GEOLOGY OF THE MINT CANYON AREA

Los Angeles County, California

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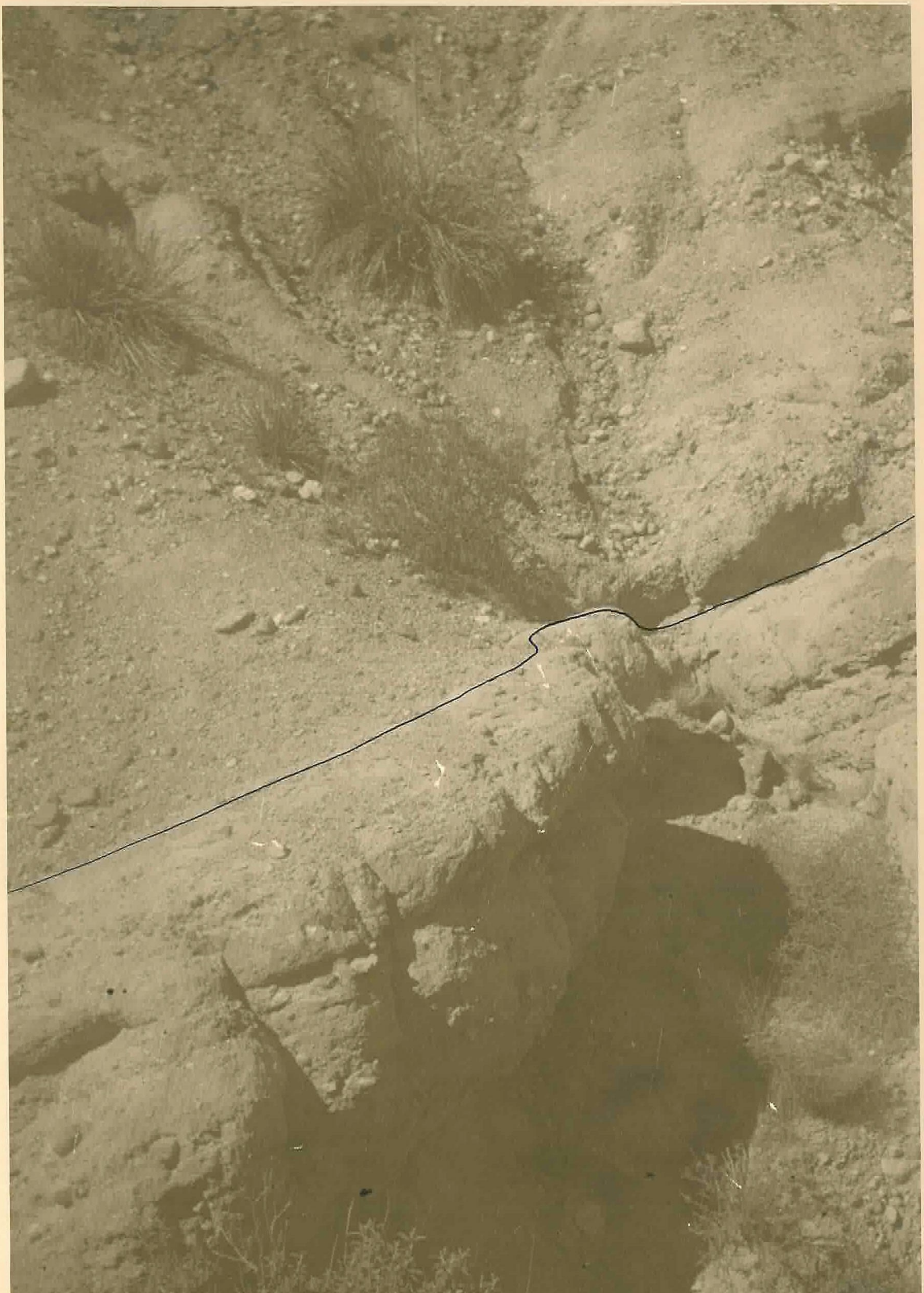
In partial fulfillment of the requirements of the degree of Master of Science, California Institute of Technology, 1946



Frontispiece Contact of the Mint Canyon and Tick Canyon formations, west side of Tick Canyon

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ABSTRACT

The area described covers approximately ten square miles in the Lang and Humphreys quadrangles, twenty-seven miles northwest of Pasadena. It comprises part of the drainage of Mint Canyon immediately southeast of the area previously described by R. H. Jahns, and continues eastward across Tick Canyon, west of an area previously described by R. P. Sharp.

A series of pre-Cretaceous gneisses outcrops in the northern part of the area as an uplifted fault block. Immediately to the south of the fault lies the Vasquez series, of doubtful Oligocene age. In this area, it is composed of two sections of coarse, colorful sandstones and gypsiferous shales, alternated with two thick flows of basaltic lava, the total thickness being about 3000 feet. Unconformably overlying the upper lava flow is the Miocene series. This series was deposited in a broad basin. The initial basinward dips have been accentuated by slight folding at a later date. The lower part of this series was named the Tick Canyon formation by Jahns. He described a section west of Mint Canyon, unconformably resting on the basin complex, which pinched out eastward. In this paper, the Tick Canyon formation is described from a section measured in Tick Canyon. The map shows that it does not entirely disappear at any point, east of Jahns' area, except where it is cut off by a series of strike slip cross faults. The Tick Canyon formation is principally composed of green sandstones, reddish siltstones, and some conglomerates, with a total thickness of over 1000 feet. Overlying the Tick Canyon formation is the

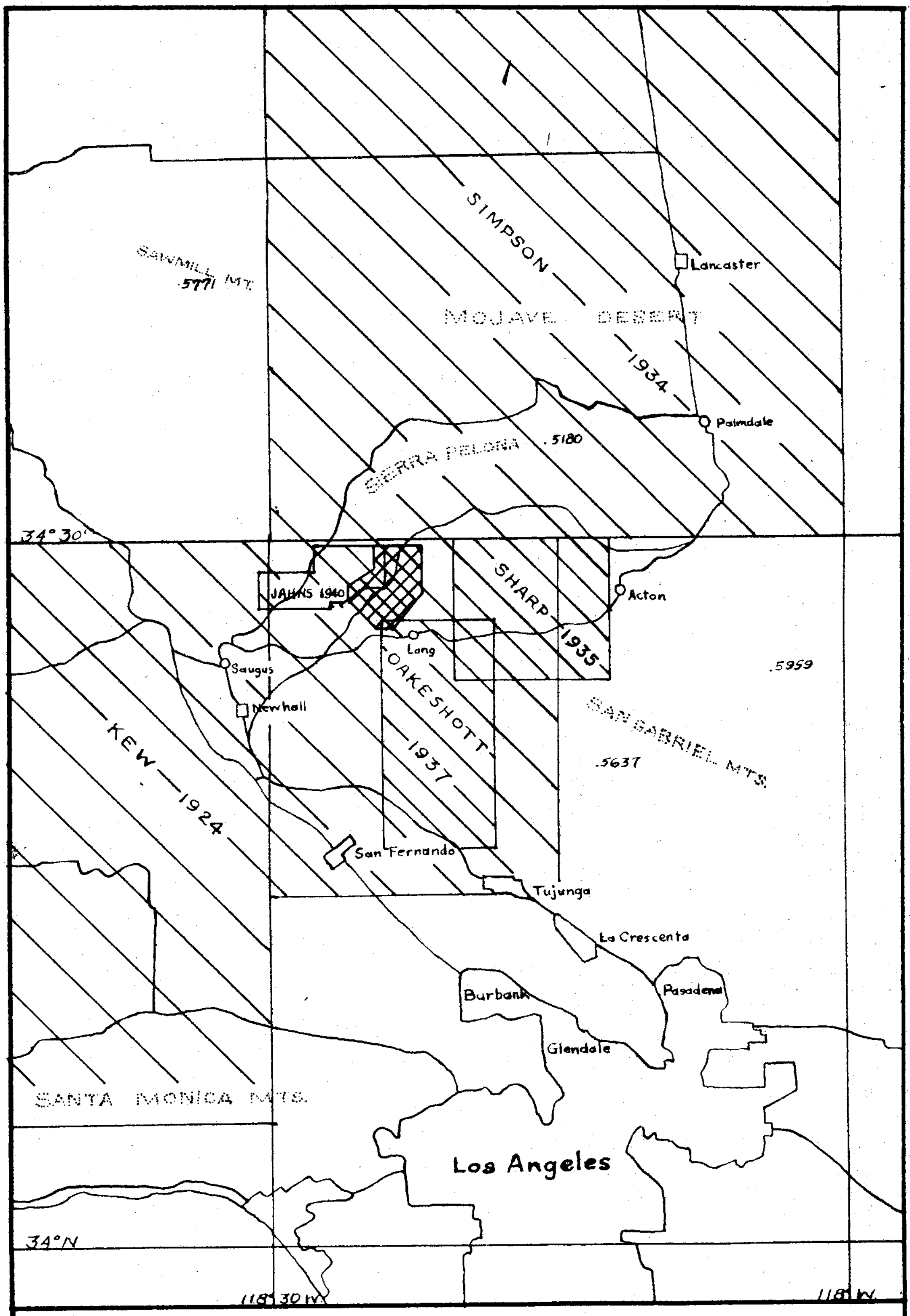
Mint Canyon formation; however, no clear evidence could be found in this area for an unconformity between the two formations, as reported by Jahns. The Mint Canyon formation is composed of continental deposits: light colored pebble to boulder conglomerates roughly interbedded with light sandstones and reddish siltstones. The total thickness of the Mint Canyon formation outcropping in the area mapped is about 3500 feet. The section is thicker than that in the area mapped by Jahns, possibly because it received coarser sediments more rapidly near the margin of the basin. A Pleistocene erosion surface, with accompanying terraces is shown on a separate map.

There is a normal fault of large but unknown displacement between the Tertiary sediments and the metamorphic complex. Several branches of this fault run into the sediments, but gradually die out to the southwest in the Mint Canyon formation. The largest branch, which causes a considerable horizontal displacement of the sediments at its northern end (west of Mint Canyon), gradually decreases in displacement to the southwest where it passes into an anticline. There are a number of northwest trending, normal, cross faults of relatively minor importance. Accelerated uplift of the San Gabriel mountains in late Miocene time is indicated by the increasing dominance of San Gabriel intrusive material in the upper members of the Mint Canyon formation. Middle Pleistocene uplift of the whole area is indicated by the stream terraces, but there is no evidence of recent faulting in this particular area.

INTRODUCTION

This study was undertaken with the primary objective of extending present knowledge regarding the Tertiary stratigraphy of the eastern Ventura Basin, with particular effort directed towards accurately surveying the Lower Miocene Tick Canyon formation. In addition to delineating the structure of the area covered, it was hoped that this study would correlate present (and possible future) vertebrate fossil localities with the previously mapped localities to the west.

Mapping was done during thirty field days, in the months November, 1945 to February, 1946. It was carried out under the direction of Dr. John H. Maxson, to whom the author is indebted for helpful assistance and criticism, both in the field and in interpretation. Certain parts of the eastern portion of the area were surveyed in cooperation with Mr. John F. Lance, who also lucidly contributed to several fundamental discussions. H. W. Agnew, H. W. Menard, and E. J. Poizner assisted in the measurement of the section of the Tick Canyon formation.



INDEX MAP

Of a portion of Los Angeles County, California
Showing area covered in this and previous reports.
Scale 1:500,000 Highways

GEOGRAPHICAL LOCATION

The area described covers approximately ten square miles in the Lang and Humphreys Quadrangles (U.S.G.S., scale 1:24,000), twenty-seven miles northwest of Pasadena. It comprises part of the drainage of Mint and Tick Canyons, and lies just north of Soledad Canyon; these canyons being tributaries of the Santa Clara River. Referring to the Index Map (Plate 1), on which the map area is marked by crosshatching, it is seen that it lies between the Sierra Pelona and the San Gabriel Mountains. These ranges bound the upper Ventura Basin on the north and south, respectively; the eastern boundary being Soledad Pass, which opens onto the Mojave Desert south of Palmdale. The map area lies at an average elevation of about 2200 feet, ranging from 1700 feet in the bottom of the canyons to 3094 feet in the northwest corner.

As shown on the Index Map, two highways provide access: U. S. 6, which runs northeastward across the map area in Mint Canyon, and a highway which runs eastward, just south of the map area, in Soledad Canyon. A secondary road follows the length of Tick Canyon and crosses over to Mint Canyon. The local railhead is Lang Station, on the Southern Pacific Railroad in Soledad Canyon, one mile southeast.

GEOLOGICAL SETTING

The eastern Ventura Basin is a southwest trending, trough-shaped basin of deposition, opening to the west and southwest. The sedimentary rocks are principally of the Tertiary period, ranging in age from Oligocene (?) to Pleistocene, and include both marine and continental facies. The total thickness of the Tertiary section in the central Ventura Basin is about 30,000 feet (Kew, 1924, Plate III).

The bottom of the trough at the east end and along the northern side is occupied by a maximum of 12,000 feet of inter-bedded lavas and coarse continental sediments of doubtful Oligocene age (Vasquez and Sespe formations). Above these, outcropping for several miles to the west and south, is a thick Miocene section, with about 4000 feet of continental conglomerates and sandstones (Mint Canyon "formation"), and about 9000 feet of marine shales and sandstones ("Modelo" formation). A wide band in the central part of the basin is filled with about 6000 feet of sediments of Pliocene-Pleistocene age, the lower portion being marine (Pico formation), and the upper portion continental (Saugus formation). Extensive Pleistocene river terraces parallel the present streams. All formations tend to be of a finer composition to the west and south, in many cases changing from fluviatile to a lacustrine or littoral facies.

This Tertiary section has been extensively folded in a series of anticlines and synclines that tend to parallel the axis of the basin and accentuate the trough-like configuration.

A series of faults, of principally oblique or dip-slip movement, run in this same general northeast-southwest direction. A number of high-angle dip-slip faults trend in a northwest-southeast direction.

The edges of the basin are outlined by upthrust blocks of older crystalline rocks. The region of the Sierra Pelona, on the north, is principally composed of schists of pre-Cambrian age, with some later gneisses and acidic intrusives along the basin edge. The San Gabriel Mountains to the south present a complex assortment of both igneous and metamorphic types, with large bodies of granite, granodiorite, andanorthosite intruding the older schists and gneisses.

For a more detailed outline of the regional geology, the reader is referred to previously published maps (Jahns, 1940, fig 3; Jenkins, 1938, Sheet V1; Kew, 1924, Plate 1).

HISTORY

The first geological exploration of the area was that of the U. S. Pacific Railroad Explorations. One of the signal contributions of this expedition was Lt. Williamson's discovery of Soledad pass, affording a practical direct railroad route from Los Angeles to the Mojave Desert and north. In exploring the pass, the party passed through Soledad Canyon, and Blake mentioned the thick section of sandstones and conglomerates and the large lava flows (Blake, 1854, pp 70-71). The California Geological Survey passed to the north at the edge of the Mojave Desert, and to the south in San Fernando Valley, but did not go into the upper Santa Clara River Valley (Whitney, 1865).

The first extensive geological work in the area was done by Hershey. Although he made only a very rapid reconnaissance, his observation was quite discerning, and some of his work is here confirmed and extended for the first time. One of the papers concerned the crystalline rocks of southern California. Hershey placed particular emphasis on the metamorphic series of the Sierra Pelona, and described the gneiss that outcrops in the map area of this report (Hershey, 1902a). He attempted to correlate the metamorphics of this area with those of northern California. The second paper described the Tertiary section of this region, and is the most important to our present consideration. He described in some detail a section of Tertiary rocks in Tick Canyon, within the map area (Hershey, 1902b). The oldest section was named the Escondido series, of doubtful Eocene age, now designated as the Oligocene (?) Vasquez. The next unit, called the Mellenia series, of doubtful Lower Pliocene age, is shown in the present paper to correspond exactly to the Lower Miocene Tick Canyon formation. The remaining upper portion of the section was designated by Hershey as Pliocene, although it is today divided into the Upper Miocene Mint Canyon and the Pliocene Saugus formations. The areal distribution of the various formations was described fairly accurately, although no map was included in his paper. Hershey's last paper contained a description of the Quaternary of southern California (Hershey, 1902 c). It is of interest here for its description of the Pleistocene river terraces, particularly those in Soledad Canyon, immediately south of the map area.

Kew mapped the entire region in some detail on a scale of 1:62,500 (Kew, 1924). He named and fixed the age of the Mint Canyon "formation" on paleontological evidence, although he did not recognize a stratigraphic break within the series. He tentatively correlated the present Vasquez formation with the Sespe formation to the west. The structure described by Kew was substantially correct in general form, but was not done in the detail of later reports.

Maxson described an upper Miocene fauna from the Mint Canyon "formation" (Maxson, 1930). These descriptions led to a long controversy as to the age of the series, and the position of the Miocene-Pliocene boundary (Stirton, 1933 to 1939; Maxson, 1938). Detailed stratigraphic and structural mapping and description of vertebrate forms from the lower beds, by Jahns, proved the existence of a faunal break within the Mint Canyon "formation". He designated the lower section as the Tick

Canyon formation, of upper-lower Miocene age.

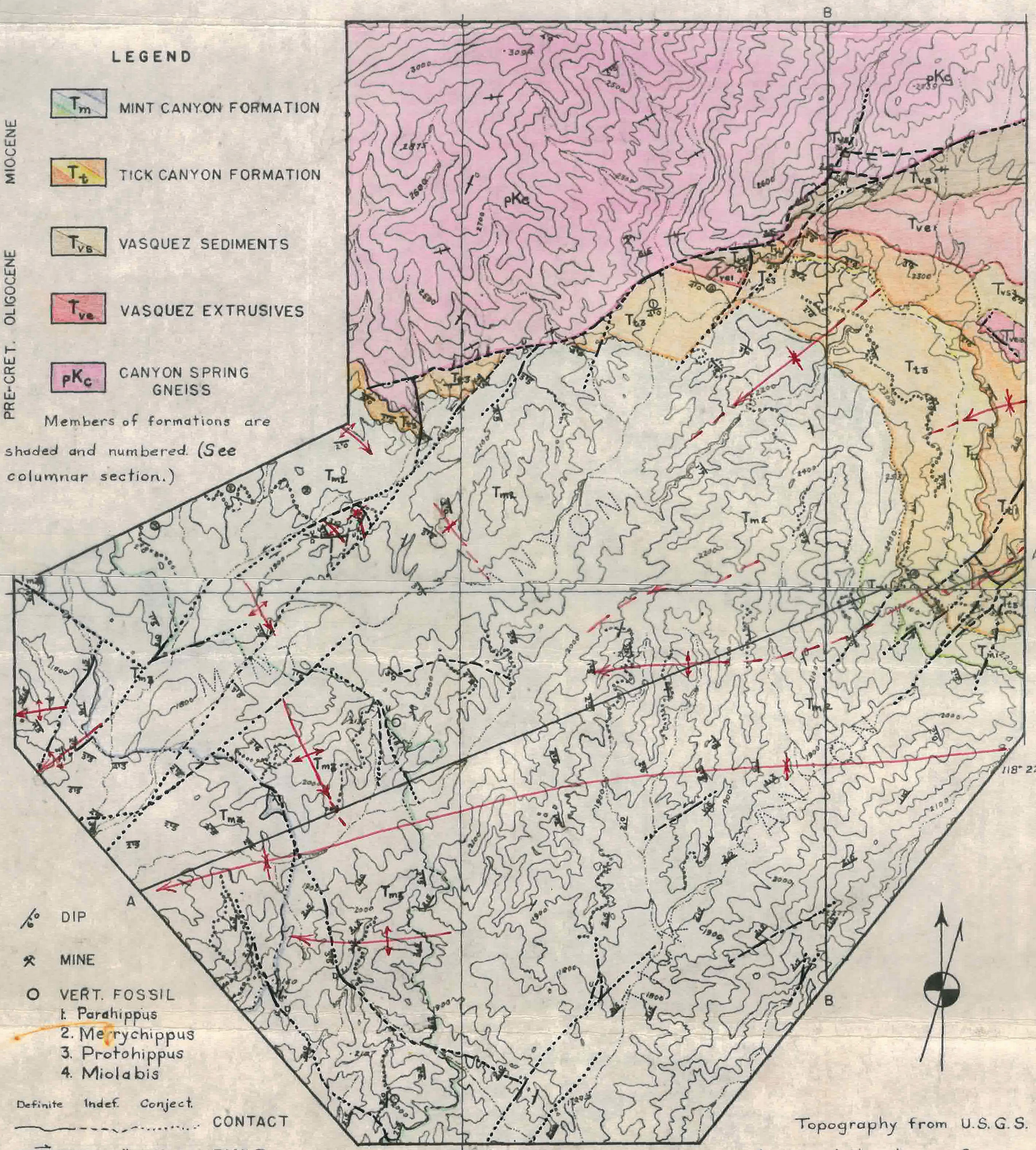
Simpson's work on the Elizabeth Lake quadrangle, immediately to the north, contributed descriptions of the basement rocks and of the lower part of the Tertiary section. The latter he called Escondido, after Hershey, but correlated it with the Miocene Topanga (Santa Monica Mountains) and the Rosamond (Mojave Desert,) (Simpson, 1934). A later paper by Sharp contained a definitive description of the lower Tertiary series, which he named the Vasquez (Sharp, 1935). Oakeshott described in detail the rocks of the San Gabriel Mountains immediately to the southeast, which was a principal source area for the Mint Canyon sediments. (Oakeshott, 1937).

The above history indicates the increase of knowledge that has occurred since the first surveys of the area. The recent work of Jahns provides a standard of detail and accuracy that is needed for a complete understanding of the geologic history. This paper attempts to extend that work, and it is hoped that a program of mapping now under way by the California Institute of Technology may soon complete it.

LEGEND

MIOCENE	Tm	MINT CANYON FORMATION
	Tt	TICK CANYON FORMATION
OLIGOCENE	Tvs	VASQUEZ SEDIMENTS
	Tve	VASQUEZ EXTRUSIVES
PRE-CRET.	pKc	CANYON SPRING GNEISS

Members of formations are shaded and numbered. (See columnar section.)



- DIP
- MINE
- VERT. FOSSIL
  1. Parahippus
  2. Merychippus
  3. Protohippus
  4. Miolabis

Definite Indef. Conject.

CONTACT

FAULT

FOLD

MARKER BED

Topography from U.S.G.S.
Lang and Humphreys Quadrangles
1929

SCALE 1:24,000

0 ½ 1 mi.

CONTOUR INTERVAL 100 FT.

MINT CANYON AREA

LOS ANGELES COUNTY, CALIFORNIA

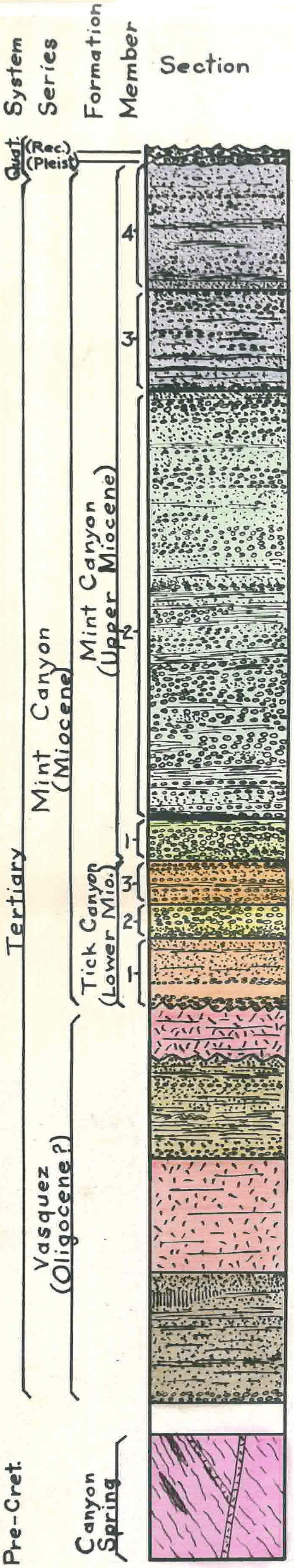
PRE-QUATERNARY GEOLOGY

Geology by W. T. Holser
1945-46

GEOLOGIC NOMENCLATURE OF THE EASTERN VENTURA BASIN, CALIFORNIA

NO SCALE

HERSHEY 1902		KEW 1924	MAXSON 1930, 1938	STIRTON 1933 TO 1939	SIMPSON 1934	SHARP 1935	JAHNS 1940			HOLSER 1946		
PLEISTOCENE TERRACE		PLEISTOCENE TERRACE			PLEISTOCENE TERRACE	PLEISTOCENE TERRACE	PLIESTOCENE TERRACE			PLEISTOCENE TERRACE		
UPPER PLIOCENE SERIES	SAUGUS DIVISION	PLIOCENE-PLEISTOCENE SAUGUS FORMATION	NOT PRESENT	NOT PRESENT			PLIOCENE-PLEISTOCENE SAUGUS FORMATION			NOT PRESENT		
	NOT PRESENT	UPPER MIOCENE MODELO (?) FORMATION	UPPER MIOCENE MODELO FORMATION	(PLIOCENE) "MODELO" FORMATION	NOT PRESENT	NOT PRESENT	UPPER-UPPER MIOCENE "MODELO" FORMATION					
	SOLEDAD DIVISION	UPPER MIOCENE MINT CANYON FORMATION	MIDDLE UPPER MIOCENE MINT CANYON FORMATION	LOWER PLIOCENE UPPER MINT CANYON FORMATION			MIOCENE MINT CANYON SERIES	MIDDLE-UPPER MIOCENE MINT CANYON FORMATION	(MEMBERS 14-27)	MIOCENE MINT CANYON SERIES	MIDDLE-UPPER MIOCENE MINT CANYON FORMATION	MEMBER 4
									(MEMBERS 10-13)			MEMBER 3
									(MEMBERS 8-9)			
	LANG DIVISION				UPPER MIOCENE MINT CANYON FORMATION				(MEMBERS 1-7)			MEMBER 2
												MEMBER 1
MIDDLE PLIOCENE MELLENIA SERIES				LOWER PLIOCENE (?) LOWER MINT CANYON FORMATION		UPPER MIOCENE MINT CANYON SERIES		UPPER-LOWER MIOCENE TICK CANYON FORMATION			UPPER-LOWER MIOCENE TICK CANYON FORMATION	MEMBER 3
												MEMBER 2
												MEMBER 1
EOCENE (?) ESCONDIDO SERIES		OLIGOCENE (?) SESPE (?) FORMATION	OLIGOCENE (?) SESPE (?) FORMATION	OLIGOCENE (?) SESPE (?) FORMATION	MIDDLE MIOCENE(?) ESCONDIDO FORMATION	MIDDLE MIOCENE (?) VASQUEZ SERIES	OLIGOCENE (?) VASQUEZ SERIES			OLIGOCENE (?) VASQUEZ SERIES		
PRE-CAMBRIAN(?) GNEISS SERIES		PRE-JURASSIC(?) METAMORPHICS	NOT PRESENT	NOT PRESENT	PRE-CRETACEOUS(?) GRANITE AUGENGNEISS		PRE-CRETACEOUS (?) METAMORPHIC COMPLEX			PRE-CRETACEOUS (?) CANYON SPRING FORMATION		



Description

Qal — Gravel and sand valley alluvium, principally derived from Mint Canyon Ser.

Qt — Unconsolidated gravel and boulder terraces, at several levels.

Tm4 — Sandstone and pebble conglomerate, white, moderately well bedded, fragments principally intrusives; and reddish, or greenish siltstone, forming badlands; interbedded in 5-20' beds. Some cobble conglomerates in lenticular masses. Basal member is hard, dark yellow sandstone.

Tm3 — Sandstone, white to gray, massive to moderately well bedded; and white conglomerate composed principally of intrusive fragments of pebble to boulder size, forming local cliffs. Some 3-15' beds of siltstone, gray-green or red, locally fossiliferous. 1-12" white tuffaceous sandstone prominent near base, in western part of area.

Tm2 — Conglomerate, buff, composed principally of extrusive fragments of pebble to boulder size, forming local cliffs; and buff, massive to poorly bedded sandstone. Some beds of reddish siltstone. All interbedded in 10-50' lenticular beds, showing extensive stream channelling. Siltstone becomes predominate over sandstone downward.

1-10' dead white cherty tuff, western part of area.

Tm1 — Conglomerate, poorly consolidated, forming slopes and demoiselles, color gray, fragments rounded cobbles and pebbles. Minor siltstone near top.

Tt3 — Siltstones, gray, red, brown, greenish, forming soft slopes. Hard green cobble conglomerates form prominent outcrops. Some interbedded sandstone.

Tt2 — Conglomerate, gray-green weathering red-brown, pebbles to cobbles, principally volcanic. Lower part forms prominent cliff.

Tt1 — Siltstone and sandstone, interbedded; buff, greenish, or gray; soft.

Sequence concealed.

Conglomerate, gray, hard; with lenses of gray sandstone.

Tve2 — Lava, basic, dark gray, weathering green and then red. Upper 50' of flow is well weathered. Shows flow structure.

Tvs2 — Shale, red, green, purple, sandy, thin bedded; and buff or reddish sandstone. There are some beds of colemanite and gypsum, somewhat contorted, and the formation is apparently lacustrine.

Tve1 — Lava, basic, dark gray, weathering bright red, exceptionally amygdaloidal.

Tvs1 — Sandstone, buff to red, hard, with interbedded shales. Near Mint Canyon extensive beds of greatly contorted gypsiferous shales form the upper part of this formation.

Sequence concealed by faulting.

pKc — Gneiss, medium grained, well banded, the principal femic mineral is biotite. One facies of the exposure shows prominent metacrysts of feldspar. Both dolerite and aplite dikes, and quartz veins, are exposed, usually nearly concordant with the gneissic banding. Inclusions of dark biotite schist in the western part of the area are also concordant.

COLUMNAR SECTION

MINT CANYON AREA

Vertical Scale 1:12,000

STRATIGRAPHY

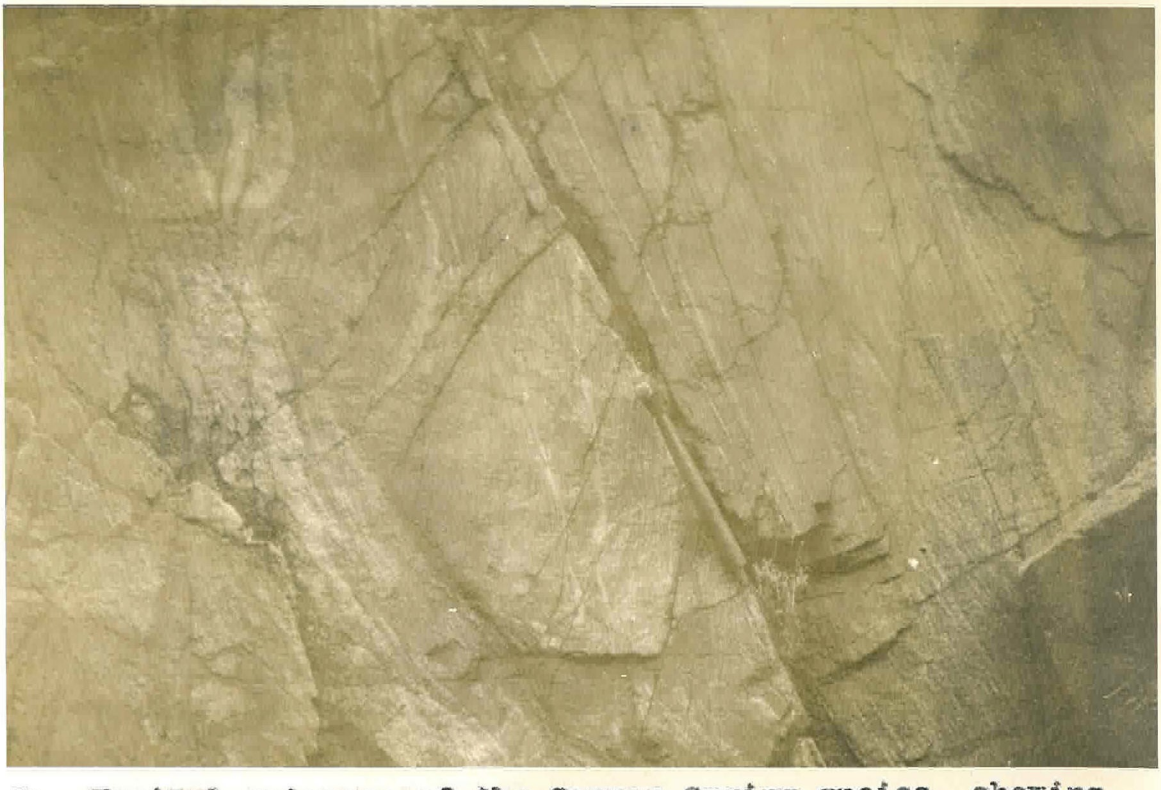
Because there has been some slight confusion regarding the nomenclature of the eastern Ventura Basin, the table, Plate 3, is given as a guide to the discussion that follows. It shows in detail what names and ages have been assigned to the various parts of the section by the various investigators. Plate 4 shows a representative section, from the area covered by the geological maps.

The areal geology is presented on two maps: Plate 2 shows the "bedrock", pre-Quaternary geology; while Plate 8 shows the Quaternary geology, of essentially unconsolidated deposits. It was thought that by this means more real, as well as interpretive, data could be presented with a minimum of confusion. It is an adaptation of the system used by the Geological Survey of Great Britain (see, for example Oswestry, sheet 137).

PRE-CRETACEOUS CANYON SPRING FORMATION

A series of gneisses of undetermined thickness outcrops over about two square miles in the northern portion of the map area, (Plate 4); correlation with adjacent areas indicates that it may cover a total area of fifteen square miles (Simpson, 1934, pl 5; and Jahns, 1940, fig 4). Although the gneiss within this small map area represent only one of a large number of igneous and metamorphic types that outcrop in the region, it is fairly consistent within itself, and seems to represent a characteristic and definite body of rock. It is therefore assigned the name Canyon Spring Formation, after a type locality in Mint Canyon, immediately south of Mint Canyon Spring, near the northern edge of the map area.

A (same scale as 5 B)



B Typical outcrops of the Canyon Spring gneiss, showing the banding and the close folds

The most common facies of the Canyon Spring formation is a lewocratic biotite-hornblende gneiss, of fairly coarse testure. The mafic constituents are well separated into thin bands, include biotite and hornblende, and show good lineation within the planar structure. The common felsic minerals are feldspar and quartz.

The average composition of the rock is approximately that of a normal granite. In the central part of the area of outcrop, the feldspar crystals grow to one inch in length, giving the rock the texture of an augen gneiss. At the northern edge of the area covered in this report, the felsic minerals become dominant, but the banded structure is still shown by concentration of feldspars. Typical aspects of the gneiss are shown in Plate 5.

There are two main possibilities as to the formation of the Canyon Spring gneiss. In the northeastern branch of Mint Canyon, immediately north of the outcrop of Vasquez sediments, the gneisses present a configuration that strongly suggests a metasedimentary nature. The gneiss occurs in definite bands varying in width from one to thirty feet, colored reddish, greenish, or almost white. Some of the layers in their banded appearance and macroscopic character resemble quartzite. The outcrop is so thoroughly fractured and weathered, however, that it is difficult to ascertain whether the banding is due to sedimentary origin, or is due to a fault that is known to parallel it (e.g., it may be a banded mylonite). On the other hand, to the west of Mint Canyon there are a number of inclusions of dark green hornblende schist, up to twenty feet in diameter. These inclusions might indicate that the mafic constituents of the gneiss originated in such a schist, which was injected lit-par-lit by a very acidic magma. Introduction of the acidic constituents by permeating magmatic solutions is possible. Simpson suggests that this rock is a border phase of the pre-Cretaceous batholith, the banding being primary (Simpson, 1937, p 385). It is impossible to determine, without a large amount of additional work, both in field mapping and petrographic analysis, exactly what the origin of the Canyon Spring gneiss may be.

The gneiss has been intruded by a few dolerite dikes, particularly in the eastern part of the area. In the western part of the area are a number of dikes of aplite and similar acidic material. Both types are usually nearly concordant with the gneissic structure.

No additional evidence bearing on the age was furnished by the present field work, so the age determination of pre-Cretaceous (?) assigned by Simpson is retained (Simpson, 1934, p 384).

OLIGOCENE (?) VASQUEZ SERIES

The Vasquez series outcrops over a large portion of the Ravenna Quadrangle to the east (Sharp, 1937), and covers a small area in the northeast part of this map, its boundaries rapidly converging towards the west. Plate 5A shows some of the most westerly exposures of the Vasquez formation.

The series is composed of two sedimentary members interbedded with two lava flows, although areas farther to the east show as many as five separate flows. The sedimentary members are composed of highly colored red, green, and purple sandstones and shales, in one-inch to three-foot well sorted beds. The sedimenta are interbedded with colemanite or gypsum in several places. There are some

A. Canyon east of upper Mint Canyon, looking north, showing contacts of Tick Canyon formation (Foreground), Vasquez basalt and gypsiferous shales (middle distance), and Canyon Spring gneiss (ridge in background)

B. Steeply dipping Vasquez lava flow in upper Tick Canyon pebble conglomerates and coarse sandstones, particularly in the upper part of the section, and this might indicate a fluviatile piedmont environment of deposition. However, some of the shale beds are quite fine grained and thinly bedded, and show ripple marks. Furthermore, the best evidence indicates that the interbedded colemanite was probably originally deposited in a playa lake (as ulexite) (Foshag, 1921, pp 212-214). It is therefore believed that the Vasquez sediments are at least in part lacustrine. It should be pointed out that this represents a quite different depositional facies than is exposed in the type section in the Ravenna Quadrangle, where the sediments are typically thick conglomerates (Sharp, 1937).

Although Kew (1924, p 39) describes the lavas as andesite, they are certainly basaltic (Simpson, 1934, p 394). A thin section petrographic examination of a typical specimen shows the rock to be very fine grained, probably devitrified. There are small phenocrysts of bytownite and pigeonite, and serpentine has completely replaced hypersthene or olivine phenocrysts. The Johannsen classification is 2312E, or normal basalt. However, the composition is not a good criterion for correlation with other extrusives (Simpson, 1934, pp 395, 401), because the variable composition of lavas of the same age is well-known in many places.

The lower flow in particular is quite amygdaloidal near its top. Flow structure is not particularly good in either flow, although the lower one seems to be rolled under near its end in Mint Canyon. Approximately the upper fifty feet of each flow shows considerable pre-Tick Canyon weathering, particularly near Tick Canyon.

Here the typical hard black rock has been weathered to a dull light green. This weathered lava has furnished the typical green color to many beds of the Tick Canyon formation. It should be noted that recent weathering of fresh lava exposures gives a characteristic bright red color, probably indicative of a different climate and length of exposure. The evidence of weathering and internal structure, together with the contact relations, indicate that these bodies are lava flows rather than near surface dikes. Plate 6B shows a typical outcrop of the lava in upper Tick Canyon.

Although the sedimentary members of the Vasquez series would seem to be favorable for preservation of fossil material, not one fragment has yet been discovered, in spite of vigorous searching by various geologists. The age can therefore only be guessed at on the basis of structure and correlation of lithology. On the basis of the unconformity at its top, and the occurence of interbedded lavas, Hershey postulated on Eocene (?) age (1902b, p 370). On the same evidence, Miller (1934, p 66), and Simpson (1934, p 395) preferred a Middle Miocene age, the difference being due to a change in ideas, in the meantime, in regard to the age of the principal Tertiary volcanism in the Western United States. Kew (1924, p 39) tentatively correlated this section with the Oligocene (?) Sespe formation on the basis of lithology. The determination of the lower Miocene age of the overlying formations has made a return to the Oligocene (?) viewpoint almost mandatory, as pointed out by Jahns (1940, p 170).

A Tick Canyon, member three, near the fossil quarry west of Tick Canyon. The conglomerates at the top represent uppermost Tick Canyon

B Typical cliffs formed by Tick Canyon member two on the west slope of Tick Canyon

MIOCENE SERIES

The remainder, and greatest part, of the map area is covered by a thick section of conformable continental sediments of Miocene age. It is divided into two formations on the basis of paleontological and lithologic evidence.

Tick Canyon Formation. Referring to the map, Plate 2, it is seen that this formation outcrops in a curve around the northeast end of the basin, overlying the Vasquez series with a marked angular unconformity. The maximum thickness is 1170 feet, but it thins rapidly from east to west, until it all but pinches out at the western edge of the map area. Farther to the west, however, it thickens again (Jahns, 1940, fig 3). It is thick and continuous for several miles to the east of the map area, although considerably faulted (Hershey, 1902b, p 358; Lance, J. F., personal communication)

The formation was first described by Hershey, who called it the Mellenia series (1902b, p 356). The name Tick Canyon formation was first applied by Jahns, but he described a section in Vasquez Canyon (1940, p 593). A section near Tick Canyon should be the type section because of geographic derivation of the name and because the formation is exposed there with about twice the thickness represented in Vasquez Canyon. Therefore, it was decided that a detailed section should be measured in that locality. The section follows below, with the basal bed of the overlying Mint Canyon formation included for comparison. This section was measured on the west slope of Tick Canyon near its upper end.

Measured Geologic Section

	Thickness (Feet)
Mint Canyon Formation (lower part of Member One).	
Conglomerate, poorly consolidated, forming slopes in badlands. Color gray; fragments rounded cobbles and pebbles	200
Sandstone, gray, hard, medium grained, with some lenses of cobble conglomerate	3
Shale, reddish, soft, with intercalcated sandstone; grading downward into sandstone	3
Conglomerate as above, with rough beds of coarse sandstone. Lower three feet well indurated	36
Conglomerate and sandstone as above. Lower 3-4 feet is a green, hard conglomerate	25

- -

	Thickness (Feet)
Tick Canyon Formation.	
Member Three	
Siltstone, buff, medium hard	½
Sandstone, buff, coarse; grading downward into sandstone interbedded with pebble conglomerate .	12
Conglomerate, green, very hard. Fragments are rounded pebbles and cobbles, mostly volcanic	3
Sandstone and pebble conglomerate, interbedded	10
Conglomerate and coarse sandstone; grading into cobble conglomerate, gray-green, hard, forming prominent outcrop	28
Siltstone, light-colored, soft; with some coarse sandstone. Worm borings (?)	74
Sandstone, bright green, coarse	2
Siltstone, light brown, massive. One two-foot bed contains worm borings. CIT Vertebrate Loc #199	10
Conglomerate, light green, very hard, forming prominent outcrops, fragments are subangular to rounded cobbles and pebbles with some boulders	10
Siltstone, gray-brown weathering red; interbedded with gray sandstone. Soft	13
Sandstone, light green, coarse	5
Siltstone and sandstone, interbedded as above (red)	48
Siltstone and sandstone, brown, soft, massive to poorly bedded	35
Sandstone, bright green, hard, massive, forming prominent outcrop	10
Conglomerate, green, hard, forming outcrop. Fragments are pebbles to cobbles	2
Sandstone and siltstone, interbedded 4 - 10' beds. Sandstone is gray-green and coarse;	

siltstone is brown and massive	35
Sandstone, gray-green, hard, coarse; with conglomerate lenses, grading downward to pure conglomerate	10
Siltstone and sandstone, alternating in 2-6' massive beds. Siltstone is red or brown and sandy; sandstone is soft, loosely consolidated, and buff or gray in color	35
Sandstone, gray, soft, poorly bedded, with lenses of coarse sandstone and pebble conglomerate . .	20
Total thickness, Member Three	362½

Member Two

Conglomerate, gray-green, weathering red-brown, pebble, with lenses of coarse sandstone decreasing downward. Size particles increasing downward	220
Sandstone, gray-green, medium hard, lenticular bedding with some conglomerate	30
Conglomerate, gray-green, weathering buff to red. Hard, forming prominent cliffs. Massive. Size, pebbles to boulders, average cobbles; mostly composed of colored (green, red, purple) extrusives, but with minor amounts of intrusives and sedimentary rocks (no metamorphics noted)	26
Total Thickness, Member Two	276

Member One

Sandstone, gray, massive, soft, lenticular	4
Sandstone, reddish to buff, soft, massive	15
Sandstone, green, grading downward to gray, massive, in 3-4' beds interbedded with siltstone, gray-brown, soft, massive	200
Conglomerate, gray-green, pebble, interbedded with sandstone; grading downward into pure conglomerate, hard, of 1" rounded cobbles	38
Siltstone, gray-brown, soft	34
Sandstone, greenish, finebedded, soft, fine grained	25
Sequence Concealed	100 (app)
Conglomerate, gray, very hard, of subangular to rounded boulders; with lenses of gray sandstone	150
Total Thickness, Member One	566

Total Thickness, Tick Canyon Formation 1204½

- - - - - - - - - - - - - - -unconformity- - - - - - - - - - - - - - -

Several characteristics of this section are distinctive in this area and may be used to recognise the section in the field;

(a) A thick conglomerate (Member two), of predominantly volcanic material, in the center of the section (see Plate 7B). This member continues some distance to the east of the area surveyed, but towards Mint Canyon it disappears entirely.

(b) A great thickness, in both members one and three, of variegated colored siltstones, usually not very well bedded. This was first noted by Maxson (1930, p 81), as a possible means of differentiating the older and younger sections of the Mint Canyon series. Towards Mint Canyon the proportion of siltstones increase until they form the principal part of the section.

(c) A very characteristic and distinctive bright green color of mahy of the sandstones and pebbles conglomerates, particularly in the eastern part of the area, and eastward of that. Microscopic examination reveals that this color is due to serpentine, probably derived from weathered extrusives of the Vasquez series, which at the time of the Tick Canyon deposition rose as a series of hills to the north. These green beds are quite consistent in color, although changing laterally in composition from coarse sandstones to pebble and cobble conglomerates. One of these beds, that could be traced for some distance, is shown on the geologic map as a marker bed (see also Plate 7A).

The age and limits of the Tick Canyon formation will be discussed below.

Mint Canyon Formation. This formation overlies the Tick Canyon formation apparently conformably, and fills the inner part of the basin. The area mapped for this report does not reach the stratigraphic top of the Mint Canyon formation; judging from the measured section of Jahns to the west. It includes only about one-half, or 2400 feet, of that section (Jahns, 1940, pp 159-162). Nevertheless, the greater part of the geologic map (Plate 2) is covered by the Mint Canyon formation, and the section here is calculated to be 4100 feet thick, representing a substantial thickening within a relatively short distance from west to east. Farther to the northwest, in the Tejon Quadrangle, the Mint Canyon series thins even more (Clements, 1937, p 216; Eaton, 1939a, pp 534-536). However, as will be seen by a comparison of the description below with the measured section of Jahns, the sediments in Tick Canyon are a good deal coarser than they are farther to the west; those in Tick Canyon are principally cobble to boulder conglomerates, whereas in Bouquet Canyon they are principally lacustrine. Therefore, although the section is relatively thick, it may be equivalent to thinner sections in other areas.

As is shown in the measured section above, the lowermost bed of the Mint Canyon formation is quite characteristic. It is a dull gray conglomerate. Its poor cementation and consequent ease of erosion are exceptional in conglomerate beds of this age in this region. Large boulders sometimes tend to protect the finer underlying material, forming small demoissellee.

The upper boundary of member one is marked by a very distinctive white bed. This bed, which varies in thickness from one to fifteen feet where it is exposed near Tick Canyon, is apparently a chertified and otherwise highly altered tuff bed. It has several gradational facies, the most characteristic being an extremely hard, dead white rock composed of what appear to be cherty concretions of pebble to cobble size, cemented with chalcedony and opal. Thin section petrographic examination indicates that much of the body of the rock is very finely crystalline devitrified feldspar. Despite the variability in composition, the bed always forms a brilliant white outcrop. Near the Tick Canyon-Mint Canyon divide, the bed disappears under terrace material, and cannot be found again in Mint Canyon. Therefore, although conglomerates very similar to the basal bed described above can be recognized in Mint Canyon, they cannot be distinguished from the overlying conglomerates, and they are therefore mapped as part of member two in that region.

Member two is a 3300 foot thick section of interbedded conglomerates and finer materials. The conglomerate is typically buff colored, composed principally of pebble to cobble extrusive fragments of lava, and forms local cliffs. In the lower 2000 feet of the member, red to brown siltstone and fine sandstone predominate as the intercalated material. It is poorly bedded and deeply cut by channels, which in some places cut entirely through the siltstone beds. This, added to the poor bedding of the conglomerates, gives a very uneven and lenticular character to the member, making it impossible to trace contacts for any distance. For this reason, the member has not been subdivided into smaller units. In the upper part of the member, buff, massive sandstones predominate over siltstones. Here, as lower in the member, the bedding is quite lenticular. West of Mint Canyon, the siltstones and sandstones predominate over the conglomerates.

Member three comprises approximately 800 feet of massive sandstones and conglomerates. This member has a light, almost dead white color that contrasts strongly with the buff to cream color of the underlying member. The change in color, which is quite sharp, is due to an upward change in the igneous constituent material of the sediments from predominantly extrusives (colored or dark lavas) to predominantly intrusives (grano-diorite, syenite, anorthosite, etc.). West of Mint Canyon extrusives begin to appear in this member, and the lower boundary becomes impossible to distinguish as a color contact. In addition to the conglomerates and sandstones, this member contains some three to fifteen foot beds of gray-green or red siltstone. These increasing in number to the west, and are locally fossiliferous. A one to twelve inch tuffaceous sandstone is prominent as a white outcrop, near Mint Canyon in the lower part of the section.

Member four is characterized by a basal bed of sixty to ninety feet of dark yellow, hard, massive sandstone. The rest of the member, making a total of about 1000 feet, is composed of white, moderately well-bedded sandstone and pebble conglomerate, interbedded with greenish, reddish, or lavender siltstone.

Mint Canyon-Tick Canyon Boundary, and the Age of the Formations. The first paleontological determination of the age of the Mint Canyon "formation" was made by Stock, and reported by Kew (1924, p 54), as upper Miocene. Later examination of a considerable amount of subsequently collected material led Maxson to assign a middle-upper Miocene age (1933, p 86). This determination was contested by Stirton, principally on the basis of the appearance of Hipparion, a classical Pliocene criterion (1933, p 570; 1939, p 131, 1940, p 184). Although the Mint Canyon formation, in the vicinity of Bouquet Canyon is unconformably overlain by a thick marine section generally conceded to be of uppermost Miocene age, Stirton insists that its age has not been proved (Stirton, 1939, p 136; Kleinpell, 1938, p 71). Just in case it should be proved, however, Stirton proposed that the invertebrate Miocene-Pliocene boundary should be pre-Nerola. The question resolves into the lack of correlation between the vertebrate and invertebrate time scales, a discrepancy that is now known to be almost world-wide. It is Stirton's contention that the vertebrate scale should be used because the forms range farther and faster, giving a better time equivalence for the appearance of any form throughout the world (Stirton, 1939, p 131). Vertebrate paleontologists who might agree with this principle still might disagree with the arbitrary choice of Hipparion as the marker for the Pliocene. On the other hand, it has been maintained that "the invertebrates reflect, in their natural unities, the epirogenic cycles by means of which the divisions of geologic time seem best delimited" (Eaton, 1939b, p 916). Eaton further points out that in California, at least, the Tertiary marine section is much more complete than is the continental section, which makes an invertebrate scale at once more authoritative and more useful. If the invertebrate scale is assumed to be essentially correct, the Mint Canyon series cannot be other than Miocene, and Hipparion appears in the Miocene. That is the assumption this writer makes. Corrobative evidence is furnished by correlation of flora of the Mint Canyon formation with the Miocene Kinnick formation (Axelrod, 1940, p 582).

Although the association of primitive and advanced faunal forms in the Mint Canyon (series) was recognized earlier (Maxson, 1933, p 85), a stratigraphic division was not made until Jahns named and described the lower part of the series as the Tick Canyon formation (Jahns, 1939, p 819; 1940, p 154). At about the same time, Eaton suggested a division into the Lower Mint Canyon formation of lower-middle Miocene age, and the Upper Mint Canyon formation, of lower-upper Miocene age (1939b, p 914). It should be noted that although Stirton once admitted that the lower part of the Mint Canyon series might be Miocene (1936, p 181), he returns it to the Pliocene in his last paper (1939, p 135).

As for the lithologic boundary which might be expected to accompany such a faunal discontinuity, it is not generally recognized that Hershey was the first to describe it (1902b, p 356). As may be seen in the frontispiece and in the section described above, the beds in Tick Canyon show a distinct lithologic break; between the hard green conglomerates and colored siltstones below, to the poorly consolidated gray and buff conglomerates above. The distinction was so great that Hershey designated it as the boundary between the "Middle Pliocene" (Mellenia series), and the "Upper Pliocene." Maxson recognized the preponderance of reddish siltstones and sandstones in the lower part of the section, but did not make a definite division on this basis (1933, p 81). Jahns recognised a lithologic break corresponding closely to the change in forms, and in addition mentions a small angular unconformity as being present in one locality (1940, p 163). The writer fixed a tentative boundary in Tick Canyon, above the highest discovered Tick Canyon fauna in that region. A critical reading of Hershey at a later date brought out the fact that this boundary corresponded almost exactly with his boundary. Inasmuch as this has been correlated with the Tick Canyon formation described by

Jahns, priority recommends the use of Mellenia formation in place of Tick Canyon formation. Because the name Tick Canyon is well established, however, its use is continued herein.

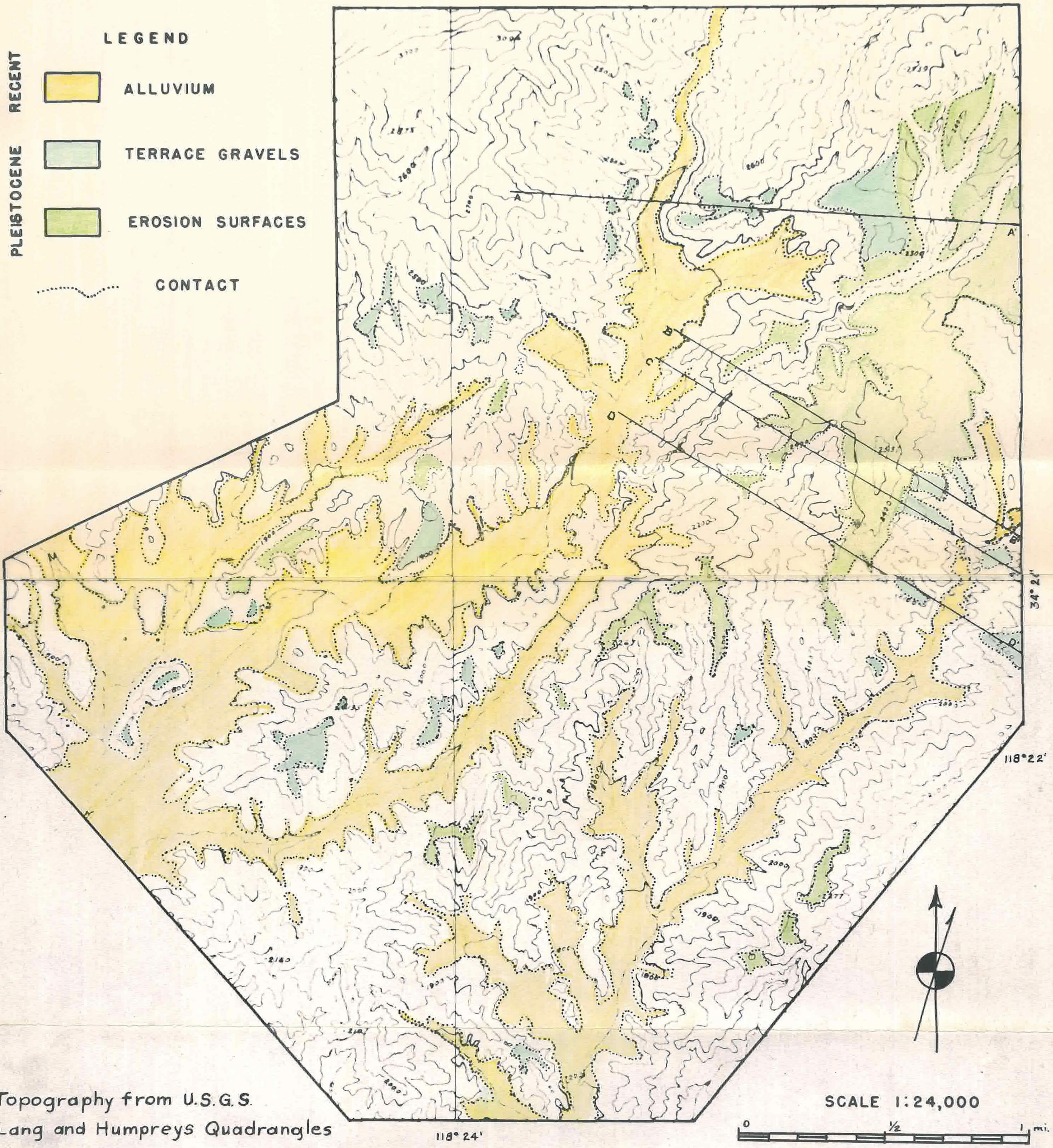
The Mint Canyon-Tick Canyon boundary may be followed on the geologic map, (Plate 2). At the west end it lies at the base of a white cherty conglomerate, a position determined by Jahns (1940, fig 3). Here the Tick Canyon formation all but pinches out against the Canyon Spring gneiss. It never entirely disappears, statements to the contrary notwithstanding (Jahns, 1940, p 154); except where it is faulted off in two places. Coming eastward, just west of Mint Canyon, the boundary marker bed grades laterally into a green cobble conglomerate. This bed is correlated with the uppermost of its kind in the section in Tick Canyon. Although the contact is obscured for some distance between Mint and Tick Canyons under terrace and regolith material, the correlation is quite certain because of the uniqueness of the bed and its stratigraphic relations. The boundary can be easily correlated across the faults in Tick Canyon, where it has been moved to the north (see Plate 12B), and can probably be traced for several miles farther to the east and south.

Along the entire boundary as described above, the writer has found no evidence of an angular unconformity of any more magnitude than the small discontinuities that are present throughout the section, due to stream scouring and the lenticular nature of the continental deposition.

QUATERNARY

The distribution of the Quaternary superficial deposits is shown on a separate map (Plate 8).

PLATE 8



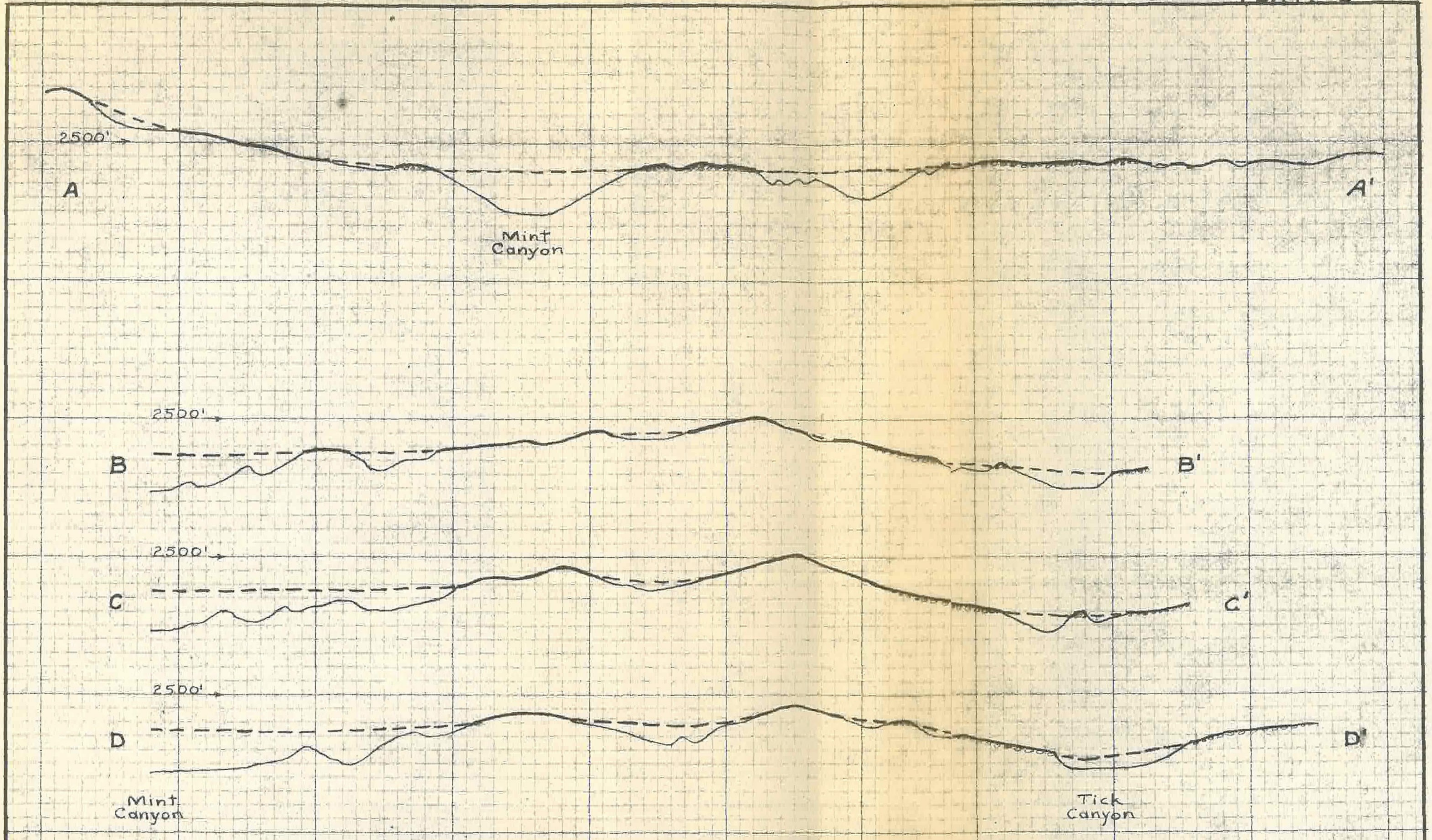
Topography from U.S.G.S.
Lang and Humpreys Quadrangles

Geology by W.T. Holser
1945-46

MINT CANYON AREA

LOS ANGELES COUNTY, CALIFORNIA

QUATERNARY GEOLOGY



CROSS STREAM PROFILES

Showing representative remnants and reconstructed sections o Pleistocene erosion surface, near the upper end of Tick Canyon. See Plate 5 for location ofsections

Vertical and horizontal scales 1:12,000

Present surface — *Old surface* — *Terrace deposits*

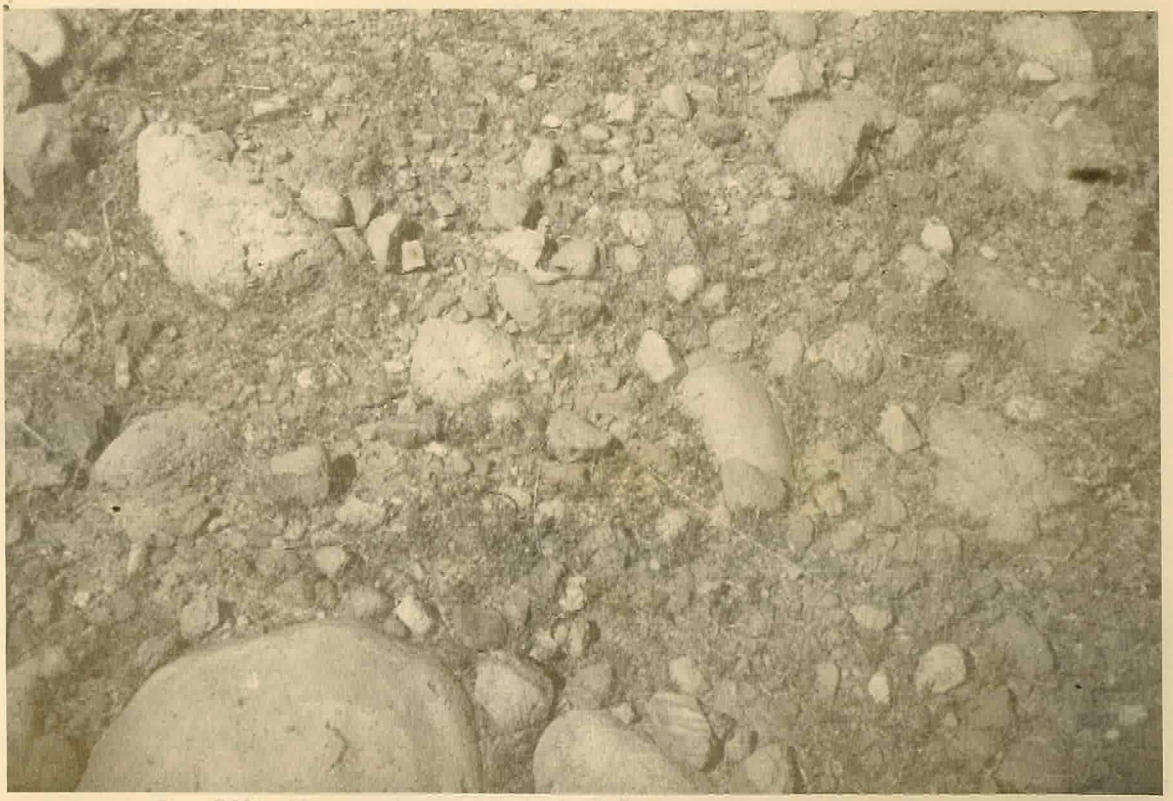
Panoramic view, southwest across Mint and Tick Canyons, approximatley along the line of section CC'. Note the remnants of the Pleistocene erosion surface onthe Mint Canyon-Tick Canyon divide in the middle distance. San Gabriel Mountains in the background.

Plate 10

Pleistocene Terraces. Unconsolidated terrace material is exposed in scattered remnants throughout the northern part of the area. It is composed principally of boulders and cobbles of extrusive and intrusive igneous rock, metamorphics, and similar materials eroded from the Mint Canyon series conglomerates and redeposited. These latter fragments make it very difficult in many cases to distinguish between terrace deposits, and a regolith where the material from the conglomerates has not suffered any appreciable transportation. The terrace deposits sometimes contain a reddish soil that serve to distinguish them. The thickness of the terrace deposits ranges up to forty feet, and they generally have the shape of weges, lying on valley sides.

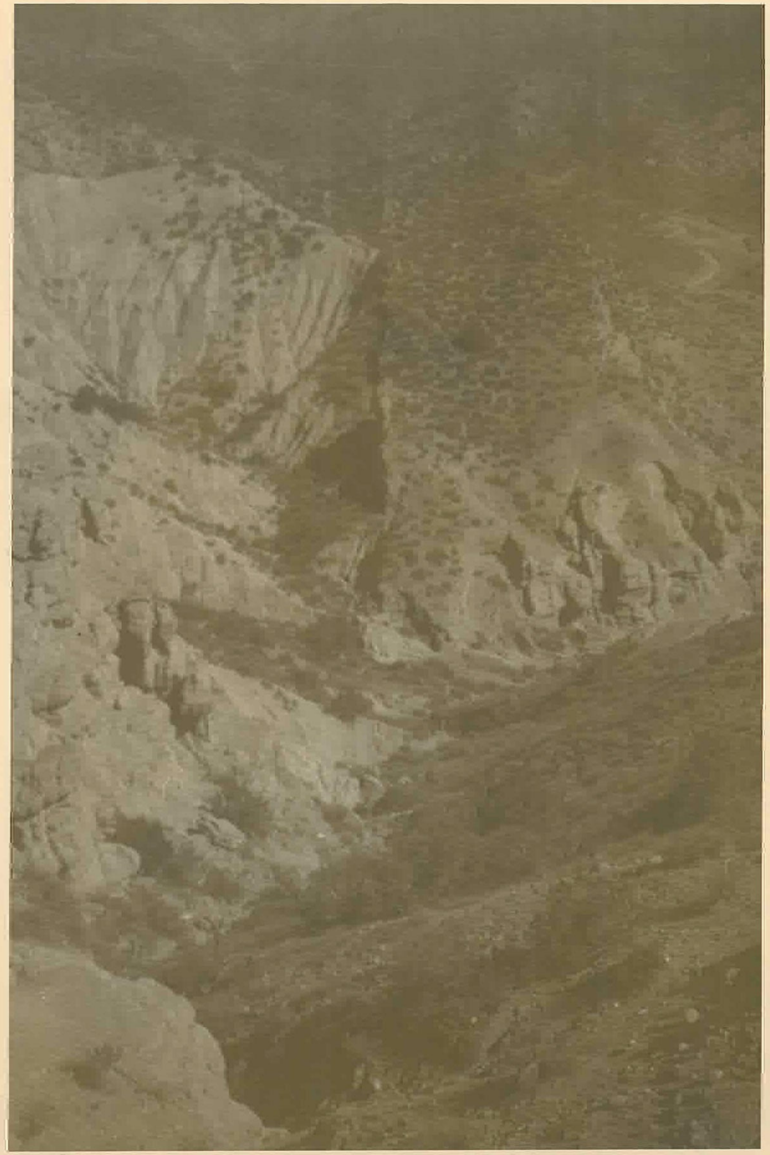
Recent Alluvium. Alluvium of undetermined thickness covers the floor of the two main canyons, and extends far up the tributary canyons; in several cases completely surrounding parts of old ridges, as shown in Plate 11A. The alluvium ranges in size from medium grained sand to boulders, and is composed of representatives of every rock type in the area.

A Recent alluviation in Mint Canyon, accented by its extensive cultivation



B Desert pavement on the surface of a Pleistocene terrace

A. Recent stream gully cut in less recent alluvium to a depth of about twelve feet.



B. Tick Canyon Fault: member three of the Tick Canyon formation displaced from the left foreground to the bottom of the canyon in the center.

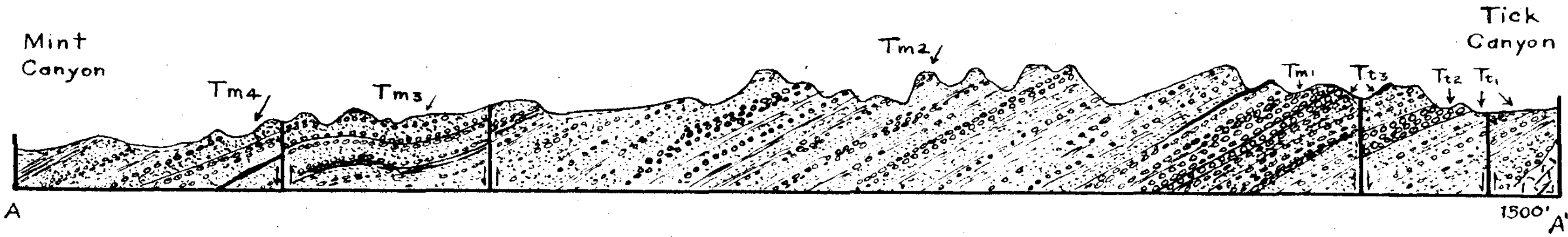
STRUCTURE

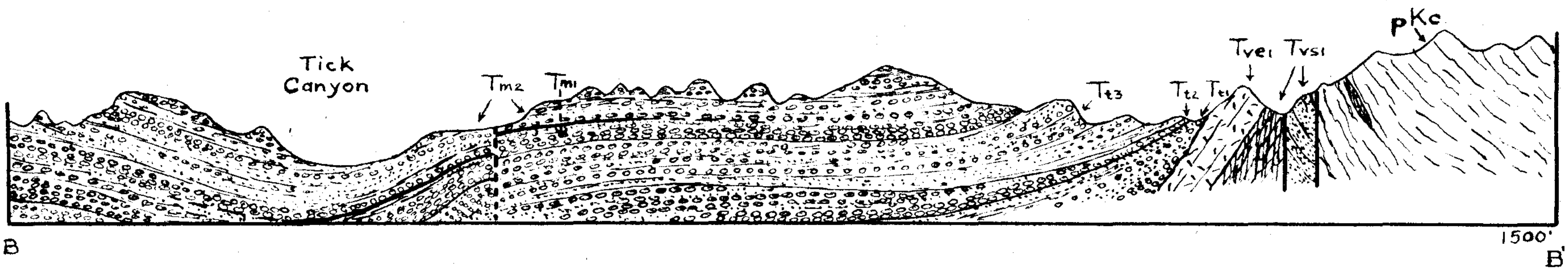
The Elizabeth Lake Quadrangle, adjacent on the north and genetically related to this area, has been considered to be part of the Great Basin structural province (Simpson, 1934, p 402). However, the predominance of rift type faults instead of vertically displaced blocks as the dominant structural type would suggest that this is not a good correlation, at least when extended to the Mint Canyon region. The San Andreas fault, which is usually considered to be the southern boundary of the Basin Range province, is apparently the controlling feature in the region. As has been suggested, it seems probable, that the numerous, parallel, strike-slip faults described below bear a gash fracture relation to the San Andreas fault (Jahns, 1940, p 169). The suggestion is made that the region of the San Andreas Rift, at least throughout this part of its length, represents a distinct structural province, separate from the Basin Range and other provinces. It has previously been shown that the entire section of the Great Basin south of Garlock Fault represents a subprovince of the Basin Ranges, markedly different in structure and physiography from the areas to the north (Noble, 1927, p 35; Nolan, 1943, p 186).

The detailed structure in the Mint Canyon area is shown in plan on the pre-Quaternary geologic map, Plate 3, and in two representative cross sections, Plate 13.

FAULTING

Faulting in this area has taken place at least three times in





GEOLOGIC STRUCTURE SECTIONS

MINT CANYON AREA

Vertical and horizontal scales = 1:24,000 the past. The earliest evidence of faulting is in the basin-like configuration of the Vasques series. Particularly when viewed on a regional scale, it is evident that this series was deposited in a wide basin. Many of the sediments are of fluviatile origin, and some are so coarse as to suggest short transport. These two facts force the assumption of a line of hills or mountains blocking out the basin on the north and east, and furnishing sediments to it. The faulting that raised these mountains therefore occurred in pre-Vasques and possibly in pre-Tertiary time. In order to cause high relief of the basin periphery, these faults must have been of the dip-slip type. If later faults have tended to follow the same plan, as is believed, they were steep normal faults rather than thrust faults.

The second epoch of faulting accompanied the folding of the Vasquez series after their deposition, and some of the complexity of the Vasquez stratigraphy, in the canyon just east of upper Mint Canyon, is probably due to faulting at this time. The Canyon Spring gneiss suffered further uplift along its bounding fault during this same orogenic period.

The most important movements of the third period of faulting in the area mapped were probably oblique slip movements. These usually took place in a general northeast-southwest direction, the east side in all cases having moved north. Typical is the Tick Canyon fault zone, one plane of which is shown in Plate 12B. Along this fault slickensides indicate that at least part of the recent movement was within ten degrees of horizontal. The old fault boundary of the Canyon Spring gneiss took part in this movement, probably moving this time with an oblique slip. The largest fault displacement that can be measured in the area is along this fault, west of

Mint Canyon, and involves the displacement of the Tick Canyon formation by roughly 2000 feet stratigraphically. All of the strike slip faults die out very markedly southward. This might indicate that the third period of faulting began before deposition of the Tick Canyon formation, and continued with diminishing displacement in Mint Canyon time. The westernmost of these faults, west of Mint Canyon, changes from a fault of large displacement (in the middle of member two of the Mint Canyon formation - note offset of marker bed), to one of small displacement in member three, and finally into a monclinal fold in member four. It is believed that this orogenic period began in the early Miocene and continued into the Pliocene.

Faulting and folding of an intense but quite local nature occurred as a result of horizontal shear between strike slip faults. A good example of the resulting complex local structure lies in the central part of the area, west of Mint Canyon (see Plate 2).

During the same orogenic period, but in general just before the strike slip faulting, minor block faulting occurred in the Mint Canyon series. The faults have a northwest-southeast trend, and while the faults are essentially normal, dip-slip faults with angles of at least 45 degrees, some of them dip to the north and some to the south. At this time, there was probably similar movement along a plane of weakness existing in the Vasquez lavas next to the Tick Canyon contact, as evidenced by silicified zones parallel to the unconformity, as well as the manner in which the overlying Tick Canyon beds appear to butt into the lavas.

In the Mint Canyon area there is no evidence in the area of recent faulting; the Pleistocene terrace deposits have been uplifted but not noticeably faulted, even where they cover faults of large displacement.

FOLDING

The Vasquez sediments and flows dip at angles varying from 65 degrees to vertical, whereas the average dip of the overlying Tick Canyon formation is only twenty degrees. This indicates a considerable amount of tilt, occurring near the end of the Oligocene or in the lowermost Miocene. Further evidence of folding of the Vasquez series is found in the canyon just east of upper Mint Canyon, where the gypsiferous shales are intensely contorted.

As a matter of fact, all of the folding in the area, with the above exception, has been of the nature of open folds, rather than of a compression into closed folds. The Mint Canyon series suffered a certain amount of this type of distortion. Because of the nature of the deposition, in a rather steep basin, the sediments had an initial synclinal structure, which influenced the later deformation. The main synclinal axis runs in an east-west direction across the center of the area. Folding along this axis began while the Mint Canyon formation was still being deposited, as indicated by the very appreciable thickening of this formation on the bottom of the syncline, in the vicinity of Tick Canyon. Just north of the main syncline, in Tick Canyon, is a definite anticline, and beyond that to the northwest the broad syncline is again dominant. The syncline is here indicated by two discontinuous axes, but in view of the broad nature of the warping, they might have been interpreted as a single axis in some intermediate position.

There are several cross structures in the west, as indicated on Plate 2. These are minor, however. Remembering further that part of the large synclinal structure is depositional, it may be stated, in summary, that intense compressive deformation has played a relatively minor role in the recent history of the Mint Canyon area. This situation is particularly striking when it is compared with that in nearby areas where the sediments have undergone intensive folding as recently as the late Pleistocene (see, for example, Kew, 1924, p 18). Although the greatest Tertiary diastrophism was in the middle Pleistocene, it has been pointed out that this was only the culmination of deformation that began in the late Moicene (Woodring, 1937; Miller, 1934, pp 72-77).

The Pleistocene deformation in the area mapped was on quite a large scale, but it was confined to tilting and uplift. Some time after erosion had removed several thousand feet of sediments, the region was again uplifted several hundred feet, this time without any appreciable tilting, as shown by the essentially undisturbed condition of the Pleistocene terraces. The recent gullying previously mentioned, and shown in Plate 12A, may have been due to a climatic change, but was probably due to a slight regional uplift.

An important structural feature of a nearby area may be inferred from one of the sedimentary features of the Mint Canyon formation. As described in the section on stratigraphy, above, there is a very pronounced change in the character of the fragments between members two and three. The dominantly volcanic nature of the sedimentary fragments in number two and lower members indicates an origin in the Vasquez formation to the north and east. On the other hand, intrusives such as granodiorite and anorthosite, found in members three and four, could only have come from the region of the San Gabriel Mountains to the southeast. This indicates accelerated uncovering of this intrusive mass, which was probably due to movement along the Soledad and Pole Canyon faults, as these are the dominant planes of uplift of the San Gabriel massif (Oakeshott, 1937, p 238). Whereas Hill says that the anorthosite masses of the northern San Gabriel (the general area in question) were uplifted not earlier than the late Pliocene (Hill, 1929, p 256), Miller dates the uplift as Middle Miocene (1934, p 77), and Oakeshott as Upper Miocene (1937, p 240). The evidence of the Mint Canyon formation indicates accelerated uplift of the San Gabriels in Late Miocene.

GEOMORPHOLOGY

PLEISTOCENE EROSION SURFACE

As indicated in the section on stratigraphy, Pleistocene terrace deposits are widespread in the area mapped (see Plate 8). Also present in the same general area are remnants of an old erosion surface of maturity. The surface is distinguished by its gentle relief and a capping of regolith sometimes ten feet thick that obscures the underlying bedrock. Although it has been pointed out that concordant ridges are not necessarily equivalent to erosion surfaces (Buwalda, 1924) some that were quite flat topped are correlated on the map as being part of the erosion surface. It is believed that if they are not exactly equivalent, at least they have not been reduced substantially from the original surface. The erosion surface remnants represent steeper slopes and a larger amount of relief than is usually correlated as representing a contemporaneous surface. However, a field examination of hill 2537, between Mint Canyon and the upper end of Tick Canyon, shows a large area of quite variable elevation and steep slopes that is obviously all one surface. This can be seen in the panorama, Plate 10. Referring to the map of Quaternary geology (Plate 8) and the cross stream profiles (Plate 9) the measure of relief and the continuous aspect of this surface may be appreciated. The mature surface is seen to cover the entire top of the 2500 foot peak in sections B, C, and D; and terrace deposits slope steeply down the Tick Canyon side. The surface is apparently in the late mature stage of development, with moderately high, well-rounded ridges and panplane valleys. The forms developed indicate a semi-arid climate. These sections prove the contemporanity of the surface with terrace deposits of rather diverse elevations. This, combined with the fact that the variability that is seen between the three sections, quite closely spaced in plan, serves to illustrate how futile it would be to attempt assignment of terraces and surfaces to closely defined elevations. It is believed that most of the higher terraces in the area are nearly contemporaneous with the major erosion surface; and that the slight extent to which they deviate from it would be very difficult to determine, in this particular area (where the old relief was so great). Such detailed correlations as have been made farther down in the Santa Clara River Valley have therefore not been attempted here. Section AA' shows a small part of the area in which such correlation would be possible, but its occurence is exceptional.

The only exceptions to the above statements of correlation are some very low terraces that are certainly later than the ones described above. These may be seen to best advantage in Mint Canyon, on the west side of the highway near the Mint Canyon school, where they lie with an angular unconformity on the Mint Canyon formation. Furthermore, the mountainous northern part of the area has not been indicated on the map as part of the erosion surface, it being difficult in this area to recognize which parts belong to it. It is probable, however, in view of the great resistance of the rocks, that much of the upper part of the mountain has not been eroded to any great extent and therefore represents part of the surface. The upper part of Mint Canyon, on the other hand, has undergone considerable erosion: it has very steep sides with small remnants of several levels of stream gravels (Plate 8), and the stream at the bottom of the canyon is essentially at grade.

An interesting feature of some of the terrace deposits in Tick Canyon is illustrated in Plate 11B. The boulders and cobbles of the top layer of the terrace have been concentrated to the exclusion of the finer material, to such an extent that the appearance approaches that of desert pavement, and the tops of the fragments are coated with desert varnish. This is a result of the semi-arid climate in this region, and the long time the terraces have lain untouched.

The stream terraces of the Ventura Basin have been studied by Hershey (1902c), Grant and Gale (1931, pp 36-40), and Putnam (1938, 1942). They agree quite closely in assigning a middle Pleistocene age to the highest and best developed erosion surface in the lower part of the basin (Timber Canyon surface of Grant and Gale, Rincon or Sulphur Mountain surface of Putnam). The date assigned is shortly after the great mid-Pleistocene orogeny. Hershey correlated the principal erosion surface and terrace level in the Mint Canyon-Soledad Canyon area with the one in the lower part of the basin. The writer believes this correlation to be approximately correct, although the entire length of the valley will have to be mapped in detail before a definite answer can be given. In any case, because of the great uplift that must have preceeded the carving of this surface, its correlation with some post-orogenic epoch of the Pleistocene is certain.

PRESENT STAGE IN THE EROSION CYCLE

The large areas covered with recent alluvium, as shown on the map, Plate 8, indicate that the streams were essentially at grade when it was laid down; that is, the small streams had to do considerable meandering to make this valley fill. This, coupled with the occurence of remnants of an old surface and strath terraces on the interstream ridges, as detailed above, indicates a middle mature stage for this area. The "available relief" of the uplift causing the erosion was less than "critical relief", as is indicated by the occurrence of both of these features at the same time (Glock, 1932).

It is interesting to note, however, that all of the streams in the area have been rejuvenated through almost their whole lengths. This is shown by narrow gullies in most of the valleys, varying in depth from two to twelve feet. A good example from one of the lower tributaries of the Tick Canyon is shown in Plate 12A.

MINERAL DEPOSITS

Within several miles in almost any direction from the area of this report, there has been a considerable amount of mining activity (if not production) in the past. This particular area, however, presents little of interest from an economic standpoint.

The most promising development was the borax deposit in the upper Vasquez sediments, immediately adjacent to or just within the eastern edge of the map area. The deposit was opened up by the Sterling Borax Company sometime in the early 1900's, and was first described by Keyes in his survey of American borax deposits (1909, p 699). Development was particularly active during World War I, but the deposits were shut down as economically infeasible to operate after the richer Trona deposits reached high production in 1923. Although extensive underground workings were developed, they are now unfortunately inaccessible due to caving.

The borax occurs principally as the mineral colemanite, although it was erroneously described as a new species, neocolemanite (Eakle, 1911; and Hutchison, 1912). The colemanite occurs interbedded with the shales of the upper Vasquez sedimentary member. The origin of the colemanite has excited considerable academic discussion, aside from which it gives important evidence concerning the type of climate and the conditions of deposition prevailing in Vasquez times. Of considerable interest in connection with the theory of the origin of the colemanite, was the occurrence of the calcic boro-silicate, howlite, and the hydrous soda-calcic borate, ulexite. The ulexite, although not plentiful, occurred occasionally as nodules, particularly in the lower levels (Foshag, 1918). It is also important to note that none of the other usual carbonate or sulphate playa minerals occur in association with the colemanite. Several racically different theories have been advanced to account for the peculiar features of the Tick Canyon deposit or the similar deposits in northern Ventura County: precipitation from sea water (lagoonal deposition), direct precipitation from a playa lake, and metasomatic replacement of playa deposited carbonates (Keyes, 1909; Eakle, 1911; Gale, 1913). The explanation advanced by Foshag, however, seems to be the most reasonable, because it is based on laboratory data, and accounts for all the facts observable in the field. Foshag notes that while colemanite cannot be precipitated directly from a solution of borax salts, it can be formed in the presence of chloride solutions according to the equation:

Ulexite + sodium chloride = colemanite + borax + water (Foshag, 1921 p 210). The ulexite nodules are therefore unconverted remnants of the original playa deposit.

The above evidence makes it certain that playa lake conditions obtained in this area during at least part of Vasquez time. Additional evidence is furnished by the occurrence of gypsum in the lower Vasquez sedimentary member just east of upper Mint Canyon. Although the deposit is mentioned in one of the early state reports (Preston, 1889, p 195), and noted by Hershey as being of considerable extent (1902b, p 354), subsequent state reports are confined to a bibliographic reference. The presence of a 200 foot crosscut tunnel and some surface workings indicate, however, that some development was attempted within recent years. It is probable that the grade was too low to compete with richer southern California deposits.

Although some placer claim monuments were found in Tick Canyon, the reports of the State Mineralogist make no mention of production or even of claim locations within the map area. One of the state field assistants observed long ago, in regard to the placers of Los Angeles County, (Storms, 1891, p 248):

> "The placer regions hereabouts, including Dry Canyon, La Canon do los Murtes, Casteca Canyon, and the San Francisquito, have all produced a large amount of gold, but to the individuals working these alluvial deposits great fortunes never came."

Except for the "large production" mentioned, this applies to the Mint Canyon area even today.

Although the Mint Canyon and Vasquez series have several structures which might be suitable for the accumulation of oil or gas, the absence of any known petroleum source rock in the immediate vicinity makes the likelihood of any discoveries in the area very small (Kew, 1924, p 55). There remains the possibility of an occurrence such as the one in the Placerita Canyon Field, five miles to the southwest. There, oil apparently migrated along faults from the Eocene sediments that there underlie the Mint Canyon series, into the San Gabriel crystalline complex (Brown and Kew, 1932).

GEOLOGIC HISTORY

The results of this study may be most easily summarized with a statement of the inferred geologic history of the area. The essential features of this history are outlined below:

1. Pre-Cretaceous (?): Formation and metamorphism of the Canyon Spring gneiss, by methods undetermined.

2. Early Tertiary: Uplift of Canyon Spring and similar formations, in the form of fault blocks delineating an intermontane basin.

3. Oligocene (?): Erosion of the fault blocks and deposition of the resultant sand and gravel in the basin. Formation of playa lakes in a semi-arid climate and precipitations of borax and gypsum as evaporation proceeded. Intermittent extrusion of basaltic lavas, probably as fissure eruptions. End of Vasquez deposition accompanied by a period of orogeny, in which the less competent parts of the sediments were folded and the whole series tilted about 45 degrees to the south. Canyon Spring formation again uplifted.

4. Lower Miocene: Erosion of the uplifted land to the north, including metamorphics and the sediments and lavas of the Vasquez series. Deposition of Tick Canyon formation in the basin, in an initial synclinal form. Initiation of strike slip faulting.

5. Middle Miocene: A hiatus in deposition, but no deformation.

6. Late Miocene: Renewed deposition in the basin, with the material suffering somewhat less transport than in the Lower Miocene. The Mint Canyon formation was in the form of alluvial fans and playa lakes. Climatological conditions similar to those of today. Warping of the syncline continues throughout the period of deposition. Resumption of strike-slip faulting, with continued movement. In the later part of period, San Gabriels uplifted sufficiently to furnish sediments this far into the basin.

8. Pliocene: Probably continued continental deposition (inferred from other areas).

9. Pleistocene: Broad folding and uplift of the whole area. Erosion of the poorly or unconsolidated deposits, including all of the Pliocene, and thousands of feet of the Miocene series, to a surface of maturity. Temperate climate similar to present. Cutting of pan planes in the consequent or antecedent valleys and deposition of alluvium.

10. Recent: Renewed regional uplift. Deposition of alluvium. Slight uplift in very recent time and consequent rejuvenation of streams.

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