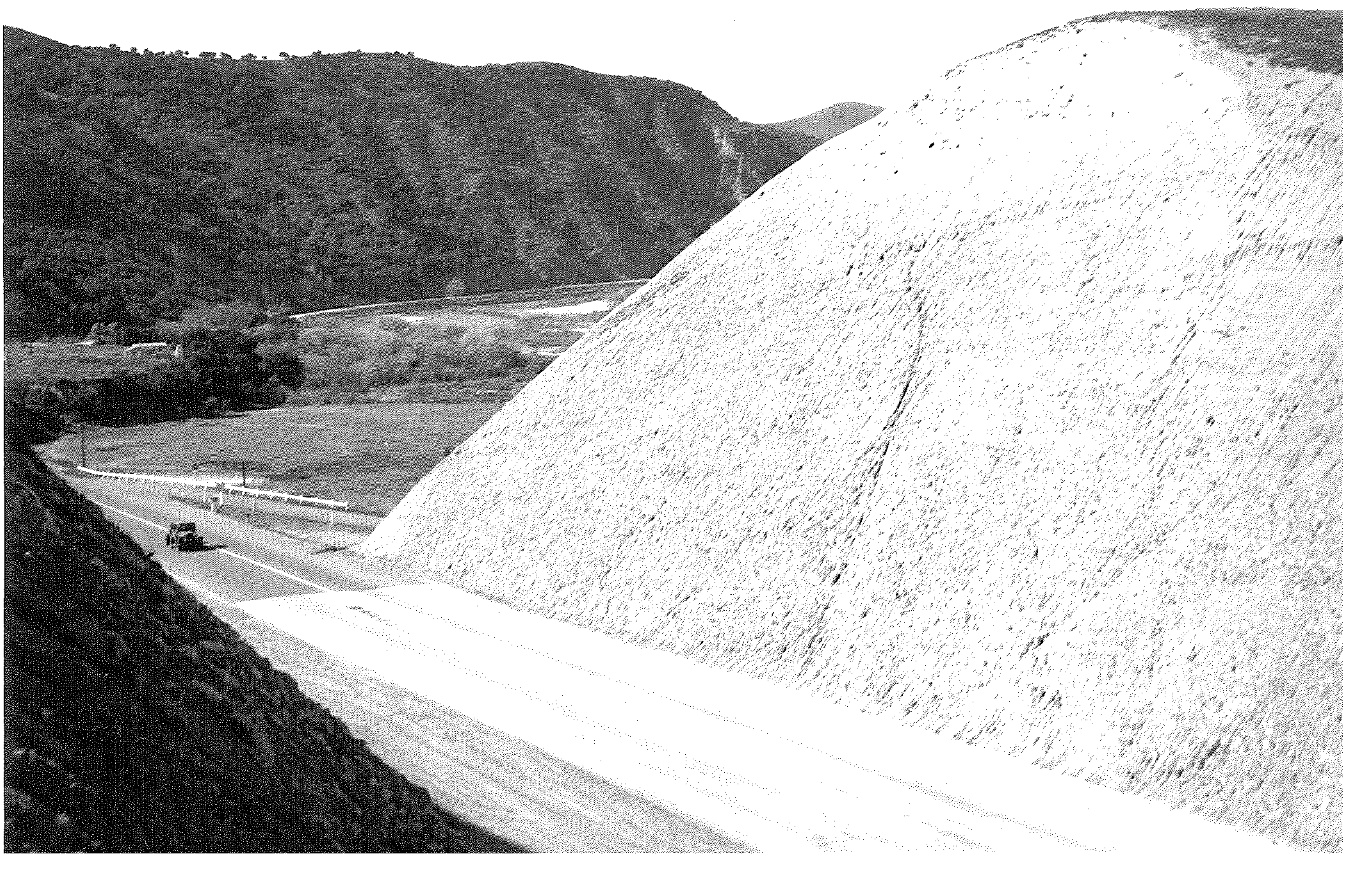
Looking West along Whittier fault system,
Mabey Canyon region, northern Santa Ana
Mountains. Typical brush covering

Martinez formation on south limb of anticline
Kroonen Canyon Region, northern Santa
Ana Mountains.

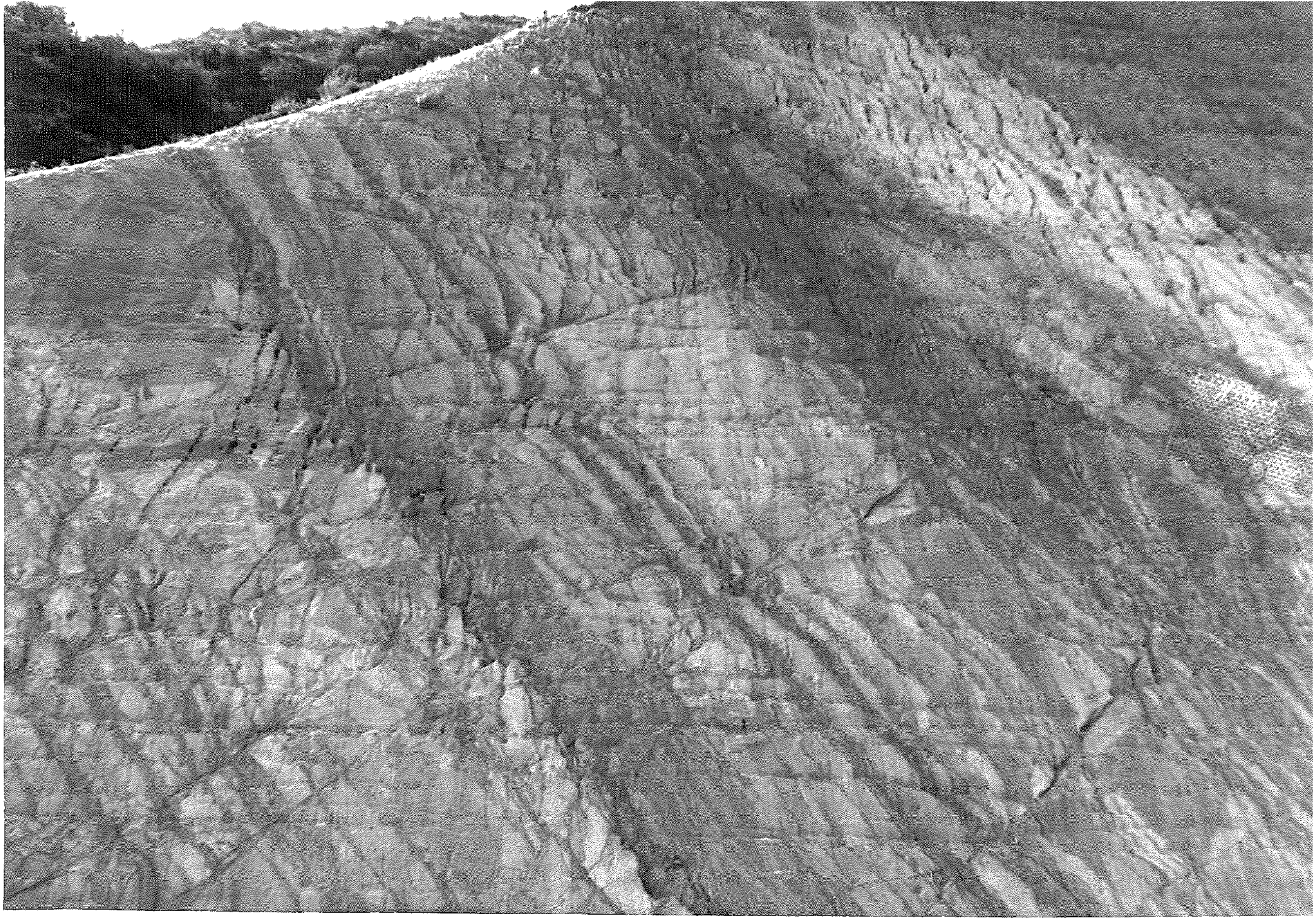
View from Sierra Peak northward, San Gabriel Mountains in the far distance. Southern tip of the Puente Hills and Santa Ana Canyon in middle distance. Lewis Orchard in Fresno Wash in left center.

Massive Martinez conglomerate, indistinct nearly vertical bedding. Along Santa Ana River Canyon Highway near east end of canyon.





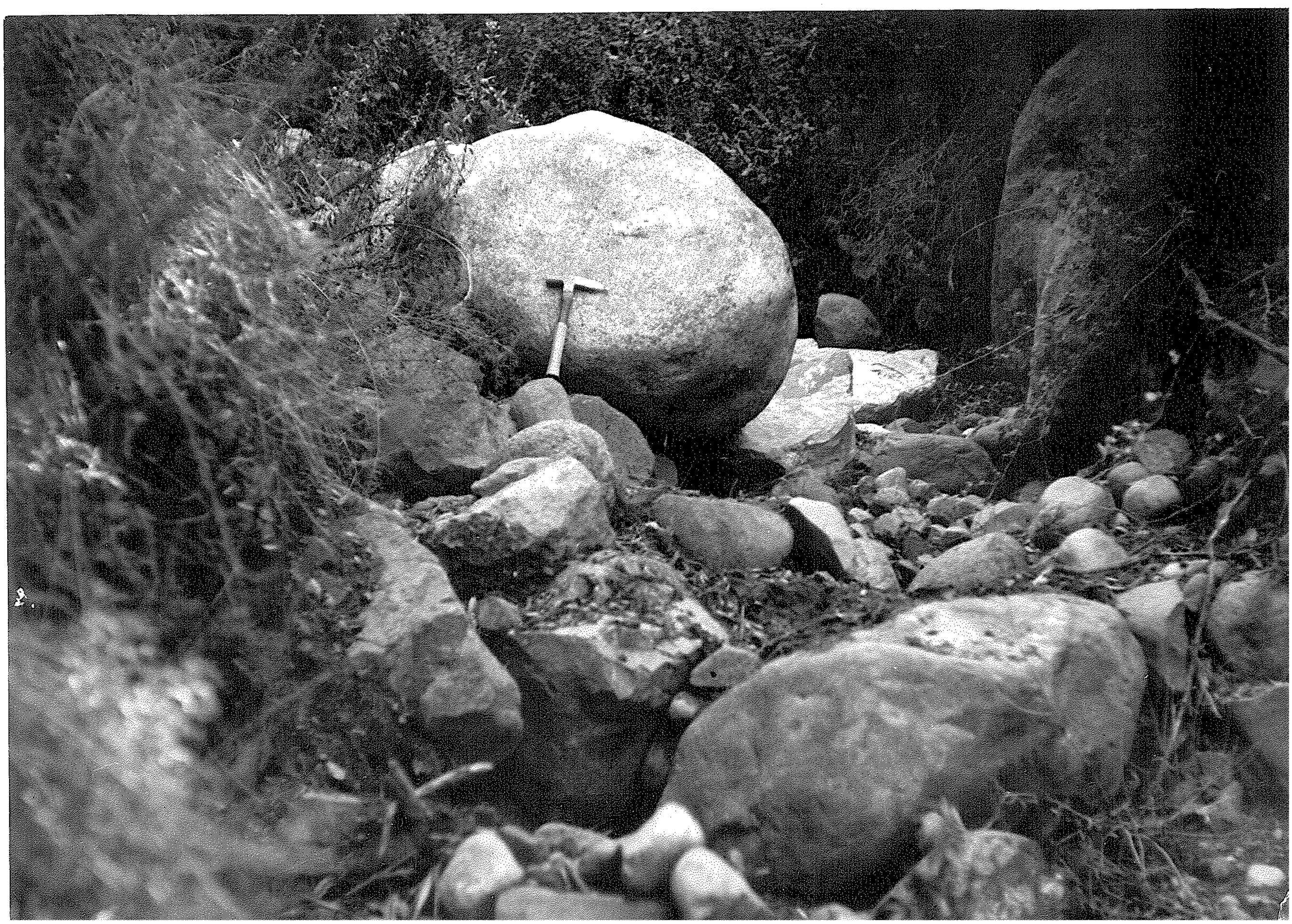
Puente sandstone along Santa Ana River Canyon
Highway, near east end of canyon.
Intercalated light sands and dark silts.



View of northeastern scarp of the
Santa Ana Mountains from Corona.

Prado Dam, eastern end of Santa Ana Canyon.
Southernmost tip of the Puente Hills
in the distance. Southern limb of west trend-
ing syncline in the Puente
formation.

Huge boulders of granodiorite derived from the basal part of the Baker member of the Cretaceous, northeastern side of the Santa Ana Mountains.



Uppermost Puente sandstone in center of syncline in southern tip of Puente Hills.

Puente sandstone, southern limb of syncline, southern tip of Puente Hills.