# G E O L O G Y   O F   T H E   U P P E R
# T I C K   C A N Y O N   A R E A,
# C A L I F O R N I A


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## ABSTRACT

The rocks of the upper Tick Canyon area comprise a pre-Cretaceous crystalline complex ("basement complex" ), the Oligocene (?) Vasquez formation, the lower Miocene Tick Canyon formation, the upper Miocene Mint Canyon formation, and Quaternary terrace deposits, alluvial fan material, and stream deposits. The oldest rocks are schists and gneisses, intruded by granitic rocks.

The Vasquez formation, more than 4,000 feet thick, contains fanglomerates, arkosic sandstones, fine-grained lake deposits, and volcanic flows. It lies against or upon the rocks of the basement complex in places with fault contact and elsewhere with depositional contact. It dips steeply, and in places it is folded into anticlines and synclines that gently plunge south of west. It contains faults of predominantly strike-slip motion in northeasterly or northwesterly direction.

The Tick Canyon formation consists of fine- rained arkosic sandstones and coarse-grained conglomerates. Its average thickness is about 600 feet. It lies with strong angular unconformity upon the eroded beds of the Vasquez formation.

The Mint Canyon beds are coarse-textured fanglomerates with some interbedded finer-grained arkosic sandstones. The Mint Canyon formation is disconformable upon the beds of the Tick Canyon formation.

The Tick Canyon and Mint Canyon formations dip moderately

to the southwest and are slightly folded and faulted along lines of deformation previously extablished during folding of the Vasquez rocks.

Some of the structural features of the area may be related in origin to the San Andreas rift.

There has been some mining in the area for gold and other metals and for borax and gypsum.

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INTRODUCTION

This paper presents the results of a study of the areal geology of the northern part of the Lang Quadrangle, California. The work was done in partial fulfillment of the requirements for the degree of Master of Science in Geology at the California Institute of Technology. Approximately thirty-five days during the years of 1949 and 1950 were spent in the field.

The area lies in the northeast part of the Ventura Basin, approximately 65 miles north of Los Angeles (Fig. 1). It is bounded on the west by Mint Canyon and on the east by Agua Dulce Canyon, and contains most of the northern portion of the drainage basin of Tick Canyon. The area comprises about eight square miles.

The area is fairly well populated, and numerous roads, most of which are unpaved, provide easy access by automobile. U. S. Highway 6 passes through Mint Canyon.

The climate is semi-arid; the mean annual rainfall at Newhall is 17.05 inches, and the mean annual temperature is 61.5° F. According to Kew (5, p.5)* most of the rainfall occurs during the months from November to March. Some snow generally falls in December and January, but rarely remains on the ground for long periods. There are no permanent streams in the area.

*- Citations in parentheses refer to publications listed at the end of this paper.

The vegetation is of the Sonoran type. Sage, yucca, manzanita, and scrub pine grow on the north-facing slopes. A few cottonwood trees grow along the larger stream channels. Density and pattern of vegetation seem to be controlled mainly by moisture. The north-facing slopes contain the more luxuriant growth. They are less exposed to the direct rays of the sun and can retain moisture for longer periods than can the south-facing slopes. In places the manzanita is so dense on the north-facing slopes that it becomes a serious hindrance to mapping.

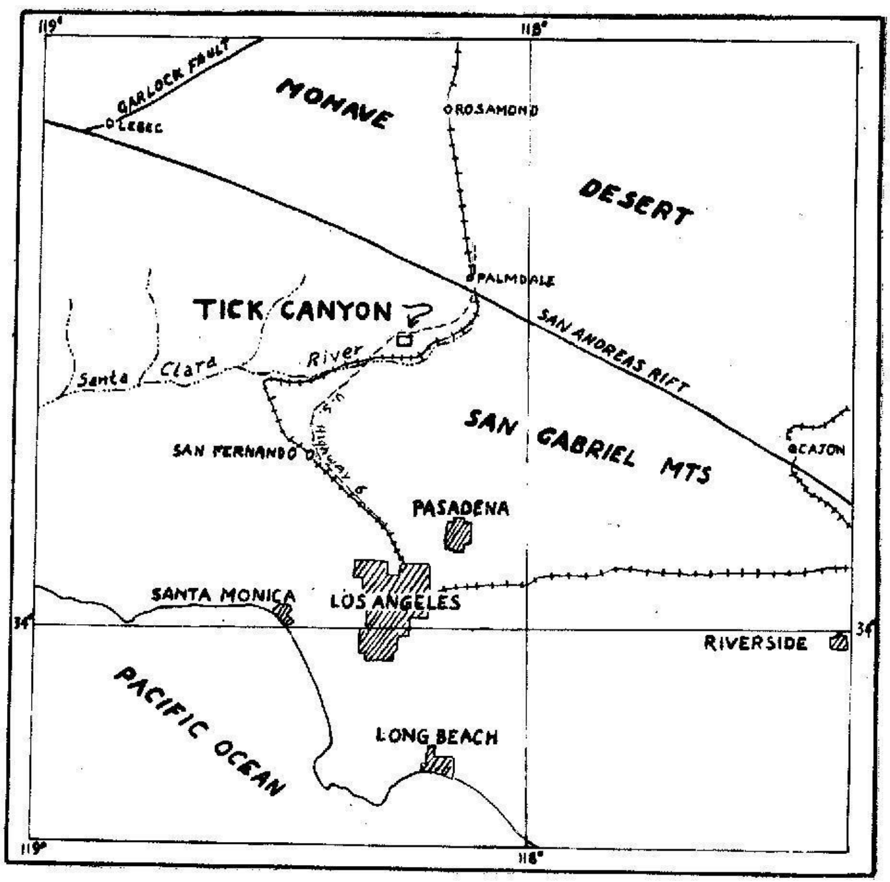


Figure 1. Geographic location of Tick Canyon area.

## TOPOGRAPHY

The highest point in the area, the top of a lava hill about 1/2 mile northwest of the Green Ranch, is about 4,000 feet above sealevel. The lowest is about 1,900 feet above sealevel and occurs in the southermost part of Tick Canyon within the area mapped. The local relief averages about 300 feet. Many of the ridge crests are accordant, and there are remnants of upland showing gentle relief.

The major drainage systems are Mint Canyon, Tick Canyon, and Agua Dulce Canyon, which trend southwest and south. They carry water from the Sierra Pelona into Soledad Canyon and the Santa Clara Valley. The stream patterns are partly dendritic and partly controlled by the structure of the underlying rocks. South of the area mapped, there is enough modification by structure to cause a strong southwest lineation of major and secondary canyons. The dendritic appearance of the upper Tick Canyon drainage is partly fortuitous because many canyons are along structural features so oriented as to give a dendritic effect.

# STRATIGRAPHY

## General Statement

The rocks of the Tick Canyon area consist of pre-Cretaceous crystalline ("basement") complex and overlying Tertiary non- marine sedimentary and volcanic rocks. The rocks are exposed in the northern part of the area. The overlying sedimentary section is progressively younger from north to south, and comprises the Vasquez, Tick Canyon, and Mint Canyon formations. Terrace gravels and alluvial sands and gravels are of Quaternary age.

Some of the previous mapping of the area had been done by Kew (5,pp.1-202) assisted by Buwalda. Kew recognized and named the Mint Canyon formation, pointing out its general stratigraphic relations. Later Jahns (4, p.152) on the basis of faunal and stratigraphic evidence, suggested separation of the lowermost beds of Kew's Mint Canyon formation, and to these he applied the name Tick Canyon formation. According to Jahns (4, p.177), the ages of formations described in this report are as follows:

| Age | Unit |
|---|---|
| Pleistocene and Recent | Alluvial sands and gravels<br>Terrace gravels |
| Upper Miocene | Mint Canyon formation |
| | |
| Middle Miocene | Tick Canyon formation |
| Lower Miocene | |
| Oligocene | Vasquez formation |
| Pre-Cretaceous | Basement complex |

The writer found no fossils that enabled him to separate the formations, but the rock units were easily distinguished by structural and lithologic features. The contact between the basement complex and the Vasquez formation is very steep and in places overturned. In some places it appears to be a depositional contact, but throughout most of its extent it is a fault. The Vasquez formation is moderately tightly folded in places and dips steeply in most of the area mapped. It is overlain nonconformably by the more gentle, southwesterly dipping beds of the Tick Canyon formation. The contact between the Mint Canyon and Tick Canyon formations is more difficult to recognize. Both formations have approximately the same attitude, but whereas the upper part of the Tick Canyon formation consists mostly of fine-grained siltstones and shales, the lowermost Mint Canyon beds are coarse conglomerates.

## Basement Complex

The rock unit referred to as the "basement complex" consists of intensely sheared and deformed metamorphic rocks that have been intruded by plutonic rocks which may be equivalent in age to the Sierra Nevada intrusives of Jurassic age. Thus this crystalline complex is thought to be pre-Cretaceous. The metamorphic rocks include schist, gneiss, and some quartzite; the plutonic rocks are gneissic, and are mainly of dioritic composition. A few pegmatite stringers occur within the area. Foliation is generally parallel to the Vasquez contact. It is likely that at least some of this foliation is secondary. In general, the basement complex forms poor outcrops.

The contact is everywhere steep and in some places overturned. That the contact is generally of the fault type was determined by two lines of evidence: the sudden disappearance of thick Vasquez conglomerate beds when traced laterally along the contact, and the increase in intensity of shearing of the basement rocks as the contact is approached. South of the Champion mine, the contact is marked by coarse conglomerate beds which may be in depositional contact against the basement complex. These can be traced westward into Tick Canyon. The contact is here mapped as depositional. East of this area, the disappearance of the conglomerate beds indicates considerable faulting along the contact. To the west the conglomerate beds are present, but the contact where seen is intensely sheared. Thus it is mapped as a fault, although the displacement may be slight.

## Vasquez formation

The Vasquez formation can be easily recognized in most parts of the area mapped, chiefly by means of its reddish color, it relative hardness, its interbedded andesite and basalt flows, and its moderately close folding. It is more than 4,000 feet in thickness. Volcanic flows and tuff and borate-bearing beds can be traced laterally for considerable distances, and thus serve as excellent horizon markers.

The sedimentary rocks of the Vasquez formation consist predominately of arkosic sandstones with interbedded silts and shales. There are few conglomerates in the western part of the area. The sandstones show much cross bedding, and the sorting is quite variable from place to place. Channelling occurs to some extent where the beds are coarse textured, and a fluviatile origin alone is implied for at least some of the sandstones. The sandstones generally form rounded bluffs.

The finer-grained sediments include siltstones, shales, and some hard, white, water-laid tuffs. The siltstones and shales locally contain borate minerals. Most of the finer sediments are marked by abundant mudcracks, ripplemarks and raindrop imprints. The colors are white, green, gray, purple, and red; the colors alternating from bed to bed. These characters indicate a lacustrine origin for the fine-grained sedimentary rocks. This conclusion is supported by the composition, texture and structure of some of the tuffs. In many places, the tuffs show moderate to good stratification, yet the presence of medium to coarse, angular biotite flakes indicates little transport by water. These conditions could best occur in a bed of ejecta which has settled in a lake.

Immediately underlying the main borate-bearing bed in which the borax mine in Tick Canyon is located, is a layer of basalt eight feet thick. It is fine-grained, almost aphanitic, black, and contains small grains of olivine. It weathers very readily and breaks down to a pebble-sized rubble. Because it is dense and fairly coarse-grained at this locality, it appears to be a sill, but the same bed elsewhere contains abundant vesicles and amygdules. This and the lack everywhere of altered wallrock seem to indicate an extrusive origin. Elsewhere, but not everywhere in the area, similar material was found in conjunction with other borate beds, and the association may imply the importance of volcanism in the origin of the borate. The lack of appearance of this volcanic material in some of the borate localities may be due simply to its poor resistance to weathering. Four separate beds of this type of material were found in the area. Cumulative evidence of the type described above indicates that all are extrusive.

Members 6 to 37 of the following section were measured from the contact between the Vasquez formation and the basement complex in Tick Canyon to the top of the southernmost volcanic flow just south of the borax mine (Fig. 2). The remaining part of the section was measured across a northeast-trending canyon immediately east of Tick Canyon and south of Davenport Road:

| Member | | Thickness (feet) |
|---|---|---|
| 1- | Volcanic flows, consisting in lower part of about 150' of what appears to be a sedimentary breccia. Subround to subangular pebbles and cobbles 3" to 8" in diameter. Matrix is fine-grained volcanic material. The cobbles, which are tabular in shape, lie parallel to the contact. Cobbles and pebbles consist mainly of basalt strikingly similar in appearance to Member 31. This is overlain by 52' of highly altered, reddish, aphanitic basalt or andesite containing 50% amygdules of chalcedony, calcite and quartz. Amygdules range from a fraction of a millimeter up to about 4mm in diameter. The uppermost portion of this unit consists of 50+ feet of flow and flow breccia, also very similar in composition to Member 31 in some places. Somewhat irregular in composition and texture, slightly vesicular; weathers to yellow-green and gray colors........................................ | 250+ |
| 2- | Sandstone, red, very coarse. Grains are angular to subangular. Poorly sorted. Moderately soft; forms rounded outcrops............................ | 13 |
| 3- | Shales, variegated orange and gray, forming bright bands in gray silts and arkosic sandstones......... | 46 |
| 4- | Shales and borate-bearing beds between two thin volcanic flows. Shales are gray, thin bedded; borate is white, thin bedded, about 3' thick. Volcanic rocks are black, amygdaloidal, and average 4' in thickness. Locally contains abundant olivine visible to the naked eye, and in some places has a diabasic texture.................................... | 15 |

| | | |
|---|---|---|
| 5- | Shales and siltstones, variegated orange and red with interbedded gray, poorly sorted sandstones... | 53 |
| 6- | Sandstone, red, gray, and lavender. Coarse to medium grained, poorly sorted. Thick bedded with thin shaly partings. Moderately resistant.......................................... | 53 |
| 7- | Basalt, dark greenish-black. Highly fractured; thin, platy parting along primary flow layers. Aphanitic, finely porphyritic. Phenocrysts comprise about 20% of the rock and range in size from about .5 mm to 2mm. Phenocrysts composed 60% olivine; the remainder is plagioclase, pyroxene and hornblende. Some columnar jointing occurs. In some places the rock is slightly vesicular..... | 186 |
| 8- | Sandstone, coarse to medium, and conglomerate. Pebbly. Green pebbles in conglomerate are 1/4" to 1/8" in diameter, subangular, composed of basalt and of basement rocks. Upper 1 foot is medium grained red sandstone, baked............... | 32 |
| 9- | Breccia, light gray, hard, jointed, fine-grained dense. Contains biotite, apparently concentrated along bedding planes................................ | 10 |
| 10- | Siltstone and shales, light green, friable, poorly bedded.............................................. | 20 |
| 11- | Sandstone, and siltstone, red, cross-bedded....... | 38 |
| 12- | Breccia, red sandy matrix with subangular light colored basement pebbles, poorly bedded. Pebbles 1/4" to 3"........................................ | 11 |
| 13- | Sandstone and siltstone, red, cross-bedded........ | 46 |
| 14- | Sandstone, coarse, light gray, thick bedded, somewhat massive.......................................... | 92 |
| 15- | Shale, light green, thin bedded, soft.............. | 15 |
| 16- | Sandstone and siltstone, gray-green, coarse to fine grained, well-bedded, hard......................... | 55 |
| 17- | Borate-bearing shale, white, thin-bedded. Contains colemanite or neocolemanite, ulexite, howlite. Shales above contain mudcracks, ripplemarks, raindrop imprints.......................................... | 10 |
| 18- | Basalt, contains olivine. Black. Easily decomposes to nut-size fragments and soil. Locally contains vesicles.......................................... | 8 |

19- Sandstone and siltstone, tan, thinly bedded....... 25

20- Tuff, white to yellow; sandy; conchoidal fracture; extensively fractured............................... 15

21- Shales and borate-bearing beds, white, locally green. Mud cracks, ripplemarks and raindrop imprints.... 86

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25- Coarse sandstone and fine conglomerate (top 10') with shaly partings. Green, moderately well-bedded, fairly hard. Subangular. Cross-bedded.... 27

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27- Andesite, dark, faintly purplish and greenish-gray. Dense aphanitic groundmass containing about 30% phenocrysts and 30% vesicles. The phenocrysts are thin, white plagioclase laths from 1 to 2 mm long. These are roughly oriented along flow lines in some places but occur in irregular radiating clusters elsewhere. The vesicles are filled with calcite, chalcedony and quartz. Many of the fillings are not complete. Some vesicles are lined with clear chalcedony and from the linings, delicate fibrous crystals radiate toward a hollow interior. The crystals may be natrolite or analcite.......................... 169

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31- Arkosic sandstone, buff, resistant, medium-grained well sorted, subrounded grains. Contains 5-10% biotite................................................... 2

32- Tuff, white. Fine-grained, aphanitic.............. 8

33- Arkosic sandstone, gray, medium-grained, moderately indurated, well sorted.............................. 5

34- Tuff, white, hard, conchoidal fracture, fine-grained................................................... 3

35- Arkose, light gray, fine to coarse, well sorted, moderately well bedded, locally well indurated. Contains a few greenish siltstones. Subangular to subround.............................................. 200

36- Coarse arkosic sandstone and siltstone, variegated red and green. Sorting poor, but locally good. Grains are subrounded. Bedding is moderately well developed, 2' to 10' thick. Appears to grade from a fanglomerate with no sharp break................. 380

37- Arkose and arkosic breccia and conglomerate, pink to green, poorly sorted. 1/4" to 3" pebbles in silty to sandy matrix. Bedding and induration poor. Has the appearance of a fossil regolith grading upward into fanglomerate.............................................. 340

Total Thickness.......................................4357+

Approximately half of the Vasquez formation within the area mapped consists of rock of basaltic or andesitic composition. Available evidence, such as the abundance and position of vesicles and amygdules, lack of baking of upper contacts, and the extreme irregularity of many flow units within any one member indicate an extrusive origin for most and perhaps for all of these rocks. No evidence for sills was found within the area. The thickest member (1370 feet) occurs near the bottom of the section. It forms moderately prominent hills of sombre appearance.

One of the best exposed rock types in the area is the flow breccia of Member 23. This extremely hard rock forms high, narrow ridges, the highest in the area. Tick Canyon, about 1,000 feet north of the Borax Mine, it forms sheer bluffs. This rock has a dull reddish color, and characteristically shows cavernous weathering. Other volcanics in the area range from dense aphanitic material to porphyritic andesite with well- developed ophitic texture. Medium to large amygdules occur in some of the flows, particularly those higher in the section. Some of the amygdules are as much as eight inches in diameter, and are filled or partly filled with calcite, zeolites, or chalcedony. Many of these are eagerly sought by mineral collectors.

The Vasquez beds decrease in coarseness from bottom to top of the formation. Most of the conglomerates occur near the base of the section, with sandstones and shales above.

The lacustrine beds occur mainly in the upper half of the section. The volcanic rocks decrease in thickness in the upper half of the section, but they are more closely spaced stratigraphically. Laterally, there seems to be an increase in coarseness in an eastward direction, with conglomerates and breccias becoming more common. About a mile east of the borax mine occur conspicuous breccia beds that can be traced eastward and southward for about two miles. One of these beds, about twenty feet thick, contains angular pebbles 1/4" to 2" in diameter, that are composed of light-colored, silicic basement rock of intrusive type. The matrix is sandy and somewhat arkosic. In places boulders as much as four feet in diameter occur. There is much channelling and graded bedding. Farther to the east the finer fragments are somewhat more coarse, but the thickness of the bed remains nearly constant. East of the Agua Dulce Canyon, in the area known as Vasquez Rocks, sandstones and breccias of this type form a large part of the section and volcanic rocks are lacking. The poor sorting, the coarse texture, and the arkosic composition of the lowermost Vasquez beds in Tick Canyon indicates rapid deposition at the base of a steep mountain front. The variations in rocks in the east-west and north-south directions indicate sedimentation at least partly from the east with intermittant periods of volcanism, the latter coming as smaller extravasations in later time. Toward the latter part of

Vasquez time, lake deposits became more common, and the presence of the borates and also some gypsum in the western part of the area indicate aridity. The local occurrence of fossil plant stems and twigs in some of the tuff beds and the carbonaceous content of some of the shales in dicate that there was some plant life.

The age of the Vasquez formation is not known, as no diagnostic fossils have yet been found. It position below the Tick Canyon formation and its similarity in appearance to the Sespe formation make a doubtful Oligocene classification seem logical for this formation. Kew (5,pp.38-39) tentatively suggested an Oligocene age for the Vasquez beds, on the basis of their resemblance to the Sespe formation, but Miller (6,p.66) suggested a middle Miocene age for the beds, noting that the Vasquez volcanic rocks are typical of the widespread Middle Miocene volcanic rocks in the western United States and that the Vasquez sediments strongly resemble the middle Miocene Topanga formation in thickness and lithology. Jahns (4,pp.170-171) points out that the Vasquez lavas are mineralogically different from all other known lavas of Los Angeles County, that the Vasquez formation is continental and should not be compared with the marine Topanga formation, and that it is overlain unconformably by the late Lower Miocene Tick Canyon formation. Because in the Tejon Quadrangle the V asquez formation is unconformably underlain by the lower Eocene Martinez formation, the Vasquez formation is restricted in time to upper Eocene, Oligocene, and lower Miocene. On the basis of its resemblence to the Sespe formation, Jahns tentatively assigns the Vasquez an Oligocene age, although he admits that the associated volcanics may indicate a time range extending into the lower Miocene.

## Tick Canyon formation

The Tick Canyon formation overlies the Vasquez formation unconformably, and more or less consistently dips about 25 degrees to the southwest and west. In the western part of the area it is only about 400 feet thick, but it thickens considerably to the east. In the vicinity of the Skyline Ranch it is more than 1,000 feet thick. West of Tick Canyon the beds are predominently siltstones and shales, with a few interbedded fine-grained arkosic sandstones. Here the beds are soft, easily eroded, and form poor outcrops. The siltstones break down into nut-sized to much smaller blocky fragments and chips, forming a rather characteristic surface debris. The colors are light pink, green, and gray. Southeast of the borax mine, one of the lower Tick Canyon beds is green in color and contains weathered fragments that appear to have been derived from one of the Vasquez lavas. The lower contact is poorly exposed west of Tick Canyon, but the two formations can be distinguished by the differences in general attitude and in lithology. Where the contact is exposed there is little or no conglomerate at the base of the Tick Canyon formation. Locally there is evidence for a fault-type contact.

East of Tick Canyon and south of Davenport Road, the Tick Canyon formation occupies most of the east-west valley in which lies the Skyline Ranch. The dip here is more to the south, and the lower contact is in some places depositional and in other places of the fault type. In this area, the beds increase in coarseness of grain. Here beds of fluviatile arkosic sandstone and conglomerate alternate with finer siltstones and shales. The coarser beds are gray, tan, and green, and contain pebbles and cobbles that have been derived from the basement complex; however there are many fragments of the hard flow breccia and other volcanic rocks of the Vasquez formation. Northwest of the Skyline Ranch the lower contact runs along the crest of the ridge just south of Davenport Road. Here the basal Tick Canyon beds consist of about 50 feet of coarse fan-type conglomerate. The pebbles and cobbles range in size from 1/4" to 4", and are composed of lava resembling the immediately underlying Vasquez flow.

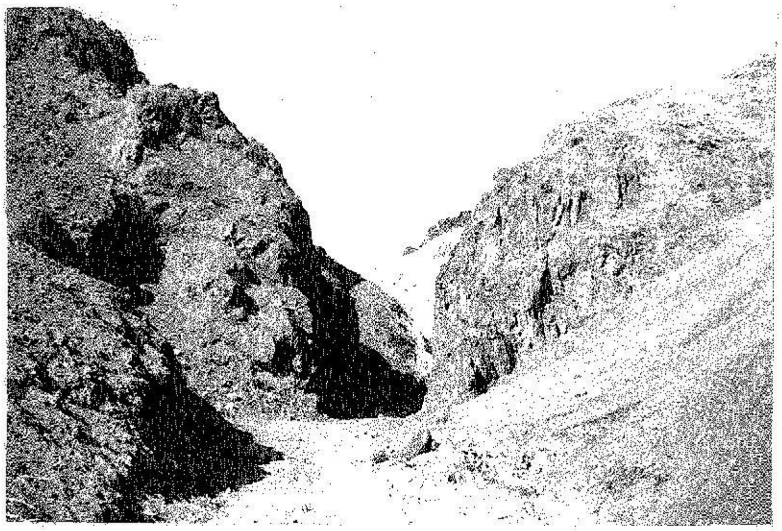
South of the Green Ranch and west of Agua Dulce Canyon the Tick Canyon beds are in fault contact with the Vasquez formation. Here the lowermost exposed Tick Canyon beds are fine-grained and incompetent, greatly resembling those in the western part of the area. The uppermost beds, however, are very coarse, poorly sorted and lenticular. There is much channelling and graded bedding. The pebbles and cobbles consist of rocks derived from the basement complex and from the lava flows of the Vasquez formation. The dip is to the west.

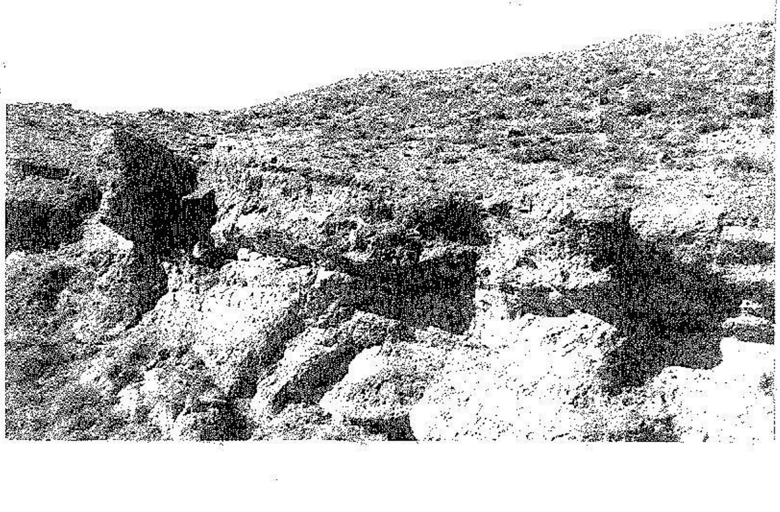
The Tick Canyon-Mint Canyon contact is obscure in the eastern part of the area, owing to the increase in coarseness of the upper part of the Tick Canyon formation and to the coarse character of the lower beds of the Mint Canyon formation. It is mapped along an indefinite zone, best traced from the west, above which there seems to be a more or less abrupt increase in coarseness of the beds. Immediately west of Tick Canyon, the contact can be more accurately mapped. The lower Mint Canyon beds form a line of prominent bluffs south of Davenport Road (Fig. 3). These rest upon much finer-grained Tick Canyon beds, and in a few localities, there appears to be slight angular unconformity (Fig. 4). In general, however the contact is one of disconformity.

The character and distribution of the various lithologic types in the Tick Canyon formation seem to indicate quiet lacustrine deposition in the western part of the area. The thickening to east, however, and the appearance of coarse fluviatile conglomerates above and below the fine-grained sediments imply initial deposition in an area of some relief, this later giving way to quiet lake deposition, and finally,

Figure 2. Vasquez volcanic bed south of the borax mine in Tick Canyon. Portal is about 8 feet wide at the base. Direction of view is northward.

Figure 3. Bluffs formed by the lowermost beds of the Mint Canyon formation south of Davenport Road. Cliff is 75 feet high.





an increase once more in stream activity. Rising highlands in the eastern part of the area late in Tick Canyon time are thus suggested.

That the topography in Vasquez time had not been completely reduced prior to Tick Canyon deposition is evidenced by the configuration of the contact between the two formations, by the coarse texture of some of the beds of the Tick Canyon formation and by their content of pebbles and cobbles derived from the lavas of theVasquez formation. Southeast of the borax mine and north of Darling Road, a tongue of the Tick Canyon formation extends eastward along a synclinal depression in the Vasquez formation. The base of this tongue lies at a present elevation of about 2150 feet above sealevel. Hills immediately to the northeast, and upon which no Tick Canyon formation occurs at present, rise to about 2500 feet. Therefore in this locality there was at least 350 feet of local relief during deposition of the lower Tick Canyon beds.

There appears to have been no volcanism during Tick Canyon time.

On the basis of mammalian fauna (Rodentia, Perissodactyla, Artiodactyla) found in the Tick Canyon formation, Johns (4,pp 174-175) dates the formation as late as lower Miocene or earliest middle Miocene.

## Mint Canyon formation

The Mint Canyon formation occupies the southern part of the area mapped. Like the Tick Canyon formation, which it overlies disconformably, it dips about 25 degrees to the west or southwest. Because of its low regional dip and great thickness, it crops out over a wide area to the south and west.

Within the area mapped, the beds are mainly coarse fluviatile conglomerates with interbedded arkosic sandstones and minor siltstones and shales. The coarse-textured beds are greenish-gray and gray in color and have sombre appearance. The rocks contain pebbles and cobbles derived from the basement complex and from lavas of the Vasquez formation. There are also cobbles that are themselves conglomeratic. The latter have the appearance of having been derived from the Tick Canyon formation.

The beds are laterally very variable in composition and texture, and good horizon markers are scarce. There is much channelling and graded bedding. A fluviatile origin is suggested.

Not enough areal mapping in this formation was done to enable the writer to determine the area from which the Mint Canyon beds were derived, and the vertical extent studied was not great enough for important differences to be determined. However, the resemblence of the lower Mint Canyon beds to the uppermost Tick Canyon beds of the eastern part of the area, strongly suggests that early Mint Canyon environment represented simply an intensification of conditions that obtained in the eastern part of the area during later Tick Canyon time. If this is correct, a progressive rising and tilting of the area from east to west is indicated.

Neither the Tick Canyon formation nor the Mint Canyon formation is strongly folded. There are broad, gentle warps indicated by gradual changes in attitude from place to place. It should be noted that the dips of the Mint Canyon formation are generally parallel to the dips of the Tick Canyon formation. This is discussed in a later section on structure.

Jahns (4,pp.172-177) suggests a middle upper Miocene age for the Mint Canyon formation. This is based on a vertebrate fauna, including Hipparion in the upper portion and Merychippus in the lowermost beds. The lower beds may be contemporaneous with the upper part of the Barstow formation.

## Quaternary deposits

Four Quaternary units were recognized in the area. These are:

| | |
|---|---|
| RECENT | Alluvium<br>Fan deposits |
| PLEISTOCENE | Younger terrace deposits<br>Older terrace deposits |

The older and younger terrace deposits are composed of coarse, unconsolidated gravels. The detritus consists mainly of fragments derived from the basement complex, including some Pelona schist fragments, but there are local abundances of sedimentary and volcanic detritus. The terrace materials are poorly sorted and poorly bedded. Older and younger terraces were distinguished partly by altitude differences and partly by relative differences in degree of consolidation. The older terrace materials are slightly more consolidated than are the younger.

Wallace (9, p. 792) describes similar terrace deposits in the San Andreas rift zone, about 10 miles north of the area. There the terrace gravels overlie Harold beds, which are of Pleistocene Age. Wallace states that the gravels are Pleistocene to Recent in age. In the Tick Canyon area, the youngest formation overlain by the terraces is the Mint Canyon formation, but reconstructions of the surfaces of which the terraces are remnants show moderately good correspondence with present drainage. This correspondence, the poor consolidation of the gravels, and their content of Pelona schist constitute enough evidence for a fairly safe correlation of the Tick Canyon terrace deposits with those described by Wallace.

In the northeast corner of the area mapped is part of a recently dissected alluvial fan. This is the southwest end of the Sierra Pelona Valley, which trends northeastward for several miles into the Red Rover Quadrangle. The material is derived mainly from the Sierra Pelona highlands to the north and to a lesser extent from the highlands that border the valley to the south and east. The material varies greatly in composition, and there are abrupt changes in texture. Figure 6 shows coarse gravel overlying sandy material. That there has been some uplift in very recent times is indicated by the incision of this material by present streams and the deposition of Quaternary alluvium in some places fifty feet or more below the fan surface.

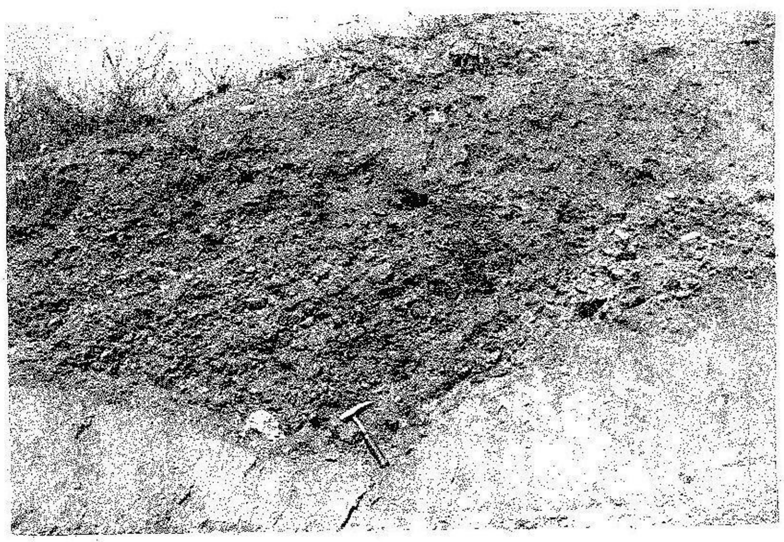
## STRUCTURAL GEOLOGY

### General statement

The most striking structural features of the area mapped are the well defined folds of the Vasquez formation and the major faults, which trend northeast and northwest. There has been some warping of the younger formations, but this has been of minor degree as compared with the folding of the Vasquez formation. The major faults of the area cut all the formations, but the Vasquez formation shows by far the most displacement. It is tentatively suggested, subject to the application of additional evidence, that the major faults of the area are related to the San Andreas rift, which lies several miles to the north. This is discussed in more detail in one of the sections following.

Figure 4. Road cut on north side of Davenport road about 1/4 mile southwest of the borax mine. Shows unconformable contact betwe en the Tick Canyon formation (below white line) and the Mint Canyon formation. Hammer is 1 foot in length.

Figure 5. Road cut about 1/2 mile west of Elkhorn Lodge. Shows contact between coarse-grained and fine-grained material in alluvial fan.



## Folding

### Folds in the Vasquez formation

The Vasquez beds dip steeply in nearly all parts of the area. In the north, near the contact between the basement complex and the Vasquez formation, the beds are overturned. In the western part of the area, the dips are southward. Just north of Davenport Road and east of Tick Canyon, the beds are folded into a syncline that plunges gently in a direction slightly south of west. The nose of this syncline is displaced northeastward more than 1,000 feet along a fault, and occurs about a mile east of Tick Canyon. Minor folds with the same trend are developed within the syncline. Another major syncline lies west of the Green Ranch, and plunges gently southwest. The folds are well outlined by and lava beds, which form good horizon markers. The general trend of fold axes is about 75 degrees east of north.

In the extreme eastern part of the area, the region of Vasques Rocks, there is the beginning of what appears to be a regional change in strike to the southeast. This may represent part of a much larger fold with the same attitude as that of the smaller folds described above.

### Folds in the Tick Canyon and Mint Canyon formations

Other than the regional southwesterly dip, there has been only slight deformation of the Tick Canyon and Mint Canyon formations. Broad, gentle warps are shown, for example, by the changes in dip from westerly to southwesterly in the areas immediately west and east of Tick Canyon. The dips west of the Skyline Ranch are more southerly and than those to the east.

There is close parallelism of the dips in the Mint Canyon formation and in the Tick Canyon formation, indicating that the warping in these formations occurred after the deposition of the Mint Canyon formation. Fold axes of the Mint Canyon and Tick Canyon formations show fairly good correspondence in position and trend with those of the Vasquez formation. There is, therefore, strong indication that warping in the Mint Canyon and Tick Canyon formations took place along lines previously extablished by the earlier structural features in the Vasquez formation. This is corroborated by fault evidence, which suggests that deformation, although most intense after Vasquez deposition, continued to occur after the deposition of the Tick Canyon formation and after the deposition of the Mint Canyon formation.

## Faulting

The faults of the area occur in two main systems. One, here referred to as the basement system, consists of faults trending about 75 degrees west of north. They occur wholly within the rocks of the basement complex or form part of the contact between the basement complex and the Vasquez formation. The other system, which for convenience is here termed the Vasquez system, contains two sets, one trending approximately 45 degrees east of north and the other approximately 15 degrees west of north. There are, in addition to these two systems, many minor faults of slight displacement and slight extent. Included among these are small bedding-plane faults developed in some of the less competent strata of the Vasquez formation. Other minor faults displace some of the Vasquez beds in the areas of well-defined folding. Irregularities in trend of the major faults are due partly to offsets along minor faults and partly to refraction by lithologic changes in the strata they traverse.

The basement system contains two essentially vertical major faults that join to form contact with the Vasquez formation at the western end of the area near Mint Canyon. These faults are obscured in many places, but they can generally be traced by zones of gouge along their strike as well as by the general brecciation of the rocks involved. These faults are displaced by some of the northwest-trending faults of the Vasquez system, but there is insufficient evidence to prove whether or not they are displaced by the northeast-trending set. In one locality near Darling Road, one of the major northeast Vasquez faults appears to merge with the basement contact fault, the motion of the former appearing to have been absorbed by later adjustment along the older basement complex fault.

Of the two sets in the Vasquez system, the faults that trend northwest are smaller in extent and displacement than northeast faults. Both sets are nearly vertical, as is evidenced by their straight traces and by their scarps which in some localities have been bared by erosion (Fig. 6).

The motion along these faults is predominantly strike-slip. Most of the slickensides plunge gently northwest or northeast. A reconstruction based on beds of different orientation displaced by one of the major northeast faults showed an essentially horizontal net slip of 900 feet. Displacements along the other major northeast faults are of the same order of magnitude. Along the northwest faults, the displacements are much smaller, most being on the order of 100 feet or less. Along the northeast-trending faults the east side has moved north, and with one or two exceptions this applies to the northwest-trending faults.

The two sets are essentially contemporaneous in origin, for although in many places the northwest faults displace the northeast, there are exceptions. It is likely that both sets resulted from a common origin.

The northwest faults die out before reaching the Vasquez-Tick Canyon contact, but the major northeast faults displace both the Tick Canyon and the Mint Canyon formations. Along the same faults, displacements are much smaller in the Tick Canyon formation than in the Vasquez, and they are still smaller in the Mint Canyon formation. Therefore it appears that, as with folding, deformation by faulting reached its greatest intensity in post-Vasquez, pre-Tick Canyon time, but was continued in post-Tick Canyon time and in post-Mint Canyon time along lines initially established at least as early as the Vasquez deformation. One of the main northeast faults, pasing just south of the Green Ranch, clearly cuts terrace and fan deposits as evidenced by small moisture seeps and lines of more luxuriant vegetation along its trace. Therefore, some movement has been quite recent.

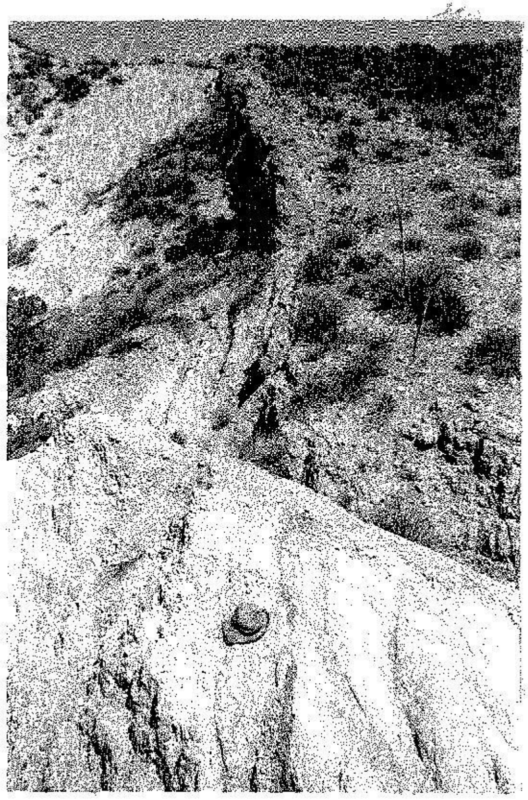
Possible relationship to the San Andreas rift

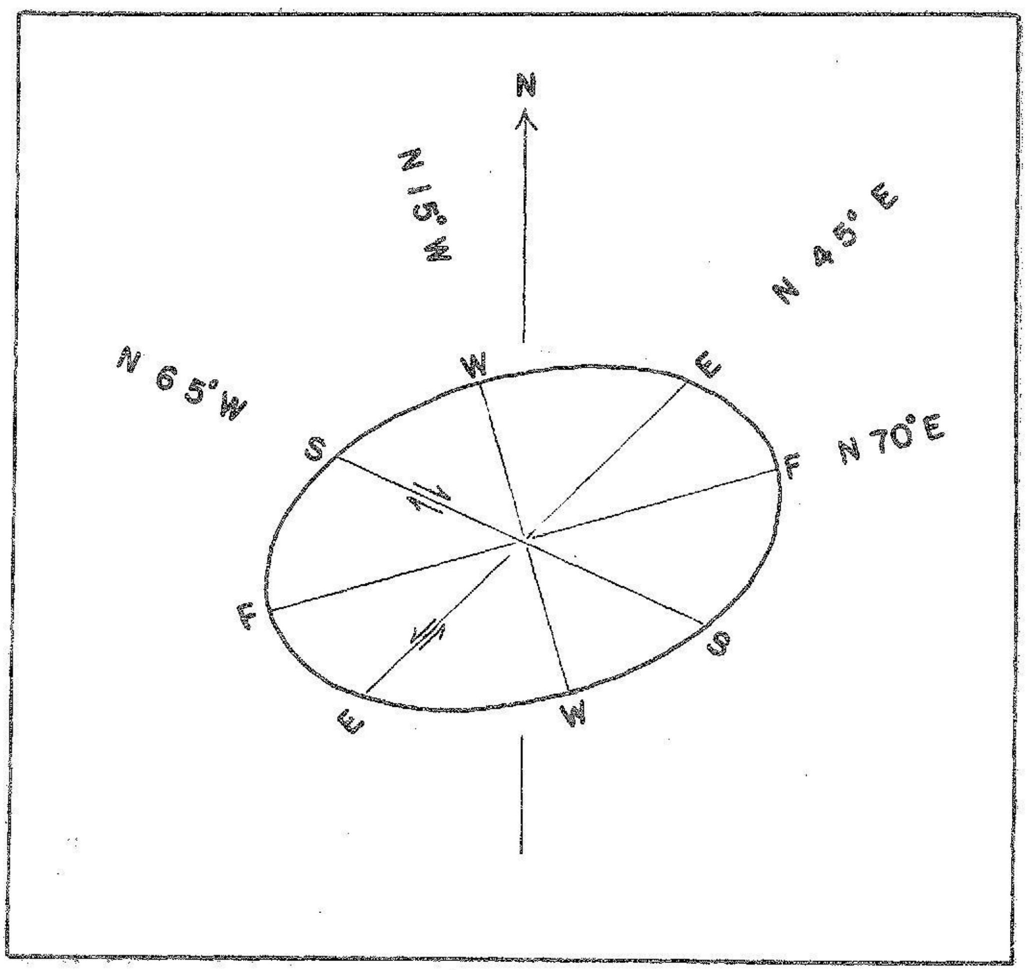
Figure 7 is a sketch showing the average directions of trends of the San Andreas rift (SS), the fold axes of the Vasquez formation (FF), and the northeast (EE) and northwest (WW) sets of the Vasquez fault system. There is no direct evidence that the structural features in the Tick Canyon area are related to the San Andreas rift, which lies about ten miles to the north, for field work was not carried into the zone of faulting of the latter. The writer was struck, however, by geometric relationships between the structural features; this may or may not be coincidental. The following argument is offerred as a tentative theory, to be tested by future work.

It appears that the trends of the San Andreas rift (SS)

Figure 6. Northward view along a fault scarp bared by erosion in the Mint Canyon formation. Location about 1 mile south-southwest of the borax mine and about 1000 feet west of Tick Canyon.

Figure 7. Sketch showing the trends of the San Andreas rift (SS), the northeast-trending faults (EE) and northwest-trending faults (WW) of the Vasquez fault system, and the fold axes (FF) of the Vasquez formation.





N
N 15° W
N 45° E
N 65° W
N 70° E
W
E
S
F
F
S
E
W

and that of the northeast set of the Vasquez fault system (EE) are oriented obliquely to the fold axes (FF) in the Vasquez formation. Furthermore, the angles made by the intersection of the San Andreas and the northeast-trending faults are very nearly bisected both by the fold trends (FF) and by the northwest-trending faults (WW). The geometric symmetry of this pattern is so striking, that an accidental relationship of the structures seems unlikely; one is led to believe that the structural features of the Tick Canyon area are related to the San Andreas rift in origin. It should be noted that the distribution of other faults in neighboring area, as shown on the geologic maps of California, seems in harmony with the fault pattern in the Tick Canyon area.

Assuming that the pattern of trends does indicate relationship of the structural units, the San Andreas rift and the northeast fault set occur in directions of shear failure in an area folded by horizontal compression in a north-northwest-south-southeast direction. Inasmuch as the San Andreas rift is a major structural feature of the earth's crust and the other faults and folds in the area are relatively local features, it is logical that the Vasquez fault sets and the folds are subsidiary to the San Andreas. The northeast faults thus would be of the type to which Nevin (7, p.136) refers as closed compression fractures. The folds are so oriented that they should occur as the result of secondary compressional forces acting in directions set up by the major shear force directions of the San Andreas.

Most workers agree that there has been considerable displacement along the San Andreas rift. Of the faults here considered, those of the northeast-trending set are next in order of magnitude of displacement, and those of the northwest set are smallest and show the least displacement. As shown in Figure 7 the northwest-trending faults occupy the direction of failure by tension; therefore little nor no lateral displacement would be expected. Thus the relative orders of magnitude of fault displacements are in accord with the concept of relationship in origin of the structural features of Tick Canyon and the San Andreas rift.

One inconsistency arises: the angles made by the intersection of the directions of the San Andreas rift and the northeast-trending Vasquez fault set are obtuse in the direction of maximum compression (WY). This is contrary to to the Hartmann experiments described by Bucher (2,pp.709-712). However, observations show that in ductile materials the shear angles are less acute than in brittle materials. Furthermore it is constantly seen that fracture cleavage and some bedding plane slippage make obtuse angles toward the maximum compressive forces.

The basement complex faults have been omitted from the Figure 7 because their orientation does not conform to the pattern formed by the directions of the other faults. The basement complex faults appear to be dip slip in nature and are probably tensional in origin. The other structures are shear or compressional structures.

If the above arguments are valid and there is a relationship in origin between the Tick Canyon structures and the San Andreas rift, then certain conclusions follow:

(1) The San Andreas fift is at least as old as post-Vasquez, pre-Tick Canyon deposition, but may be younger than the basement complex.

(2) Either the activity of the San Andreas rift was more intense in immediately post-Vasquez time than in any succeding time, or the later activity was due to forces different from those which produced the major deformation of the Vasquez beds. Thus, later motion along the San Andreas rift would not necessarily cause much readjustment along the earlier related breaks.

(3) It is conceivable that much more light may be thrown on the nature of the San Andreas rift by detailed mapping of structures related to the rift itself.

## GEOMORPHOLOGY

The present topography of the Tick Canyon area shows some control of streams by structure of the bedrock. Although the drainage appears to be dendritic, this is partly accidental. Many of the canyons are cut along fault lines or nearby zones of brecciation. The southwest lineation of major stream pattern is at least partly induced by the northeast-southwest Vasquez fault set. The occurrence of the soft Tick Canyon strata in an east-west belt, as well as the general east-west trend of many of the formations, controls tributaries to the major canyons. Many of the folds in the eastern part of the area are outlined by ridges composed of the more resistant strata. These show up well on air photographs.

One of the most striking features of the present topography is the straight, narrow aspect of upper Tick Canyon between the Champion mine and the Borax mine. This is immediately apparent on the air photograph, and is strongly suggestive of a fault. Throughout this portion of its traverse, the stream is cutting across the most resistant strata of the Vasquez formation; the beds strike very nearly at right angles across the trend of the stream. They are not offset along any fault parallel to the stream bed, but the stream bed may occur along a zone of close jointing.

Reconstruction of the surfaces of which the terraces are remnants reveals a drainage system somewhat similar to the present system. The older drainage lines were parallel to those of the present and occupied the same positions with respect to the geographic coordinates, but the stream valleys were more broad and open. At least as early as the older terraces, the drainage was southward and the major streams were already in existence.

## GEOLOGIC HISTORY

The Cenozoic history of the area mapped can be summarized as follows:

1. Early Tertiary deformation with formation of a basin bordered, at least on the east by rocks of the basement complex.

2. Oligocene to perhaps early Miocene: rapid deposition of fanglomerate, arkose, and later lake beds. Continued subsidence during deposition, the subsidence taking place to a lesser degree in later time (during the upper part of Vasquez deposition. Much extrusion of volcanic and andesitic lava with subordinate pyroclastics throughout most of the time of Vasquez deposition. Extravasations smaller in later time.

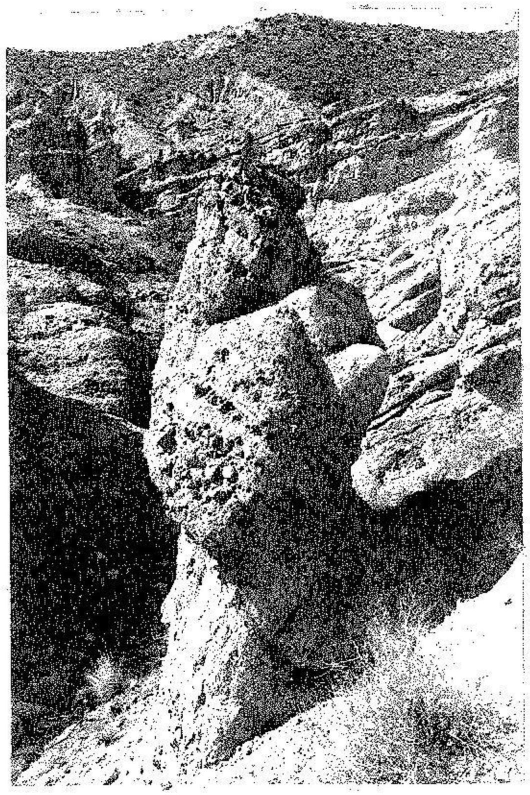
3. Late Oligocene or early Miocene: strong folding and faulting of the Vasquez beds, establishing the major structures of the Vasquez formation and elevating it high enough to cause active erosion.

4. Lower Miocene: rapid deposition from east of coarse fanglomerates and sandstones of the Tick Canyon formation, this giving way to quiet lacustrine deposition, and followed by late uplift in the east and deposition of coarse material.

5. Middle Miocene: slight uplift and faulting of the Tick Canyon strata along lines previously established by Vasquez structural features. Uplift enough to produce only mild erosion.

6. Middle Miocene: deposition of coarse fluviatile

Figure 8. Pedestal rock formed by differential stream erosion in the Mint Canyon formation. Location about 1 mile southeast of the borax mine.



sediments of the Mint Canyon formation.

7. Post Middle Miocene: tilting of the whole region to the southwest; continued slight faulting and warping of the Mint Canyon formation along the older structural lines.

8. Pleistocene and Recent: formation, uplift and dissection of at least two sets of terrace deposits, later fan deposits, and recent alluviation along the major streams.

## MINERAL RESOURCES

### Metals

Some metal mining has been carried on in the rocks of the basement complex. Many prospect pits and tunnels were excavated along some of the faults where mineralization was noted. The minerals include pyrite, chalcopyrite, and galena. The largest of the workings from the Champion mine, which lies in the northern part of Tick Canyon. The mine is idle at present.

### Borate minerals

Several beds of borate minerals occur in the Vasquez formation. The largest, in which is located the Borax mine in Tick Canyon, is about twenty feet thick. This bed can be traced eastward for about two miles, and is offset to the north along several faults. Another bed, which occurs just north of Davenport Road, is involved in the synclinal folding at that locality and reappears east of Tick Canyon and south of Davenport Road.

The borate deposits were worked in the earlier part of the century by the Sterling Borax Company of Los Angeles. At present no work is going on. According to the State Mineralogist's Report (8,p.201) the commercial beds are as much as 50 feet in thickness and have been mined for several thousand feet in length.

The deposits are mainly calcium borate minerals. Neocolemanite, colemanite, ulexite, and howlite occur. The howlite, a calcium silicate of boron, occurs as nodular to botryoidal masses with a cauliflower-like appearance. According to Eakle (3) the howlite was separated as an impurity from the neocolemanite.

The origin of the borate is probably related to the volcanism in the area. The association of borate beds with thin lava flows is striking. Eakle (3) believes that lake charged by nearby volcanism with boracic acid reacted with and converted carbonate deposits into the calcium borate minerals. The howlite arose through conversion of siliceous travertine portions of the original carbonate deposits.

## Gypsum

In the western part of the area, about 1 mile east of Mint Canyon, a deposit of gypsum occurs in the Vasquez formation. It is located in the sedimentary section just south of the basement contact. The gypsum bed is about 8 feet in width and is considerably deformed. The deposit is briefly described in

Aubury (1,p.286). It was worked during the turn of the century, but there has been no commercial production in recent years.

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