GEOLOGY OF THE AGUA DULCE CANYON AREA, LOS ANGELES COUNTY, CALIFORNIA

Thesis by

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ABSTRACT

The Agua Dulce Canyon area is in the northwest quarter of Los Angeles County, California. Within it are exposed 4000 feet of the Oligocene (?) Vasquez series and 1400 feet of the Miocene Tick Canyon formation. These are clastic sedimentary rocks distinguished by their unusual coarseness.

The Vasquez series is composed of sandstones and conglomerates, with some siltstone at the top of the section. These were deposited in a narrow continental basin that drained to the west, and were derived from neighboring highlands to north, south, and east. Most appear to have been laid down in the form of alluvial fans or piedmont alluvial plains. A 3000 foot section of anorthosite-rich conglomerates, here referred doubtfully to the Vasques series, is exposed in a fault block in the south part of the area.

The Tick Canyon formation lies unconformably above the Vasquez series. Only its basal parts are exposed within the Agua Dulce Canyon area. These consist wholly of conglomerate beds, the lowest of which contain numerous cobbles derived from lavas of the Vasquez series.

Quaternary gravels form a maximum of thirty feet of terrace capping, and also fill Pleistocene and Recent stream channels.

Two groups of faults cut the Tertiary sediments. These are located within the area as follows: the Soledad fault is near the southern border, the Burke fault and Little Escondido fault are in the southeast corner, the Bee Canyon fault and Escondido fault are in the center, and the Green Ranch fault is in the northwest corner. The Soledad fault and Bee Canyon fault are older than the others, which are en echelon faults. Vertical

movement has been predominant.

A gentle syncline trending northeast-southwest folds Vasquez and Tick Canyon rocks in the northern half of the area.

A subdued erosion surface existed in Quaternary time. Remnants can now be seen near the northern border of the area. Well developed stream terraces in Agua Dulce Canyon were contemporaneous with this surface. It is now being dissected by rejuvenated streams.

INTRODUCTION

NATURE AND SCOPE OF THE INVESTIGATION

North of the junction of Agua Dulce and Soledad Canyons is a great thickness of coarse conglomerates composed, in large part, of anorthosite boulders. Kew (1924) and Sharp (1935 b) have mapped the area in reconnaissance and assigned a doubtful Miocene age; however, it appeared possible to many subsequent workers that more detailed mapping might establish an earlier age for the conglomerates. The author undertook this mapping as partial fulfillment for the degree of Master of Science at the California Institute of Technology.

In the course of the present study, the author devoted some twenty days to the field mapping of an area of approximately seven square miles. In addition, more than three days were employed in careful examination of aerial photographs. The conglomerates, which were of particular interest, could be mapped only because contacts not evident on the ground could be seen on the photographs.

ACKNOWLEDGMENTS

This investigation was under the supervision of Drs. Richard H. Jahns and John H. Maxson, and acknowledgment is made of their helpful advice, thoughtful guidance, and aid in the field.

Mr. John Lance contributed freely of his knowledge of the geomorphology of the region, and of the detailed geology of adjacent areas. In addition, Mr. Lance and Mr. Richard Brooks were of assistance in the field.

Dr. Ian Campbell made identifications of most of the crystalline rocks which the author found in the conglomerates.

LOCATION AND GEOGRAPHY

The Agua Dulce Canyon area is located slightly northwest of the center of Los Angeles County, California (Figures 1 and 5). It is

Figure 1
Location of the Agua Dulce Canyon Area

drained by Soledad Canyon, Agua Dulce Canyon, and tributaries of these streams.

The area is easily accessible by road and rail. It may be reached over a good surfaced road by turning east from U. S. Highway 6 at Solamint, and proceeding twelve miles to Agua Dulce Canyon. Dirt roads are so spaced within the area that all points are within a mile of such routes of travel. The San Joaquin Valley line of the Southern Pacific Railroad follows Soledad Canyon, and two stations, Russ Siding and Lang, lie within or just outside the area.

Information for the Field Geologist

Steep sided hills produce some 1000 feet of relief. Cliffs are common and the conglomerates composing them do not give secure footing. The Santa Clara River and Agua Dulce Creek are seldom dry; but the other creeks and rills flow only for a week or so after a rain. Vegetation is limited to brush which is only occasionally dense enough to form an impediment to travel. West of the Agua Dulce Canyon, the bushes teem with rather innocuous ticks. Rattlesnakes have been reported but none were seen during the present investigation.

STRATIGRAPHY

GENERAL STATEMENT

The Agua Dulce Canyon area is underlain by pre-Cretaceous crystalline rocks and middle Tertiary non-marine sedimentary rocks. The crystalline rocks are faulted against the sedimentary rocks. The Tertiary rocks comprise two major units, the Tick Canyon formation of Miocene age and the Vasquez series of Oligocene (?) age. Together they are about a mile thick. Thin Pleistocene and Recent gravels cover terraces and stream channels.

CRYSTALLINE BASEMENT COMPLEX

The crystalline rocks which are well exposed south of Soledad Canyon consist of a great mass of anorthosite with a profusion of melanocratic inclusions. According to Miller (1934) these rocks are composed of white anorthosite with metadiorite inclusions and also dikes of biotite granite, granite pegmatite, and diorite.

VASQUEZ SERIES

General Statement

The Vasquez series has a doubtful stratigraphic position because no fossils have been found, it has no conformable contacts with sediments of known age, its coarse fragments suggest it was deposited in a local basin, and it is extensively faulted. Consequently, the coarse red and white conglomerates and sandstones cropping out around Agua Dulce Canyon have been asigned to Eocene to Middle Miocene time under a variety of names since they were first described by Hershey (1902b) as the Escondido series of Eocene age. The various names and age determinations have been compiled in Table 1.

The name "Vasquez" was applied to the series by Sharp (1935) to replace the name "Escondido" which was preoccupied (Wilmarth, 1931). He

Name	Author	Suggested Age	Basis of Age Determination
Escondido	Hershey (1902)	Eocene	Well established Eocene age of other volcanic rocks
Sespe (?)	Kew (1924)	Oligocene (?)	Lithology strikingly similar to that of Sespe formation
"Escondido"	Miller (1934)	Middle or possibly Lower Miocene	(1) Presence of interbedded lavas (Gale (1931) had shown middle Miocene to be the time of great concentration of Tertiary volcanic activity in the west) (2) Correlation with the lavas of the Topanga formation (Middle Miocene), which lies unconformably beneath a Miocene section free of lavas
Escondido	Simpson (1935)	Middle Miocene	(1) Correlation with the Topanga formation on the basis of stratigraphy and lithology (2) No basalts known older than Topanga
Vasquez	Sharp (1935)	Pre-Upper Miocene	Underlies Mint Canyon formation of upper Miocene age (determined by Maxson (1930))
Vasquez	Jahns (1940)	Oligocene (?)	Vertebrate fauna indicates Tick Canyon to be of late Lower or earliest Middle Miocene; Vasquez lies between this and the Lower Eocene Martinez formation

Table 1 - Name and Age Determinations of the Vasquez Series

defined it as the series of coarse clastic sediments and lavas cropping out in the Ravenna and Lang Quadrangles; and considered it to be of only local extent. Sharp's usage is followed in this paper, with the understanding that the Vasquez series is probably a correlative of the Sespe series. Within thirty miles of this area are widespread outcrops of coarse continental beds generally called the Sespe "formation". They lie unconformably between formations of upper Eocene and middle Miocene age. The deposition of the Vasquez was not necessarily contiguous or even entirely contemporaneous with any particular part of the Sespe; but, the two series are so similar in lithology and stratigraphic position that it appears to the author that the various outcrops of the Sespe, and the Vasquez, represent local alluvial fans and piedmont alluvial plains that were deposited in a small continental basin existing throughout late Eocene, Oligocene, and early Miocene time.

The arguments for assigning a Miocene age to the Vasquez have been refuted in some detail by Sharp (1935 b) and Jahns (1940), and will not be repeated in detail here. According to Jahns (1940), the vertebrate fauna of the overlying Tick Canyon formation indicates that it is of late Lower or earliest Middle Miocene age. The faulting, tilting, and erosion of the Vasquez prior to the deposition of the Tick Canyon suggests a definite hiatus, though not necessarily one of prolonged duration. Further, although the Vasquez lies directly on basement rocks, its correlative - the Sespe - lies unconformably above both Lower and Upper Eocene formations (Kew, 1924, Clements, 1937). Its range, therefore, is limited to post-Upper Eocene and pre-earliest Middle Miocene time, and it is referred doubtfully to the Oligocene.

Generalized Columnar Section
of the
Rocks Cropping Out in the Agua Dulce Canyon Area

Scale 1/12,000

Section measured on map

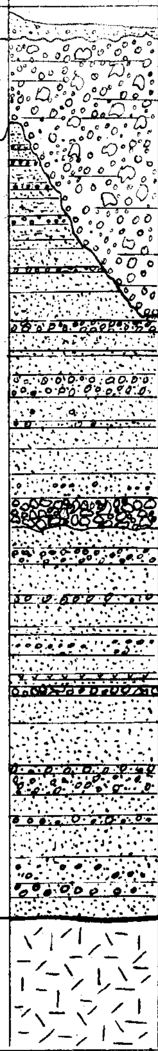
Age	Name	Columnar Section	Thickness	Character
Pleist.				Brown sandstone and conglomerate forming terraces and channel fill.
Miocene	Tick Canyon Form.		420' to 1420'	Coarse, massive, brownish conglomerate. Basal section buff to grey, hard, resistant; cobbles derived from Vasquez formation. Upper section reddish brown, resistant.
Oligocene (?)	Vasquez series		1910'	Red and white sandstone with some conglomerate. Upper beds less resistant and finer grained than those below. Pink crystalline tuff, 10' thick, near top.
			140'	Massive brown lava-rich conglomerate, very lenticular.
			800'	Coarse, red and white sandstone and conglomerate. Red amygdaloidal lava, 15' thick, in lowermost section.
			50'	Resistant buff conglomerate.
			1130'	Coarse red and white sandstone and conglomerate.
Pre-Cret.				Crystalline basement complex. Anorthosite with some metadiorite inclusions and granitic dykes.

Figure 2.

Lithology

Complex faulting has obscured the Vasquez stratigraphy and it is difficult to correlate beds across the faults because of lateral variation in the sediments. Consequently the stratigraphic sequence remains in doubt.

Within the Agua Dulce Canyon area, there is only a fault contact between the Vasquez series and the crystalline rocks; but in the Ravenna Quadrangle to the east it rests with depositional contact on the Parker Mountain quartz diorite (Kew, 1924).

North of the Bee Canyon fault is 4000 feet of Vasquez strata (Figure 2). These are sandstones and conglomerates strikingly colored in shades of red and white, except for a few dull green beds. The strata are not particularly coarse compared to other parts of the Vasquez, although boulder and cobble beds are not infrequent. In the top 1900 feet of the section the coarse sediments grade upward into finer and finer beds, the finest being arenaceous silts. These silts are interbedded with thin conglomerate beds. A fifteen-foot flow of amygdaloidal lava crops out in the lower half of the section. The cobbles that compose most of the conglomerate at the base of the Tick Canyon formation are composed of a similar lava but it is much harder. Near the top of the section is a pink crystalline rhyolitic or andesitic tuff ten feet thick. Intermixed gravel indicates it was water laid. Kew (1924) and Bonillas (1935) have reported over 3000 feet of basic lavas lower in the section, but the presence of a minor silicic phase of vulcanism in the Vasquez has not hither-to been noted in the literature.

In the middle of the section is a poorly sorted, reddish brown, very lenticular conglomerate with a maximum thickness of about thirty feet. Unusual evidences of turbulence during deposition are shown in excellent exposures in Escondido Canyon. The poor sorting, lenticularity and false bedding due to turbulence suggest that the rock is a lithified mud flow that was deposited in much the same fasion as the mud flows described by McGee (1897). A peculiar feature of the deposition of the mud flow is illustrated in Figure 3. It appear to be a conglomeratic sill pushed into unconsolidated sands as a result of a coincidence of high hydrostatic pressure in the mud flow, a steep initial dip in the sands, and a preexisting channel that exposed a bedding plane in the sand (Figure 4).

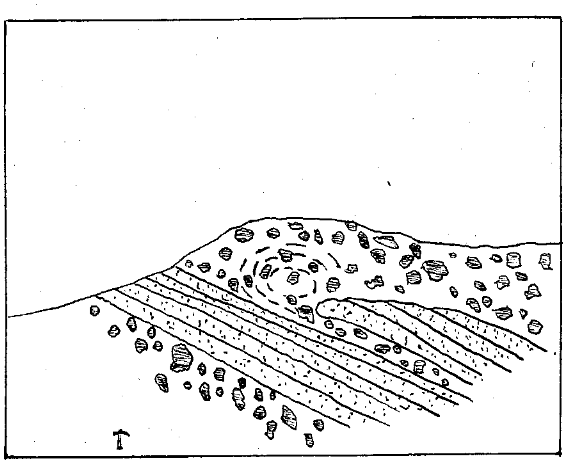


Figure 3
Outcrop in Escondido Canyon

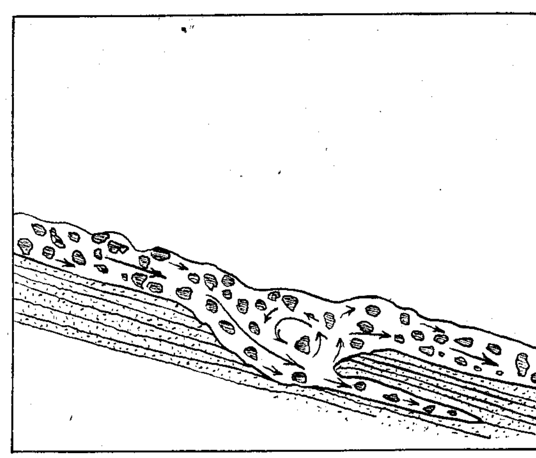


Figure 4
Deposition of conglomeratic sill

Most of the conglomerates are poorly sorted, but some beds, in which the particles are more rounded and appear to have been transported for a few miles, are faily well sorted. The largest fragments are three foot boulders and the smallest are sand grains; but there is only a small proportion of boulders, and pebbles predominate in most of the conglomerates. Particles are commonly sub-angular to sub-rounded, although those composed of quartz diorite may be angular due to gneissoid structure.

The Vasquez sandstones are more resistant to erosion than the interbedded conglomerates. Alternation of the two, in combination with a steep dip, produces a very irregular topography which has its best development in the Vasquez Rocks.

Origin and Sources of the Vasquez Sediments

The chief sources of the Vasquez conglomerates have been determined. Not only are single fragments large enough so that source rocks can be distinguished, but the main sourse rocks are readily identifiable in the field. The principal ones are white anorthosite and quartz diorite with gneissoid structure and prominent hornblende phenocrysts. Other, less distinctive, crystalline rocks were also deposited in the conglomerates. The present areal distribution of some of the source rocks is shown in Figure 5.

The large size (one to five feet) of the boulders in much of the Vasquez makes it apparent that transportation was over steep slopes and for distances of only a few thousand feet. On the north side of the Soledad fault are anorthosite rich conglomerates that can be distinguished only with difficulty from anorthosite in place on the south side of the fault. Sharp (1935 b) and Jahns (pers. comm.) have reported other occurrences of such conglomerates, and Sharp has further noted that the basal Vasquez conglomerate resting on the Parker Mountain quartz diorite is composed exclusively of huge angular quartz diorite boulders. A small fault block in the southeast corner of the Agua Dulce area contains a similar quartz diorite rich conglomerate, although it is faulted against anorthosite and is more than three miles from the nearest quartz diorito outcrop.

Within the Agua Dulce Canyon area, the Vasquez series is divisable into a quartz diorite-rich facies on the north and an anorthosite-rich facies on the south. Each facies is rich in fragments of the kind of crystalline rock which crops out nearest to it at the present time. This indicates that the basin in Oligocene (?) time had the same general configuration as at present. Two exceptions are worthy of note. No fragments of Pelona schist, which presently forms a highland to the north, are in the Vasquez beds, even where they are faulted against the schist in the Elizabeth Lake Quadrangle to the north (Simpson, 1934). The conclusion is therefore inescapable that the present Pelona highland did not exist when the Vasquez series was deposited. Moreover, Sharp (1935 b) reports that conglomerates composed exclusively of anorthosite crop out in the northwest part of the Ravenna Quadrangle. At present this area is much nearer to the syenite and quartz diorite basement than it is to the anorthosite. If the position of this anorthosite conglomerate may not be attributable to faulting, then the configuration which now obtains must have been somewhat different from that of the Oligocene highlands.

Vasquez (?) Series

About 3000 feet of conglomerates containing a large proportion of anorthosite crop out between the Bee Canyon and Soledad faults. Although some anorthosite boulders are eight to ten feet in maximum diameter, cobbles and pebbles predominate; so these conglomerates have been transported for a little distance before deposition. There can be little

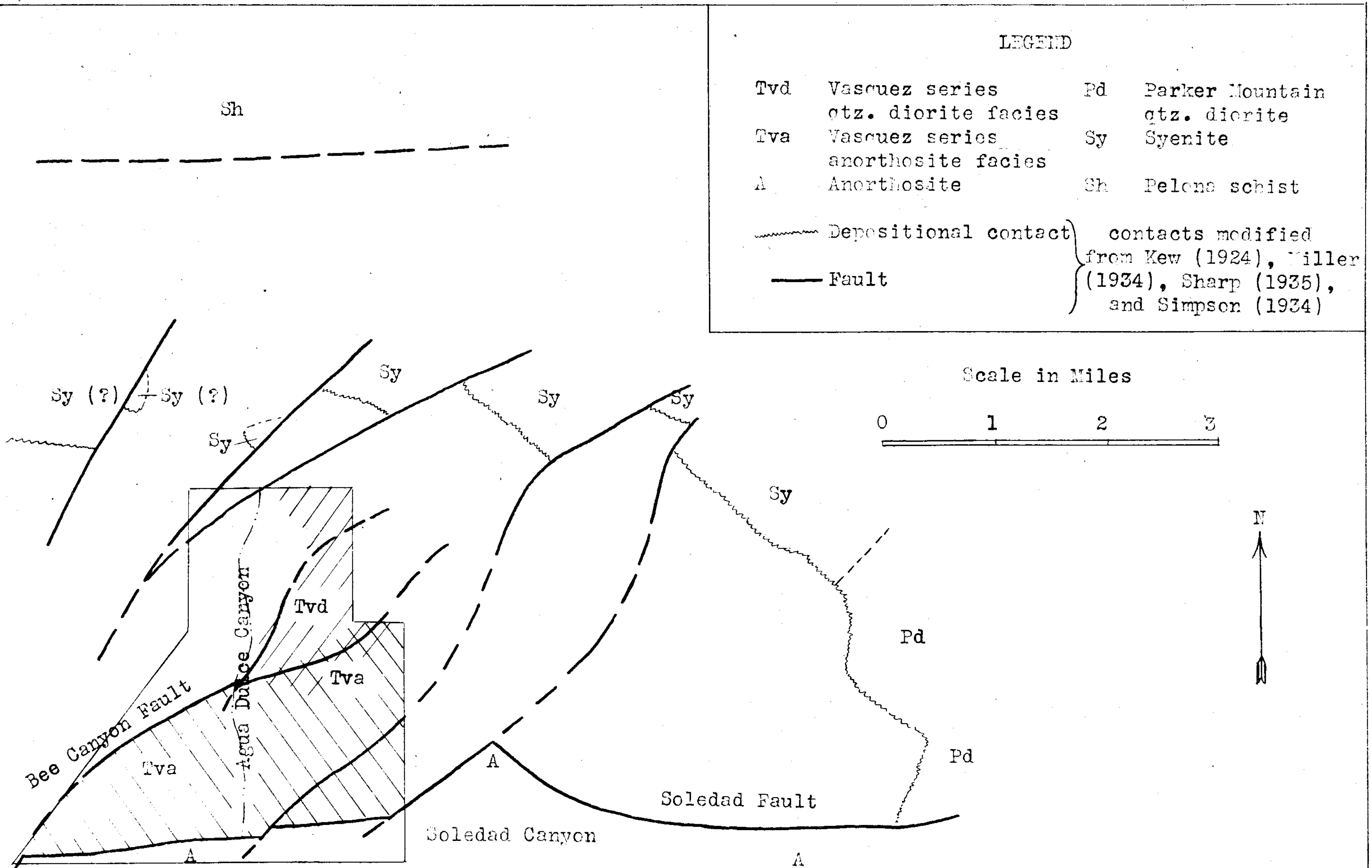


Figure 5. The areal relation of the source rocks to the lithological facies of the Vasquez conglomerates cropping out around Agua Dulce Canyon

question, however, but that they were derived from some portion of the anorthosite highland which crops out directly across the Soledad fault.

The stratigraphic position of the conglomerates is obscured because they are bounded by faults. Within the fault block, the conglomerates rest on red and white sandstones that are unquestionably Vasquez beds, but the contact is not sufficiently well exposed to establish whether or not it is conformable. Kew (1924) and Sharp (1935 b) have referred this conglomerate mass to the base of the Mint Canyon group on the evidence of similarity of lithology and of character of outcrop. Superficially, the resemblance to the abutting Tick Canyon formation (equivalent to the basal Mint Canyon formation of Kew and Sharp) is striking. However, as a result of detailed field mapping and a further study of the lithology, it now appears that the conglomerates are a part of the Vasquez series.

The evidence pertaining to the correlation of these rocks with the Vasquez series or the basal Tick Canyon formation is as follows:

1. The basal Tick Canyon conglomerate north of the Bee Canyon fault and the anorthosite-rich conglomerate south of the fault have thicknesses of 420 feet and 3000 feet respectively. However, the same basal conglomerate is 1420 feet thick a mile north of the fault, so thickness is very variable and a divergence in thickness of 2600 feet might be possible.

2. The Tick Canyon formation generally contains fragments of Vasquez lavas; the anorthosite-rich conglomerate does not. However, it does contain fragments of quartz diorite which would have had to pass over the lavas (if they had been exposed) in order to be deposited in the conglomerate.

3. Wherever the base of the Tick Canyon formation can be seen north of the fault, it is a conglomerate composed chiefly of well rounded lava cobbles. No such lava-rich conglomerate is exposed at the base of the anorthosite-rich conglomerate.

4. The basal Tick Canyon formation contains particles that are much more rounded than those in the anorthosite-rich conglomerate. However, some of this increased rounding might be attributable to increased distance of transportation.

5. The conspicuous resistant pink tuff found in the upper Vasquez series north of the fault cannot be found below the base of the anorthosite-rich conglomerate.

6. Movement on the Bee Canyon fault has apparently resulted in the northern block being downthrown. If the effects of this faulting are discounted, the anorthosite conglomerate would no longer be touching the basal Tick Canyon but would be separated from it.

The problem of the stratigraphic position of these rocks may be definitely solved if the displacement of the Bee Canyon fault can be established by detailed mapping in the Ravenna Quadrangle. Meanwhile the evidence presently available indicates that the anorthosite conglomerates are a part of the Vasquez series.

TICK CANYON FORMATION

The Tick Canyon formation was named by Jahns (1940) to distinguish the basal beds of Hershey's (1902) Mellenia series from those which lie above. It was called the Mint Canyon formation by Kew (1924). According to Jahns, the mammalian assemblage obtained from the Tick Canyon beds indicates they are of late Lower Miocene or earliest Middle Miocene age. In the type section three miles to the northwest, it consists of "693 feet of reddish brown clay siltstone and sandstone with a thick irregular zone of poorly lithified boulder to cobble conglomerate at the base".

The Tick Canyon beds exposed in the Agua Dulce Canyon area are the equivalent of the basal conglomerate in the type section. They consist of 420 feet to 1420 feet of massive red-brown to grey conglomerate resting with unconformable contact on the Vasquez series. At the very base, the conglomerate is composed almost wholly of well rounded lava cobbles derived from the Vasquez series. Anorthosite fragments are very rare in this lava-rich conglomerate, but they are abundant higher in the basal conglomerate where it crops out in Bee Canyon. At the same horizon, a few miles to the north in Agua Dulce Canyon, anorthosite fragments are rare, probably because of increased distance from the source.

On the evidence of field mapping in the adjacent area to the west, Lanse (pers. comm.) has stated that the top of the Tick Canyon lies 650 feet above the top of the basal conglomerate found in the Agua Dulce Canyon area. This indicates that the Tick Canyon formation is 1000 feet to 2000 feet thick. It is therefore considerably thicker than it is in the type section.

QUATERNARY GRAVELS

A veneer of Quaternary gravel lies on the remains of an old erosion surface. It varies in thickness up to an estimated thirty feet in Soledad Canyon. It is distinguished from the underlying Tertiary sediments by poor consolidated and horizontal bedding. The gravel commonly contains calcedony nodules derived from lavas of the Vasquez series.

Unconsolidated Recent alluvium covers the bottoms of most valleys.

STRUCTURE

GENERAL FEATURES

The structure in the Agua Dulce area is essentially that of a trough formed by differences in the primary dip of the sediments. This trough has been tilted toward the west and folded into a broad east-west syncline. It is bounded by steep faults which expose crystalline rocks, and has been vigorously sliced by en echelon faults trending northeast-southwest.

FAULTING

General Features

It is not surprising that this area has been deformed, for it is transected by the Soledad fault along which thousands of feet of vertical displacement have occurred, and about ten miles northeast is the San Andreas fault which may have a horizontal displacement of twenty four miles (Noble, 1927). Nor, considering the very competent nature of the sediments, is it surprising that the resulting strain has been relieved by faulting rather than folding. The faults present are of two distinct groups; the older Soledad and Bee Canyon faults, and the younger set of faults which trends northeast-southwest.

Soledad Fault

The Soledad fault forms the northern boundary of the San Gabriel Mountains. It faults anorthosite against several thousand feet of Tertiary sediments. It is a normal fault that dips northward. Miller (1934) reports dips of 60°, but dips of 70° have been observed by the author. The total displacement along this fault can only be estimated, but it is certainly large. According to Miller (1934) the upthrown block at present is 2000 feet above the downthrown solely as a result of post-Tertiary uplift. It cannot be established whether the fault actually marks the

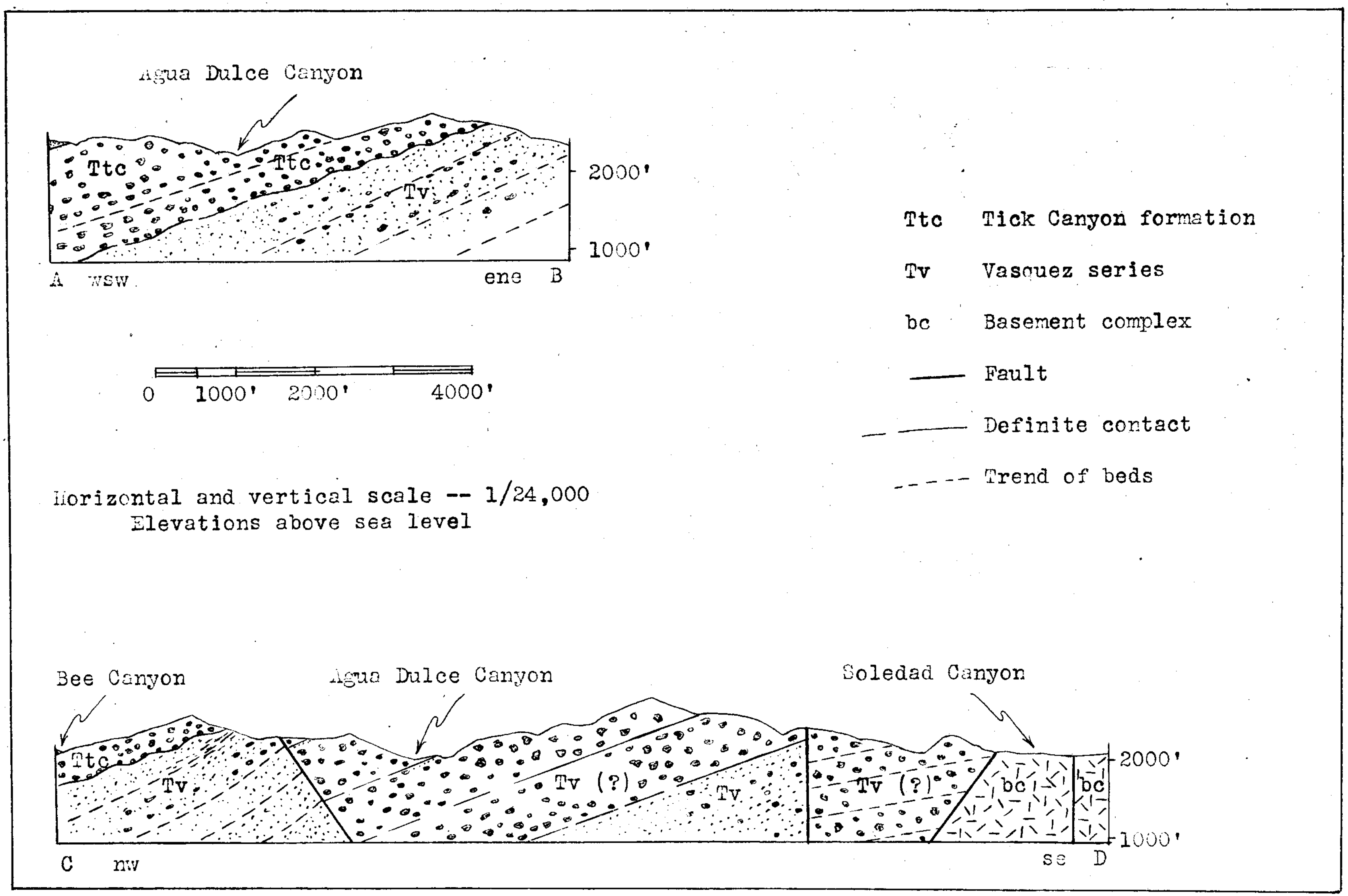


Figure 6. Structure sections across the Agua Dulce Canyon area

boundary of the San Gabriel Mountains as they existed during Tertiary time, but the very large anorthosite boulders in the bordering conglomerates makes the postulation of high relief due to faulting appear reasonable. If so, displacement on the fault during Tertiary time must have been sufficient to keep these mountains in existence as a rugged highland while more than 8000 feet of sedimentary and volcanic rocks were deposited in the adjacent basin. The fault appears to have been active during post Oligocene (?) pre-Recent time because it truncates Vasquez beds and does not disturb Quaternary gravels. However, this fault (or an equivalent nearby) must have existed while the Vasquez series was deposited in order to have a high-standing source for the conglomerates; so it was probably active prior to or during Oligocene (?) time. It is possible that the San Gabriel Mountains were not bounded by faults during early Tertiary time, but it appears unlikely, especially if one considers the statements of Noble (1927) and Miller (1934), that San Gabriel faulting probably existed in early Tertiary time.

Bee Canyon Fault

The Soledad fault is covered by alluvium at the junction of Bee and Soledad Canyons. It either continues westward or turns sharply southward and joins the Pole Canyon fault that forms the western boundary of the San Gabriel Mountains. From this point of junction, the Bee Canyon fault has an "S" shaped trend to the northwest and passes completely across the Agua Dulce Canyon area. It is a reverse fault that dips 60° to 70° southeast. Neither the magnitude nor the relation of vertical to horizontal movement is known, but a stratigraphic displacement of at least

1200 feet is indicated by the position of the anorthosite conglomerates south of the fault in relation to a comparable thickness of Vasquez sandstones and conglomerates. On the basis of inconclusive field data, the nature of the faulting is thought to be as shown in Figure 7. It is, therefore, a tear fault resulting from movement on the Soledad fault.

En Echelon Faults

A set of four northeast-southwest faults cuts through the area (Figure 5). From north to south they are the Green Ranch fault, the Escondido fault, the Little Escondido fault, and the Burke fault. The movement on each of these faults is such that the northern side appears upthrown. The Burke and Little Escondido faults offset the Soledad fault, and the Escondido fault cuts the Bee Canyon fault; so one may infer that one group of faults is later than the other. The last movement on the faults was post Tick Canyon; but Lance (pers. comm.) has observed that displacement along the faults, in the area adjacent on the west, is greater in the Vasquez series than in the Tick Canyon formation; hence it would appear that the initial movement was in pre-Tick Canyon and post-Vasquez time.

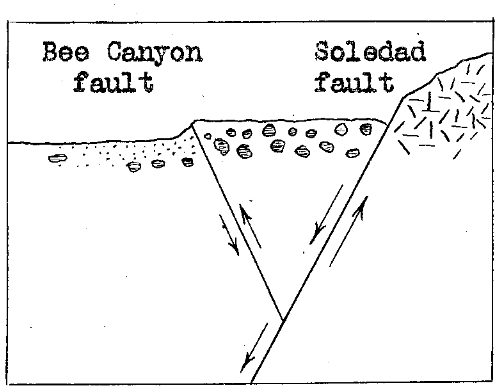


Figure 7
Nature of Bee Canyon fault

The Green Ranch and Burke faults are exposed for only very short distances in this area, and no detailed report can be made about them.

The Little Escondido fault appears to be the southwestward continuation of the fault mapped by Sharp (1935 b). It is nearly vertical but locally it has steep north or south dips. A stratigraphic displacement of about 350 - 400 feet is indicated by a doubtful correlation of sandstones on the north side of the fault, with conglomerates on the south side. This displacement agrees fairly well with that observed by Sharp (1935 b) some three miles to the northeast along the fault. A definite relation of vertical to horizontal movement was not established. There is a marked difference in the attitude of the fault blocks north and south of this fault. The southern block appears to have been rotated downward to the northwest. If this rotation occurred, some of the movement on the fault must have been vertical.

The Escondido fault definitely has the sinuous strike which the other faults in this group appear to have. Because of a series of excellent exposures in Escondido Canyon, a number of conclusions can be drawn about the movement and attitude of this fault. It could not be determined in the Agua Dulce Canyon area whether these conclusions apply to the other faults. Because the strike of the beds is fairly constant and the fault has a sinuous strike, it is both a dip fault and a strike fault. This makes it possible to establish that the resultant movement in the fault plane was at an angle of 35° with the vertical; and thus was oblique slip with a predominatly vertical component. It is a normal fault which has a steep dip to the southeast and stratigraphic displacement of 150 feet.

A sinuous strike is characteristic of this set of faults. Chamberlin (1919) has mapped similar sinuous en echelon faults but without comment on their sinuosity. Sherrill (1929) has noted the influence of the strike of the faulted beds upon the strike of straight en echelon faults. In the Escondido fault, the strike which forms the middle part of the "S" pattern corresponds to the bedding strike, and some correlation seems to exist. The fault has a trend at an angle acute to the bedding strike, this trend bends into the bedding strike for some distance, and emerges from the bedding strike with a trend parallel to the original one.

According to Chamberlin (1919) and Sherrill (1929), torsion is one cause of en echelon faulting. Nevin (1929) has emphasized the importance of vertical movement. Vertical or torsional forces appear to have been predominant in the present instance. It is difficult to conceive of hundreds to thousands of feet of strike slip occurring on a system of approximately parallel sinuous faults. Moreover, the direction of movement is predominantly vertical on the only fault where it is known. Miller (1928) has suggested that the San Gabriel Mountains south of the Soledad fault have been tilted toward the east. Such a tilt would be capable of producing a torsion which in turn could produce en echelon faults with the trends observed. The question of causative forces probably will not be settled until detailed field work to the north and east has established the direction of movement on a number of the other en echelon faults.

FOLDING

The competent sediments of the Vasquez and Tick Canyon lend themselves to folding only with difficulty. Despite the marked tectonic stresses to which the faults bear witness, the rocks have been folded only slightly.

The one clearly evident fold is a broad gentle syncline in the northern half of the area. It trends north 60° east and plunges gently southwest.

This syncline continues into the Tick Canyon beds to the west, and thence into the Mint Canyon formation (Kew, 1924); the folding therefore occurred in post-Mint Canyon time.

Minor variations in dip and strike of the sediments occur throughout the area; but they are generally near faults and have been interpreted by the author as warps due to displacement on the faults.

UNCONFORMITY

The Tick Canyon formation overlies the Vasquez series with a nonconformable contact. The differences in dip and strike are not very pronounced; further, any detailed accurate measurements of the nonconformity suffer from the absence of bedding in the basal Tick Canyon. However, the differences in strike appear to be ten to twenty degrees, those in dip about five to ten degrees.

The general trace of the nonconformity is irregular but easily distinguished. In sharp contrast to the obscure relation of dips and strikes are the excellent exposures of resistant red and white Vasquez sandstones truncated by the amorphous brown Tick Canyon conglomerate.

PRIMARY STRUCTURE

Primary Dip

The Vasquez sediments were deposited on alluvial fan or piedmont slopes, and consequently had a primary dip. It is now difficult to separate evidences of primary from structure dip, because the basin is broken into a number of fault blocks. However, the general swing in strike from north to northeast, which is apparent in the southern third of the area, probably reflects the primary dip.

<u>Stream Channels</u>

During Vasquez time, this basin must have been dissected by a number of gullies and arroyos along which floods rushed down from the surrounding mountains in time of rain. Such an old channel is exposed 2000 feet east of the junction of Escondido and Agua Dulce Canyons (Figure 3).
Very conspicuous Quaternary channels may be seen in the large road cuts in Soledad Canyon. Brown stream gravels fill channels cut in the white anorthosite. These channels represent old meandering courses of the Santa Clara River, if one can judge by their position and trend.

<u>Minor Evidences of Local Unconformities</u>

The fine grained sandstones of the upper Vasquez series frequently exhibit minor surface features. These are best shown in the area west of the Vasquez Rocks, where both current ripple marks and mud cracks may be found in hard platy sandstones and siltstones.

GEOLOGIC HISTORY

The geological history of this general area has been discussed by Jahns (1940), and it will not be treated further in this report except in so far as the Agua Dulce area contains field evidence pertaining to the history. The sequence of geological events appears to have been as follows:

1. A narrow continental basin, trending approximately east, was formed in late Eocene time, probably as a result of block faulting. The Soledad fault or some equivalent may well have been its southern boundary. It was bordered on the north, south, and east by crystalline highlands, and it drained toward the west. The basin shows no evidence of having been filled by the Eocene sea, and it contains sediments of Oligocene (?) age; therefore it probably was formed in late Eocene to early Oligocene time.

2. In the basin during Oligocene (?) time, streams deposited 8000 - 10,000 feet of very coarse sediments. About 3700 feet (Kew, 1924) of interlayered basalt and andesite lavas were also deposited. The basin, therefore, continued to sink with respect to both the surrounding highlands and sea level. The stream deposits formed a sedimentary trough pitching to the west because of the increase in their initial dip from the center of the basin toward the surrounding mountains. Near the close of Vasquez time, the mountains did not stand so high above the basin, and sandy and silty sediments were deposited in shallow playa lakes.

3. A set of faults trending northeast probably first became active in the hiatus between Vasquez and Tick Canyon deposition. During the same period, the Vasquez series was tilted about four or five degrees to

the west, elevated, and eroded.

4. In late Lower Miocene time, the Vasquez lavas served as a source of stream cobbles that formed the conglomerate at the base of the Tick Canyon formation. Deposition of these gravels continued, and the lowlands carved in the Vasquez series were rapidly filled in by cobbles and boulders, derived chiefly from the surrounding crystalline highlands.

5. The earlier northeast trending faults again became active after deposition of the Tick Canyon and Mint Canyon sediments. A broad, gentle syncline was formed with approximately the same position and trend as the original depositional trough. The basin was tilted fifteen to seventeen degrees to the west and eroded.

6. The area has continued to be subaerially eroded until the present time. During the Pleistocene period it was characterized by rather subdued topography. Mature streams carried gravels from the Vasquez series and from the crystalline basement complex to the north, south, and east. Owing to stream rejuvenation since that time, the area is at present being dissected toward the heads of the valleys.

GEOMORPHOLOGY

OLD EROSION SURFACES

Pre-Tick Canyon Surface

The marked variations in thickness of the basal conglomerate of the Tick Canyon formation suggests that the surface of the Vasquez series was very irregular at the beginning of Tick Canyon time. The area southwest of the Vasquez Rocks appears to have been particularly low relative to the reeminder of the basin.

Quaternary Surface

The flat surface covered with Quaternary alluvium, along the northern fringe of the area, is the remnant of a once extensive Quaternary erosion surface. Terraces in Agua Dulce and Soledad Canyons were contemporaneous with it. The surface appears to have been more subdued than the present one. Streams were mature because they must have been graded to cut terraces.

PRESENT STAGE OF EROSION

At present, the area is in a youthful stage of the erosion cycle. Streams have been rejuvenated and they are eroding the heads of their vallyes and dissecting the old Quaternary land surface.

DIP SLOPES

The present topography of this area is dominated by dip slopes. The close correspondence of the attitudes of the surface and the underlying beds can be seen very clearly in Figure 6.

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PHOTOGRAPHS

Photographs of the Vasquez series in the vicinity of the Vasquez. Rocks may be found may be found in papers by Kew (1924) and Simpson (1934).

Photo 1 - Vasquez series butting into the overlying Tick Canyon formation. Looking west from just south of the Vasquez Rocks.

Photo 2 - Old erosion surfaces in Agua Dulce Canyon. Looking north.

Photo 3 - Lithified mudflow. Note conglomeratic sill under the author's feet. East 1000 feet from juncture of Agua Dulce and Escondido Canyons.

Photo 4 - Margin of Quaternary stream channel. North side of Soledad Canyon just south of subject area.