GEOLOGY OF THE TICK CANYON AREA

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Abstract

(handed in with map)

GEOLOGY OF THE TICK CANYON AREA.

Introduction

The eastern part of the Ventura Basin contains great thicknesses of non-marine Tertiary sediments. The lower formations of the Tertiary strata outcrop in the Tick Canyon Area and are described in this report. Emphasis is placed on the description of the Vasquez formation which is the lowest Tertiary unit in the Tick Canyon Area and which contains the only Tertiary lavas found in the East Ventura Basin.

The field work for the report consisted of about 20 da ys of mapping on the scale of 1 inch equals 1000 feet for Geology 121 -- a required field course at the California Institute of Technology. The field descriptions of rocks given in this report have not been checked by microscopic work.

The only detailed maps of the area are those done by students of previous years who were either fulfilling the requirements for a course in field geology or doing a problem for a master's thesis.

O. H. Hershey (1902)* described some Tertiary formations of southern California. W. S. Kew (1924) described parts of the Tertiary strata and discussed the oil resources. The Vasquez formation was named and described by R. P. Sharp when he worked on it east of the Tick Canyon Area. The Tick Canyon and Mint Canyon formations were described in detail by R. H. Jahns (1940).

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* figures in parenthesis refer to reference.

Aknowledgments:

The writer wishes to convey his thanks to Carel Otte for any instruction recieved in the field and to Professor R. H. Jahns for information he divulged during conducted tours of the San Gabriel Mountains and East Ventura Basin.

He also wishes to extend this thanks to Mark Meier for taking any pictures requested and to Fred Barker for his inspiring comments and appropriate topographic names.*

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* Mr. Barker's comments and names have been censored.

General Geography.

The Tick Canyon Area is about two miles square and lies in the northern part of the Lang quadrangle.(see figure 1). The Davenport road, which crosses the southern part of the area, is easily accessible by car from Pasadena via Foothill B oulevard and Highway 6.

The topography is subdued compared to that found in the San Gabrial Mountains. The sediments are easily eroded giving rounded hills, but the volcanic members are relatively resistant and form hills which rise to a maximum elevation of 3100 feet and which give the area a total relief of 1000 feet. Drainage, when water is plentiful, is mostly to the southwest into Tick Canyon. A few creeks in the eastern part of the area drain to the southeast into Aqua Dulce Canyon.

This district has a sem-arid climate with an average yearly rainfall of about 15 inches. It is subject to long dry periods and to flash floods which cause rapid erosion and which often wash out parts of Davenport road.

Vegetation differs on southern and northern slopes. The southern slopes have a sparse growth of cacti, yucca, and a few junipers and the northern slopes usually have a thick growth of oak, manzanita, and juniper. Because of the scarcity of vegetation on the southern slopes, and because of the resulting ease with which disintegrated material can be washed from these slopes, the rock units are easily followed along then. In contrast to this, the vegetation on the northern slopes makes traversing them difficult and so impedes removal of soil that only the most resistant units form outcrops.

In many places, good exposures are afforded by the small adits which were dug by prospectors in search of borate-rich beds.

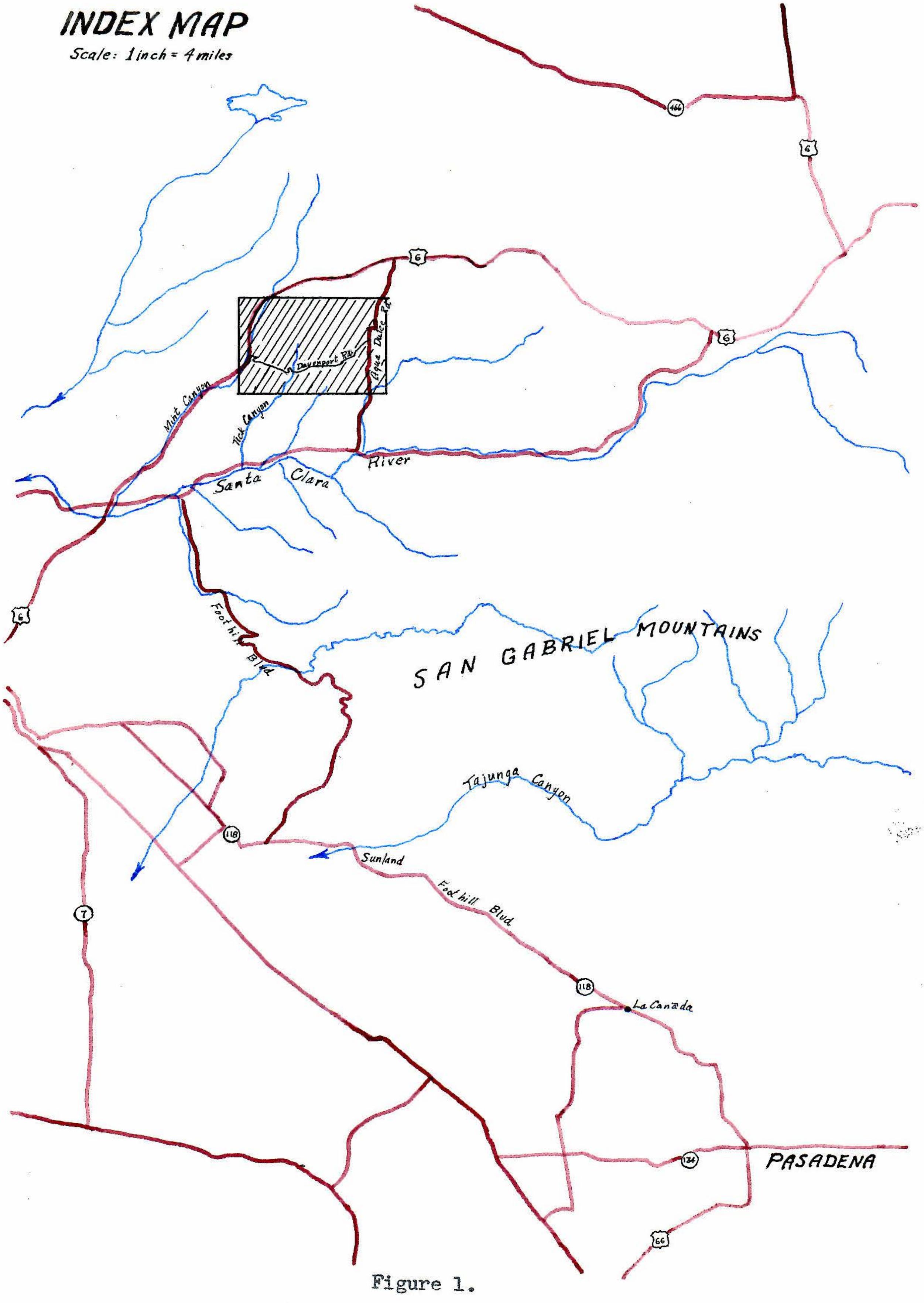
INDEX MAP
Scale: 1 inch = 4 miles
466
6
Davenport Rd.
Agua Dulce Rd.
Mint Canyon
Tick Canyon
Santa Clara River
Foothill Blvd
SAN GABRIEL MOUNTAINS
Tajunga Canyon
118
Sunland
Foothill Blvd
7
La Canada
124
PASADENA
66

Figure 1.

Statigraphy and Lithology.

This report deals with only the Vasquez, Tick Canyon, and Mint Canyon formations of the Tertiary period. The following complete table of the Tertiary formations of the East Ventura Basin and Northern San Gabriel Mountains in included to give the reader the relative positions of the three formations described.

Quaternary:

Recent Alluvium
Terrace Gravels
------unconformity------

Tertiary:

Pico formation	Middle Pliocene	marine beds
------conformable-------		
Repetto formation	Lower Pliocene	marine beds
------unconformity------		
Modelo formation	Uppermost Miocene	marine beds
------unconformity------		
Mint Canyon formation	Upper Miocene	non-marine beds
------disconformity-----		
Tick Canyon formation	upper Lower Miocene	non-marine beds
------unconformity------		
Vasquez formation	Oligocene (?)	non-marine beds
------unconformity------		
Martinez formation	Paleocene	marine beds
------unconformity------		

Pre-Cretaceous: (Crystalline Complex)

Younger Igneous Rocks (Pacifico granodiorite, Parker Mountain quartz diorite, and Wilson intrusive)
Anorthosite Complex

San Gabriel Complex

Pelona Schist

The ages used in the above table are those supplied by R.H. Jahns.[1] The ages of the Vasquez, Tick Canyon, and Mint Canyon formations have been discussed by R. H. Jahns (1940 ,p.169) in his report on the statigraphy of the East Ventura Basin.

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1. verbal communication

Include variation diagram for Vasquez formation

(handed in with map)

Figure 2

Basement Complex.

The Basement Complex, in this area, is a fine- to medium-grained gneissic rock which is probably related in age to the Pelona schist.

Quartz and white feldspar constitute most of the rock. The mafic minerals, which usually constitute less than 10 percent of the rock, are highly altered to chlorite. Orientation of the mafic minerals and of a few orthoclase (?) phenocrysts gives this rock a very regular gneissic structure.

Lenticular and dike-like masses of dark green or black rock are quite common in the gneiss. Some of the dike-like masses are aphanitic and have a sharp contact with the gneiss. They are probably dikes. Others are fine-grained phaneritic and seem to grade outward into true gneiss. They may be basic segregations or inclusions. An oil mount of fragments of the later type revealed that the dark minerals were hornblende and pyroxene.

The presence of the gneissic structure and of numerous cross fractures makes the gneiss weak and easily sucseptible to mechanical disintegration. As a result, the gneiss forms rounded hills, and outcrops of it are confined to steep sides of gullies or to adits and road cuts. Alteration of the mafic minerals releases iron which, on oxidation, gives the rock fragments a rusty color.

Vasquez Formation.

The Vasquez formation consists of 2500 feet of lacustrine and fluvatile sediments interbedded with 3200 feet of basic volcanics. For mapping purposes, the formation has been subdivided into the following twelve members:

	Maximum Thickness (feet)	
Lang Lava	600	
Tadpole Sediments		180
Goat Volcanics	400	
Davenport Sediments		570
Sterling Member	100	320
Matterhorn Member (volc.)	800	
(sed.)		140
Ocotillo Member		200
Zeola Lava	170	

(Vasquez members continued)

Yucca Sediments		140
Champion Volcanics	1200	
Manzanita Sediments		550
Juniper Conglomerate		500

Juniper Conglomerate:

This member is characterized by well-rounded boulders which were not derived from the Basement Complex in the immediate vicinity. These boulders are up to six inches in diameter and consist mostly of plutonic and a few volcanic rocks. Boulders examined are composed of gabbroic, dioritic, and granitic material, massive milky quartz, purplish porphyritic andesite (?), gneiss similar to that in the local B asement Complex, and dark green aphanitic dike rock from the Basement Complex. Mixed with these rounded boulders are angular fragments derived from the local gneiss. The gneissic fragments range in size from granules to 6-inch boulders.

The ratio of rounded to angular boulders changes acutely with increasing distance from the basement contact. A short adit near the contact reveals breccia which is composed of angular gneiss fragments between 1/16 and 6 inches in diameter and a few rounded boulders. This grades within 50 feet to conglomerate which is composed of predominantly rounded boulders of the foreign rocks.

The upper three quarters of this member has a buff or grey arkose groundmass (quartz, feldspar, and a few biotite grains). Rounded boulders both of the foreign rocks and of gneiss occur in lenses in this coarse arkose. Near the top of the member, the lenses of conglomerate become much scarcer and lenses of very fine arkose occur.

Cementing material is practically absent in this conglomerate and as a result the only outcrops are those of road cuts of addits.

B asement Contact: No conclusive evidence was found to prove whether this contact is depositional or faulted. The presence of much caliche along the contact could probably indicate either type of contact. The large ratio of angular gneiss fragments to foreign rounded boulders at the contact indicates that this conglomerate was deposited in the immediate vicinity of its main source--the Basement Complex. The large angle (about 45 degrees) between the dip of the contact and the dip of the adjacent sediments points to a fault contact. However, such a condition could be abtained if the B asement Complex had originally formed a steep-walled basin of deposition for the overlying sediments. The thining of the member eastward could also be explained by either of the above conditions. It seems probable thet the intense folding which tool place in the thin-bedded, relatively incompetant members of the Vasquez Formation should have produced some slippage along the contact with the underlying mare massive B asement Complex. Whether or not this is the only movement is unknown, but a fault contact has been assumed.

Manzanita Sediments:

In Tick Canyon, this member is characterized by massive beds of grey and buff arkoses.

The lower 30 feet consists of varigated (red, buff, grey, green) arkoses in 1-foot to 10-foot beds. These beds contain lenses of granules and angular boulders of gneissic Basement Complex. This part of the member is a gradation from the Juniper conglomerate to the Manzanita arkoses.

The arkoses of the middle part of the member are grey and contain lenses of granitic granules and lenses of siltstone. In parts of it, calcite forms a resistant cement and a white caliche lining on the fracture planes.

The upper part of the member has no carbonate but is cemented by limonite. Limonite coats the fractures and gives the outcrop a rusty color. This arkose is composed of quartz and feldspar grains and a few flakes of bleached biotite. About 200 feet from the top of the member is a 6-inch bed of resistant white tuff which breaks into angular fragments that, on weathering, acquire Liesegang's rings.

The increase in coarseness of the Manzanita arkoses eastward is so great that 1000 feet east of Tich Canyon, parts of the member are largely sharpstone conglomerate with arkose groundmass. The fragments are of granitic rock and range in size from granules to 6-inch fragments.

Champion Volcanics:

This member is composed of several different lava flows. The lower part in Tick Canyon consists of black basalt contaioning numerous small plagioclase phenocrysts and a few irregular amydules. With increasing distance from the bottom of the member, the size of phenocrysts increases and the number and size of the amygdules increases. The resestance to weathering and the color also vary. The rock of the lower part is hard and black and that of the upper part is purplish, contains numerous amygdules, and disintegrates easily. Many of the irregular vesicles are filled with opal. In places, dark bluish-green serpentine lines irregular vesicles and fractures.

Most of the lavas of this member exhibit a prominent fracture set in which the fractures are between one-half and two inches apart and are usually parallel to the bedding of the adjacent sedimentary members. In a few cases, the fracture planes are curved and have no preferred orientation.

Several dikes, which are usually under 4 inches in thickness, have been intruded along fractures in one place in Tick Canyon. These are composed of very hard greenish aphanitic rock.

In the eastern part of the area, at least the upper half of the member is composed of flow breccias in which angular fragments of purple porphyritic lava are surrounded by a groundmass of lava of slightly different color. These breccias are more resistant to weathering than the lava flows and so form prominent outcrops north of Zweihorn. One line of such outcrops lies just north of the contact between the Champian Volcanics and the Yucca Sediments. Bob, Job, and Sob Knobs form another parallel set.

Yucca Sediments:

This member changes only slightly in color, resistance to weathering, and thickness throughout the area and so forms a very good horizon marker. Thickness ranges from 100 feet in Tick Canyon to 140 feet east of Yucca Peak. The sediments change from dominantly fine-grained arkoses in Tick Canyon to arkoses and conglomerates east of Yucca Peak.

Red iron oxide, which cements the sediments and gives them their red color, is usually more highly concentrated in the darker-colored,finer-grained sediments. The fine siltstones are very dark in color and form such distinct beds that bands only 1/100 inch thick can be traced for several feet.

In Tick Cayon, most of the sediments are of siltstone or sandstone size but a few of the thicker beds contain angular granitic fragments up to one-half inch across. The outcrops of these coarser beds are being rounded by exfoliation which forms shards under one-half inch thick. The fine arkoses and siltstones show graded bedding, cross bedding, and penecontemporaneous deformation structures. Differential weathering, controlled by iron oxide content, results in irregular holes and resistant ridges. Evaporation of moisture leaves a white foul-tasting salt (probably borax) on parts of the outcrop.

East of Yucca Peak, the member is light grey or pinkish in color and consists of arkoses containing granitic fragments. Variations in size and number of fragments in the arkoses gives the member a coarse graded bedding. The arkose of the lower part of the member has a mottled purple and pink color and contains angular fragments of tuff and granitic rock. Much of the granitic rock in the member contains little pockets of epidote which is probably an alteration product of hornblende.

Cavernous weathering has produced spherical holes in places in the coarser parts of this member. They are especially well developed in the purple and pink mottled bed. In one place the cliff face dips south at about 50 degrees and a line of 10-inch cavities have formed about two feet above the bottom of the cliff. Textural differences could hardly have controlled the localization of these cavities because the cliff face is nearly parallel to the bedding planes.

Zeola Lava:

This lava disintegrates very easily and does not form conspicuous outcrops, but it is very uniform in thickness and texture throughout the area. The groundmass has a dark purple color which is probably the result of the alteration of the iron-bearing minerals. Phenocrysts of plagioclase two to three millimeters long comprise up to one quarter of the rock.

The characteristic feature of this lava is the abundance of irregular zeolite amygdules. Some of the vesicles have been completely filled. Some vesicles have well-formed prisms of natrolite projecting outward from the walls and others have a coating of isometric analcite crystals. Both types of crystals are present in many of the vesicles.

Ocotillo Member:

The sediments of this member are slightly coarser than those of the Yucca Member.

In Tick Canyon, the member consists of green and grey arkoses which contain angular granitic fragments. Variations in distribution of these fragments results in coarse graded bedding. The color of the upper three feet of arkose grades upward from grey to very dark red. The overlying lavas have probably changed the iron of the oxide from the ferrous state to the ferric state.

The most easterly part mapped of this member has a groundmass of buff arkose and contains angular and sub-angular granitic fragments. These are usually somewhat gneissic and are usually under six inches in diameter. Variations in abundance of the fragments gives a crude bedding. In places, differential erosion leaves resistant elongated outcrops in which the bedding of the sediments is at angles of up to 30 degrees to the direction of elongation of the outcrops.

In the middle of this member, is a very consistant 10-foot bed of white tuff. The tuff is hard and resistant to weathering. It has three prominent fracture planes and breaks up into small sharply angular blocks. The tuff contains numerous minute black crystals in a white vitric (?) groundmass.

Matterhorn Member:

This member is the most variable one mapped. In Tick Canyon, it is composed entirely of volcanic material whereas, on Zweihorn, it is composed of interbedded volcanics and arkosic sediments.

The volcanic rock is a breccia with a very resistant, dark red groundmass. The fragments are usually of a much lighter color than the groundmass and are of several types of rock. Intermediate to basic flow rocks and thinly bedded tuff with purple and white banding constitute most of the fragments in the basic groundmass. This breccia is a very resistant rock and forms high, steep-sided hills such as Matterhorn and Zweihorn. Differential weathering produces small caves in the breccia. A good example exists in the cliff faces in Tick Canyon where the hawks have used the caves for homes.

A buff-colored tuff separates this breccia from the overlying arkoses of the Sterling Member. The tuff has a buff-weathering groundmass in which are embedded fragments of volcanic rock. Most of the fragments are purple in color and angular to subangular in shape. The tuff is not very resistant to erosion and so does not form consistant outcrops, but it does help to differentiate volcanic beds because no other bed like it occurs in the area.

On Zweihorn, the two thin central volcanic beds are purplish amygdaloidal flow breccias in which the included fragments are similar to the rock of the groundmass.

The sediments of this member are buff-weathering arkoses. The central bed is massive and has granules of granitic rock. The parts that have considerable carbonate cement are very resistant to weathering and form tooth-shaped 20 feet in height.

Sterling Member:

The borates, for which Tick Canyon is famous, occur in this member. Coleminite, ulexite, howlite, and proberatite are reported to have been produced at the Sterling Mine during the first part of this century. Two main borate horizons have been mapped. The borates are thinly-bedded and have shale partings. They grade upward, downward, and laterally into very thinly-bedded buff shales and siltstones which have borate partings. Because of their incompetant nature, the borate beds were severely drag folded when movement occurred in the adjacent beds. In spite of their soft and incompetant properties, the borate beds often form the tops of ridges. This is probably largely attributable to the resistance of the adjacent tuff beds.

Three very prominent white vitric-tuff beds have been mapped in this member. All the tuffs are white in color and, on weathering, yield sharply angular fragments. ~~Tuff~~

Tuff I (lowest tuff) does not outcrop west of Champion Fault and it probably pinches out near Daverport Road in the east part of the area. Its best development is south of Zweihorn where it is a very resistant yellowish-weathering, 30-foot bed.

Tuff II (middle tuff) could not be found east of Darling Fault. It is about 20 feet thick in Tick Canyon where it occurs below the borate bed. The tuff is very cherty and probably contains much shale. It occurs in 1-foot to 2-foot beds with interbedded purple siltstone partings. It grades downward and laterally into arkoses.

Tuff III (upper tuff) is the most consistent of the three tuff beds and can be traced along the lower boundry of the Sterling Member from Tick Canyon to Davenport Road. Very good outcrops in Tick Canyon and in the Whirligig reveal a yellowish-wearthing, very resistant tuff which attains a maximum thickness of 40 feet.

Another characteristic feature of this member is the occurrence of lens-shaped beds of basic amygdaloidal lava. Many of these beds pinch out laterally in a very short distance. The most consistant of them is the bed which forms the east slope of the Whirligig. The lave disintegrates very easily and so outcrops of it are scarce.

The sediments of the Sterling member are mostly buff arkoses. In the eastern part of the area, there is a large increase in amount and coarseness of these sediments. Between the two borate beds just north of Davenport road, there are beds composed of angular granitic fragments in a groundmass of granitic granules. West of Mount Green, there are small lenses that consist of 1-foot angular granitic bounders in a groundmass of 1/2- to 4-inch fragments. The large boulders constitute 60 percent of the lenses.

Spherical concretions with concentric structure occur in some of the buff arkoses (see figure). The concretions are one to two inches in diameter and have a red resistant outer zone and grey and yellow central zones.

Davenport Sediments:

The member consists of red, green, grey, and buff arkoses, siltstones, and sharpstone conglomerates. In Tick Canyon, the lithology is as follows: lower part--- thinly-bedded variegated siltstones and arkoses; central part -- two beds which contain angular granitic granules and fragments; and lower part -- arkoses with granitic granules.

The texture becomes coarser eastward. The central beds of sharpstone conglomerate can be traced throughout the area and have been marked on the map to indicate structure. In places, especially along the north side of Davenport road, this coarse horizon forms resistant outcrops composed of angular granitic fragments in a relatively small amount of carbonate-bearing red sandstone. Many of the fragments are gneissic in structure and contain the alteration product -- epidote. A few large boulders up to three feet in diameter occur.

In the fine-grained arkoses, graded bedding, ripple marks, and evidence for penecontemporaneous deformation have been found.

Goat Volcanics:

These lavas differ only slightly from those of the Champion volcanics. They are dark basic lavas containing numerous plagioclase phenocrysts. Irregularly-shaped agate amygdules are more abundant than in the Champion volcanics. A set of closely-spaced parallel fractures are also present. Weathering processes working outward from these fractures have turned the rock a dark red color and, as a result, these volcanics are much redder than are the Champion volcanics.

Tadpole Sediments:

These sediments are characterized by the absence of sharpstone conglomerates. Thinly-bedded, variegated (red, purple, grey, buff) siltstones and fine-grained arkoses predominate. In the middle of the member, is a horizon of interbedded limestones and shales.

Lang Lava:

This volcanic member is a flow breccia in which the fragments which constitute most of the rock are of different color and texture from the groundmass. The fragments on a fresh surface are dark basic lavas with small plagioclase phenocrysts. These fragments weather to a dark grey color in contrast to the groundmass which remains dark purple.

Numerous closely spaced fractures cut these lavas. Weathering along these fractures produces rounded remnants of the rock in a matrix of brownish-grey disintegrated rock.

General (Vasquez Formation):

The sediments of the Vasquez formation are fluvatile and lacustrine deposits. The great increase in thickness of members and coarseness of sediments eastward indicates that the source was east of the area mapped. It was probably an uplifted block which exposed the igneous rocks of the Basement Complex.

Intermittant volcanic activity produced the lavas and flow breccias which are interbedded with the sediments. Textural and compositional changes in individual members indicate that many members consist of more than one lava flow. Some of the volcanic members such as the Matterhorn member interfinger with the sediments.

The beds of white vitric (?) tuff, which grade laterally to tuffaceous arkoses, were deposited as volcanic ash in the lake and on the surrounding land. The sharp contacts between the tuffs and adjacent beds are probably the result of direct deposition in the lake whereas the gradation of tuff to arkoses resulted when the tuffs and sediments from the surrounding land were washed into the lake.

Tick Canyon Formation

The Tick Canyon formation has been subdivided into a lower member composed of coarse conglomerate and an upper member composed of siltstones.

Lower Tick Canyon Member:

This member is a very coarse boulder conglomerate that contains rounded and sub-angular granitic and volcanic boulders up to one foot in diameter. Usually the conglomerates are well indurated and show crude stratification.

In the basal part of the conglomerate, the groundmass for the large boulders consists of granules of greenish volcanic material containing rounded granitic and volcanic pebbles. Near the top of the conglomerate, the groundmass contains a large proportion of granitic granules and the proportion of granitic boulders increases.

Many of the sub-angular boulders of the conglomerate are easily recognized as volcanic rocks from the volcanic members of the adjacent Vasquez formation.

The talus slopes of the pre-Tick Canyon land surface have been included in the conglomerate member. In places north of Davenport road, the angular fragments of talus seem to grade into the partly rounded boulders of the regular conglomerate.

Upper Tick Canyon Member:

The lower part of this member contains grey and pink arkoses and siltstones, the middle part is largely buff and grey arkoses containing lenses of conglomerate, and the upper part is variegated (pink and grey) fine-grained siltstones.

<u>Mint Canyon Formation</u>:

In the Tick Canyon Area, the Tick Canyon formation is overlain conformably by the Mint Canyon formation. The contact was assumed to be at the base of a coarse conglomerate which forms a very prominent ~~hogsback~~ cuesta above the contact.

This basal conglomerate is the only part which has been examined and mapped. It consists of a coarse boulder-conglomerate in which volcanic boulders predominate and in which granitic boulders increase in importance eastward. Where the contact cross Davenport road, the boulders of the conglomerate are lined with red iron oxide and with dark green material which is probably serpentine. Lenses of arkose and of pebble conglomerate are common in this basal boulder-conglomerate.

<u>Whonoz Formation</u>:

This formation has been examined on Mount Green where it consists of a boulder conglomerate with a groundmass of grey, buff, and reddish arkoses. The groundmass contains scattered boulders and lenses comprised soley of boulders. The boulders are well-rounded and are composed of volcanic and granitic rock.

At the top of Mount Green on a north-facing cliff, weathering has produced lace work. The bed consists of reddish-brown arkose containing thin lenses of small pebbles. The lines of lace work are locallized by these pebble lenses.

The Whonoz formation is separated from the Vasquez, Tick Ganyon, and Mint Canyon formations by the Skyline Fault. Drag indicates that the east block has moved northward, but the exact amount of displacement is unknown. The Whonoz formation is probably the same as the basal conglomerate of the Mint Canyon formation, but limited field work prevented confirmation of this idea.

General: (Tick Canyon and Mint Canyon Formations):

The Tick Canyon, Mint Canyon, and Whonoz formations are fluvatile and lacustrine deposits. At least part of the volcanic material of the Tick Camyon formation was derived from the Vasquez formation in the north part of the area. The fact that the ratio of granitic to volcanic b oulders in the Mint Canyon basal conglomerate increases southward and eastward would indicate that the source for the volcanic material of the Mint Canyon formation also lay to the north and west. The source for the granitic material probably lay to the south-east.

Structure.

Highly folded and faulted Vasquez sediments and volcanics are unconformably overlain by gently dipping Tick Canyon and Mint Canyon formations.

The major folds in the Vasquez formation consist of the westward plunging Whirligig and Skyline synclines separated by the Davenport anticline. The anticline has a saddle towards which both ends plunge, the the western part plunging gently eastward and the eastern part plunging steeply westward. The axes of the folds diverge eastward. In the extreme eastern part of the area mapped, the two synclinal axes are 1200 feet apart, but a mile west of this the axes are a probable 2500 feet apart.

Major cross faults such as the Champion, Darling, and Zweihorn faults offset the fold axes. Only the apparant horizontal displacement of the faults can be measured, but vertical components of displacement are inferred. The Champion fault, for example, displaces the vertical or northward-dipping Yucca sediments about 1400 feet, whereas the displacement on the southward-dipping Davenport sediments is only 700 feet. A large vertical component of displacement has to be assumed because the difference in dips of the two members mentioned is only 20 to 30 degrees. At least the main part of the displacement on these faults took place before deposition of the Tick Canyon formation because the corresponding large displacements cannot be found in the Tick Canyon and Mint Canyon formations.

There are numerous minor faults with displacements up to 200 feet but these can only be traced for relatively short distances. They are usually parallel to the larger foults and have the same direction of movement.

One major low-angle thrust fault has been assumed. It dips about 30 degrees east and offsets many of the larger steep faults.

Most of the faults have a NNE strike and the east side has been displaced northward. A few faults have an E-W strike and these have displacement in which the south side has moved westward.

Some of the faults, especially those in the nose of the folds, were formed during folding of the strata. The NNE faults and the Matterhorn Thrust could have been formed by subsequent forces from the SE acting in a NW direction. The E-W faults are probably later and may be post Mint Canyon in age. The forces which produced them probably also produced the bends found in the trace of the Champion fault and in the axis of the Skyline syncline.

The Mint Canyon and Tick Canyon formations are conformable to one another, but they overlie the Vasquez formation with a profound erosional unconformity. These formations are tilted about 25 degrees to the south and to the west, but they have no significant folds. The dip was partly formed during the regional uplift which followed deposition of the Mint Canyon formation, but much of it is due to initial dip and to compaction of the sediments. Along Davenport road, the Tick Canyon sediments have a gentle dip from both sides of the basin toward the axis the the underlying ~~axis of the~~ Whiligig syncline. This is probably also due to initial dip and to differential compaction.

Besides the Skyline fault, only small faults with vertical displacements of less than 50 feet were found in the Mint Canyon formation. The Skyline fault cuts the Mint Canyon and Tick Canyon formations. Its horizontal displacement is over 3000 feet but limited field work prevented determination of its exact movement.

Geomorphology.

Drainage:

The drainage system has a dendritic pattern in which only small details are controlled by the underlying geologic structures.

The major streams flow in a southerly direction and cut across the weak and the resistant beds. They have been superimposed from the Mint Canyon surface upon which they were probably consequent. The remarkable linear aspect of the upper part of Tick Canyon is not contrelled by the present geologic structure but it is parallel to the strike of the nearby Mint Canyon strata and is probably owes its straightness to structures which formerly existed in the Mint Canyon formation.

Some of the smaller tributaries are parallel to the strike of the strata and are controlled by the resistance of the beds. The gullies which drain the south slope of Matterhorn are consequent upon the slope of the hillside, but, at the foot of the hill, they join an E-W subsequent stream.

The best subsequent streams found in the area, are those which, in places, follow the contact between the indurated conglomerates of the Lower Tick Canyon member and the solt siltstones of the Upper Tick Canyon member.

Relief:

The relative resestances of the various members of the Vasquez formation are reflected in the relief of the area. The very resistant volcanic breccias of the Matterhorn member form the backbone of such hills as Zweihorn, Matterhorn, and Pinnacle Peak. The Goat volcanics and the Champion lavas also form hills and ridges. With the exception of a few small prominent outcrops, the clastic sediments are non-resistant and usually underlie the lower parts of the area. The borate beds , in combination with the resistant white tuff, form long low ridges such as the Whirligig. The

The basal conglomerate of the Mint Canyon formation overlies the soft siltstones of the Upper Tick Canyon member. Removal of the soft siltstones by erosion is rapid compared to the rate of disintegration of the overlying conglomerate and, as a result, a steep cliff is maintained along the contact of the two formations.

Geologic History.

1. Deposition of the volcanics and the lacustrine and fluvatile sediments of the Vasquez formation in a basin of deposition underlain by Basement Complex. The source of the coarse clastics was east of the area mapped.

2. Intense folding of the Vasquez formation accompanied by movement along the Basement contact and by faulting in the Vasquez members, especially in the noses of the folds.

3. NNE faults cut the Vasques formation. The movement was such that the east sides of the faults were displaced northward. The ~~stresses~~ forces were probably from the SE.

4. Erosion of the Vasquez formation leaving a rugged topography.

5. Depression of the area and deposition of the Tick Canyon formation. This elimenated the rugged relief and covered up large piles of talus which had accumulated at the foot of the steeper slopes. Much of the volcanic clastics came from the local Vasquez formation. The granitic material had its source east of the area.

6. Uplift and erosion of the Tick Canyon formation. No evidence of this erosion interval was found in the Tick Canyon Area, but such an interval has been reported by R. H. Jahns (1940).

7. Deposition of Mint Canyon formation with disconformity on the Tick Canyon formation.

8. Faulting which produced the large Skyline fault and the minor faults which show in the Mint Canyon formation and probably the E-W faults found in the Vasquez formation.

9. Uplift and minor tilting which may have accompanied or preceded the latest faulting.

10. Erosion of the area to its present form. In places, the

the surface existing before deposition of the Tick Canyon formation has been removed. Along Davenport road, this surface is just being exposed and the ancient talus slopes can be seen.

Figure 3.

View of Zweihorn from the SE:
The Matterhorn volcanics form the two ridges of prominent dark outcrops. These are separated by Matterhorn arkose which forms the sharp light-colored outcrops.
The Zweihorn fault is traced in red and TuffI of the Sterling member is traced in blue.

Figure 4. Concretions in arkose of the Sterling formation.

Figure 5. Hogsback formed by basal conglomerate of Mint Canyon formation.

Figure 6. Lace work in Whonoz formation on north-facing cliff of Mount Green.

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