THE SANTA SUSANA THRUST FAULT AND ITS RELATED PROBLEMS
A PROGRESS REPORT.

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Submitted to the California Institute of Technology as a Thesis for the Bachelor of Science Degree.

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ILLUSTRATIONS.

INTRODUCTION.

The results of previous geological investigations of this area are found in the U.S.G.S. Bulletin # 691 "Structure and Oil Resources of the Simi Valley" by Wm. S. Kew and in U.S.G.S. Bulletin #753 "Oil and Gas Possibilities of Ventura and Los Angeles Counties" by Wm. S. Kew. The work that Kew carried on consisted of mapping the major portions of the area covered by the San Fernando-Santa Susana-Piru-santa Paula and the northern portions of the Hueneme-Triunfo Pass and Calabasas sheets. The work was done under the auspices of the U.S. Geoligical Survey and, in as much as the Survey was primarily interested in the economic possibilities of the region, Kew made no attempt to work out complicated structural relations. It was for the above reasons, coupled with the fact that the writer could, from the map, be aided in his inexperience with the formations involved, that Professor John Peter Buwalda suggested the Santa Susana Thrust Fault to the author as a problem for his thesis for the Bachelor of Science Degree from the California Institute. The work was started about the first of the year of 1928 and this paper bears on the writer's progress on the partial solution of the problem at the date of writing, the middle of May.

Previous work

Purpose Of work

The sum of the field days spent in this area amounts to about five weeks.

Time spent

Acknowledge
ments

The writer wishes to acknowledge with particular emphasis the great help and time that Dr. Buwalda has so willingly accorded in clarifying the writer's hazy notions. To my fellow students at the Institute many thanks are also due.

Abstract

SUMMARY.

The Santa Susana thrust is a major structure in the Santa Susana- Oak Ridge division of the Coast Range. A movement of several miles has occurred along the fault in which the northern over-riding block has apparently added many thousands of feet to the sedimentary section of the region.

The fault structure has an exposed length of about twenty miles. Its eastern end has been terminated by another faulted so that the original true termination is not visible in the field. Folding of the fault surface has also occurred.

The age of the thrust faulting is probably early or middle Pleistocene.

GEOGRAPHY.

Location

The Santa Susana thrust is a structure that tends E.N.E. and whose trace lies in the Santa Susana and Oak Ridge mountains. The thrust block is north of the trace, it runs across Santa Susana and part of the Piru quadrangles. The distance from one end to the other is about 20 miles in a straight line. The area studied in this report covers the trace of the fault, and such structures adjacent to the fault that seems to have bearing on the thrust, from Los Angeles-Ventura County line north of the town of Santa Susana to the edge of the Santa Susana sheet S.E. of Mission Point.

Length

Scope of report

Accessability

The major portions of the western part of the area lies within easy hiking distance of the roads which lead up Brown's Canyon. The public is allowed to use these roads. To the east, however, the ranch owners are rather strict about trespassers and permission must be gained in order to go up Limekiln and Aliso canyons. A new real estate sub-division with its attendant good roads lies just south of the most eastern portion of the area.

PHYSICAL CONDITIONS. FEATURES

Water Supply

There are numerous springs along the fault from which highly mineralized waters, containing much sulphur, issue. However, they lose their objectionable taste after a few minutes of flow down stream.

Relief

San Fernando, Simi, and Santa Clara valleys lie at an elevation of about 1000 feet. The Santa Susans mountain ridge lies at about 3400 feet average elevation. Thus the relief is about 2400 feet. Within the areas studied, it is about 1700 feet exists.

Drainage

Streams in the area that flow into the Simi and Santa Clara valleys gain direct access westward to the sea. Those that go into the San Fernando valley eventually drain into the Los Angeles River to the southeast.

Vegetation

Sandstone formations in the area usually support a brushy growth, particularly on the north side of the hills. The brush in the canyons is often impossible to penetrate. Shale members of the formation are usually covered by grasses and wild oats.

Exposures

Exposures of the fault in the canyons are very good. On the spurs, the Modello shales of the over-riding block have slid down over the fault trace and have obscured the contact in many places completely.

The recency of the movement along the fault is shown by the fact that the structure of the hills is still reflected in the present topography, a remarkable phenomonen for the majority of structures in the California Coast Ranges.

Control of present physiography by the Fault

Are you sure the scarp is not due to differential erosion?

To the north of the fault trace are to be found many elevations above 3000 feet, some of them attaining 3800 feet, while south of the fault, no elevations are to be found higher than 2700 feet. This, and the fact that the trace is always on the south side of the ridge, force the author to believe that the overthrust structure has had some control of the topography.

An old erosion surface is to be seen in the Piru sheet, a table land with a mature topography on its top and with a topographic unconformity on each side lies north of the town of Santa Susana. The evidences of this cycle of erosion are not nearly as clear on the east side of the Sant Susana Pass. There are some evidences of this cycle in the long gently sloping ridges which, when one is above them, can be easily correlated into fans which are now dissected. This probably represents a partial cessation of the uplift of the ridge and then a renewed uplift as represented in the renewed power of the streams.

Cycles of erosion

STRATIGRAPHY.

Topanga Formation (Middle Miocene)

This formation consists mainly of well bedded tan and brown colored sandstone containing large round concretions and minor thicknesses of conglomerate. Upon weathering, the sandstone becomes mottled in places and is seen to be very irregularly bedded. Hard dark brown concretions are often found. Apparently interbedded with the sandstone are layers of soft brown fine grained sandstone which apparently grade upward into the Modelo shales.

The Topanga is cut by a great many dikes and has a great many flows interbedded with it that are of a quite basic character. A badly weathered andesite or basalt mass occurs in the Topanga at the head of Brown's Canyon. The material has the following characteristics:-

Intrusive rocks

It is a dark green finely crystalline rock with no phenocrysts. The main distinguishable minerals are olivine and hornblende, although this determination is difficult due to the alteration of the rock. It is occasionally filled with amygdules of calcite, opal, and ,very infrequently, zeolites.

The author regards the material as an interbedded flow for the following reasons. ~~1st.~~ The material has a very regular thickness for over one mile of good exposure. That this is a sheet is extremely improbable in a sandstone formation. 2nd. The material appears to be perfectly

conformable with the beds of sandstone.

However, its apparent lack of viscicularity and other evidences of flow structure place rare difficulties obstacles in the path of this view. The extreme weathering is probably due to the action of waters perculating down through the fault-brecciated formations.

2 rather unrelated ideas in same ¶

Fossils are common in certain horizons of the Topanga. The fauna of this area resembles in many ways the fauna of the Temblor formation of San Joaquin Valley. — Fossil correlation

The Topanga outcrops in this area at the nose of the thrust at Brown's canyon. — Exposures

A thickness of about 50 feet, overlaid by the Modelo and underlaid by the basalt flow which lies on the fault contact, is exposed at the head of Brown's Canyon. It again outcrops below the Modelo and above the fault surface in the vicinity of Aliso Creek in the eastern part of the area.

Modello Formation (Upper Miocene)

Lithology

In general, the lithology of the Modello is fairly distinctive so that it can be easily separated from the other formations. It is composed, primarily, of shale, within which are several large lenses of coarse sandstone, and in the eastern portions sometimes conglomerates.

Shales

The shale of the Modello is mainly of an argillaceous variety containing a considerable percentage of organic matter. In fresh surfaces, its color is a dark bluish gray to black, but it weathers to light gray or buff color and forms a brownish soil. When fault-brecciated, it turns a dark brown on the surface, which is in marked contrast to the usual light tan. The sandstone is rather coarse grained, in some places conglomeratic. Clay shales, particularly, where the sandstone grades into the shale are interbedded in thin layers with it. In color, the sandstone is ordinarily brown tan or buff, though a dark brown is by far the most common in this area.

Sandstones

Differences in formation within area

In the eastern portion of this area, the Modello contains comparatively little shale, being composed largely of conglomerates and sandstone.

SAUGUS FORMATION.

The Saugus formation is a great series of unlithified sand, gravel and clay. Its physical features indicate that it has a marine origin and was formed close to shore. Pectens and whalebones occur are to be found in the formation in this area. Farther to the east, it gradually merges into a terrestrial deposit probably formed by a sinking coast. not direct, not concise Just how? Not clear.

Lithology

In general, the Saugus formation is uniform in lithology, consisting mainly of light colored gravel and sand, usually more or less consolidated with interbedded lenses of soft fine sandstone and brown well-cemented conglomerate. The formation contains cross-bedding in many places. For the most part, the beds are unfossiliferous although certain horizons contain a great many invertebrates. A few scattered whale bones were found by the writer. A partial section of the Saugus formation in Brown's Canyon gives some idea of its nature in this area.

Representative section

Upper member of gravel and light colored sand which is in the main unfossiliferous except for very infrequent whale bones - ---- ----125-to 150'

Yellow or buff-colored sand stone and conglomerate with light colored fine sandstone lenses in which some cross-bedding is found

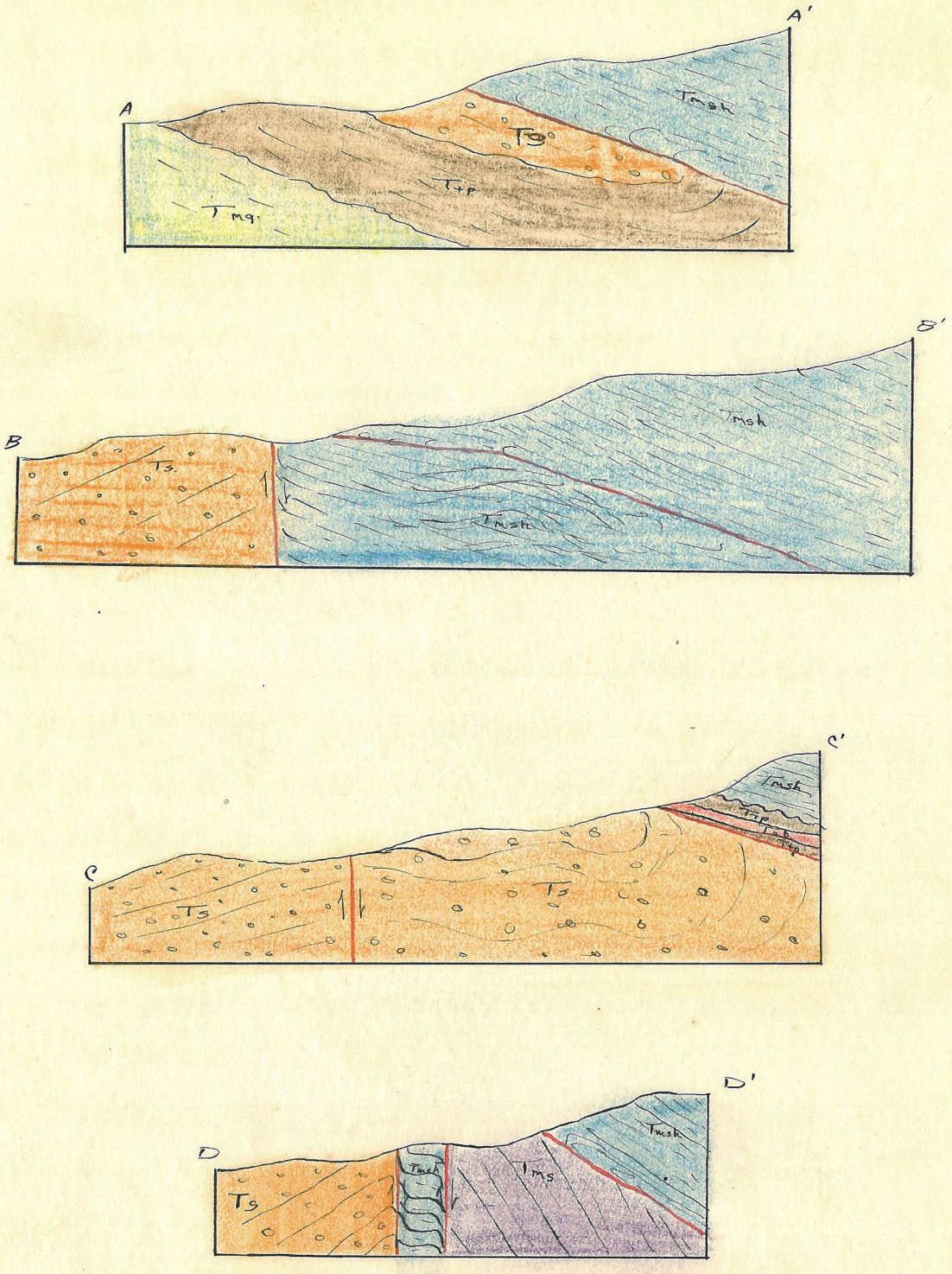
Very fossiliferous, one 5' bed consisting almost entirely of solid shells - ---------- -------190'

Dark brown conglomerate and sand not as
well bedded as above, some fossils
to be found in it - - ---------- 93'
Yellowish brown and tan colored fine
grained conglomerate, rarely fossiliferous-300'
Total partial section approx-700'

Cross-bedding in the Saugus formation

CROSS SECTIONS

North



Vertical and horizontal scales - - - - 2 inches=1 mile

This is two times the scale of the accompanying map.

A Legend should appear on this sheet to explain significance of colors.

STRUCTURE.

Regional

The coast ranges of which the Santa Susana and Oak Ridge mountains are a part, is in general characterized by short length structures that have a general direction of east and west. Probably the two largest structures in this area are the Happy Camp Syncline and the Santa Susana thrust fault (or overthrust).

Parallelism of the Santa Susana & San Gabriel faults

The thrust, according to Kew's map, runs approximately parallel to the San Gabriel Range? and then merges into it in a vertical system of faults called by Kew the "Sierra Madre Faults".

The western ends of the Santa Susana and San Gabriel faults, in addition to their parallelism, start opposite each other. The San Gabriel is apparently a normal fault in this region and it may be possible that this fault system may be the compensating factor that thrust faulting theoretically requires. That is, it may partially or wholly make up for the shortening of the crust by the thrust.

Landsliding

Land-sliding is very prevalent in the region. The badly fault-shattered sediments, which often contain much heavy material in the shape of conglomeratic boulders, seem to landslide very easily. Along the thrust this is particularly true, apparently because of the heavy dead weight of the well consolidated Modelo shales. The shales have been badly shattered by the thrusting, and consequently, offer no resistance to gravitational stresses.

A rather striking feature concerning the nature of the thrusting is the relative incompetence of the two formations, Modelo shales anf Saugus conglomerate, involved in the actual differential movement. In the normal case, the shales being well consolidated, hard, brittle, and mainly siliceous, should suffer less than the more recent and less consolidated Saugus formation. In the field of this area, however, the opposite is the true picture. The Saugus shows comparatively little deformation in contrast to the brecciation of the Modelo.

Relative incompetanc of the Modelo and Sa Saugus formations

In the thrust fault zone in which differential movement between Saugus and Modelo has occurred, the Modelo usually has 20 to 150 feet of badly brecciated material which looks as though it had been churned over and over. No trace of the original bedding is to be found. This zone usually stands out boldly in the field as a sharp vegetationless step running around the topograph. Its coloration is a dark reddish brown.

Zone of brecciation

The evidences of the fault in the field as one approaches the actual contact are:

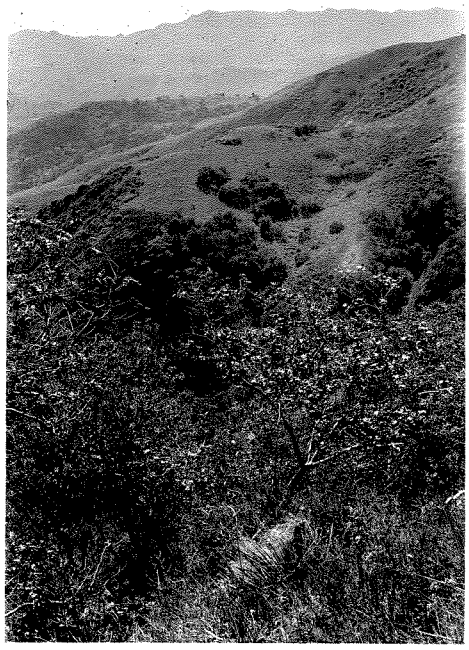
Evidences of the fault

1st. Overturning of the hanging wall formation as one approaches the fault trace.

2nd. Brecciation, slickensliding, and gouge

3rd. Abnormal relations of the formations involved, that is, Modelo lying upon Saugus.

4th. Marked unconformity. This is not an unconformity. Unconformities are always depositional not fracture features or structures



Landslide at head of Browns canyon. The photo is taken looking west from the east bank. The Piru table land is in the far diatance.

Fault-brecciated Zone in the Modelo

Overturning of the formations of the over riding block is not a general case and seems to be limited to a shale contact and comparatively massive beddinf contact. That is, overturning was clearly shown in the Modelo shales above the fault when the shales were actually cut by the fault and the Saugus formation formed the lower bottom surface of the gliding plane. When Topanga was faulted against Saugus, very little evidence of true overturning was observed in either the Topango, or Saugus, or Modelo shale section. When the fault trace ran through the Modelo shale section, no overturning was observed either above or below the thrust surface. The age of the fault is fairly quite accurately closely determined placed by the fact that the overriding block rests on the Saugus formation. Dr. Stock gave as his opinion views that the Saugus is late Pliocene or even early Pleistocene in age. As some five to ten thousand feet of sediments have been stripped off the overriding block, the age of the movement is Pleistocene, in all probability lower or middle.

Overturning of Modelo at fault

Age of fault

The total movements, vertical and horizontal, were not measured by the writer due to the lack of time and the difficulty of finding a place where the sections could be measured. Probably the best place for this task would be on the north side of the Santa Susana Mountains where the sediments are laid out arranged in regular order. The thickness of formations vary greatly in the Coast Ranges from place

Total Movements

nearest point

to place but this is the closest place to the area where the sections can be measured with any accuracy. However, the vertical movement must amount to many thousands of feet and the horizontal to quite a number of miles. Some evidence for this imp. statement should be briefly stated.

Since the overthrusting, the fault plane has been folded and faulted to a major degree, as will be shown below. considerably

differs greatly in attitude from place to place.

Divergent dips of the fault

The Santa Susana thrust, apparently, has very widely divergent dips. According to Kew's map, the dips along the fault vary from 5 degrees at the nose of the fault at Brown's canyon to 90 degrees at the east end of the fault. The writer agrees admits that the dips along the fault do vary considerably but he does not believe that they have such widely divergent dips as postulated by Kew. The writer offers as an alternate theory, that it may be possible that at the eastern end of the thrust, the fault plane may have been cut off by a vertical fault which makes the thrust seem to merge into a vertical system.

Faulting of earlier

Local structure

The structure on the Aliso Canyon (west) is highly complicated. The Williams Anticline, which is continued westward and whose axis is indicated on the map, runs under the Santa Susana overthrust and changes the dip of the plane from about 23 degrees on either side of the "nose" to about 5 degrees on the nose itself. This anticline is further warped so that a distinct dome,

Western portion of area.

as clearly shown by outward dips on all sides of the

axis, lies at the head of Aliso Crek(west) north west of the Williams oil well. A variation of the usual relation of Modelo overriding the Saugus formation is to be found on the west side of the nose in which the underlying Topango and Modelo shales are exposed under the fault trace. The writer experienced no little difficulty in determining the cause for the discrepancy of the dips in the fault plane in the vicinity of the nose.

There are, he believes, two possible explanations to account for the phenomena:

1. Landsliding to the south may have carried the fault trace downward from its true original position so that the lesser dips are obtained. As has been mentioned before in this report, landsliding is very prevalent in this area. However, several difficulties (objections) arise to this theory; the gradient does not appear steep enough to give the necessary force to bring this sliding about, altho the force would be comparatively low due to the nature of the loading of the Saugus by the heavy shales and the fault brecciation of the region. Another objection to the landslide theory is the total lack of topographic expression of the slide. Recent slides are usually shown by unconformatable topographic drainage. Tilting of sediments towards the stripped hill is another criterion for the determination of landsliding.

what gradient? Not clear

disarranged

surface of sliding

No such thing as topographic drainage

The hill to the southern tip of the nose does not have any great break in slope. The dips in the badly fault shattered formations do not seem to indicate any tilting.

at?

2. Warping of the fault plane by folding along the Williams anticline. This anticlinal structure has strong folding in the Saugus and has probably folded, to some degree, the fault plane. This condition is not surprising when one stops to consider the rapidity in which deformation has been taking place in the Coast Ranges both in the immediate geological past, and at present.

this is not really a difficulty but merely an alternative explanation not yet eliminated.

The actual relations along the fault at this point are, in the main, rather obscure due to the shale detritus creeping floating down over the contact. Good exposures are to be found on either side of the nose at the head of Brown's Canyon and Aliso Canyon and at the tip of the nose only.

At the tip of the nose, the thrust has been cut off by a vertical fault whose differential movement has resulted, further west along the fault, in the Cretaceous Chico beds on the south being faulted into juxtaposition with Eocene Meganos beds on the north. This fault, the writer believes, is a continuation of the Sierra Madre fault system and it will be so designated in this report.

Sierra Madre(?) fault

The exact amount of movement of the Sierra Madre(?) fault at this point, in which the southern block has risen, the writer was unable to judge determine.

A great many landslides on the side walls of Brown's Canyon occur near the head of the

stream. The creek has incised rather deeply in the softer Pliocene beds in comparison to the rather flat-topped Modelo ridges.

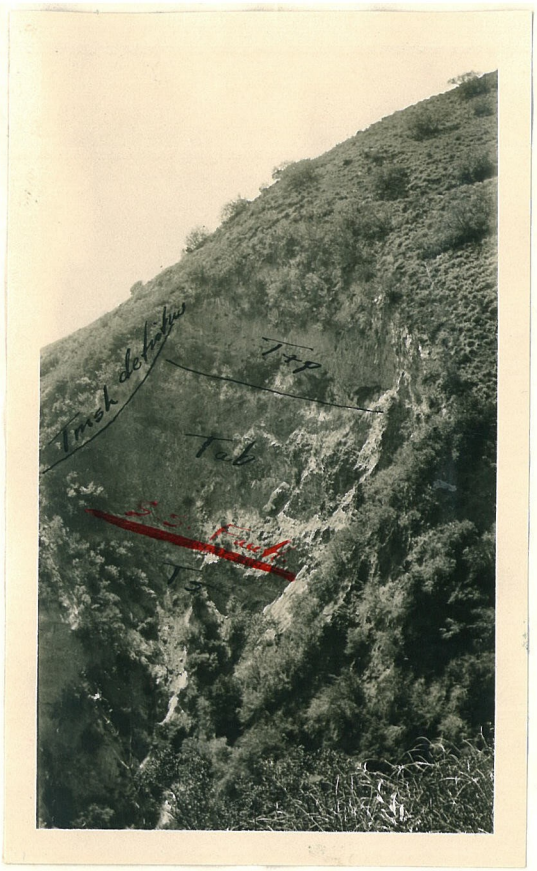
Head of B Browns Canyon

At the head of Brown's Canyon, the usual Modelo shale contact at the fault is displaced by a small thickness of Topanga formation which has been faulted against the Saugus. In the Topanga formation at the actual fault trace, a crystalline mass of basalt or andesite occurs. A comprehensive discussion of this mass was given under stratigraphy of the Topango. As a glance at the map will show, the outcrop of this mass is limited to this one locality within the area.

The Sierra Madre(?) fault continues eastward from the nose, although the evidence of the fault is not so clear, due to the fact that the same formation, the Saugus, is to be found on both sides of the fault. However, the sharp saddles, the canyons which run in the brecciated fault zone, line up with one another, and so the writer feels safe in carrying the fault up to the point where it disappears under the alluvium.

Limekiln Canyon

In the vicinity of Limekiln Canyon, the thrust occurs at the surface in the Modelo shale. Its trace is recognizable chiefly by the brecciated zone described above. The writer was again able to get a dip of the fault and measured it on the east side of the canyon as



Photograph taken in Browns Canyon of the Topanga-
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Igneous flow-Saugus contacts. The Modelo shales lie just above. The detritus of the shales is shown in a manner which brings out the difficulty of accurate mapping of the fault contact without actual outcrops in the area.

about 5 or 6 degrees to the north. However, it steepens somewhat in the vicinity of Aliso Creek (east) where the dip amounts to almost 35 or 40 degrees. At this point, it is closely associated with two other faults which lie immediately to the south of the thrust. The first one to the south may be correlated with the thrusting faulting but it seems to be much more reasonably explained as a step fault in the fairly large vertical movement along the fault to the south. The most southern of these three faults emerges from under the alluvium about on a line with the so called Sierra Madre(?) fault of which the writer spoke above. Its direction of movement is the same and so the writer believes that this fault should be also called the Sierra Madre(?) fault. This zone of movement merges into the Sierra Madre system to the east.

Eastern portion of area

Sierra Madre? fault

The nature of the movements along the Sierra Madre(?) fault are only indicated by drag folding in the Modelo shales north of the contact, and in the Saugus on the south. This, of course, is a poor criterion but the writer wishes to point out the following facts.

1st. The shales are exposed for about 100 yds. in one place lying almost flat anf showing little deformation. As one approaches the fault, the shales gradually take on a greater and greater dip to the north.

using this word begs the question

2nd. Aside from this drag folding, very little deformation is to be seen. If the movement had been oscillatory, we would expect to find much more crumpling.

Indistinct and yet fairly definite drag is also to be observed in the Saugus, pointing to the same direction of movement.

These criteria are strengthened by the drag on the auxiliary fault to the immediate north. The drag in the shales on the south block, the sandstones on the north block, again point to the same nature of movement in which the second fault is but a second step. The thrust fault north of these faults seems to dip about 35 or 40 degrees.

Not a very clear statement

Discussion of the Santa Suaana - Sierra Madre? fault relations

About one mile to the east of the canyon, all three of the faults seem to merge (together). The writer believes that the Sierra Madre(?) faults have cut off the Santa Susana thrust by upward or downward movement on the south side of the Sierra Madre(?) system. The cutting off by erosion of the top of the south block would remove the plane of the thrust from this block. Further erosion should expose the fault relations on the north block when the land surface becomes lower than the southernmost part of the thrust plane.

One other solution to the problem of the relations in the field remains to be mentioned spoken of. If the so-called Sierra Madre(?) fault movement

had had its main direction the dropping of the southern block, the same result would be obtained. The movement, in this hypothesis, would have to be large enough to bring the Saugus of the over riding block in juxtaposition with the Modelo shales of the same unit. The wide belt of alluvium of the San Fernando valley would hide the thrust fault trace that would crop out on the southern block. This last theory is more in accord with the nature of the movement of the Sierra Madre and San Gabriel faults to the east in which there has been large uplift of the northern block. However, shear faulting in which there has been reversal in direction of movement along a fault plane is not uncommon in the complicated geology of the Coast Range.

ECONOMIC GEOLOGY.

As in most of the coast ranges of the southern part of California, the main economical interest is in the petroleum possibilities. With the exception of a few gravel pits and a small roasting furnace where the shells of an extremely fossiliferous bed in the Saugus formation are burned to make lime for local use, the main economical activity of a geological nature has been in the search for petroleum. Quite a number of wells have been drilled in this area, most of them quite a number of years ago in the vain search for oil. Only one well, the Williams well, whose location is shown on the map, is now being drilled. This well is down about 4300 feet. The drillers passed through a gas sand at 1500 feet and, at present, their main activities are confined to an effort to cut back to that level in an endeavor to obtain the gas for fuel purposes. The well is located just south of the axis of the Williams anticline and the conditions are fairly favorable for a production of petroleum except for the fact that the region is so badly cut up by faults. It seems improbable that the oil would have found any barrier which would collect the liquid in this badly shattered area. It is a very peculiar fact that no oil has ever been found on the north side of San Fernando valley. Some factor, either the enormous number

Russel-Williams oil well

Possibilities of Petroleum production

of major faults to be found in this region or some other element that governs the little known problem of the manner of petroleum collection has entered into this case.