GEOLOGIC REPORT ON A PORTION OF THE LANG QUADRANGLE.

by

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Abstract

The area investigated in the Lang quadrangle, California includes about seven square miles with desert vegetation and a maximum relief of about 1000 feet.

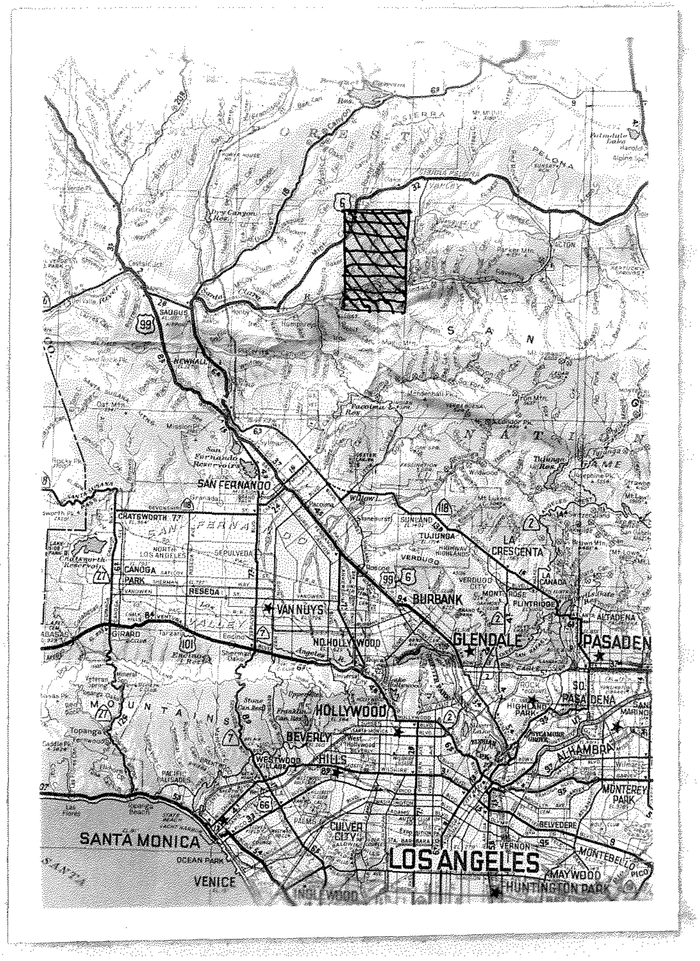
The area consists of two formations separated by an angular unconformity of about 30 degrees, the Escondido tentatively placed in middle Miocene, and the Mint Canyon, either upper middle Miocene or lower upper Miocene. The Escondido formation consists of alternate beds of sandstones and shales and lava flows. The Mint Canyon formation is a series of sandstones, conglomerates, and coarse terrace gravels all of terrestial origin.

The Escondido formation is folded into a tight pitching syncline with minor folds on it southern flank. A great deal of faulting has complicated the otherwise simple structure. The Mint Canyon formation is warped into a broad syncline and anticline which are almost exclusively depositional in origin. A great deal of minor faulting may be seen in this formation not to be correlated with that in the Escondido except in a few cases.

The historical geology has been summarized on page 35.

The economic deposits are unimportant and of no economic significance.

Plate I.



Index map **showing** location of Lang Quadrangle, California.

Fig. 1.-Fault pattern showing a tendency toward stream control in the Lang Quadrangle.

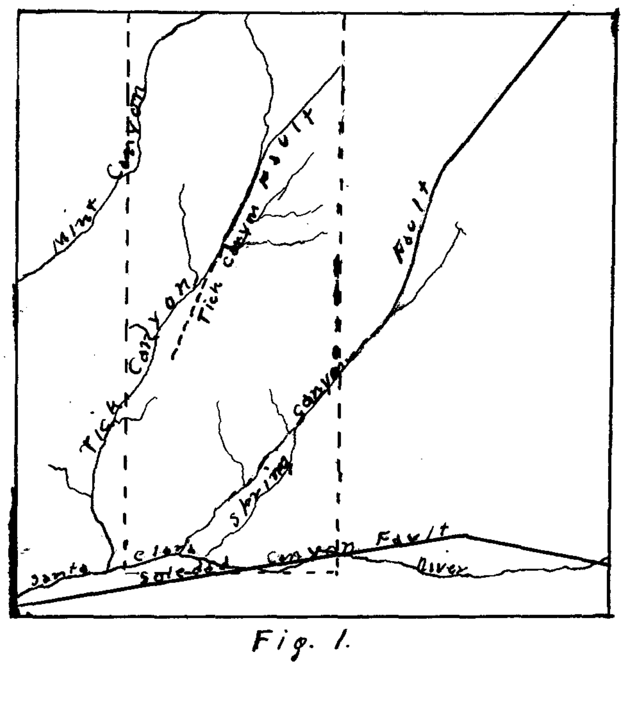


Fig. 1.

GEOLOGIC REPORT ON A PORTION OF THE LANG QUADRANGLE

Introduction

Location of Area

The area mapped lies in the northwest one quarter of the Lang quadrangle, in Los Angeles county, California. The Lang quadrangle lies just east of Mint Canyon and generally north of Soledad Canyon about fifty-six miles from Pasadena; it may be reached by going directly to Saugus and proceeding eastward from there on U.S. Highway 6. Turning off of Highway 6 at the Solemint store and traveling eastward the boundary of the quadrangle is crossed just before the mouth of Tick Canyon is reached. The major part of the detailed mapping was done about five miles north of the mouth of Tick Canyon in the beds underlying the Mint Canyon formation which is extensively exposed in the quadrangle. (See Plate I)

Size of Area

The total area mapped comprises about seven and one half square miles. It extends about four miles northward from the mouth of Tick Canyon and about two miles eastward from this point. It is roughly a rectangle, with its length constituting a section from the basement rock on the south side of the Santa Clara River to the basement rock in the northern part of the quadrangle.

Purpose of Investigation

The purpose of the investigation was to develop field mapping technique and ability on a not too complicated area with a minimum of instruction. The only assistance given was of the nature of personal supervision and all of the mapping was done individually. This thesis with its accompanying map fulfills one of the requirements for a Bachelor of Science degree in Geology at the California Institute of Technology.

Basic Map and Method

All of the work was done by foot traverse and by Brunton compass. Most of the contacts were placed by topography and shot in by compass from time to time as a check. This was possible because the map was a very recent edition (1933) and mapped in 1929. The mapping was done by the county surveyor's office of Los Angeles county, based on controls of both the United States Geological Survey and the United States Coast and Geodetic Survey. The scale was 1/24000 and the datum plane mean sea level. As only slight inaccuracies in the contouring were found, plotting by topography was considered to be accurate enough.

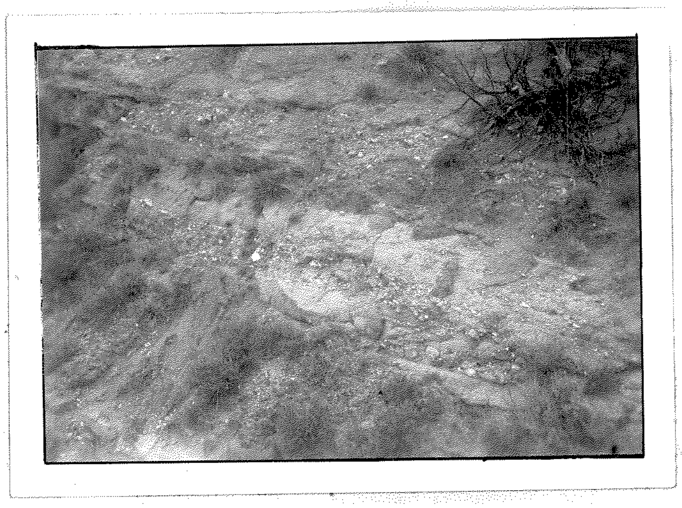
Vegetation and Relief

As the basin lies only about thirty miles from the Mohave desert and is relatively low, its climate is nearly arid and its vegetation is mostly of the semiarid type. Sagebrush and greasewood form the dominant plant types with cactus in many spots and a few trees along the stream bottoms. As the rainfall is rather sporadic but of cloudburst proportions when it does fall, the erosion is very intermittent. This type of weathering gives rise to a variety of topographic forms with a typical "bad lands" topography rather dominant. The difference in elevation of about 1000 feet in the 5 miles between the basement complex and the Santa Clara river gives a fairly steep stream gradient which also aids the erosion.

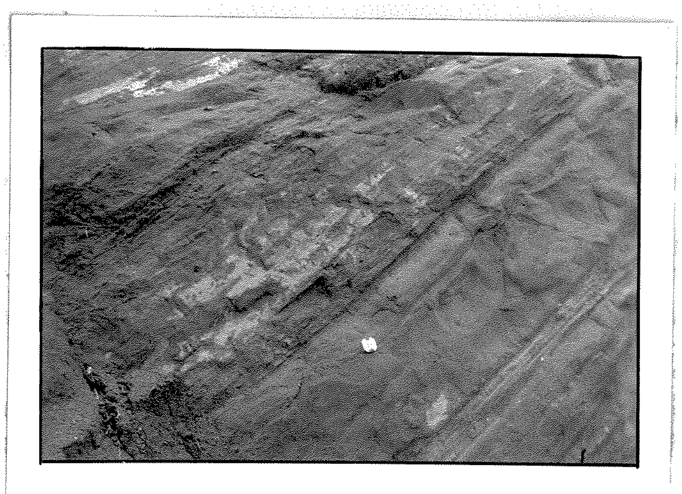
Drainage

The major stream of the region is the Santa Clara river which flows down Soledad canyon and drains the whole southern flank of the Sierra Pelona ridge and the northern side of the extreme western edge of the San Gabriel mountain block. In the Lang quadrangle the two major tributaries are Tick canyon in the western half of the quadrangle and Agua Dulce canyon in the eastern half. These streams are consequent and have been more or less superposed on the Escondido formation but there are indications that they were originally controlled by faults in the Escondido at least in their upper portions. The small creeks and washes that drain into the main streams show in many cases small faults which have very definitely con-

Plate II.



Outcrop of Mint Canyon formation east of the mouth of Tick Canyon. Note the poor sorting and the coarse bedding.



Outcrop of Escondido formation at the Borax Mine in Tick Canyon.

trolled the drainage pattern throughout the whole quadrangle. (See Fig. 1.)

Exposure

The exposures in the area are very good in some portions and extremely poor in others. In the area just north west of the borax mine in Tick canyon there are only a very few exposures and the contacts are so vague due to the presence of drift over the whole section that accurate mapping was practically impossible. In Tick canyon itself the reverse is true and the exposures are very good. Much of the geology of the area may be seen by simply walking the length of Tick canyon. (See Plate II)

Acknowledgements

I wish to acknowledge the helpful criticism and suggestions of Dr. John H. Maxson of the California Institute of Technology under whose supervision the mapping was done. He did much to further the work as did many of the members of the staff of the Geology Department of the California Institute.

Stratigraphy of the Area

The rocks of the region may be divided into two formations separated by an unconformity of about 30 degrees and underlain by a basement complex which is metamorphic on the north and consists of the younger(?) San Gabriel igneous complex on the south. (See Plate III) The lower formation called the Escondido[1] formation contains interbedded tuffs, lava flows, sandstones and shales. The upper formation named the Mint Canyon[2] is a series of terrestial sandstones, conglomerates and mud stones. —In the area mapped the formation consists of red beds containing gypsum overlain by a series of alternating mud stones, sandstones, and conglomerates, which are in turn overlain by a thick series of terrestial terrace gravels.

The Escondido formation outcrops with a thickness of a little more than 3500 feet in Tick Canyon just north of the Davenport road. Through this part of the region they are rather fine grained and show very good bedding. Farther to the east the Escondido formation becomes a great deal coarser and is composed of large poorly sorted conglomerates showing little or no bedding. The character of the material in the eastern part of the region indicates that it has been transported only a short distance and has been derived

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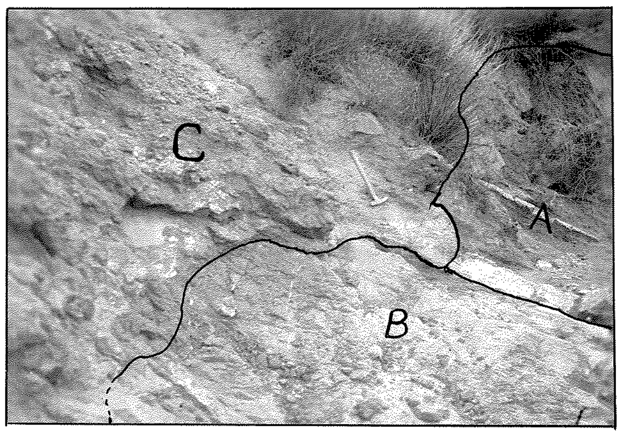
1. So named by Hershey, O.H., "Some Tertiary Formations in Southern California"; Am. Geol., vol. 29, pp. 350-355, 1902.

2. Kew, W.S.W., "Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California.", U.S. Geol. Survey, Bull. 753, 1924.

Plate III.

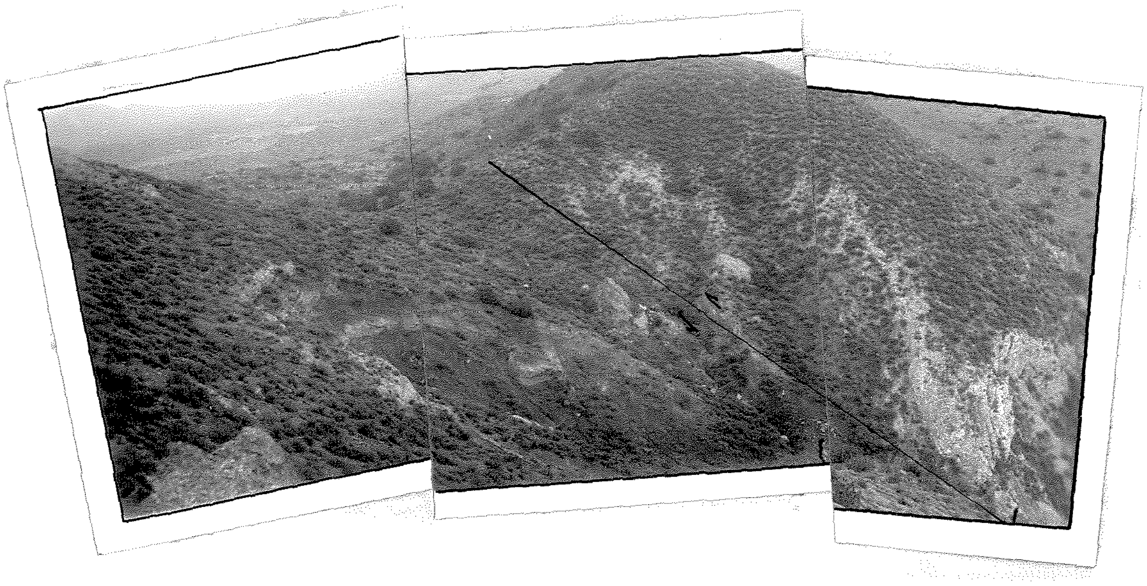


Unconformity between Mint Canyon formation (C), Escondido volcanics (B), and Escondido sediments (A).

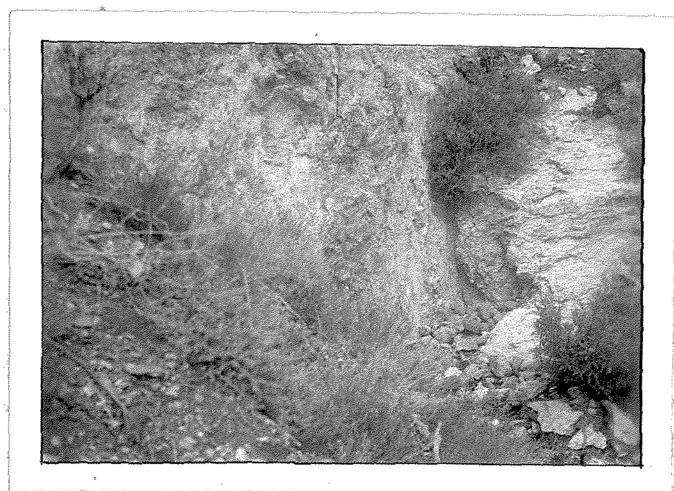
from all of the basement rocks which outcrop in the region. Around the upper end of the basin the igneous history has been very complicated and Sierra Pelona ridge while being made up very completely of schist at the western end has been intruded by quartz-syenite and other igneous rocks at the eastern end. In the coarse conglomerates it is easy to determine the source of the sediments, but as the section is followed to the west the formation becomes successively finer grained. The larger eastern portion of the formation is cut off by a large fault from the western part. (See Plate IV) The finer grained seds are also incorporated in a large syncline which pitching toward the west, also tends to separate them from the eastern part of the section. In the area mapped we are concerned only with the finegrained sandstones, shales and tuffs.

The sandstones form the greater part of the sediments in the section and are generally reddish colored or a yellowish brown. They are very finegrained and in massive well-bedded units between 1 and 20 feet thick. (See Plate II) While they are not too well cemented, they are very compact. The cement is calcareous, the rock effervescing freely in cold dilute HCL. The grains are mostly very minute quartz grains combined with another mineral which could not be determined from the hand specimen: it may possibly be a feldspar. There

Plate IV.



Fault to east of area showing red beds of the Mint Canyon formation faulted against gypsiferous Mint Canyon conglomerate.



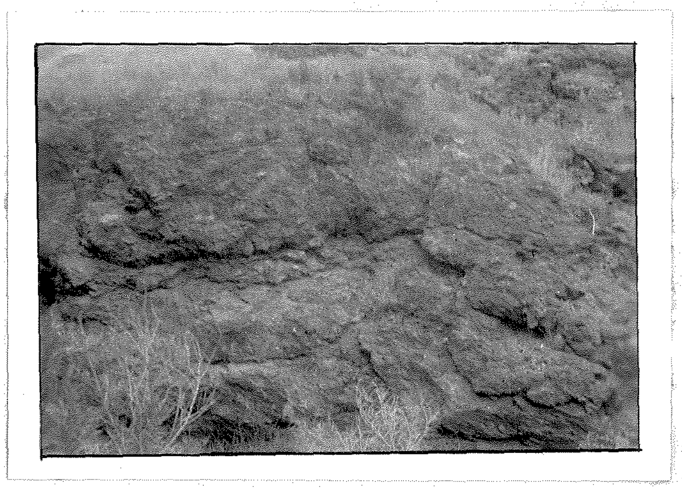
Detail of Gouge zone on fault pictured above.

are numerous flakes of chlorite which is apparently the only dark constituent. The reddish color is undoubtedly due to iron coloration. This is a typical sediment in the Escondido formation. The sediments make up about one third of the section, the remaining two thirds is made up of lava flows.

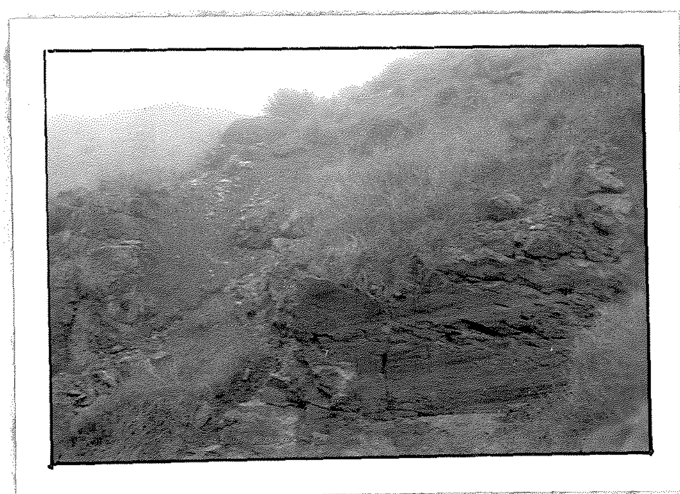
The flows are generally andesites. They are rather vesicular and large quantities of chalcedony amygdules can be picked up from the surfaces of weathered flows. Many of the cavities are also filled with zeolites, principally analcite and chabazite. The andesite is rather dark colored weathering to a light reddish brown. In the hand specimens from the ordinary flows no varietal minerals can be identified, although Bonillas reports Hypersthene andesites from Tick canyon. Well-twinned plagioclase phenocrysts are numerous, but they are rather severely decomposed. The most spectacular flow in the region is an andesite which is a true flow breccia (See Plate V) containing inclusions of sandstone and shale in addition to inclusions of basaltic glass and andesite. This is a very resistant rock and it has weathered to very sharp promonontories thereby serving as good marker bed.

There are a few beds of tuff (See Plate XII) interbedded with the flows, which are very clearly defined because of their typical white color. They

Plate V.



Outcrop of andesite flow breccia in Tick Canyon.



Slickensiding in flow breccia along Borax Mine fault in Tick Canyon.

contain very few dark minerals, being made up almost exclusively of feldspar grains and fragments of other light colored rock.

The only members of the section left are the sandy shales and the very coarse sandstones found near the top and bottom of the section respectively. The coarse sandstones have nearly the same composition as the typical members described above and grade into conglomerates at the very base of the section. These conglomerates are fairly angular indicating that they are not far from their source. The boulders are mostly of the basement rock of the country, chiefly being hornblende quartz-diorite with the other types also well represented. They are imbedded in a sandy matrix very similar to the above mentioned sandstones. Traveling to the west along the strike of beds in the base of the section the conglomerates become very thin and are overlain by red beds and a thick lens of gypsiferous strata. The gypsum occurs in beds from a few inches to nearly a foot in thickness. It is interbedded with mud and fine sandy shale which is also included in the gypsum itself. (See Plate X) There are small veinlets of secondary selenite which has been apparently dissolved and reprecipated.

The sandy shales (See Plate VI) are more important as they form the wall rock for the borax beds. On the footwall of the borax beds, they are fine sandy, mud-like, purple shales grading into greens and browns. In the hanging wall they are very sandy with great numbers of concretions of sandstone much like the type sandstone but not calcareous. These very sandy members are brownish with little flecks of red limonite all through them. The contacts with the borax beds are not sharp but gradational. The chief borax mineral obtained is colemanite with also howlite and ulexite. The material is mostly massive with the ulexite and the howlite occurring in the so-called "puff-balls". The good borax beds are only about five feet wide and confined to one horizon so that the grade of the ore is rather low. (See Plate VI) The deposit was mined from about 1910 to 1921 or 1922 by the Sterling Borax Company but has been shut down for many years. The presence of ulexite appears to be rather conclusive evidence for a playa lake type of deposition.

The complete Escondido section represents a continous deposition interspersed with lava flows in a rather arid isolated basin. Starting at the base of the column, there was a short period of rapid deposition during which time only coarse conglomerates were laid down overlain by rather coarse sandstones. The sandstones are less and less coarse as the section becomes thicker. These are followed by a series of

Plate VI.

Shales in footwall of borax beds. Borax Mine, Tick Canyon.

Borax beds, showing contortion and relation to shales of the footwall. Borax Mine, Tick Canyon.

lava flows. Most of the flows are acidic enough to be classed as andesites and reach a thickness of nearly 2000 feet. Over the whole region the flows were not continuous and interbeds of sandstone and conglomerate are found in what were probably old stream courses in the flows. These are followed by more terrestial deposition with finegrained sandstones and sandy shales. Above these occur a few small beds of tuff with interbedded andesite flows and sandstones. Overlying these the large flow breccia is followed by a few beds of fine-grained sandstones and shales with these overlain by the shales of the playa lake and the borax beds. The borax beds are overlain by a series of shales which become sandy and finally grade into fine-grained sandstones. The sandstones exposed to a thickness of about 650 feet in Tick canyon are overlain by another andesite flow and then the section is covered by the Mint Canyon formation. Because of the high degree of contortion and the great amount of faulting in the section an accurate measure of the thickness is difficult to obtain and I have estimated the total thickness that is exposed as about 4000 feet.

For the sake of description the Mint Canyon formation may be divided into two distinct members: A series of very coarse conglomerates and a series of fine sandstones, mudstones and ash beds. All of these are more or less calcareous and some contain gypsum. The gypsiferous beds are near the base of the section and probably indicate arid conditions much as when the Escondido was being laid down. (See Plate IV) The section is composed almost entirely of coarse conglomerate lenses and beds, some very huge, indicating more of a flood plain or valley deposition than in Escondido time.

The conglomerates are very massive and make very bold outcrops wherever erosion has cut them to any extent. (See Plate VIII) They contain grains ranging in size from small peas to boulders 1 and 2 feet in diameter. The principle boulder constituents are the basement rock and the San Gabriel anorthosites, but there are also rounded pebbles and boulders of the Escondido andesite flows and some of the more resistant sandstones. The matrix is very sandy and calcareous, with the rock very well-cemented and very hard. It is more or less typical that they are a dull brown color but they may be green or reddish brown. In the southern part of the area where they have been derived almost exclusively from the anorthosites they are a grey white. The beds are in units measurable in feet and in tens of feet and dips and strikes cannot be obtained from them directly but must be determined indirectly by sighting on points of equal elevation in the same bed.

In their massive units they are well stratified and fairly well-sorted, but in detail they show no sorting whatsoever. When a specimen is studied carefully, pebbles from nearly every formation known within the confines of the basin may be identified in the conglomerate no matter from what part of the series the specimen is taken. (See Plate II)

The sandstones are generally very thinly bedded and weather to a crumbly, shaly mass. They are very fine-grained grading into the mudstones. No mineral species can be recognized in the hand specimen, but from the way in which these sandstones react to weathering I would suspect that they consist mainly of quartz grains cemented with a slightly calcareous cement. They are very brittle and fracture easily. They are colored either reddish, reddish brownish or greenish, typically with alternating bands of red and green and these interbedded with a green or brown conglomerate.

The ash beds are rather limited in extent and do not make up very much of the section. They are composed of fragmental material which has been cemented by a calcareous cement but in which the fragments are highly siliceous. This combination causes the beds to be very resistant except when they are exposed in the bed of a wash. They thus form ridge caps and very prominent features wherever they are relatively free from flowing water. They contain large quantities of fossil twigs in many places. They are generally very white just as the tuffs of the Escondido formation. The twigs in them have become thoroughly silicified, and there has been some recrystallization around them.

The stratigraphy of the Mint Canyon formation presents a distinct problem in itself and is being made the subject of very detailed study for a minor thesis for a doctor's degree by Richard H. Jahns at the California Institute of Technology. Within the scope of this paper only a generalized section can be given. The base of the formation in this area consists of a series of mudstones, slightly calcareous, which generally dip less steeply than the overlying conglomerates. The conglomerates are well-stratified in this part of the section and overlain by more mudstones which are slightly sandy. Then follows a very thick section of alternating conglomerates, sandstones and mudstones with an occasional bed of ash or tuff. Toward the top of this series, the conglomerates become thicker and more angular and less well-bedded. They are overlain by a thick series of terrace gravels showing no sorting and rather angular large fragments mixed with smaller rounded pebbles. These terrace gravels have some old terraces cut on their surfaces by the old Mint Canyon stream, which flowed in post

Mint Canyon time. The terrace gravels seem to indicate a flood plain or old valley type of deposition as the last phase of the period during which the Mint Canyon formation was laid down.

In contrast to the Escondido formation, which contains no fossils at all, the Mint Canyon formation contains, in certain isolated portions, fragments of limb bones, and horse teeth. These, however, are not plentiful, and the dating of the formation by means of these fossil remains has been rather difficult. Among the diagnostic fauna that have been found are two camel skulls which were found by Dr. J. H. Maxson[1] of the California Institute of Technology. These have been identified by Dr. Maxson as being a high middle or upper Miocene species but it is evident that a great deal more work must be done before the exact age of the formation can be determined. The fossils occur in only the mudstones and ash beds and seldom appear on the surface except as a powdery drift to which they decompose. The points where fossil remains have been found are indicated on the map accompanying this report. In time I believe that enough diagnostic forms may be found to perfectly date the formation but a great deal of work remains to be done.

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1. Personal communication.

The other rocks in the area, comprising the two types of basement complexes are the San Gabriel anorthosites and the southeastern extension of the Pelona schist. I have referred to this extension of the Sierra Peolona ridge as the Pelona schist somewhat erroneously, as there are no true Pelona schist outcrops found in the area. The ridge in this part of the area has been faulted off and separated from the main mass of the Sierra Pelona by Mint Canyon. Thus the basement rock on the north of the area is really an outer facies of the San Gabriel batholith. It is separated, however, from the main body of the batholith by the Soledad Canyon fault and is an isolated fault block transitional between the San Gabriel block and the older (?) Pelona Schist. The rock is a complex series of diorites, quartz-diorites and syenites. E.C. Simpson[1] describes it as being quartz-diorite for the most part grading into hornblende diorite on one hand and aplite on the other. There is some quartz monzonite also in this series. The dioritic rocks have hornblende for their chief ferro-magnesian constituent while the monzonites contain mostly biotite. These rocks can be

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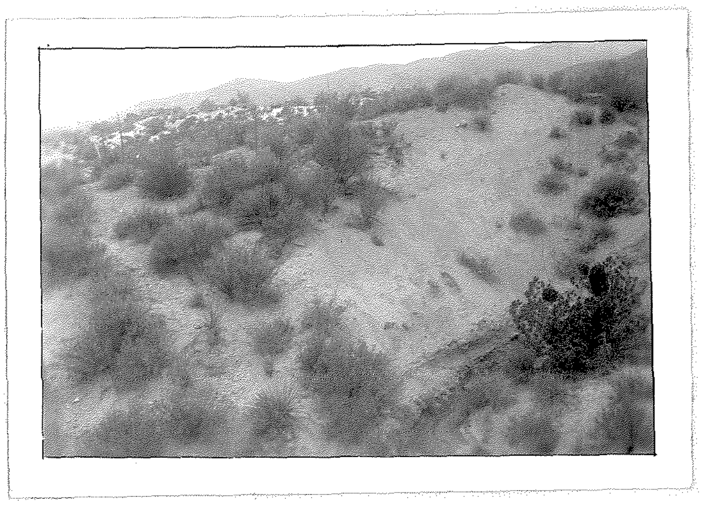
1. Simpson, E.C., "Geology and Mineral Deposits of the Elizabeth Lake Quadrangle, California", Calif. State Mining Bureau, 30th Report of the State Mineralogist, 1934, pp. 371-415.

Plate VII.



Weathered mudstone outcrop in Mint Canyon formation. Champion Mine Road.

Outcrop of anorthosite in Soledad canyon showing basic dikes. Soledad Spring.

traced into some of the Mint Canyon conglomerates where they are easily differentiated from the andesites and the anorthosites. The relations between each of the facies are very complicated and according to Simpson[1] the contacts are all gradational indicating that the intrusions are more or less contemporaneous. The whole series is cut by quartz veins intruded along faults and fractures, somewhat lens-like and pinching in and out throughout the series. There are no continuous features in the area except for a rather general schistosity which strikes parallel to the basement fault throughout the area and may be correlated with the faulting on both sides of the block.

The anorthosite of the San Gabriel batholith were first described by W. J. Miller[2] in 1931. The plagioclase feldspar has been shown to be somewhat more sodic than Miller[2] thought, being in many cases andesine. The rock is cut by many basic dikes and somewhat to the south has been found to merge into a facies containing large segregations and concentrations of magnetite and ilmenite. In the only outcrop in the area in the extreme southeastern corner, the rock is grandly exposed

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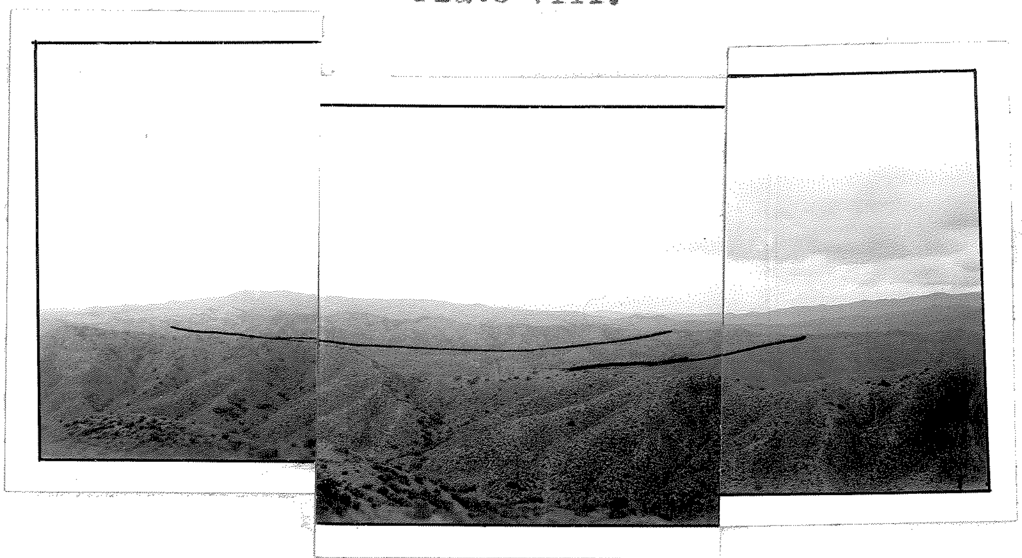
1. Simpson, E.C., Ibid.

2. Miller, W.J., "Anorthosite in Los Angeles County", Jour. Geol., vol. 39, pp. 331-344, 1931

Plate VIII.



Gentle syncline in Mint Canyon formation looking west from Tick Canyon.

Pitching anticline in Mint Canyon formation looking south from Davenport Road. Beds on extreme right dip westward, while those on the left dip to the south. Note boldness of conglomerate outcrops.

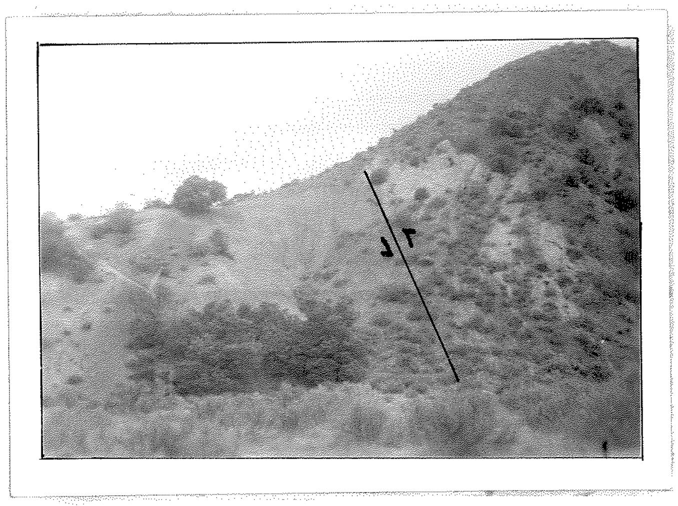
in the road cuts of the Soledad Canyon road. (See Plate VII) It appears very fresh and is fairly resistant to weathering. The Mint Canyon formation which is faulted against the anorthosite has been derived from it almost entirely and is a white conglomerate, very coarse. Even in the boulders of the Mint Canyon formation the anorthosite is remarkably fresh, a feature which must be attributed to its more sodic composition.

Structure of the Area

The structure of the region is rather complicated in localized areas but is generally rather simple. Having been deposited in a rather local isolated basin, the region has also been rather isolated from anything but local structural disturbances. The Escondido formation shows a great deal of deformation and faulting in the particular area mapped, but farther to the east in the type locality in Escondido Canyon it has been only slightly folded. The Mint Canyon formation shows only one large syncline and one anticline (See Plate VIII) in the area mapped but as the formation is followed westward more folds appear on both the north and south. The basement complexes have been faulted up on both sides of the basin and the influence of these large faults has made itself felt to some extent in the sediments lying between. The general rule seems to show that the upper end of the basin has suffered relatively little deformation while the sides have been more or less crumpled. As should be expected the center of the basin has been relatively undisturbed, showing only large open folds and small local faults.

In the area mapped, the Escondido formation is rather complicated structurally. The dominant feature is the steep attitude of the beds which are all dipping to the south at angles of from 70 to 90 degrees. There are a few exceptions to this but I will show the reason for these in a moment. The steepest dips are very near the basement contact some being northward and gradually become shallower toward the southern part of the section. Just before the Escondido formation disappears beneath the Mint Canyon formation a series of tight synclines and anticlines may be seen just to the east of my area. These would seem to be simply drag folds on the limb of a larger pitching syncline which is indicated by lessening of dip toward the south and can be conclusively demonstrated farther to the east. The dips in the extreme northern part of the formation near the basement contact are clearly the result of faulting along the basement contact. As the fault here is a steep reverse fault the beds have been overturned in places due to the movement and thrusting action on the basement fault.

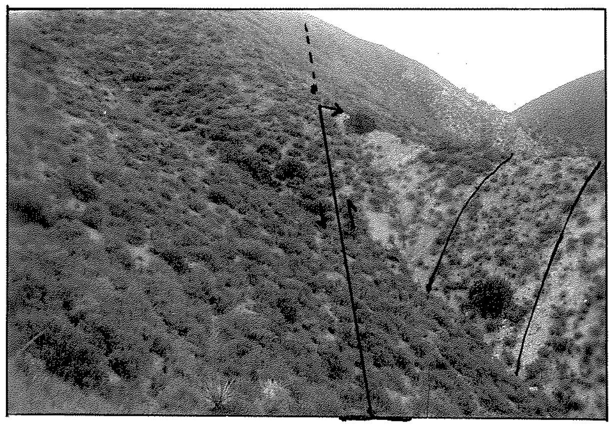
Plate IX.



Outcrop of Basement fault in Mint Canyon north of Davenport Road. (A) Mint Canyon formation. (B) Basement.

The formation is cut by a large number of faults, some of which have controlled the present topographic features and others which are of minor importance. The fault of major importance in this series is the fault dividing the basement complex and the formation. From this point on it will be referred to as the Basement fault. This fault outcrops on the western side of the Mint Canyon highway just north of Davenport road. It is here exposed as a steep reverse fault with a dip of about 70 degrees. (See Plate IX) The northern side has gone up raising the basement high above the level of the surrounding area. At this point of its outcrop it is in contact with the lower part of the Mint Canyon formation but across the highway to the east it is in contact with Escondido and remains that way throughout the rest of the area. About half a mile east of the highway the Basement fault is displaced by a small more recent fault which shifts the Basement fault about 250 or 300 feet to the north. (See Plate X) This fault also cuts off completely at this point the Escondido formation which reappears for a short distance about a quarter of a mile to the west. This cutting off of the beds and displacement of the basement contact were taken as evidence of faulting in addition to a drag effect which was apparent in the strike of the Escondido beds. No

Plate X.



Fault displacing Basement fault east of Mint Canyon. Arrow indicates strike of Basement fault. Note the gypsiferous beds of the Escondido formation dipping to north indicating overturning by Basement fault.

slickensides or direct evidence could be found at this point and the fact that the fault did not outcrop in the Mint Canyon formation on the southern side of the little valley across which it was striking suggested that the apparent cutting off and displacement were simply the results of a small turn in the Basement fault itself. This possibility was studied both in the field and at home on the map. The chief objection to it is that it requires the Basement fault to make two turns of nearly 90 degrees within 200 feet of length. While this is not impossible, it would seem much more logical to assume a more probable explanation. Another possibility which suggests itself is that we simply have two different basement faults giving an arrangement similar to an echelon faulting in sediments. This explanation is substantiated by the presence of a small amount of slice faulting about 200 yards farther to the east on the Basement fault. Also about 400 yards to the north of the Basement fault there runs a parallel fault in the basement complex which is indicative of a general fault zone rather than one clearly defined fault. However, these two faults diverge to the eastward and may be two separate zones of weakness rather than indicators of a large fracture zone. Thus the simplest explanation, that of a fault offsetting the Basement fault, was chosen as the most logical reason for the break in the contacts. With more detailed work in this particular area more evidence in support of one of these contentions may be found. The real proof of the existence of such a fault would be to trace it back into the basement complex. As the field work was supposed to be confined to the sedimentary formations this tracing was not attempted in the time allotted. The fault is assumed to die out under the alluvium because it does not appear on the south side of the valley, a phenomenom common in the Escondido rocks of the area.

The slice faulting just to the east faults in a small section of the Escondido both against the basement and itself, making a fault zone of the Basement fault rather than a well-defined fault. This zone merges into a single fault zone about 10 feet wide at its widest extent which becomes very hard to trace. It is offset again by another small fault with a displacement of about 300 feet near the center of the area. This figure is only approximate as the offset occurs in a zone of drift and the contacts can only be plotted approximately. The Basement fault can again be clearly demonstrated in Tick canyon with brecciation showing in the sediments for a distance of 20 or 25 feet to the south. After crossing Tick canyon the fault gradually turns southward and leaves the area trending about N30W.

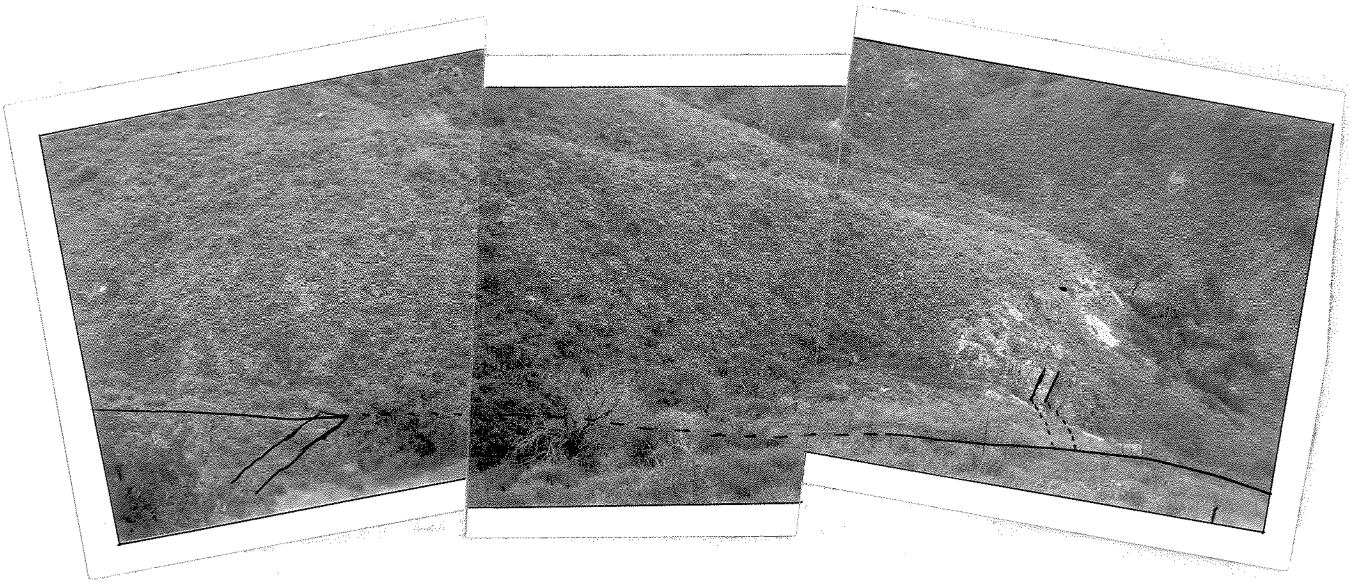
Plate XI.

Small scarp in andesite on Tick Canyon fault where Davenport Road crosses Tick Canyon.

Throughout its entire length in the area it has produced overturning in the beds very close to it and this is taken to indicate that it maintains its steep reverse character along this particular section.

Two other faults in the section have affected the physiography to some extent because of their offsetting of some of the very resistant andesite flows. The major one which I shall call the Tick Canyon fault trends about N40E as it enters the area and swings to the south down Tick Canyon striking the canyon just below the borax mine. (See Plate XI) It is traceable into the Mint Canyon formation for about one mile before it dies out. In the Escondido formation the only component which can be measured is a rather large strike-slip displacement, while in the Mint Canyon formation only a vertical displacement is apparent. The Tick Canyon fault intersects the other important fault in the area very close to the borax mine and offsets it about 150 feet. This fault which I shall call the Borax Mine fault is striking about N25W and shows a slight drag effect in its strike near its offset. (See Plate XII) The Borax Mine fault shows only a strike-slip component and offsets the Basement fault by about 200 feet. On the east side of the Tick Canyon fault, the Borax Mine fault dies out very rapidly and cannot be traced. More or less on the line of strike of the Borax Mine fault out of the area

Plate XII.



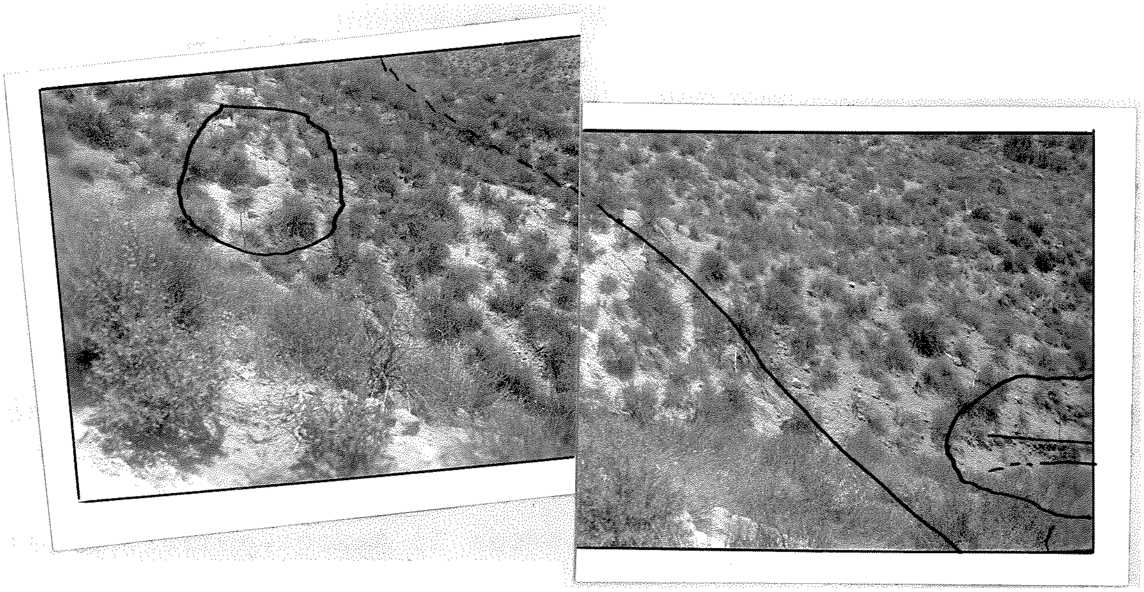
View of tributary to Tick Canyon
showing offset in beds on Borax Mine
fault. White beds on right are tuff.

to the east there is a highly fractured zone very close to the Mint Canyon contact which is also a fault contact at the extreme eastern edge of the area which may be the intersection of these two faults. If so, the extensive amount of fracturing which is more than would be expected at this point, is easily explained.

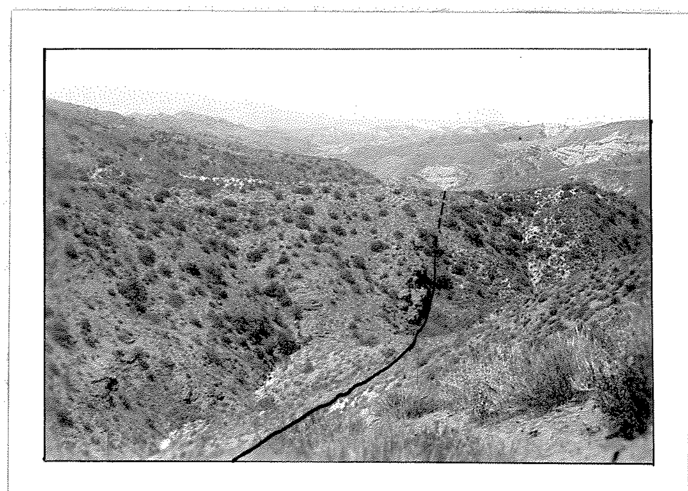
The fault along the Mint Canyon contact is short but it runs along the edge of an overturned anticline and is probably the result of a renewal of the same forces which caused the overturning of the fold. While the fault itself has a slight thrusting component, the greater resistance of the Mint Canyon conglomerates to weathering cause them to form a small scarp. (See Plate XIII) The fault is striking about N65E curving slightly to the south. To the east it dies out in the Escondido formation and to the west it dies out rapidly in the Mint Canyon formation. It has both a vertical and a strike-slip component with the vertical component much the larger.

There are numerous minor fractures scattered throughout the whole outcrop of the Escondido formation, particularly in the andesites. These minor faults are taken to simply mean rather large deformational strains over a short period of time and are probably contemporaneous with the extensive folding in the section. A typical fault of this type runs along a 20 degree

Plate XIII.



Detail view of fault between Mint Canyon and Escondido formations showing Mint Canyon conglomerates faulted against Escondido sandstones.



Small scarp formed by differential weathering on fault shown above.

change in dip in the borax mine but it outcrops in only one place and shows only a few feet displacement. Faults of this type could not be mapped on the scale which was used so they are indicated on the map by a small strike line and are only used to indicate from which directions the regional forces were applied.

As mentioned before, the Escondido formation is folded into a large syncline which is pitching to the west and which contains on its southern limb the overturned anticline spoken of above. This anticline, which is a normal fold farther to the east shows the overturning very nicely by dips of from 45 to 55 degrees on its north flank and dips of 65 to 75 degrees on its south flank. The Mint Canyon formation masks what else may happen farther to the south.

In direct contrast to the Escondido formation the Mint Canyon formation shows structures so vast that ordinary detailed mapping is very difficult to interpret, appearing on the surface to have a monotonous sameness. In the area there are two broad folds, pitching to the west, which dominate the structure. From north to south the section consists of a broad pitching anticline followed by a broader pitching syncline. (See Plate VIII) Locally to the east of the area there are small kinks on the nose of the syncline much as occur in the Escondido formation below. Going to the west the anticline disappears and the syncline becomes broader and broader. There are minor folds on the syncline far to the west near the contact of the Mint Canyon formation with the overlying Modelo series. In the area mapped only the suggestion of the major folds is apparent beause of the small width of the area.

There are no large faults in the area of the Mint Canyon outcrop in the area mapped. There are, however, innumerable small fractures some with only a few feet displacement which run at random throughout the entire formation. Some of the larger fractures of this type may be seen to control the drainage of the region because of the greater ease of erosion along the slightly brecciated zones. The Tick Canyon fault runs down Tick Canyon about three-quarters of a mile and dies out in a fractured zone which can be traced a short distance beyond although showing no displacement. (See Plate XI) It appears very probable that the course of Tick canyon has been controlled by this fault, insofar as it shows displacement down the canyon. The canyon has cut directly across two resistant lava flows in following the fault trace rather than erode the sediments which are less resistant.

Another canyon which shows a definite control by faulting is Spring canyon in the south eastern part of the area. At its extreme northern end to the east of the area mapped, a very large fault can be traced into the canyon and then the displacement can no longer be determined. The canyon runs very straight throughout the most of its length and seems to indicate a fault along it. Along the length of the canyon in many places a zone of much fracturing can be noted but no other evidences of faulting. It seems highly probable that the canyon has been controlled by faulting although the only evidence that can be found now is the fractured zone running down the canyon. These two fracture zones, the Tick Canyon and the Spring Canyon zones, constitute the only evidences of extensive faulting in the formation. All of the other faulting is very localized with faults having nearly 100 feet displacement dying out in 100 or 200 feet.

The detailed structure of the basement rocks was not studied, but enough mapping was done to establish one major fault more or less paralleling the Basement fault in the northern part of the area. Located at several points which show some mineralization are prospect holes and in its outcrop in Tick Canyon is located the Champion Mine. The mine is closed down now and filled but was apparently prospecting the vein for gold. In the extreme eastern end of the basin there is a producing gold mine located near Acton in the same type of rock, but there have been no values taken out in this vicinity. Numerous other faults cut the basement mostly trending parallel to the Basement fault and showing the same type of high angle thrusting. The displacement on these faults is not measurable but it is probable that they are in no way comparable to that on the Basement fault. They are probably fractures which took up some of the strain which was developed in the basement block due to the faulting up of it.

Thus we see that the principal deformation has taken place in the Escondido formation with the Mint Canyon only slightly flexed lying unconformably above it. From this consideration we must realize that the area has been relatively quiescent structurally for some time and much of the evidence indicating certain orogenic movements has been clouded or completely removed.

Historical Geology

The history of the region has been one of mostly sub-areal deposition in a rather arid climate. There has been a period of rather extensive structural deformation and the region has remained more or less static since with only a slight renewal of the forces from time to time. The basement complex is intrusive in origin but no residuals of the country rock into which it was intruded can be found. It is nearly certain that these intrusions have had some effect in metamorphosing still further the Pelona schist although Simpson[1] states that their intrusive relationship to the schists cannot be proved directly. Simpson[1] suggests that the basement complex may be pre-Cretaceous in age or perhaps associated with the same general period of late Jurassic and early Cretaceous intrusion as the Sierra Nevada and the San Gabriel batholiths. W. J. Miller[2] has reported an intrusive relationship between these rocks and the San Gabriel batholith and has expressed the opinion that this granitic series is of pre-Cambrian or even Archean age, but no evidence has been presented that would support and substantiate this view. I am inclined to believe that the basement in the area is no older than the Jurassic intrusions because of the lithologic similarity and because of the relative freshness of the rock.

Between the intrusion of the basement rock and the deposition of the Escondido formation there was a long interval of time for which no evidence is available within the confines of the area. Simpson[1] reports that the Escondido formation or rocks which he has correlated with the type Escondido of this area and

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1. Simpson, E. C., Ibid.
2. Miller, W. J., Ibid.

Escondido canyon rest unconformably on the Martinez formation of early Eocene age. The Escondido formation can therefore be no older than Eocene and no younger than late Miocene. The formation was laid down in a rather arid basin as indicated by the gypsum deposits in the western exposures. The conglomerates in the eastern part of the section show proximity to the source of the sediments which was a mountainous mass lying to the east and north.

Starting with the red beds in the western part of the area the basin was rapidly filled, much of this early filling being due to rather large thicknesses of lava flows which accumulated on the slopes and in the center of the basin. Between the periods of extrusion sedimentation took place and the sandstones and shales were laid down along with the tuffs. All of these deposits were sub-areal and formed by terrestial deposition. After more lava flows were extruded, the basin became somewhat dammed and drained more slowly causing a playa lake to be formed. In this playa the finely bedded shales were laid down and the waters which were leaching the lava flows and sediments of their soda and calcium content in the form of soluble salts began to be concentrated in the playa.

The volcanic activity is believed to have furnished the boron for borate ions because, as the deposits are interbedded with lava flows, it is highly probable that hot springs and fissures which were relatively rich in boron solutions were very active at the time. This is not uncommon phenomenon as the same type of deposition is occurring at the present day at Sulfur Bank, Lake county, California. The concentration of sodium and calcium borates, in this manner will form only ulexite, while the major ore mineral in the deposits in Tick canyon is colemanite.

Eakle[1] and Gale[2] considered that the colemanite was formed by replacement of a limestone or marl country rock by hot, concentrated solutions of boric acid emanating from the lava flows. An older theory held that the colemanite was formed by chemical precipitation during periods of great aridity. Foshag[3] states that Van't Hoff's work demonstrates that, under the conditions existing in playa lakes, ulexite forms instead of colemanite and in order to split the ulexite into the single sodium and calcium borates, the sodium borate must be removed as fast as it is formed.

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1. Eakle, A.S., University of California Publication Department of Geology, vol. 6, No. 9, 1911.

2. Gale, H.S., Professional Paper 85, U.S. Geological Survey, p. 3, 1914.

3. Foshag, W.S., "The Origin of Colemanite Deposits in California", Economic Geology, vol. 16, pp. 199-214, 1921

Plate XIV.

Latest lava flow of Escondido formation in Tick canyon looking south. Note extreme fracturing and contortion due to Tick Canyon fault which passes about 100 yards to the east of this point.

Foshag[1] further states that the origin of the colemanite is due to the conversion of the ulexite by percolating chloride solutions after deposition. These opinions are based on field evidence collected for the most part from the Tick canyon mine so I believe that Foshag's theory best explains the origin of the borax deposits.

After the deposition of the borax beds the sedimentation continued with one final period of igneous activity. (See Plate XIV) The remainder of the depositional history is masked by the overlying Mint Canyon formation. While the whole series is conformable there are slight local unconformities between various beds indicating at least a seasonal rather than a continuous deposition.

Following the period of deposition, the area was subjected to compressive forces trending nearly north and south causing a fairly high degree of folding into a large syncline with smaller anticlines and synclines on its southern flank, indicating that the major forces were from the south. The beds were tilted rather sharply and differential erosion began on the lava flows and the sediments. Due to the same forces which caused the folding some faulting occurred, but this earlier

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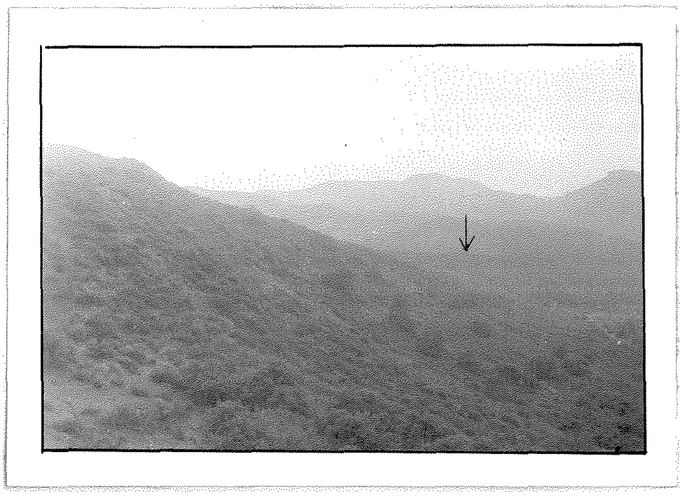
1. Foshag, W. S., Ibid.

faulting has been fairly masked by a renewal of movement along the old lines at a much later time. From the present evidence the Tick Canyon fault is the more recent movement, but it is certain that it has been displaced at least once by the Borax Mine fault. This is indicated by the large amount of fracturing and slickensiding found in the flow at the borax mine dump. (See Plate XIV) The differences in thickness of the outcrops on opposite sides of the fault indicate a greater amount of vertical displacement than is measurable on the most recent movements as shown in the Mint Canyon formation farther south. Following this period of movement the region was subjected to a long interval of erosion. After being reduced greatly during this time, the orogenic forces set in once again. During this period the Basement fault appeared causing uplift, overturning of some of the beds in the Escondido and renewal of faulting along the old lines. Again the forces were compressional from north and south, as indicated by the steep reverse character of the Basement fault. Probably during this time the most of the cavities left in the borax beds by the conversion of ulexite to colemanite were removed by the compressing and compacting of the beds due to these forces. With the appearance of the basement, the area was rejuvenated and the Mint Canyon formation began to be deposited on the Escondido erosional surface. This surface was not a peneplane by any means but it was flat enough to allow deposition to occur on it with the renewal of erosion.

Shortly after the renewal of the erosion and the deposition of the basal part of the Mint Canyon formation, the San Gabriel anorthosites arose rather suddenly and great sheet floods of very coarse and very angular fanglomerates were laid down in the Mint Canyon formation. These did not extend very far to the north or west but graded into the finer and more rounded sediments coming from the northern basement. At intermittent times during this period there was activity on the Basement fault maintaining a fault contact with all of the formations during the major part of the period. After the deposition of the heavy basal conglomerates which were deposited in periods of heavy flood during a relatively arid period, the old valley deposits of mudstones and sandstones were laid down. At times, very thin beds of volcanic ash were laid down indicating volcanic activity somewhere in the vicinity but not in the Mint Canyon formation itself. The deposition of the Mint Canyon formation was apparently accompanied by a regional planation because another period of coarse terrace gravels followed the flood plain deposition which was itself interspersed with periods of heavy erosion as evinced by the conglomerates in the section. The formation of the terrace gravels indicates that the streams which were flowing down Mint Canyon, Soledad Canyon and Tick Canyon were approaching grade. (See Plate XV) Before very extensive terraces were cut in the area, there was a general regional uplift accompanied by a last renewal of faulting along all of the old fault lines. This took place in a definite order with the Basement fault moving first, then it was displaced by the small fault near Mint Canyon and also by the Borax Mine fault which was in turn offset by the Tick Canyon fault. This final displacement was only a matter of 75 or 100 feet which died out rapidly to the south. During this time the only deformation which occurred in the Mint Canyon formation took place. The syncline and anticline which were almost entirely depositional in origin were flexed slightly and made continuous. In the overturned anticline the deformational limit was reached and a steep reverse fault appeared on the south limb of the anticline, faulting the Escondido formation against the Mint Canyon formation. (See Plate XIII) Since these movements the area has been undergoing erosion in a desert climate and its present topography is due to the relative resistance of the formations rather than any structural controls. The streams which

Plate XV.



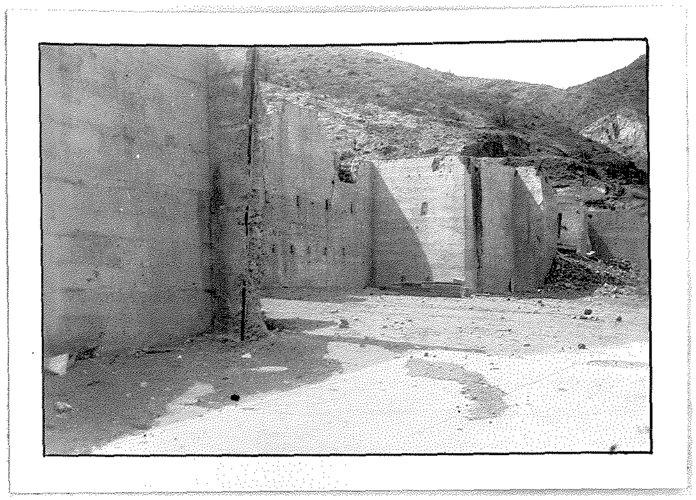
Pleistocene (?) terrace formed by Tick Canyon.

were determined by structures much earlier in their history have maintained their courses by rapid down-cutting to keep pace with the regional uplift.

The history of the region may be summarized as follows:

1. Intrusion of the basement complex into an unknown country rock. Tentatively dated as being pre-Cretaceous and no older than Mesozoic.
2. Long interval of erosion during which the old country rock was extensively eroded.
3. Deposition of the Escondido formation basal conglomerates and coarse sandstone. No earlier than Eocene and no later than middle Miocene.
4. Continued deposition of the Escondido formation with extrusions of lava from time to time.
5. Formation of the playa lake and deposition of the borax beds followed by a period of sedimentation and extrusion.
6. Close of depositional period with intensive folding and faulting. Uplift causing rapid erosion.
7. After some erosion, faulting on the Basement fault began and the first Mint Canyon formation appeared. Dated by fossils and structure as being upper Miocene just earlier than Modelo time.

Plate XVI.



Ruined workings of Borax mine in Tick Canyon indicating extent of the plant.

View of cut in lava flow for narrow gage railway from Lang. Slope on right is portion of one of the mine dumps.

8. San Gabriel anorthosites faulted up and sheet flooding.

9. Deposition on old valley surface in the Mint Canyon with the laying down of extensive terrace gravels.

10. Slight rejuvenations causing the cutting of stream terraces, followed by a general regional uplift and a renewal of faulting along the old fault lines in a definite order. Old terraces probably Pleistocene and later.

11. Recent erosion reducing the area to its present topographic level. (See Plate XV)

Economic Deposits

The economic possibilities of the area have been rather thoroughly exploited and after being worked for varying lengths of time have been abandoned. Chief among these was the borax mine in Tick canyon, which was large enough to merit a narrow gauge railway from the main line of the Southern Pacific in Soledad canyon to the mine. The mine was worked for about ten years before being forced to shut down due to competition from Trona. (See Plate XVI)

A drift was put into the gypsum beds in the Escondido formation evidently attempting to exploit the deposit, but very little work was done. The deposit is very extensive but is highly impure and of a low grade. Numerous prospect holes have been put into outcrops of small faults in the basement complex looking for gold in the quartz intrusions of these rocks. These have also been generally unsuccessful. A large prospect called the Champion mine was sunk on the major fault paralleling the Basement fault, but this was also unsuccessful. These many prospect holes now furnish good wells and good water may be obtained from them. The extensive faulting in the area has also served to make good water traps in many places and year-round wells are common.

The most recent venture in the region was the drilling of an oil well apparently trying for the axis of the overturned anticline but in reality it was directly on the axis of the large pitching syncline. There are no outcrops of oil bearing strata or of the rocks generally considered to be the source rocks of the oil in this general Ventura basin, so the chances for success are very small. At this writing the well was shut down for temporary repairs and I doubt if it will ever be reopened.

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