VOLCANIC TUFF BEDS

of the

MINT CANYON FORMATION

by

ROBERT EARL WALLACE

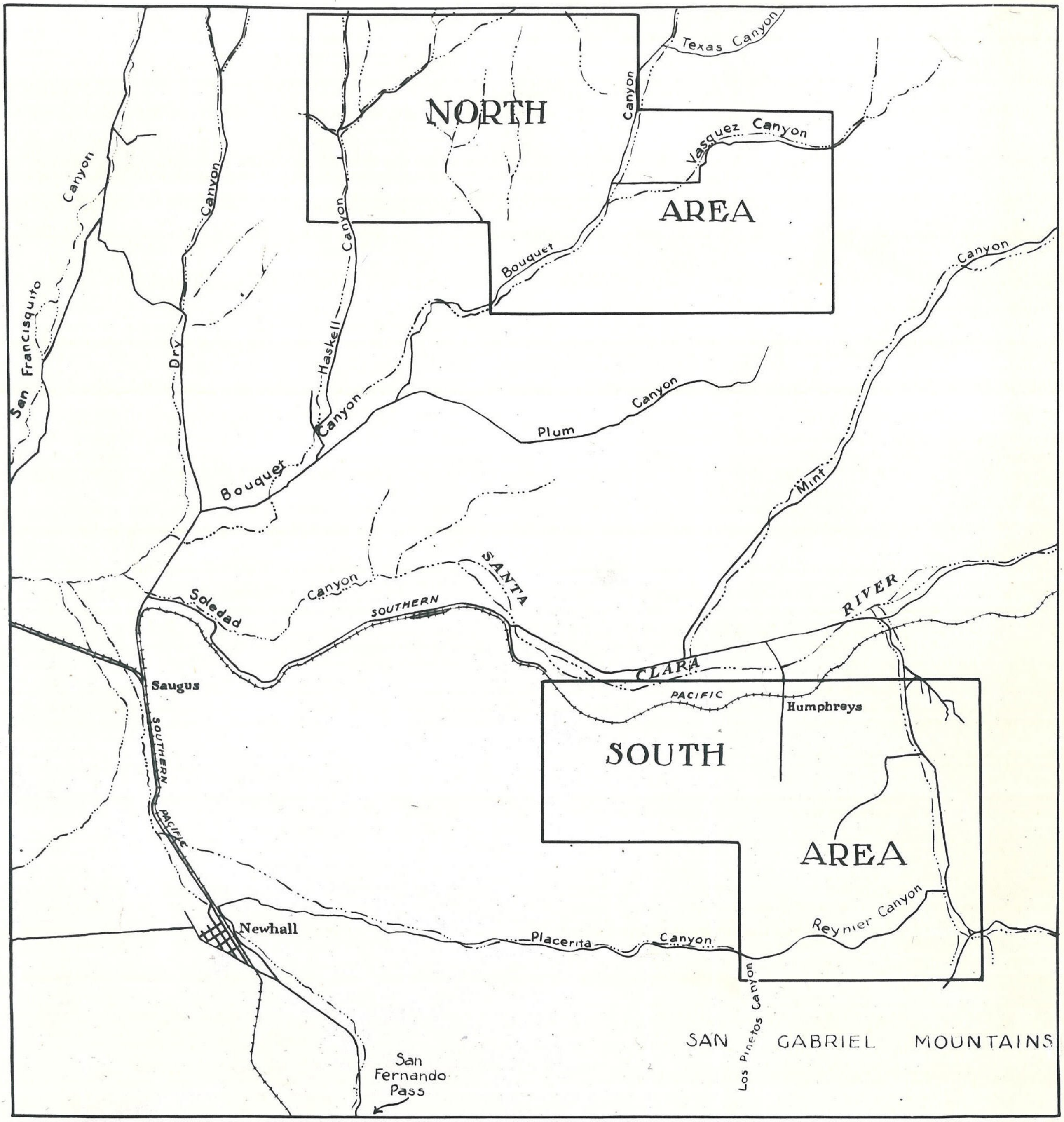
A thesis submitted as partial fulfillment of the requirements for the Degree of Master of Science

California Institute of Technology

Pasadena, California

June, 1940

Table of Contents



N

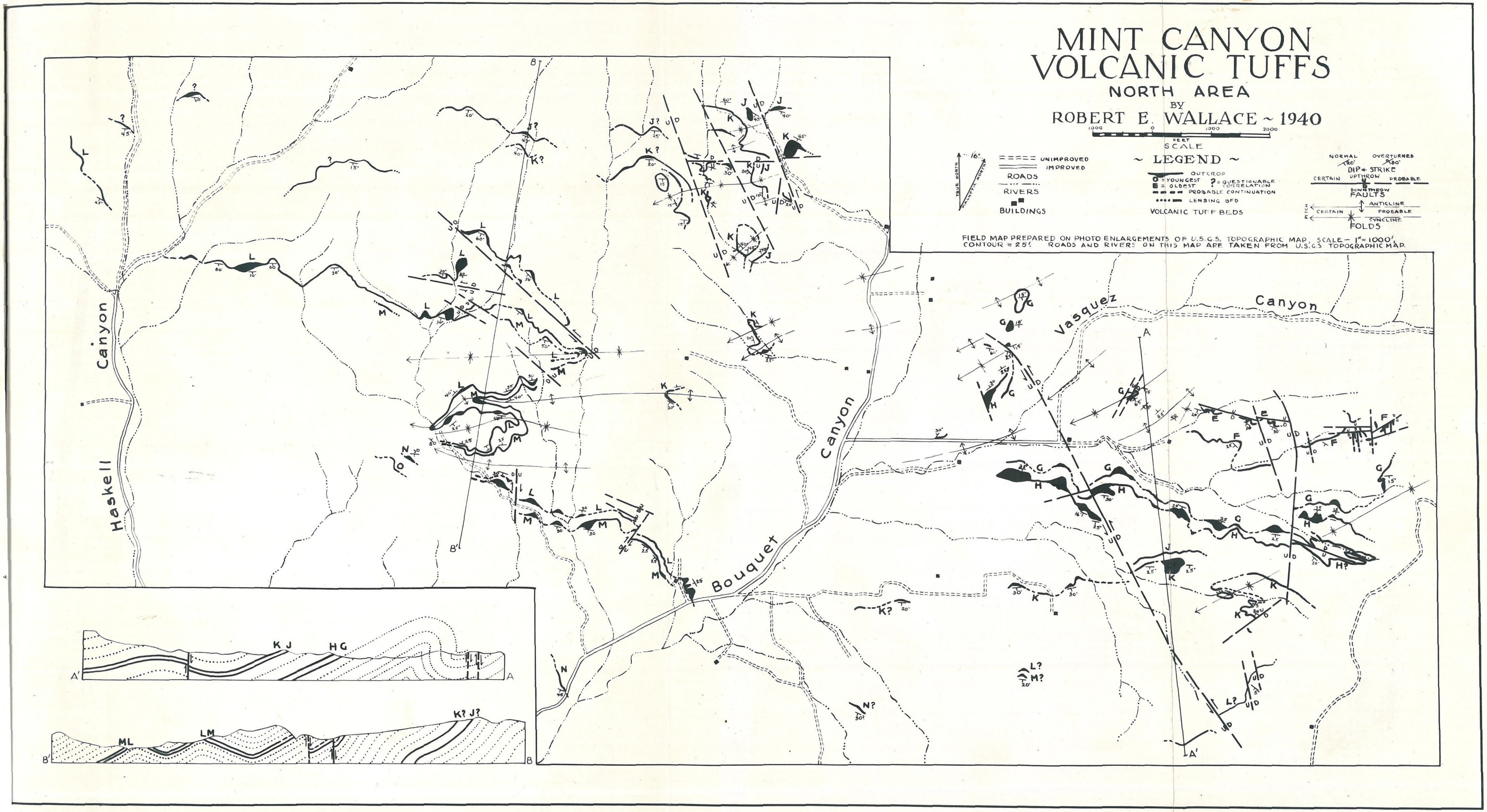
INDEX MAP

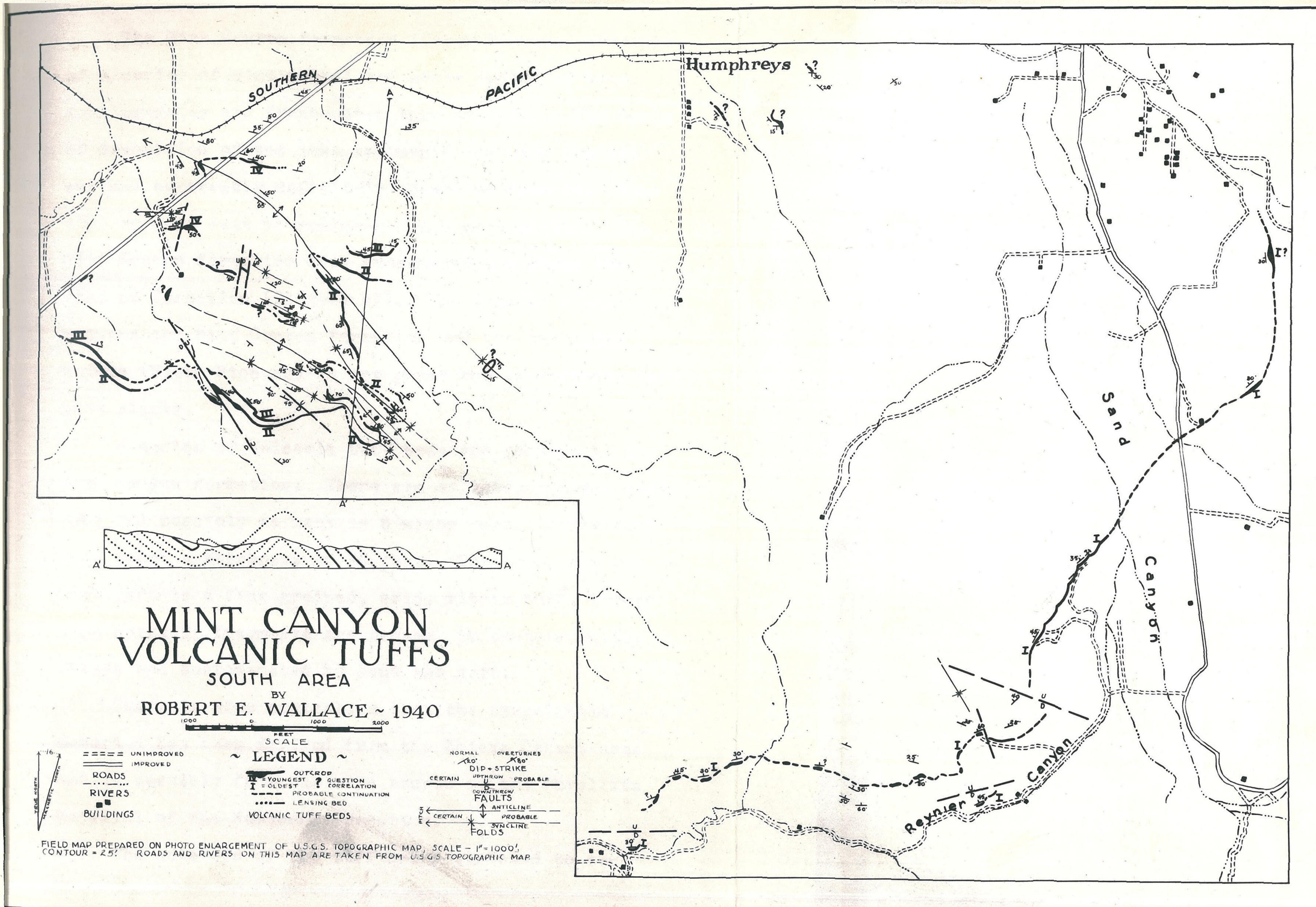
SHOWING AREAS INCLUDED IN THE STUDY OF THE VOLCANIC TUFF BEDS OF THE MINT CANYON FORMATION

BY

ROBERT E. WALLACE ~ 1940

0 1 2 3
MILES
SCALE


MINT CANYON
VOLCANIC TUFFS
NORTH AREA
BY
ROBERT E. WALLACE ~ 1940
1000 0 1000 2000
FEET
SCALE
~ LEGEND ~
TRUE NORTH
MAGNETIC NORTH
16°
UNIMPROVED
IMPROVED
ROADS
RIVERS
BUILDINGS
OUTCROP
O = YOUNGEST
E = OLDEST
? = QUESTIONABLE CORRELATION
PROBABLE CONTINUATION
LENSING BED
VOLCANIC TUFF BEDS
NORMAL
OVERTURNED
20°
80°
DIP + STRIKE
CERTAIN
UPTHROW
PROBABLE
DOWNTHROW
FAULTS
PITCH
ANTICLINE
CERTAIN
PROBABLE
SYNCLINE
FOLDS
FIELD MAP PREPARED ON PHOTO ENLARGEMENTS OF U.S.G.S. TOPOGRAPHIC MAP, SCALE – 1" = 1000',
CONTOUR = 25'. ROADS AND RIVERS ON THIS MAP ARE TAKEN FROM U.S.G.S. TOPOGRAPHIC MAP.
Haskell Canyon
Bouquet Canyon
Vasquez Canyon
A
A'
B
B'
K J
H G
K? J?
ML
LM


MINT CANYON
VOLCANIC TUFFS
SOUTH AREA
BY
ROBERT E. WALLACE ~ 1940
SCALE
FEET
~ LEGEND ~
UNIMPROVED
IMPROVED
ROADS
RIVERS
BUILDINGS
OUTCROP
= YOUNGEST
= OLDEST
QUESTION CORRELATION
PROBABLE CONTINUATION
LENSING BED
VOLCANIC TUFF BEDS
NORMAL
OVERTURNED
DIP + STRIKE
CERTAIN
UPTHROW
PROBABLE
DOWNTHROW
FAULTS
ANTICLINE
CERTAIN
PROBABLE
SYNCLINE
FOLDS
PITCH
TRUE NORTH
MAGNETIC NORTH
FIELD MAP PREPARED ON PHOTO ENLARGEMENT OF U.S.G.S. TOPOGRAPHIC MAP, SCALE - 1"=1000', CONTOUR = 25'. ROADS AND RIVERS ON THIS MAP ARE TAKEN FROM U.S.G.S. TOPOGRAPHIC MAP.
SOUTHERN
PACIFIC
Humphreys
Sand
Canyon
Reynier
Canyon

Abstract

The Mint Canyon formation (Upper Miocene) consists of a series of continental sediments including both fanglomerates and fresh-water lake deposits. The basin of deposition of the lake sediments was near the sea but was apparently definitely seperated from it. Some 4000 or more feet of sediments have accumulated. The Mint Canyon formation lies nonconformably above the Vasquez formation (Oligocene?). The angular discordance between the Mint Canyon formation and the overlying Modelo (Upper Miocene) is not great but is definite in many places.

A series of volcanic tuff beds are present in the Mint Canyon formation. There are at least 8 major tuff beds and possibly as many as 5 minor ones. Individual beds reach a thickness of 10 feet. The tuff, for the most part is a fine grained, acid, vitric tuff, though some crystal fragments are present in certain units. Others are contaminated by sand and grit.

There is some suggestion that the pyroclastic material has been derived from the Mojave Desert area and is possibly from the same source as the rhyolitic material of the Rosamond formation.

The outcrops of the tuff are restricted to two

main areas, one on either flank of a broad, westerly-pitching syncline which is the major structural feature of the Mint Canyon area. In each of these areas, local sections of overturning are present. It is believed that these are the surface manifestations of faulting in the basement complex.

Faulting is present to a moderate degree. The major faults are probably steep with vertical movement being most important.

Plant fossils are preserved in the fine tuffs. The flora indicates a biseasonal distribution of rainfall with possibly slightly greater annual average than at present. The Mint Canyon flora is part of the Mojave floral province.

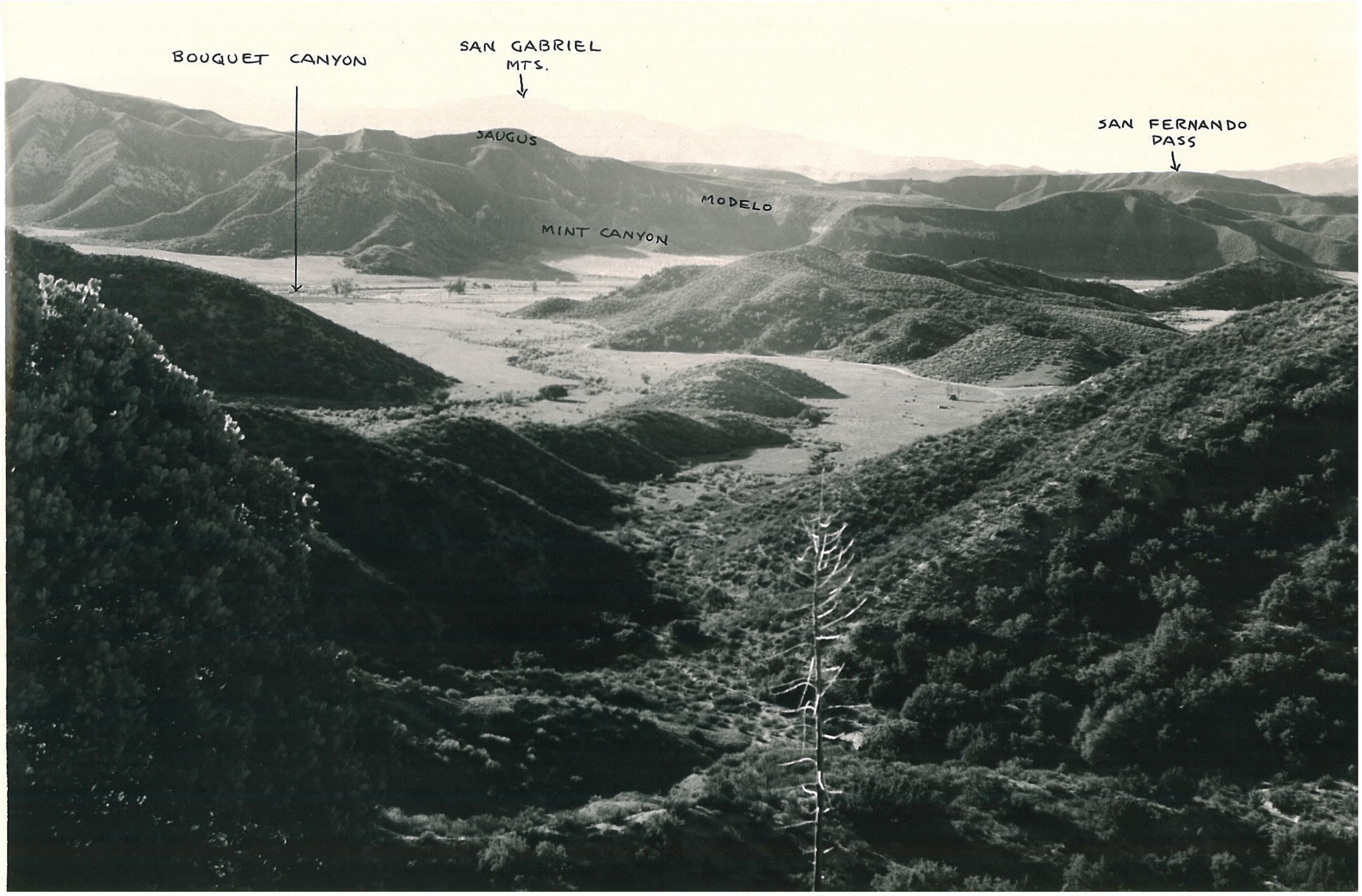
Fine grained units of the tuffs are quarried and used to a limited extent as surfacing material on asphalt shingles and roofing material.

Fig. 1. South area. View looking west along Santa Clara vâlley toward Saugus. River terraces are well displayed.

Fig. 2. South area. View looking north toward Santa Clara River 1 mile west of Humphreys. Tuff beds II and III are exposed in near cliff.

Fig. 3. North area. View looking southward toward San Fernando Pass. Note how alluvium "drowns" the topography.

Fig. 4. North area. View from junction of Vasquez Canyon and Bouquet Canyon roads showing badlands developed in Mint Canyon sediments. Note the contact between the Saugus and the Mint Canyon formations.


BOUQUET CANYON
SAN GABRIEL MTS.
SAUGUS
SAN FERNANDO PASS
MODELO
MINT CANYON


SAUGUS
MINT CANYON

Introduction

Nature of Problem

This paper deals with a series of volcanic tuff horizons which form distinctive marker beds in the Miocene, Mint Canyon formation of Southern California.

Previously, study of the vertebrate fauna and oil considerations of the Mint Canyon has received most attention. The study and mapping of the volcanic tuff beds was undertaken with a hope of obtaining a more complete understanding of the mode of deposition of the Mint Canyon sediments, besides accumulating information regarding the structure of the region which would add both to the data on the stratigraphic relationships of isolated vertebrate localities in the area as well as to the information concerning the disputed relationship of the Mint Canyon and the overlying Modelo formation.

The investigation was undertaken as partial fulfilment of the requirements for masters degree in geology at the California Institute of Technology, Pasadena, California.

Acknowledgments

The writer is indebted to Dr. John H. Maxson of the California Institute of Technology, not only for introducing the problem to him but also for valuable

advice and assistance in the field work and the helpful suggestions in the preparation of the final paper. Richard H. Jahns, of the United States Geological Survey, aided greatly in many of the problems met with in the field. Dr. Daniel I. Axelrod, of the National Museum in Washington, D. C. was kind enough to undertake the study of the collection of plant fossils which were obtained from the tuff beds, and thereby added greatly to the general picture of conditions during the time of deposition. Dr. Ian Campbell, of the California Institute of Technology offered valuable suggestions in connection with the petrology and petrography of the tuff beds.

Previous Work

The first geologic report including this area was the work of W. L. Watts[1] of the California State Mining Bureau. A paper by O. H. Hershey[2], "Some Tertiary formations of southern California", was published in 1902, in which he gave the Mint Canyon formation its first name, the "Mellenia series". In 1901-2 G. H. Elridge[3], of the United States Geological Survey, made a survey of the Santa Clara River valley in Los Angeles and Ventura counties, and later a detailed map of this region was published. In 1917 W. S. S. Kew[4] of the United States Geological Survey, began a survey of the geology and oil resources of a part of Los Angeles and Ventura Counties. A report and map were published in 1924, and the name "Mint Canyon formation" in place of "Mellenia series" was suggested. A study of the vertebrate fauna made by J. H. Maxson[5] was published in 1930. Later R. A. Stirton[6] criticized some of the identifications

---

1. Watts, E. L., Calif. State Min. Bur. Bull. 11, 1897, Bull. 19, 1900

2. Hershey, D. H., Some Tertiary Formations of Southern Calif., Am. Geol., vol. 29, pp. 356-358, 1902.

3. Elridge, G. H. and Arnold, Ralph, The Santa Clara Valley Puente Hills, and Los Angeles Dist. of Southern Calif., U.S.G.S. Bull. 309, 1907.

4. Kew, W. S. W., U.S.G.S. Bull. 753, 1924.

and interpretations of Maxson. Jahns[7], in 1939, continued the work on the vertebrate fauna and was able to establish a division of the Mint Canyon formation. In 1940 K. A. Richey presented some new evidence on the faunal relations of the Ricardo, Mint Canyon, and Barstow formations.

*

---

5. Maxson, J. H., Carnegie Inst. of Wash. Pub. # 404, 1930.

6. Stirton, R. A., Am. Jr. Sci., Vol. 26, 1933.

7. Jahns, R. H., Am. Jr. Sci., Vol. 237, 1939.

8. Richey, K. A., New Evidence of the Faunal Relations of the Ricardo, Mint Canyon, and Barstow Formations. A paper presented at the Cordilleran Section, G. S. A., April 1940.

Geographical Setting

Location

The area of outcrop of the Miocene, Mint Canyon formation, part of which is under discussion in this paper, occupies the eastern-most portion of the Santa Clara Valley of Southern California about 25 miles air line north of Los Angeles. It is easily accessible by highways and good side roads. The plan distribution of the Mint Canyon formation is roughly triangular in shape and covers an area of about 40 square miles. Its southwestern border trends northwest-southeast and lies about four miles northeast of the town of Saugus, California, which is on the San Jaoquin Valley route of the Southern Pacific Railroad between Los Angeles and San Francisco. It extends to Agua Dulce Canyon about fourteen miles east of Saugus. The northern boundary of the Mint Canyon formation is about seven miles northeast of Saugus near Texas Canyon, and it extends southward for a distance of about eight miles to the base of the San Gabriel Mountains south of the Santa Clara River.

Since the problem was the study of the volcanic tuff beds of the Mint Canyon formation, the areas mapped were confined to outcrop areas of volcanic tuff beds. There were two such areas mapped. One, which is called the "north area" in this paper, extends from Haskell Canyon eastward across Bouquet Canyon to Puckett Mesa and includes the mouth of Vasquez Canyon. The second, called the "south area" in this paper, lies west of Sand Canyon, south of the Santa Clara River, and north of Placerita Canyon. It extends to a point about two miles west of the town of Humphreys on the Southern Pacific Railread.

Climate

The climate can be classed as semi-arid. The annual rainfall is about 17 inches, and is confined almost entirely to the period from December to March. According to the United States Weather Bureau records, the mean annual temperature at Newhall, a few miles south of Saugus, is 61.5° F. August is the hottest month. During the summer the temperature is often over 100° in the middle of the afternoon, but drops to below 60° most nights.

Most of the streams are intermittent. Even the major drainage channels such as the Santa Clara River are dry in many places during the summer months.

Vegetation

Yucca and various types of sage, as well as other brushy growth such as manzaneta, abound on the sand

and gravel covered slopes of the area. In more moist portions, as in draws, live oaks form good shade trees, and along the streams, sycamore. On the flat uplands, which are often underlaid by Quaternary terrace gravels, dense thickets of juniper make passage almost impossible at times. The most easily traversed portions in doing field work are along the sharp ridges which often have relatively less vegetation, and along alluvium covered stream bottoms which are usually fairly open. Narrow draws are often impassable due to the density of vegetation.

In general, good accordance is found between the type of vegetation and the underlying rock type. Grasses often cover shaley horizons while the brushy vegetation is found overlying the conglomerates and sandstones.

Physiography

The area under consideration, as previously stated, lies in the Santa Clara Valley. The most prominent physiographic feature of the region is the Sierra Madre Range which forms a 2,000 - 5,000 foot barrier to the south. The San Gabriel Mountains are the portion directly to the south of the area described. The Santa Susana Mountains are the western extension and are separated geographically from the San Gabriels by San Fernando Pass. These mountains are in a youthful stage of dissection. Several renewals of uplift are evidenced by physiographic unconformities such as old erosion surfaces, hanging valleys, and sharp, narrow valleys combined with rounded ridges.

The Sierra Pelona Mountains to the north separate the Santa Clara Valley from the Mojave Desert.

The Santa Clara River flows westwardly through this basin-like area and empties into the Pacific Ocean about 50 miles west of the Mint Canyon area, near Ventura, California. Besides the Santa Clara River, in the area under discussion, the major streams, located in Bouquet and Mint Canyons, are tributaries of that river and flow southwestwardly from their headwaters in the Sierra Pelona Mountains. A small intermittent stream flows northward in Sand Canyon in the south area and has its head waters in the San Gabriel Mountains.

In that part of the valley region studied, the elevation ranges from about 1400 feet to 2300 feet. The average relief is of the order of a few hundred feet.

The relatively unconsolidated sediments of the Mint Canyon erode to form many bad land areas, as in photographs, figures 4, 14. Where actual bad lands are not developed, the ridges are usually sharp and the valleys have angular profiles, except of course, the valleys of the larger streams. Quaternary alluvium fills the valleys of these larger streams and drowns the rugged topography, as in photograph, fig. 3 , forming many embayments of alluvium as one might find embayments along a submerged coastline.

The base level of the streams has apparently been lowered in recent times, possibly by uplift of the region, causing the tributaries to dissect the alluvium and form deep, narrow arroyos toward their mouths, as shown in photograph, fig. 5 .

Drainage in the smaller tributaries is often subsequent, following the softer shale and poorly consolidated sandstone horizons and leaving the more resistent conglomerate, sandstones, and tuff beds as positive expressions in the topography. The tuff beds are quite resistant, and tilted tuff horizons are frequently stripped of overlying strata forming large, bare dip-slope areas.

The larger streams, however, flow directly across the formations. Their courses possibly formed on an old erosion surface, or on some overlying sedimentary stratum such as the Saugus. In either case, their down cutting has proceeded at a greater rate than uplift of the region so that they have maintained a path transecting the structure.

Fig. 5. North area. Recent gully developed in Quaternary alluvium indicating recent rejuvination.

Fig. 6. South area. Landslide near Santa Clara River.

Stratigraphy

The beds of the Mint Canyon were originally called the "Mellenia series" by Hershey[1]. Since this was not a place name as required by rules of nomenclature of the United States Geological Survey, Kew[2] renamed them the Mint Canyon formation.

Kew placed the Mint Canyon formation near the upper Miocene stage after a study of a small vertebrate fauna had been made by Stock. Later Maxson[3], having additional collections, made a more extensive study of the fauna, and corroborated the preliminary determination of Stock. He also concluded that the Mint Canyon was Upper Miocene in age.

Stirton[4], however, disagreed with Maxson and favored a Lower Pliocene age for the Mint Canyon formation on the basis of appearance of Hipparion.

An Upper Miocene age is supported by invertebrate evidence which places the overlying Modelo in the uppermost

---

1. Hershey, D. H., Amer. Geol., Vol. 29, pp. 356-358, 1902.
2. Kew, W. S. W., U.S.G.S. Bull. 753, pp. 52, 1924.
3. Maxson, J. H., Carnegie Inst. of Wash., Pub. 404, pp. 82-86, 1930.
4. Stirton, K. A., Amer. Jr. of Sci., Vol. 26, 1933.

Miocene, which would require the Mint Canyon formation to be older than Uppermost Miocene.

In his first work Maxson recognized that primitive forms were apparently associated with more advanced forms. Later he collected a fauna of Middle Miocene aspect in the lower beds. This lower fauna was turned over to R. Jahns for study. Jahns[1] was able to separate a lower portion of the Mint Canyon formation as distinct and unconformable below the upper part. He suggested that this be called the Tick Canyon formation and the upper part be called the Mint Canyon formations restricted.

Richey[2] reviewed the previous work and compared the Barstow, Ricardo and Mint Canyon horses. He concluded that the Mint Canyon horses are close to advanced Barstow forms and comparable to lower Ricardo. This conclusion is not inconsistent with an Upper Miocene age for the Mint Canyon.

The age of the Mint Canyon formation, therefore, is still in dispute. The discrepancy, however, becomes one of a general nature, that is, between the relationship of the established California invertebrate time scale and that of some vertebrate paleontologists.

---

1. Jahns, R. H., Am. Jr. of Sci., Vol. 237, pp 818-825, 1939.

2. Richey, K. A., Paper before the Cordilleran Section G. S. A., April 1940.

It is the opinion of J. H. Maxson[1] that the vertebrate evidence is not in discord with the invertebrate evidence. The ultimate solution will naturally be arrived at only after more complete correlation between vertebrate and invertebrate scales.

In this paper the Mint Canyon formation will be considered as Upper Miocene, because this age appears still to be accepted by the majority of California paleontologists and geologists.

The Mint Canyon formation overlies the Vasquez formation unconformably. The Vasquez series has been referred to as the Escondido series by Hershey[2] and Simpson[3] and as the Sespe by Kew[4]. Sharp[5] gave it the present name, since the name Escondido was preoccupied.

No fossil record from the Vasquez series is available to determine its exact age.

The Modelo formation overlies the Mint Canyon formation unconformably. Since Kew's[4] first record of an unconformity,

---

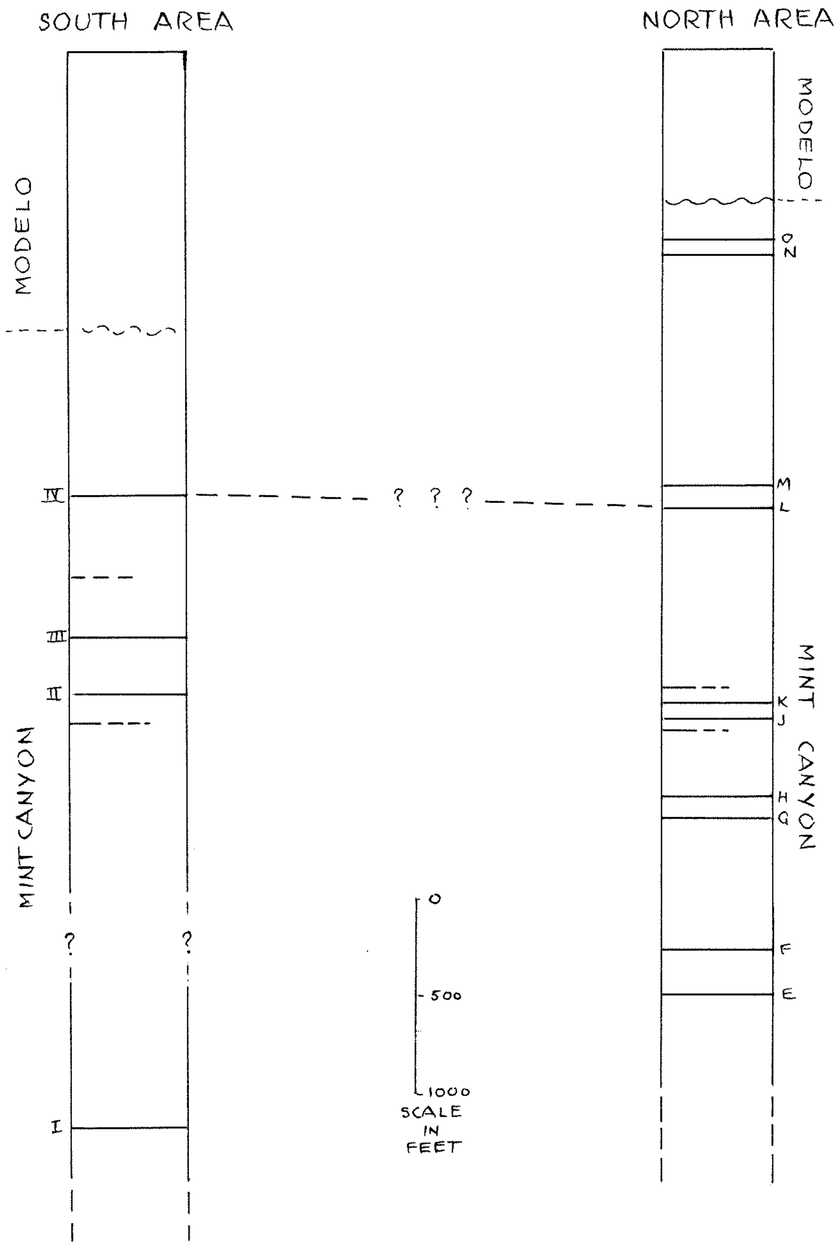
1. Maxson, J. H., Personal communication.
2. Hershey, O. H., Am. Geol., Vol. 29, 1902.
3. Simpson, E. C., Calif. Jr. of Mines and Geol., Vol. 30,1934.
4. Kew, W. S. W., U.S.G.S. Bull. Vol. 753,1902
5. Sharp, R. P., Pan Amer. Geol., Vol. 63, pp. 314, 1935.

doubt has been expressed as to its presence, and a suggestion that it is possibly an interfingered relationship in the northwestern extremity has been made. Mapping by several California Institute students has shown a definite unconformity in the area near Bouquet Canyon. This evidence is supported by the work of the author, and some additional evidence has been found to reinforce this view.

The Modelo[1] has been determined on invertebrate evidence as being Upper Miocene and more specifically has beencorrelated with the Neroly.

---

1. Maxson, J. H., Pacific Section, Am. Assoc. Petrol. Geol., Los Angeles, Calif., 1938.



Section showing the distribution of volcanic tuff beds in the upper part of the Mint Canyon formation.

Paleontology

Vertebrate Paleontology

The vertebrate fauna has received considerable attention by Kew[1], Maxson[2], Stirton[3,4,5], Jahns[6], Eaton[7], Richey[8].

The principal vertebrate forms represented in the Mint Canyon are listed below.

Mint Canyon formation

Merychippus sp.

Merychippus sumani

Trilophodon

Protohippus intermontanus

Aelurodon sp.

Alticamelus ? sp.

Hipparion near mohavense

---

1. Kew, W.S.W., U. S. G. S., Bull. 753, 1924
2. Maxson, J. H., Carnegie Inst. of Wash., Pub. No. 404, 1930
3. Stirton, R. A., Am. Jr. of Sci., Vol. 26, pp. 569 - 570, 1933
4. Stirton, R. A., Am. Jr. of Sci., Vol. 32, pp. 174 - 186, 1936
5. Stirton, R. A., Jr. of Paleo., Vol. 13, pp. 125-136, 1939
6. Jahn's, R. H., Am. Jr. of Sci., Vol. 237, pp. 818-825, 1939
7. Eaton, J. E., Am. Jr. of Sci., Vol. , pp. 899, 1939
8. Richey, K. A., Abstract of Paper presented before the Cordilleran Section, G. S. A., April, 1940.

Tick Canyon formation

Merychyus

Parahippus

Miolabis californicus

Maxson suggests the following ecological conditions as represented by the vertebrate fauna: "Presence of hypsodont horses, antelopes, camels, and rabbits, indicates that the vegetation must have been at least as abundant as that supported by a semi-arid region. The climate was necessarily more humid than that characterizing the Mohave Desert at the present time. Great numbers of fresh-water gastropods occuring locally in fine grained sediments indicate the presence of fresh-water lakes. The occurrance in the Mint Canyon fauna of a turtle, possibly related to Clemmys, is supplementary evidence. Rabbits and large tortoises, related to Testudo, may have frequented the more arid districts. The grazing types of mammals with long crowned teeth occupied the grass covered plains. Parahippus, the peccary, and possibly oreodont, mastodon, and Miolabis may have found congenial wooded areas along the streams and beside the lakes."[1]

---

1. Maxson, J. H., Carnegie Inst. of Wash., Pub. No. 404, pp. 82 - 86, 1930

Invertebrate Paleontology

The invertebrate fauna is limited almost entirely to a single form of gastropod. It has been identified as Paludestrine imitator Pilsbury by Dr. G. D. Hanna.[1] Dr. Hanna noted fragments of a larger species, which, however, could not be identified. The author has also found fragments of a larger form associated with Paludestrina but they could not be identified. The presence of such an abundance of a single form of fresh water gastropod such as Paludestrina imitator Pilsbury strongly suggests fresh water lake deposits.

Paleobotany

Dr. Daniel I. Axelrod of the National Museum of Washington, D. C. was kind enough to undertake the study of the plant fossils collected by Dr. J. H. Maxson, of the California Institute of Technology, Mr. W. H. Holman of the Standard Oil Company of California and the author. A preliminary statement has been arranged for publication by Dr. Axelrod.

Plant fossils have been found at several localities. Almost all the outcrops of "K" in the north area contained some plant material as did most of those of

---

1. Kew, W. S. W., U. S. G. S., Bull. 753, 1924

"I" in the south area. The best collections were obtained from a quarry in "I" of the south area near the mouth of Reynier Canyon. They occur scattered through some of the tuff beds with no apparent orientation with respect to bedding. In other quarries, however, they are found in more normal attitudes on bedding planes. The lack of orientation in some of the fine tuff beds might indicate that the ashy material was in a very soft ooze-like state.

Axelrod has identified 15 plants from the present collection.

<u>Fossil species</u>

Ceanothus precuneatus Axelrod

Ceanothus n. sp.

Cercocarpus cuneatus Dorf

Crossosoma n. sp.

Diospyros n. sp.

Fraxinus edensis Axelrod

Roemontia lobata Axelrod

Lyonothamnus mohavensis Axelrod

Mahonia mohavensis Axelrod

Platanus paudicentate Dorf

Quercus convexa Lesquereus

Quercus dispersa (Lesq.) Axelrod

Quercus Lakevillensis Dorf

Rhus sonorensis Axelrod

Robinia californica Axelrod

From this limited collection he has made suggestions regarding the nature of flora, climate or the region and relationships of the Mint Canyon to floras in adjacent areas. His tentative conclusions concerning these points are probably best set forth in a brief way in the abstract of his paper, as follows:

"The Mint Canyon flora is an integral part of the arid north Mexican vegetation that characterized the Mojave area in Middle Miocene time, and which, by the end of the epoch, had migrated westward into southern and central California, northward through the Great Basin, and eastward into the High Plains.

"The flora is essentially an oak savanna community whose nearest related modern equivalent species now occur in southern California, southern Arizona, and northern Mexico. At least four habitats contributed to the flora, lake-border and riparian, savanna, woodland and chaparral. The Mint Canyon climate was largely similar to the present conditions in the region, but differed in having a biseasonal distribution of rainfall and winter temperatures which may have been slightly higher.

"A comparison of the Mint Canyon with the Tehachapi flora of the western Mojave desert, and the Puente of the Los Angeles basin, shows that the Mint Canyon flora lived in a semi-arid interior region and was a part of the Mojave floral province."[1]

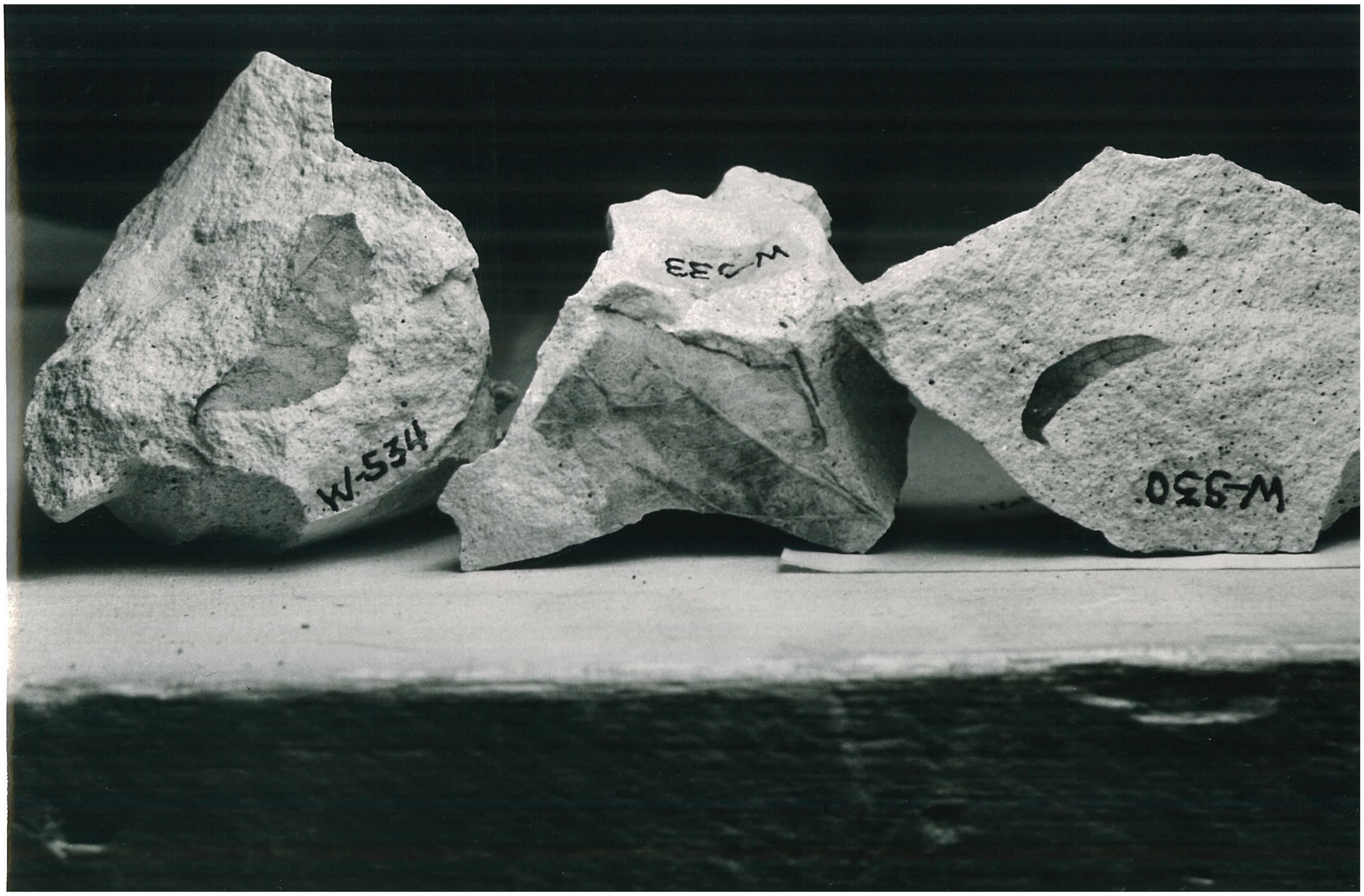
Just recently the author found small plant fossils which were not included in the collection studied by Axelrod. With the assistance of Dr. Willis Popeno of the California Institute of Technology, they were identified as a form of Chara, possibly Chara Knowltoni Seward. The fossil material represented fruit cases and stems of the Chara. The Charophyta are plants containing chlorophyll, living in fresh or brackish waters. This supports the evidence supplied by the presence of Paludistrina that the sediments are fresh-water.

---

1. Axelrod, D. I., Unpublished paper.

Fig. 7. Plant fossils from tuff bed "I".
(These photographs have not been checked with specimens since the plants were identified.)

Fig. 8. Plant fossils from tuff bed "I".


W-534


W-524
W-525

Fig. 9. Plant fossils from tuff bed "I" in
specimen on left.
On right, plant fossils from tuff bed
"K".

Fig. 10. Plant fossils from tuff bed "I".


W-K01

Fig. 11. Plant fossils from tuff bed "I".

Fig. 12. Plant fossils from tuff bed "I".


W-531
W536

Description of Tuff Beds

Introduction

The terminology outlined by C.K. Wentworth and Howell Williams[1] is used in the following description of the tuff beds. Brief definitions of the terms used are listed below for reference.

Ash	- Uncemented pyroclastic debris consisting of fragments mostly under 4 mm. in diameter. Coarse ash - 4-½ mm. Fine ash - less than ½ mm.
Tuff	- Indurated pyroclastic rocks of grains generally finer than 4 mm.; i.e., the indurated equivalent of volcanic ash or dust.
Crystal tuff	- Indurated deposite of volcanic ash dominantly composed of intra-telluric crystals blown out during eruption. Over 75% crystals.

---

1. C.K. Wentworth and Howell Williams, Bull. Nat. Resh. Council, No. 89, 1930-1932

Vitric tuff	-	Indurated deposits of volcanic ash dominantly composed of fragments of volcanic glass. Glass over 75%.
Crystal-vitric tuff	-	Between 50% and 75% crystals.
Vitric-crystal tuff	-	Between 50% and 75% volcanic glass.
Vitroclastic	-	Structure typical of fragmental glassy rocks, in which pieces usually have crescentic, rudely triangular outlines, or somewhat concave borders.

The tuff beds were assigned letters arbitrarily. Letters were chosen near the middle of the alphabet for the first ones named in the north area so that later beds found could be assigned letters appropriate to their position in the stratigraphic column. The beds therefore, go from oldest to youngest, in going from "E", the lowest one found, to "O", the youngest one found. Only the relatively prominent tuff beds were assigned letters. "I" was dropped after further work, as it was only a very minor tuff horizon. There were several other lenses of ash and tuff, and also many ashy sandstones and ashy shales which were omitted for the sake of simplicity.

In the south area numbers were used instead of letters so that there would be no confusion in the relation of the beds in the south area to those in the north. As can be seen in the columnar section including the tuff beds, an attempt at correlating the two areas has been made, but since the south area is not as complete as the north area, only an approximation is possible.

A rough traverse which was carried from the Santa Clara River across to Mint Canyon supported the idea that the tuff beds of both areas were in approximately the same stratigraphic position. A careful traverse will be necessary before the tuff beds can be correlated with certainty.

Fig. 13. North area. View from near the mouth of Vasquez Canyon looking west toward Bouquet Canyon showing dip slopes on tuff bed "H". Tuff bed "G" is exposed lower on the hill near the right side of the photograph.

Fig 14. North Area. Badlands at north end of Puckett Mesa. Tuff bed "G" can be seen to lens out in near cliff. This is near the eastern extremity of the lake system in the north area.

Fig. 15. North area. Tuff bed "G" at its thickest part near the mouth of Vasquez Ganyon.

Fig. 16. North Area. Tuff bed "G" showing cube-like fracture fragments.

Fig. 17. South area. Quarry in tuff bed "I". Most of the plant fossils were obtained from this locality.

Fig. 18. North area. Typical,small,intraformational unconformity which are common in several of the tuff beds. (Just above head of hammer.) Note the gradation from coarse to fine in the tuff above the unconformity.

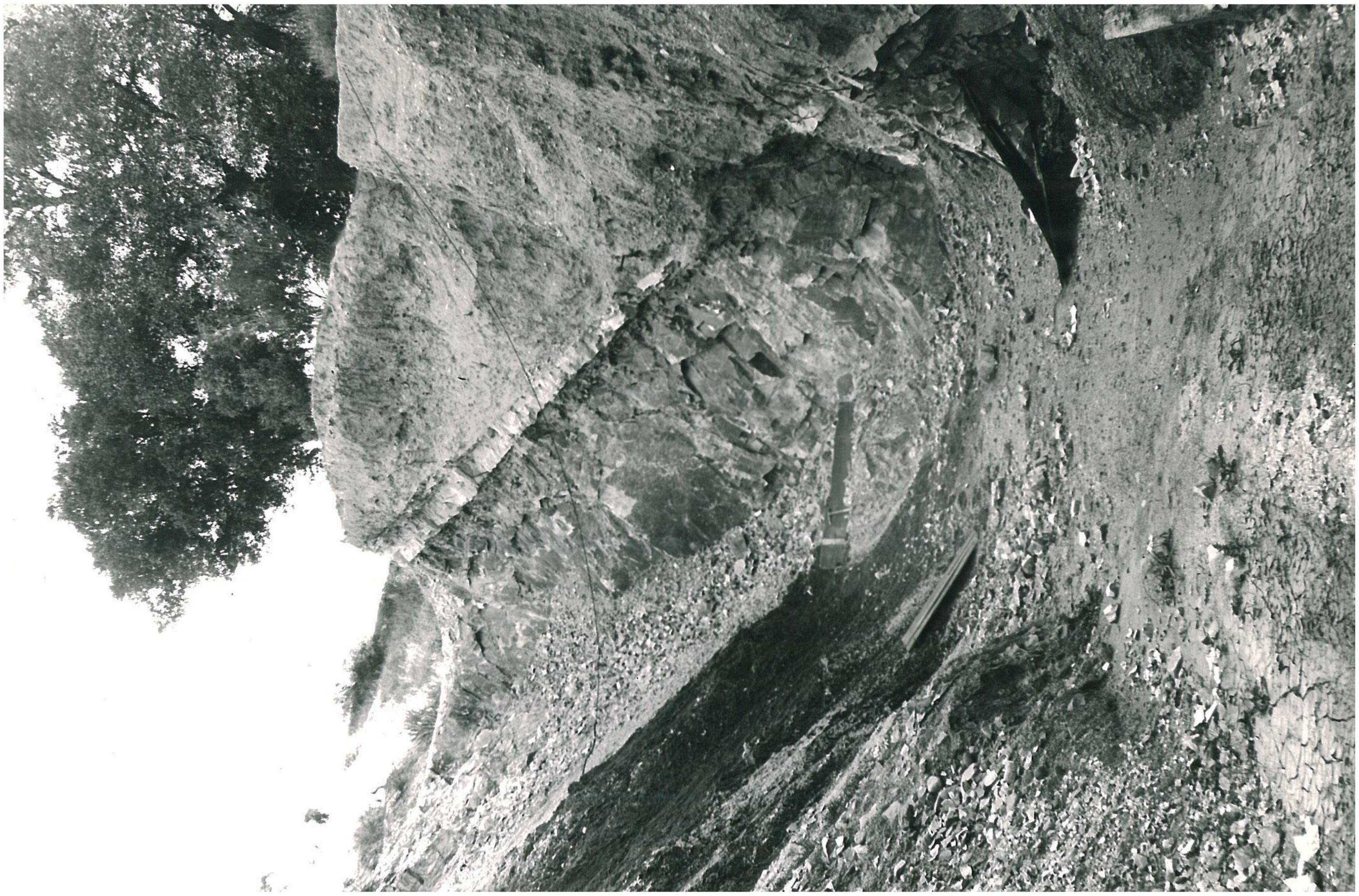


Fig. 19. South area. Quarry in tuff bed "I". Note the difference in dip between the tuff beds and the overlying Modelo beds (upper right hand corner). This shows the unconformable relation of the Mint Canyon and Modelo formations.

Fig. 20 North area. Exposure of tuff bed "F" showing its typical bedding and fracture.

Fig. 21. South area. Exposure of tuff bed "II" showing angular, cube-like fracture fragments.

Fig. 22. South area. Dip-slope on tuff bed "II". Bed "III" is exposed in the high peak.

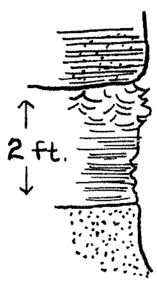
North Area

Tuff Bed "E"

Tuff bed "E" is visible in patchy outcrops in several draws northeast of Puckett Ranch. It strikes approximately east-west over its fairly limited lateral extent of about 1500 feet. The bed is lost on both ends through faulting and poor exposures.

It is, for this part, made up of pyroclastic material ranging from 1/8 mm. in diameter down to very fine dust. It is essentially a vitric tuff, but a few grains of acid feldspar and quartz are also present. The transparent portions, glass and crystals, make up only about 15 to 20% of the tuff. Surrounding these fragments is material which is white in reflected light and nearly opaque in transmitted light. It is difficult to determine what this material is. On first appearance it was identified as kaolin, but when the hardness and consolidated nature of the tuff was considered that was doubted. It may be that impregnation by silica has cemented a kaolin and glass mixture making a resistant, compact rock. It might also be made up of extremely fine volcanic dust, plus a certain amount of devitrified glass plus some kaolin. The tuff is thinly but roughly laminated and is quite friable. It is essentially a single unit, differing from some of the other tuff beds which are made up of alternating horizons of coarse and fine material.

The basal portion of this bed is regularly laminated but the top part is characterized by irregular bedding. (See section on sedimentary features.)



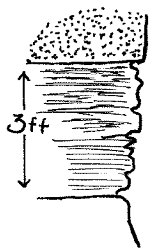
Brown ashy shale

Vitric tuff, thinly laminated, grading from regular at bottom to irregular at top

Brown to tan sandstone

Diagramatic section of tuff bed "E."

Tuff Bed"F"



Reddish, shale and sandstone

Fine grained vitric tuff at bottom grading to thinly bedded clay and ash at top.

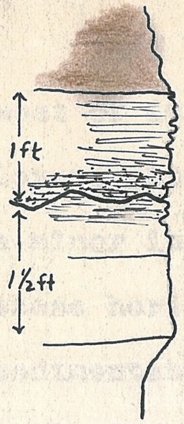
Red, shaley sandstone

Diagrammatic section through tuff bed "F".
(See photograph, fig.)

Tuff bed "F" lies about 200 feet stratigraphically above tuff bed "E". The main tuff beds in the north area occur in pairs which are close together stratigraphically and are usually similar in composition. Beds "E" and "F" may be characterized as being a pair. Tuff bed "F" is very similar to "E" both in extent and in physical nature. It tends to be slightly more massive that "E" and shows more regular bedding than do parts of"E". Some outcrops of "F" show considerable silicification and along some fracture planes manganese dendrites are well developed.

It extends from just north of Puckett Ranch to the head of the bad lands amphitheater under the north end of Puckett Mesa, and varies in thickness from about 1 to 3 feet.

Tuff Bed "G"

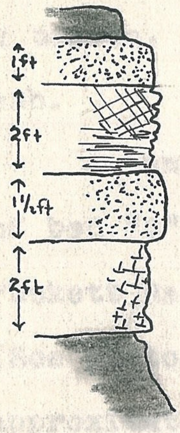


Fine grained, brown shale

Coarse, sandy ash at bottom grading to thinly bedded, fine grained, white tuff at top.
Interformational unconformity

Unevenly bedded, crossbedded near top

Fine grained, porcelaneous, creamy white tuff.



Grey, fine grained, ashy sandstone

Fractured, fine grained, white, porcelaneous, brittle tuff

Coarse, grey, ashy, sandstone

White, fractured, fine grained, porcelaneous tuff

Ash bed "G" extends from the bad lands amphitheater at the north end of Puckett Mesa to a point on the east side of Bouquet Canyon northwest of the mouth of Vasquez Canyon. Its lens-like nature is beautifully shown where it thins out and grades into coarse terrestrial deposits in the face of the badlands amphitheater. From this it thickens to about 10 feet opposite the mouth of Vasquez Canyon and south of the Vasquez Canyon road. At its most northwesterly exposure it is only about one foot thick.

Tuff bed "G" is made up of several units over most of its extent. Fine grained, white, porcelaneous layers alternate with coarse sandy horizons. Often a minor intraformational unconformity will separate these horizons. Excellent examples of sorting through sedimentation are sometimes exhibited by these small units in that one layer will start at the bottom as a coarse, sandy unit and will grade upward into fine ash.

A sample of the fine, massive tuff at the top of bed "G", taken from an outcrop directly south of Puckett Ranch showed the following constituents. (See photograph, fig. 25, 26.) The section in fig. B above approximates the section from which the following samples were taken.

Glassy material -- fine dust size

a. Unaltered glass fragments -- 15%

b. Opaque material as described under "E". Possibly made up of extremely fine volcanic dust, plus some products of devitrification and some kaolin. -- 75%

Crystalline material -- 10%

a. Quartz --------- 40%

b. Feldspar

Oligoclase -- 20%

c. Hornblende ----- 10%

d. Biotite -------- 10%

e. Garnet --------- 11%

f. Opaque minerals- 20%

Photograph in fig.23 shows a thin section of a sample from the middle of the tuff bed at the same locality. It is a much coarser clastic, and, though a considerable amount of tuffaceous material can be observed in this section, a great deal of it is apparently non-pyroclastic in nature being derived merely from weathering of the basement complex in the mountains surrounding the Santa Clara Valley.

The basal part of tuff bed "G" is practically identical in thin section to the upper part.

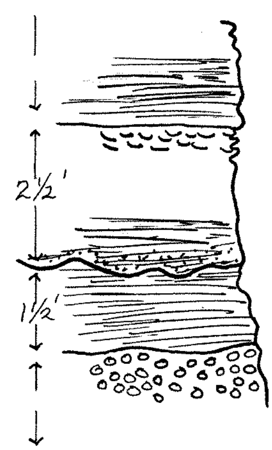
---

* these percentages are only approximate

<u>Tuff</u> <u>Bed</u> "H"

Tuff Bed "H" is separated from "G" by about 60 feet of sediments. Above "G" the fine ashy sandstones grade up into coarse conglomerates. The conglomerate is made up of pebbles and cobbles which are smooth and well rounded and appear to be stream gravels. These occur nearer the border of the lake and grade into sandstones to the west near Vasquez Canyon.

Tuff beds "H" and "G" are very similar and constitute a so-called pair as were "E" and "F". "H" is similar to "G" in that it is made up of coarse and fine units of tuff, and that the fine parts are often porcelaneous in nature. "H" does not extend quite as far east as "G" and does not reach the thickness of "G". However, since it is above "G", it is the one to form the large dip slopes which are so prominent.



Thinly bedded, sandy clays

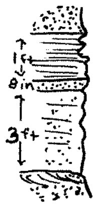
White, fine grained, porcelaneous, grades to coarse
Coarse, sandy, ash
Intraformational unconformity locally, dies out elsewhere
Fine grained, fairly massive tuff
Pebble and cobble conglomerate. Iron stain around pebbles

Under the microscope the fine grained massive tuff appears very similar to the massive section described under "G". In a thin section of "H", however, secondary, cryptocrystalline, opal-like silica seemed to be present. This is also apparent in the hand specimens in their porcelaneous character. This impregnation by silica seems to vary with the grain size, the finer portions being most affected. In some instances sandstones underlying ash horizons are indurated and very resistant. West of Bouquet Canyon, under tuff "J", opal-like material fills fractures in the underlying sandstones.

The coarse units of "H", as in "G", are mostly sandy clastics with some fine ashy material filling the interstitial spaces. The coarse material for the most part does not appear to be pyroclastic, but rather products of weathering and erosion.

Fracturing of these porcelaneous units is peculiar. They tend to break up into fragments which might be described as roughly cube-like in shape and generally are of the order of one inch on a side. The fracturing is apparently not controlled by sedimentary structures nor is it typical conchoidal fracturing, see photograph, fig. 38.

Tuff Bed "J"



Interbedded ash and sandy clays
Consolidated ashy sandstone
Ash and sandy clay
Coarse sandstone, massive, crossbedded

Tuff bed "J" is the lower and least prominent of the pair next highest in the section. It lies about 350 feet above "H" and is separated from it by a series of alternating sandstone and shaley horizons. Some of the sandstone horizons are relatively well consolidated.

This bed does not have pure ash units in it as do most of the others described, but is made up of sandy ash horizons. The pyroclastic material involved includes both glass fragments and fine grained opaque material as described under "E" and "G". Some of the glass fragments from "J" were tested with index oils. The indices were found to cluster around an index of 1.5018. A few went as high as 1.5119 and some as low as 1.4875, but these were exceptions. This index corresponds to a glass with a silica percentage of above 70% according to George's [1] work on natural glasses.

---

1. George, W. O., Jr. Geo., Vol. 32, p. 365, 1924

Tuff Bed "K"

Coarse ashy sandstone
Ripple marks

Fine, massive, white tuff

Sand and ash mixed in swirls and wavey laminations
Coarse sandstone, grading to pure ash at top

Tuff bed "K" is very similar to both "G" and "H" in that it is made up of massive fine ashy horizons together with sandy and shaley units. It extends from the Puckett Mesa bad lands amphitheater across Bouquet Canyon and possibly is represented near Haskell Canyon by ashy sandstones that have apparently the same stratigraphic position.

The massive horizons are not as porcelaneous as some of those in "G" and "H", and silicification does not appear to have proceeded to such an extent.

East of Bouquet Canyon bed "K" is made up of units containing much more sand and clay material than west of Bouquet Canyon where it becomes more pure ash and obtains a thickness of five to six feet. This thickest section can probably be regarded as being near the center of the body of water in which it was deposited. In this same section, minor ashy horizons of no great lateral extent or thickness occur both above and below "K". Farther west near Haskell Canyon, lenses of ashy material which appear to be in nearly the same stratigraphic position as "K" become very sandy. This probably can be taken to represent the western edge of the body of water.

Ripple marks, irregular bedding, and intraformational unconformities were observed in "K" as in "G" and "H". In the north area "K" is the only ash bed in which good plant fossils have been obtained. In some of the other beds, however, a little charcoal has been found.

Tuff Beds "L" and "M"

The next highest pair of tuff beds are distinctly different from those lower in the section. Petrogrographically"L" and "M" are nearly pure volcanic glass over much of their extent. These glassy portions have a characteristic blue grey color as compared to the creamy white color of "G" and "H". The fragments show typical vitro-clastic structures and vary in size from about 1/6 mm. down. The material is practically unaltered, and no devitrification was noticed. Gas bubbles were seen in a number of fragments but no liquid was noticed in any. As in bed "J", the glass has an index of about 1.5018. Some fragments have indices as low as 1.488 and some as high as 1.516, but these were the exception. This corresponds to a silica content of about 70% according to George. [1]

Near the thickest portion of "L", fine, amorphous-like, white, material as described under "G" and "H" is present.

Both east of Bouquet Canyon and west of Haskell Canyon "L" becomes very sandy where it lenses out and disappears.

---

1. George, W. O., Physical Properties of Natural Glasses, Jr. of Geo., Vol. 32, p. 365, 1924

"L" and "M" are not as well consolidated as "G" and "H" and show no porcelaneous characteristics so typical of "G" and "H". They do not break up into small fragments in the manner of "G" and "H", but are more friable and pulverize easily. Sedimentary structures are not as well preserved in "L" and "M" as in "G" and "H".

Tuff Bed "N" and "O"

Tuff bed "N" is not well exposed and can not be traced for any great distance. A few isolated outcrops indicate that it extends from a little east to about a mile west of Bouquet Canyon.

It has both glassy units similar to "L" and "M" and also white units similar to "G" and"H". Considerable sand is present throughout much of it.

Tuff bed "O" is possibly not worthy of note, since it is only an ashy conglomeratic zone and not a true tuff bed as are the others described. It is, however, the highest in the section and is possibly valuable for correlation purposes.

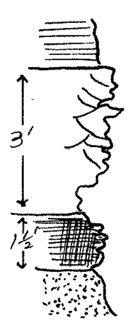
Tuff Bed "O"

Grey to tan sandstone

Blue-grey, ashy, pebble horizon

Reddish pebble conglomerate horizon

Tuff Bed "N"



Fine grained, grey, ashy silt and sand

Grey, slightly glassy, tuff, highly fractured

Fine grained, ashy silt

White ashy highly fractured into small fragments

Massive, even grained, grey sandstone

South Area

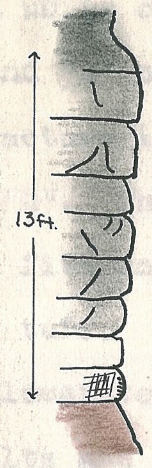
Tuff Bed "I"

Ash bed "I" extends from near the mouth of Los Pinetos Canyon to a point about 3 miles northeast on the east side of Sand Canyon. It is being quarried in Reynier and Sand Canyon and at this point is best exposed. In these quarries the tuff bed reaches a thickness of about 13 feet. The top ten feet is massive, fine grained, grey tuff which breaks up into large blocks. It is made up of pyroclastics ranging in diameter from 1/6 mm. down. White opaque material described in "E" and "G" of the north area makes up about 25% of this tuff, and appears more like kaolin in this tuff than in some of the others. A certain amount of impregnation probably counteracts the weakening effect of kaolinization.

The lower two feet of the tuff bed is more porcelaneous than the main portion, and breaks up into small kernels similar to the fine grained horizons in "G", "H", and "K" of the north area.

On the east side of Sand Canyon this tuff bed thins to only a few inches and becomes quite sandy and shaley.

The best collections of plant fossils so far obtained have come from these stone quarries in tuff bed "I". Men who have worked in the quarries say that the plants come mostly from the lower half of the tuff beds.



Dark grey clay

Massive, fine grained, grey tuff

White, fine grained tuff, fairly massive
White, porcelaneous tuff, fractures into small kernels
Dark brown clay

Tuff Bed "II"

Approximately one mile west of Humphreys is an area of tight folding. Tuff bed "II" is the lowest, and most prominent tuff in this area.

It is made up of units of massive fine grained tuff and units of porcelaneous tuff similar to those in "G" and "H" of the north area. These porcelaneous units fracture into the cube-like forms described under "G" and "H". The beds grade from poorly defined sandy units to five and six foot thicknesses of massive, fine grained, tuff. The beds below are coarse sandstones and conglomerates while these above are generally finer silts and clays.

The ash is nearly all glassy material including the white, kaolin-like material mentioned previously. Very few crystals fragments of quartz, biotite, and feldspar are present. In this respect it is similar to "I", parts of "E", "F", "G", "H", and "K". The size of the grains, as in "I", are, in general, below 1/6 mm. in diameter.

Tuff Bed "III"

Tuff bed "III" is very much like "II", and its identification where found alone is not certain in many cases. The tuff itself is practically the same as "II", but the bed can be identified by the overlying and underlying horizons which differ with the different tuffs. These are not always consistent, though, but usually they aid greatly in identifying a bed.

Tuff bed "III" is not continuous over the extent of "II", but parallels it over short distances and then lenses out.

Both "II" and "III" are somewhat fossiliferous, and this fact led the author to first believe that beds "I" and "II" or "III" were the same bed in the south area and that they corresponded to "K", the fossiliferous horizon of the north area. The fact that "L" and "M", which overlie "K" are very similar to "IV" supported this belief. The distribution of the beds after further mapping, however, shows that "I" and "II" are not the same beds. Correlation based on tuff characteristics is therefore vague if possible at all.

Tuff Bed "IV"

Tuff bed "IV" is the only other bed in the south area that could be determined to be an individual and separate bed. In comparing it to the beds of the north area, it is most nearly similar to "L" and "M". There are only a few patches of it exposed. It is glassy as are "L" and "M", and has the characteristic blue grey color of these beds.

Most of its extent is covered by alluvium. Its eastern limit grades into a well consolidated, medium grained, grey sandstone. The ash bed does not appear to lens out as some do, but rather is replaced by the sandstone horizon.

Thin, brown, fine grained, resistant ss.

Grey, friable, glassy, thinly bedded tuff
slightly fossiliferous

Brown to grey sandstone, poorly consolidated

Petrographic Summary

In the north area tuff beds "E" and "F", "G", and "H", and "J" and "K" are characterized in the hand specimens by having a white to creamy white color and by being relatively highly indurated. "L" and "M", on the other hand, are typically blue grey in color and pulverize easily. The white color of the first group is due to a material which appears opaque with transmitted light under the microscope and is white in reflected light. At first glance it might be called kaolin, but when the hardness and compactness of the tuff are considered, it seems as though it is not. It may be that it is kaolin, but that the whole mass is so impregnated with silica that it is held together in a compact resistant mass. It may also consist of very fine particles of glass or products of devitrification of the glassy material which make up most of the remaining volume of the tuff. Some units also contain crystal fragments.

"L" and "M" are almost pure glass fragments ranging from 1/6 mm. down.

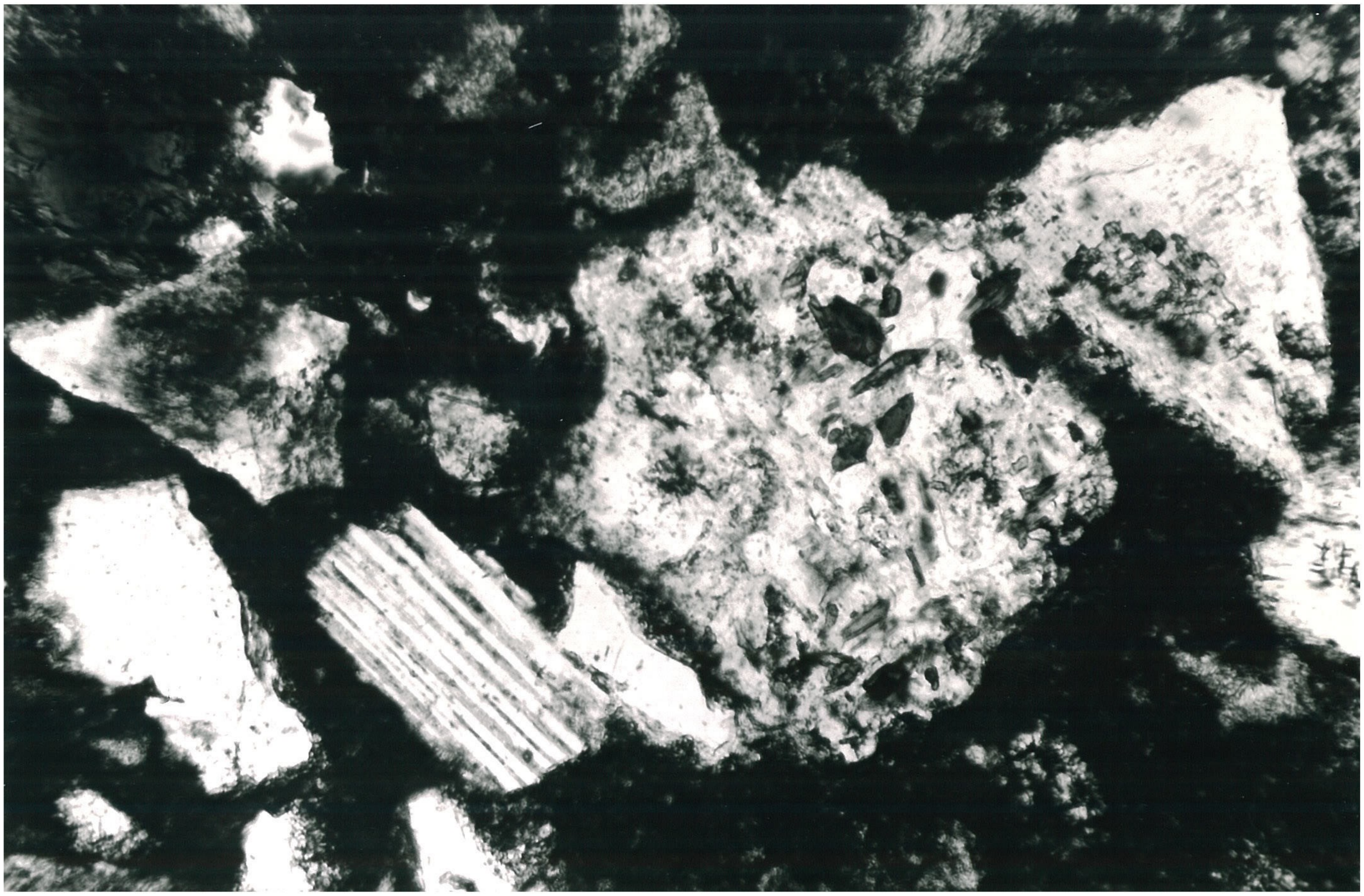
The tuffs are quite acid. Indices of the glass are about 1.50 which corresponds to a silica percentage of 70%. The crystalline portions of the tuffs also indicate an acid nature of the material.

In the south area tuff bed "I", "II", and "III" are of the white type of the north area while "IV" is of the blue-grey type.

In general the tuffs can be described as fine grained, acid, vitric tuffs with varying degrees of alteration and silicification.

Fig. 23. North area. Photomicrograph of thin section from middle unit of tuff bed "G" showing angular mineral, glass, and rock frogments. The opaque portions are a kaolin-like material making up much of the bed. Un-X nicols, x120.

Fig. 24. North area. Photomicrograph of thin section of lower unit of tuff bed "G" near Vasquez Canyon. This combination of volcanic glass shards and opaque, kaolin-like material is typical of many of the tuff beds. Un-X nicols, x120.



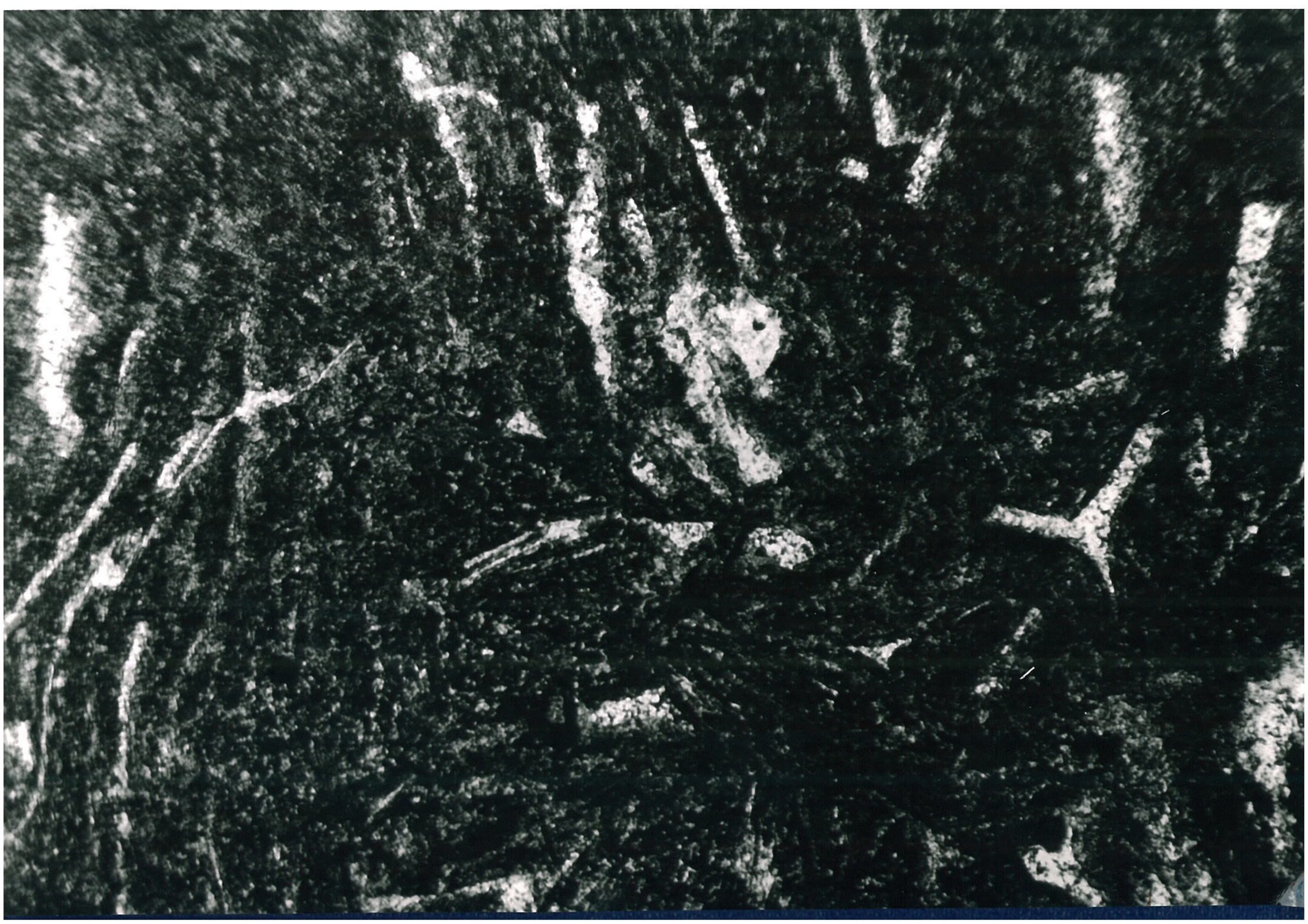
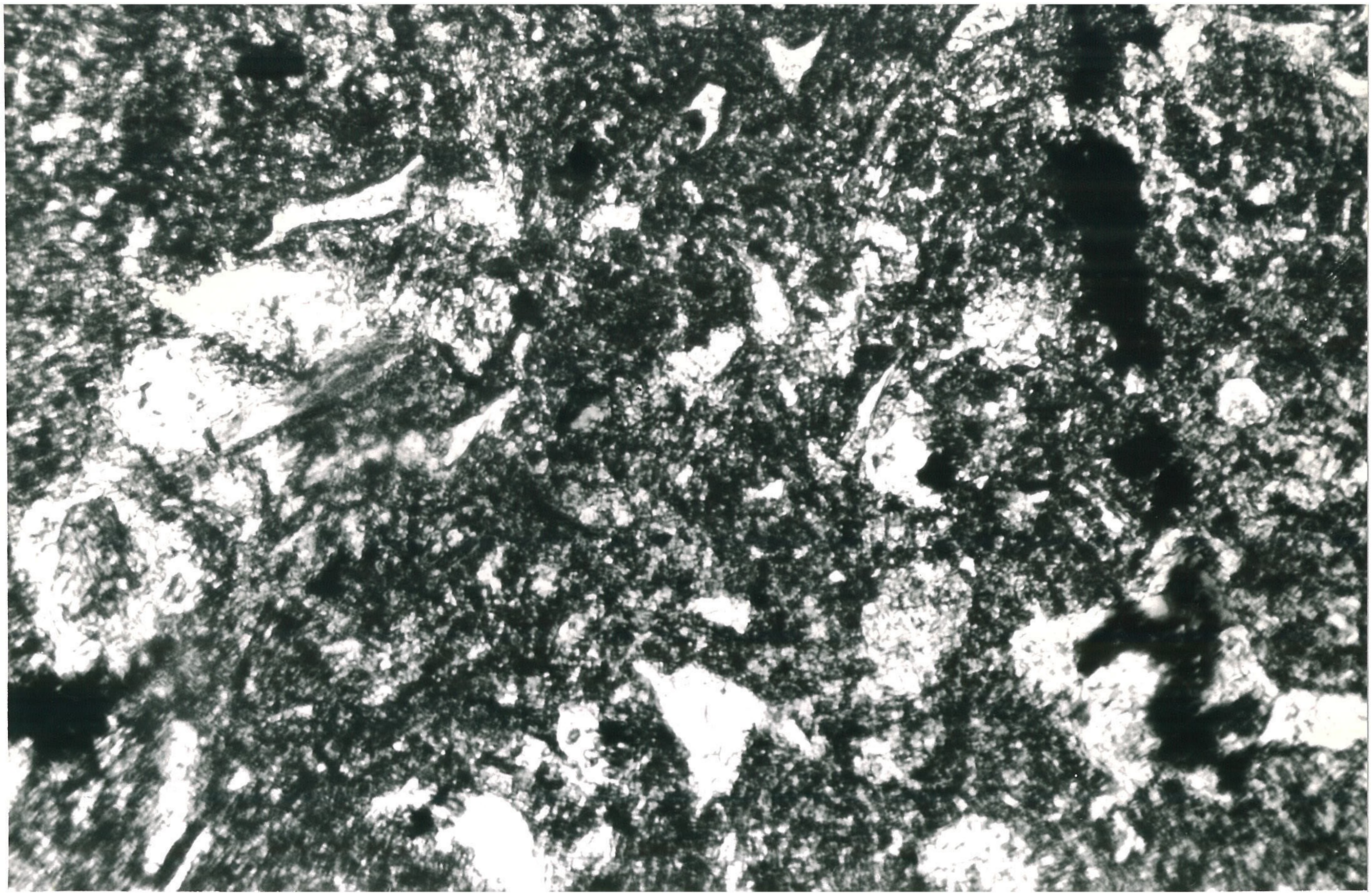


Fig. 25. North area. Photomicrograph of top unit of tuff bed "G" near Vasquez Canyon showing volcanic glass fragments and crystalline material. Un-X nicols, x 120.

Fig. 26. North area. Same field as above but with crossed nicols. This gives an approximate idea of the proportion of crystalline to glassy material. x120.



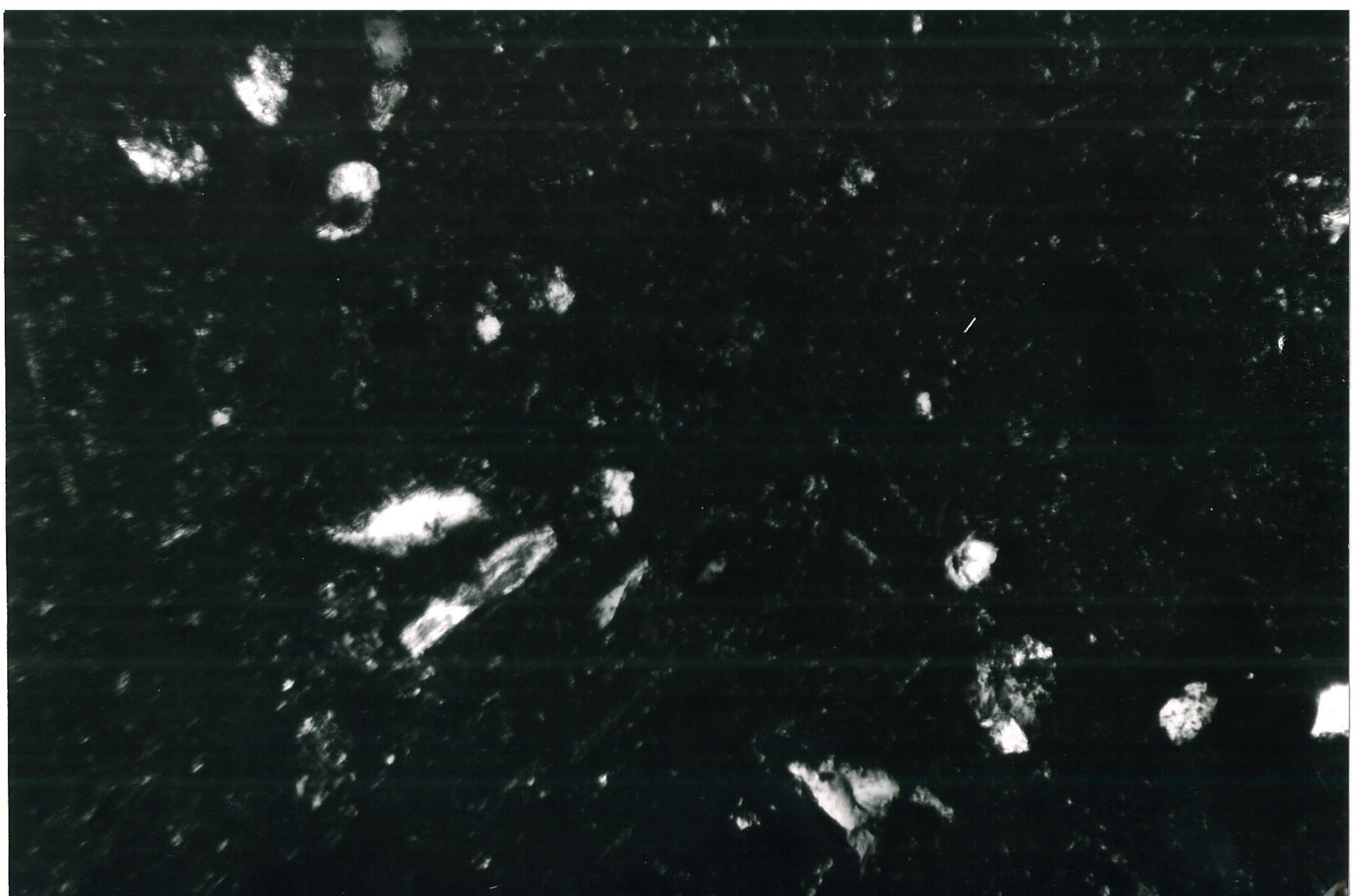


Fig. 27. North area. Photomicrograph of thin section of tuff bed "K" west of Bouquet Canyon. The elongated nature of the glass frogments is peculiar. Perhaps they originated as a sort of Pele's Hair. Un-X nicols, x120.

Fig. 28. North area. Photomicrograph of thin section of tuff bed "H" near Vasquez Canyon. This section is typical of many of the tuffs showing a combination of glass shards, opaque, kaolin-like material and a little crystalline material. Un-X nicols, x120.

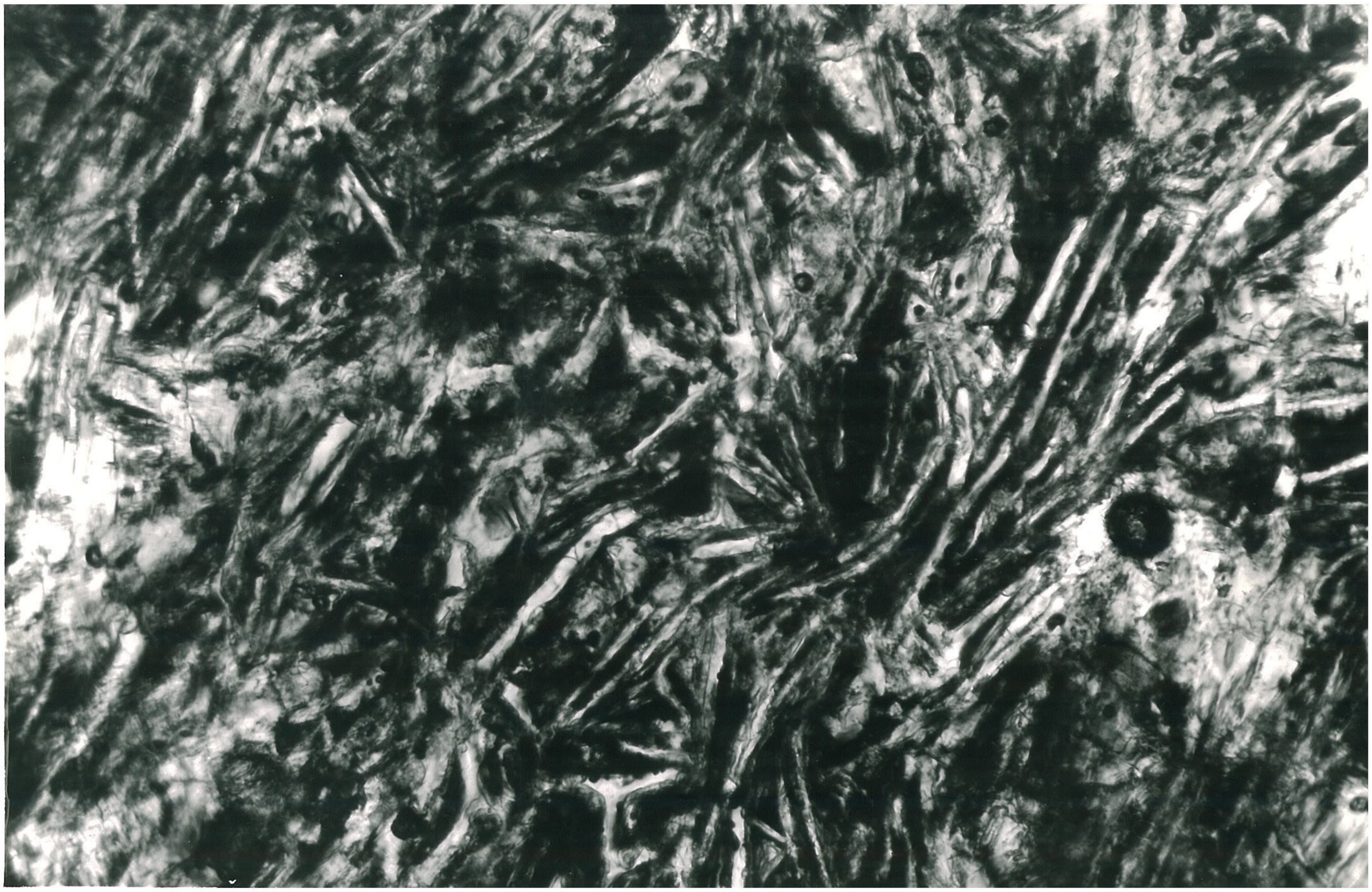
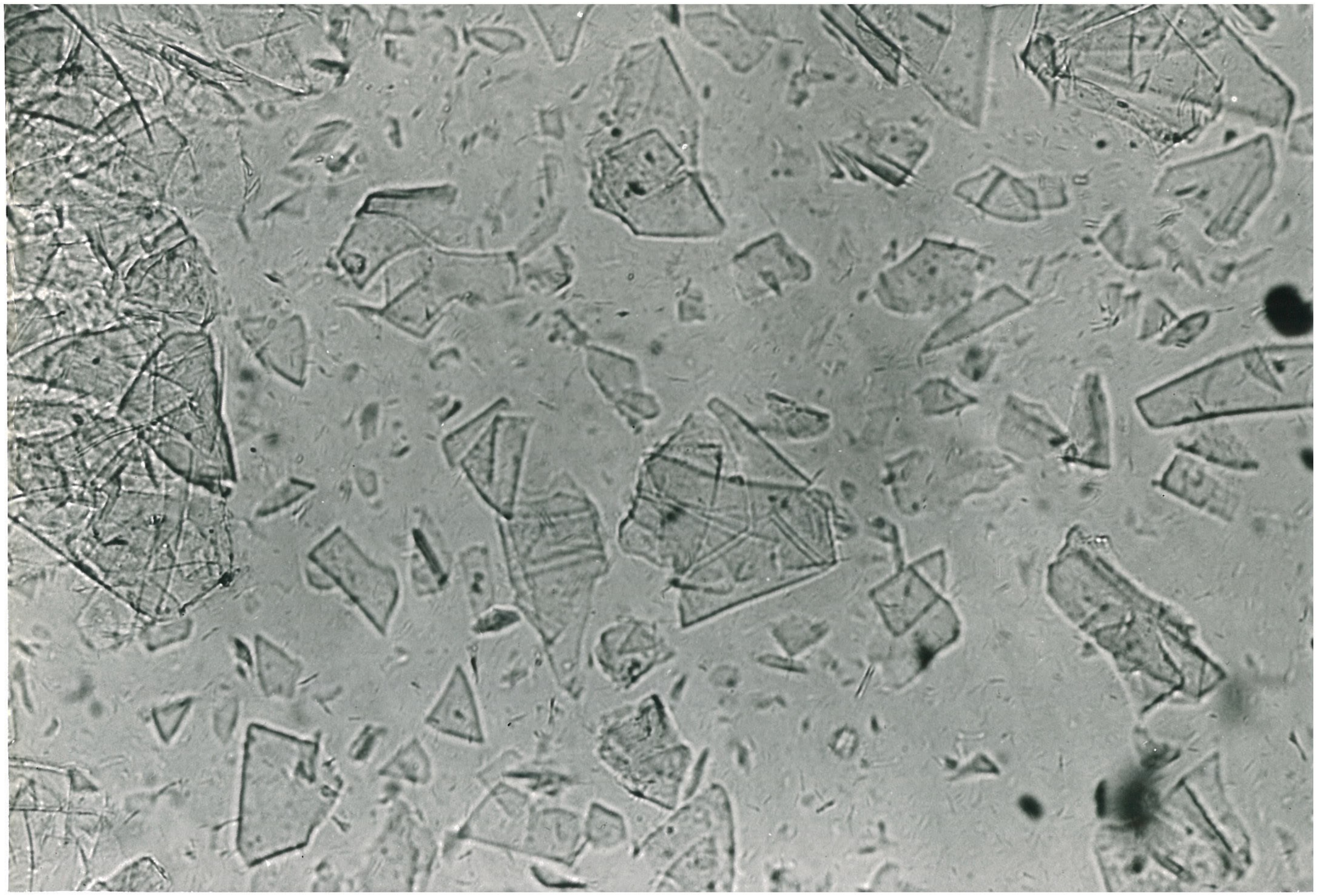


Fig. 29. North area. Photomicrograph of volcanic glass shards from tuff bed "M", immersed in cedar oil. Tuff bed "M" is composed almost entirely of fine glass fragments. The field was thrown slightly out of focus in order to make the glass fragments more distinct. Un-X nicols, x120.



Summary of Distribution of the Tuff Beds

The tuff beds of the north area trend east-west in their outcrops, and are generally lenticular in form. They thin and die out toward the east and west, and usually become sandy toward the edges. Their greatest thickness is about ten feet. Their linear extent ranges between a mile and three miles in the case of the more prominent tuff beds.

Considering the thickest portions of each tuff as the center of the body of water in which it was deposited, and the lateral limits as the edges of a body of water, and also taking into consideration folding and faulting, it seems that the basin of deposition migrated westward from the time of the deposition of the first tuff bed to that of the last.

If the north area and south area are joined under the Mint Canyon syncline, the body of water in which they were deposited had a much greater north-south than east-west extent, being of the order of two miles east-west and ten miles north-south.

There is no conclusive evidence that they are joined, however, even though they are contemporaneous. Then, too, all the beds of the north area apparently are not present in the south area.

Special Sedimentary Features

Ripple Marks (See photographs, figs. 30,31, 40,41)

Ripple marks are fairly common, both in the ash beds and also in consolidated sandstone and shale members of the Mint Canyon. Some dozen exposures of ripple marks observed showed all symmetrical oscillation ripples. They ranged in wave length from 1 inch to 2 3/4 inches. Ripple indices ranged from about 6 to 11. These ripples fall within the range of aqueous oscillatory ripple marks as described by Twenhofel[1] and could not be aeolian ripple marks. According to Twenhofel, the relation between ripple sizes and depth of water is not accurately known. Small ripples do not necessarily indicate shallow depths as they also can form at great depths, but since large waves can not form in shallow water, the ripples there will always be small. The distribution of the sediments in the section under discussion seems to eliminate the possibility of great depths so that the relatively small size of the ripples observed suggests shallow water. They may naturally have formed near a shore line, but in several cases noted they occurred at

---

1. Twenhofel, W.H., Principles of Sedimentation, 1939

the thickest section of ash which in other respects appears to be the center of the body of water. This fact, together with the fact that no larger ripples were found, strongly suggests a shallow body of water.

Cross-laminations (See photographs, figs. 34, 35, 36)

Cross-laminations occur in both the tuff and other sedimentary beds. For the most part, they are on a small scale, of the order of size shown in photographs, figs. 34, 35. All those observed were units bounded by parallel planes which were aqueous cross-laminations according to Twenhofel.[1]

Some of the cross-laminations are ripple-mark cross-laminations as in fig. 36 .

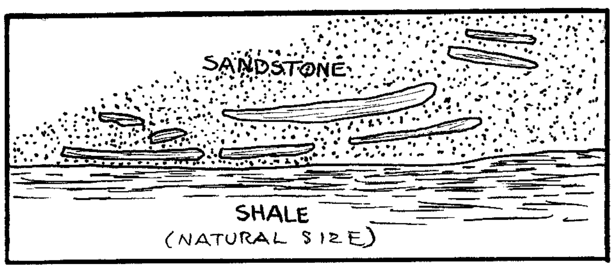
---

1. Twenhofel, W. H., Principles of Sedimentation, 1939

Mud Cracks

Mud cracks are not common and were noted in only one case in the north area. Here they occur in shale with sandstone filling the cracks. The segments were of the order of five inches in diameter and formed a typical mud crack pattern.

Mud flakes occurred at one outcrop in the south area, stratigraphically near tuff bed"IV". A cross section as observed in the outcrop is sketched below.



Rain Drop Imprints

At one outcrop of well consolidated sandstone in the north area, what were thought to be rain drop imprints, were observed. See photograph, fig. 39 .

Irregular Bedding

Peculiarities of bedding that can not easily be classified were observed. One type is well shown in fig. 38. This botryoidal-like parting was observed in several beds, but especially in "H". In some cases where it was especially regular it gave the impression of prints of organic material such as leaves or wood. It appears to be due to original structures in the tuff. In other cases as in fig. 32,33, coarse and fine material appeared to be kneaded together. Small fold-like structures were also noted.

All these structures seem to suggest a condition in the fine ashy sediment of an ooze-like nature in which phenomena such as contemporaneous folding through slumping, stirring and mixing of sediments, and differential compaction would take place. Stirring would create irregularities in the sediment similar to bedding but which would not follow ordinary bedding planes. This would create planes along which parting would take place.

Another suggested explanation is that the fine colloidal-like ash in settling through the water would be coagulated, possibly electrostatically or chemically, into irregular clods of ashy material which would create differences sufficient to control the irregular parting after lithification.

Some of the minor irregularities in bedding are undoubtedly due to a sort of scour and fill process. Some of the small fold structures are due to contemporaneous folding.

Fig. 30. South area. Oscillation ripple marks in sandstone above tuff bed "IV".

Fig. 31. North area. Oscillation ripple marks near top of tuff bed "H" near Vasquez Canyon.

Fig. 32. North area. Peculiar nixing or "kneading" of fine and coarse material in tuff bed "G". This phenomena was observed in several localities near Vasquez Canyon.

Fig. 33. North area. Similar to above.


1 - INCH

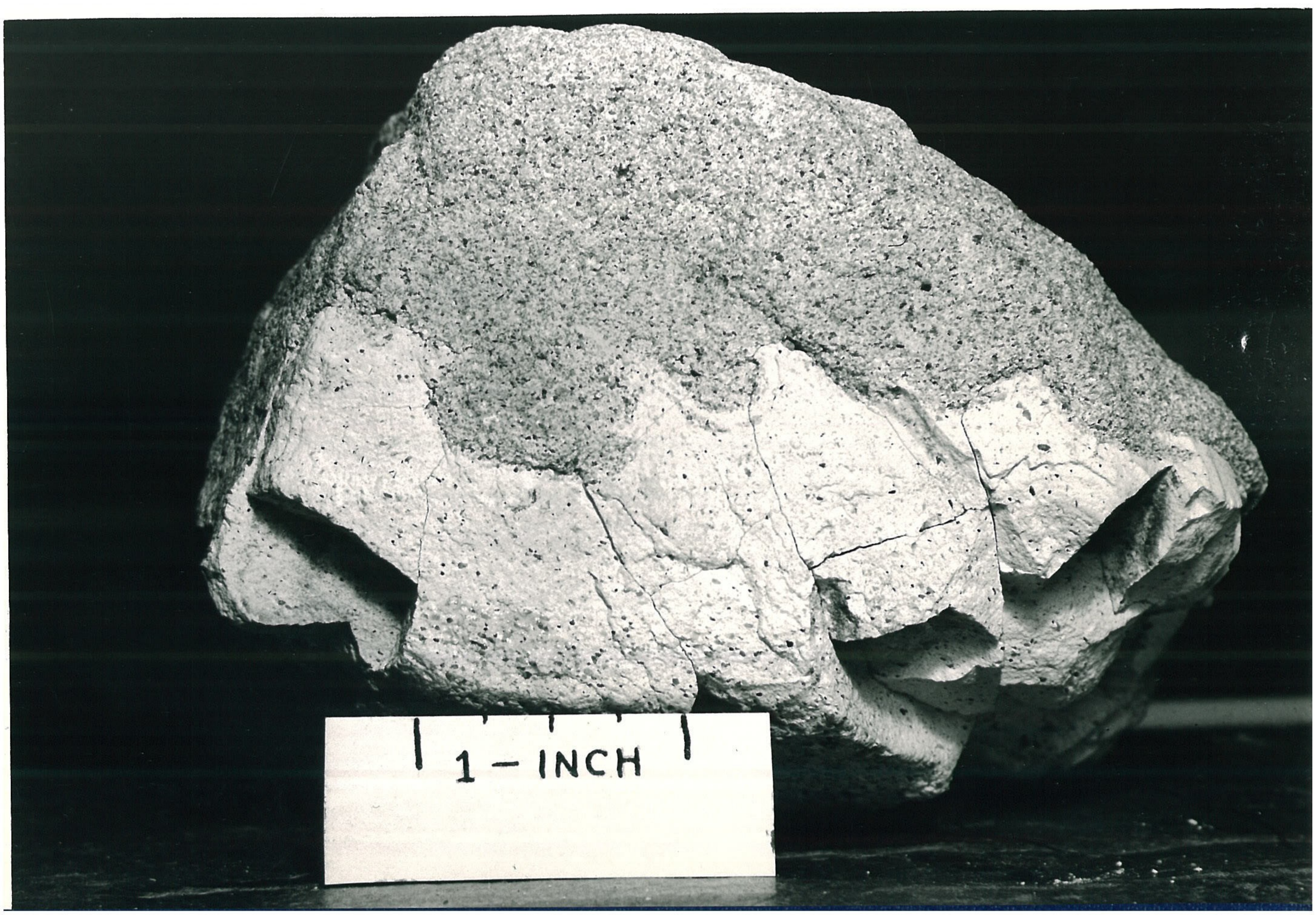
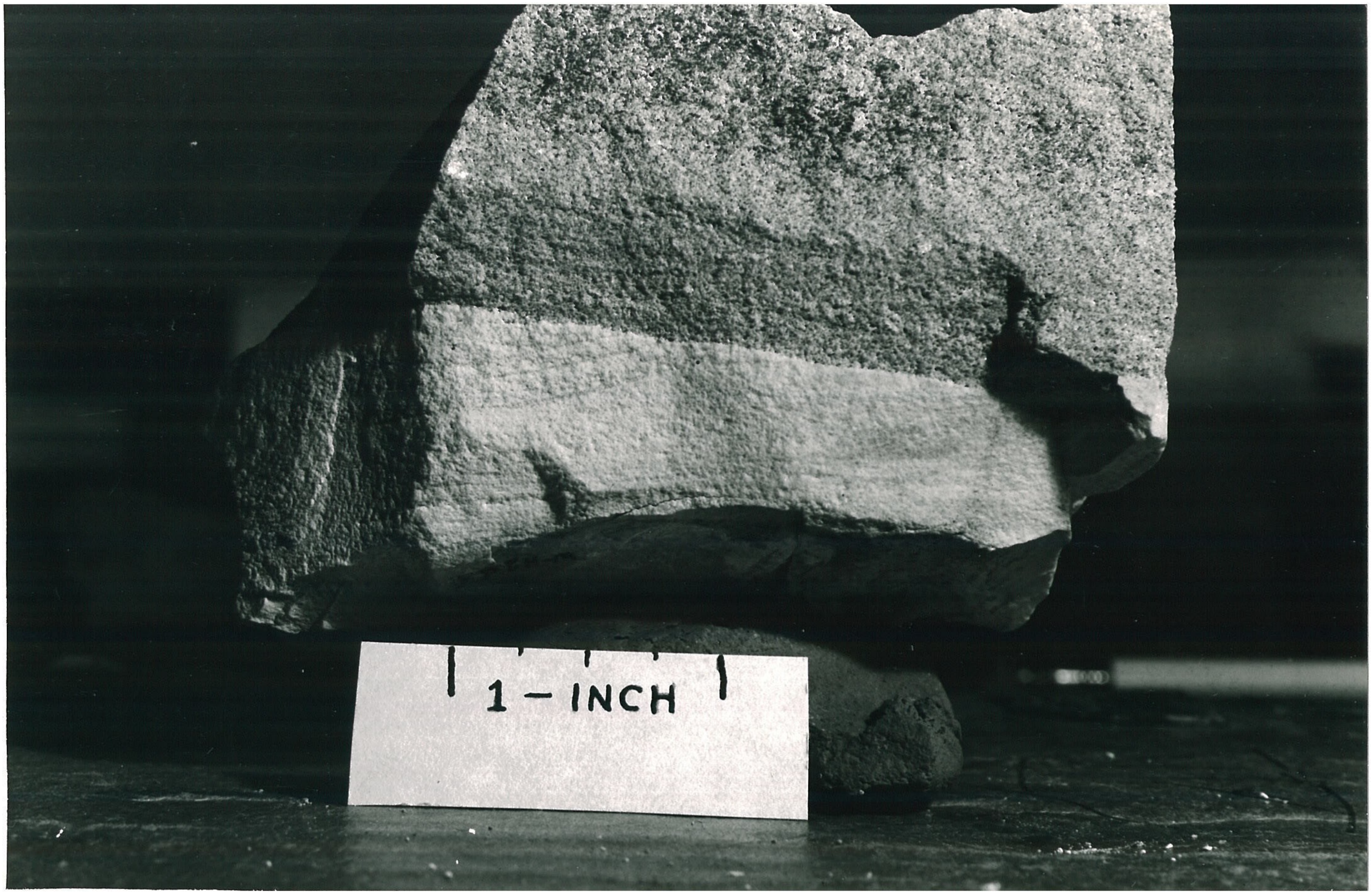

1 - INCH

Fig. 34. and 35. North area. Typical examples
of small-scale cross laminations as
seen in tuff bed "H".


1 - INCH

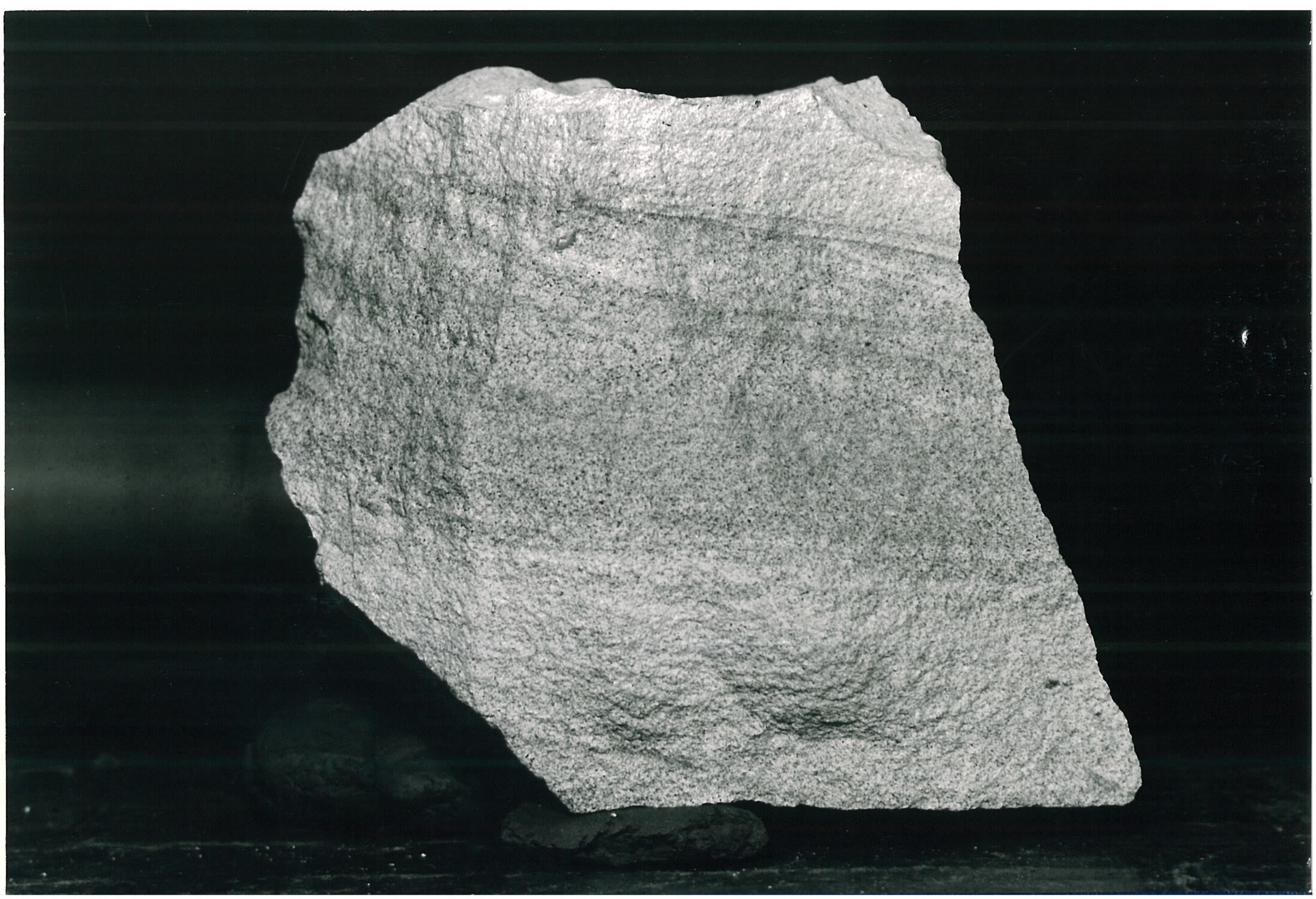


Fig. 36. North area. Ripple cross laminations in tuff bed "H".

Fig. 37. Fresh water gastropods, _Paludestrina imitator_ Pilsbury, which occur in the lake sediments at many localities.


1 - INCH

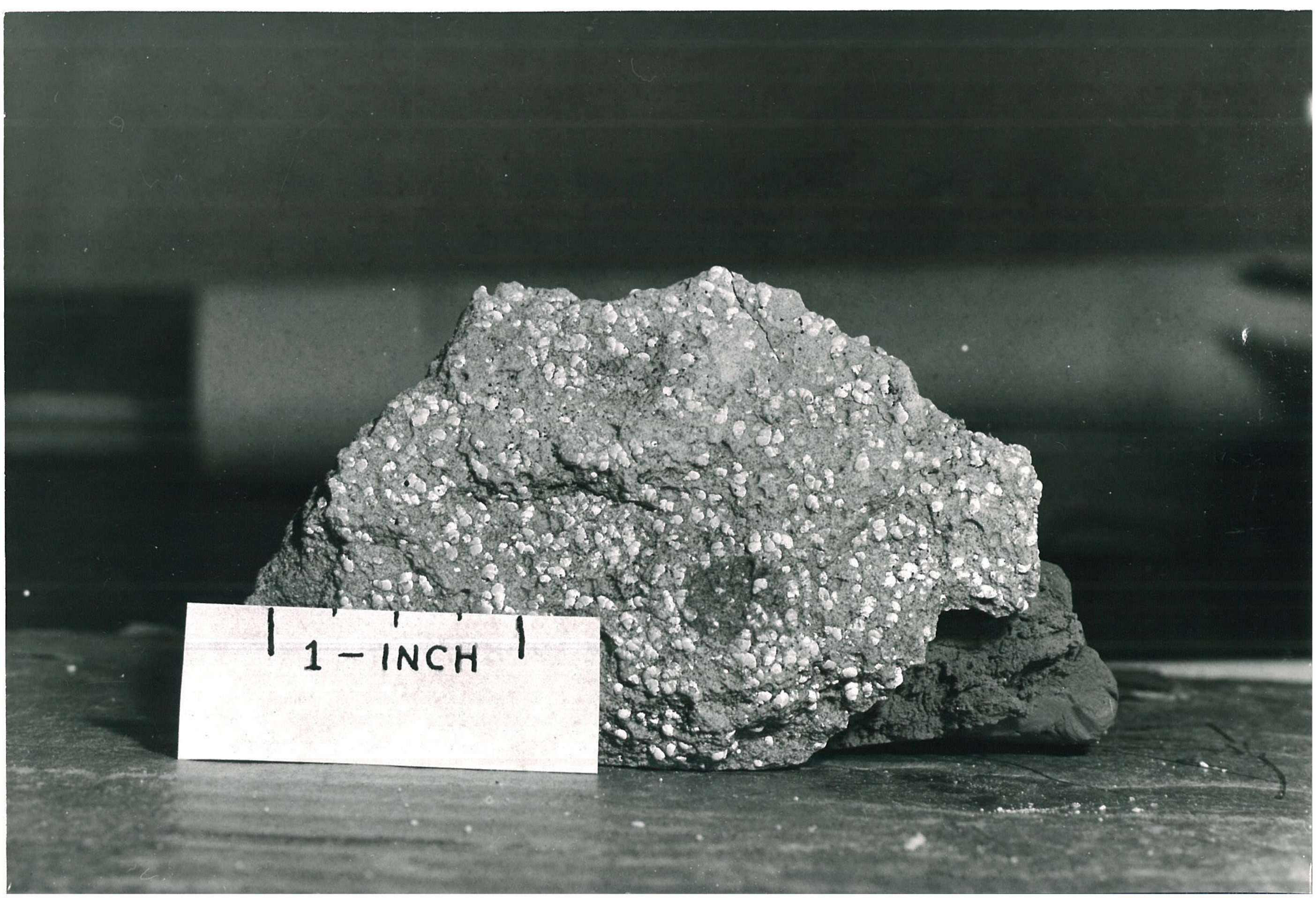

1 - INCH

Fig. 38. North area. Peculiar botryoidal-like parting as exhibited in tuff bed "G".

Fig. 39. North area. Rain drop impressions (?) in sandstone near base of Mint Canyon formation, west of Bouquet Canyon.


1 - INCH

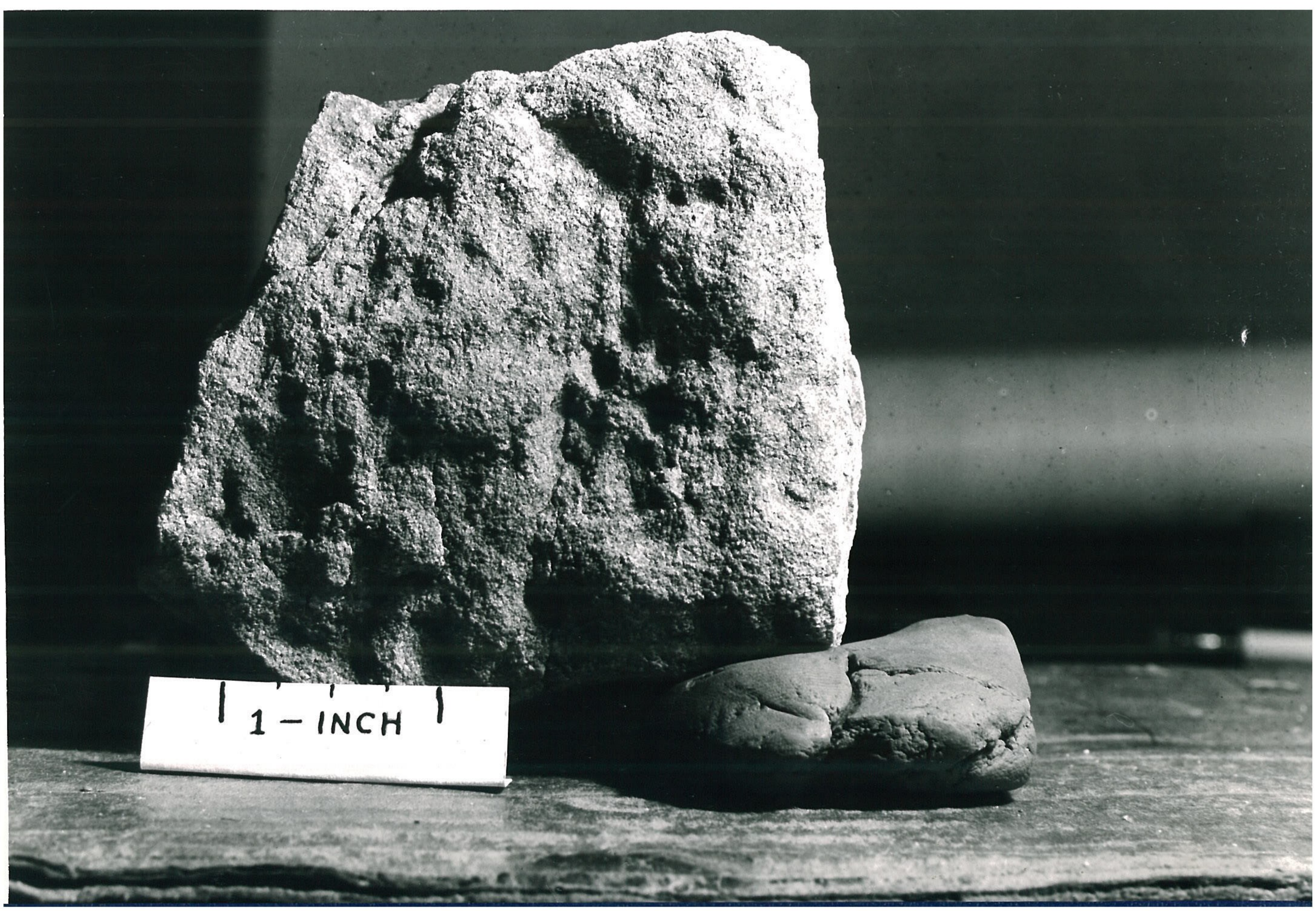
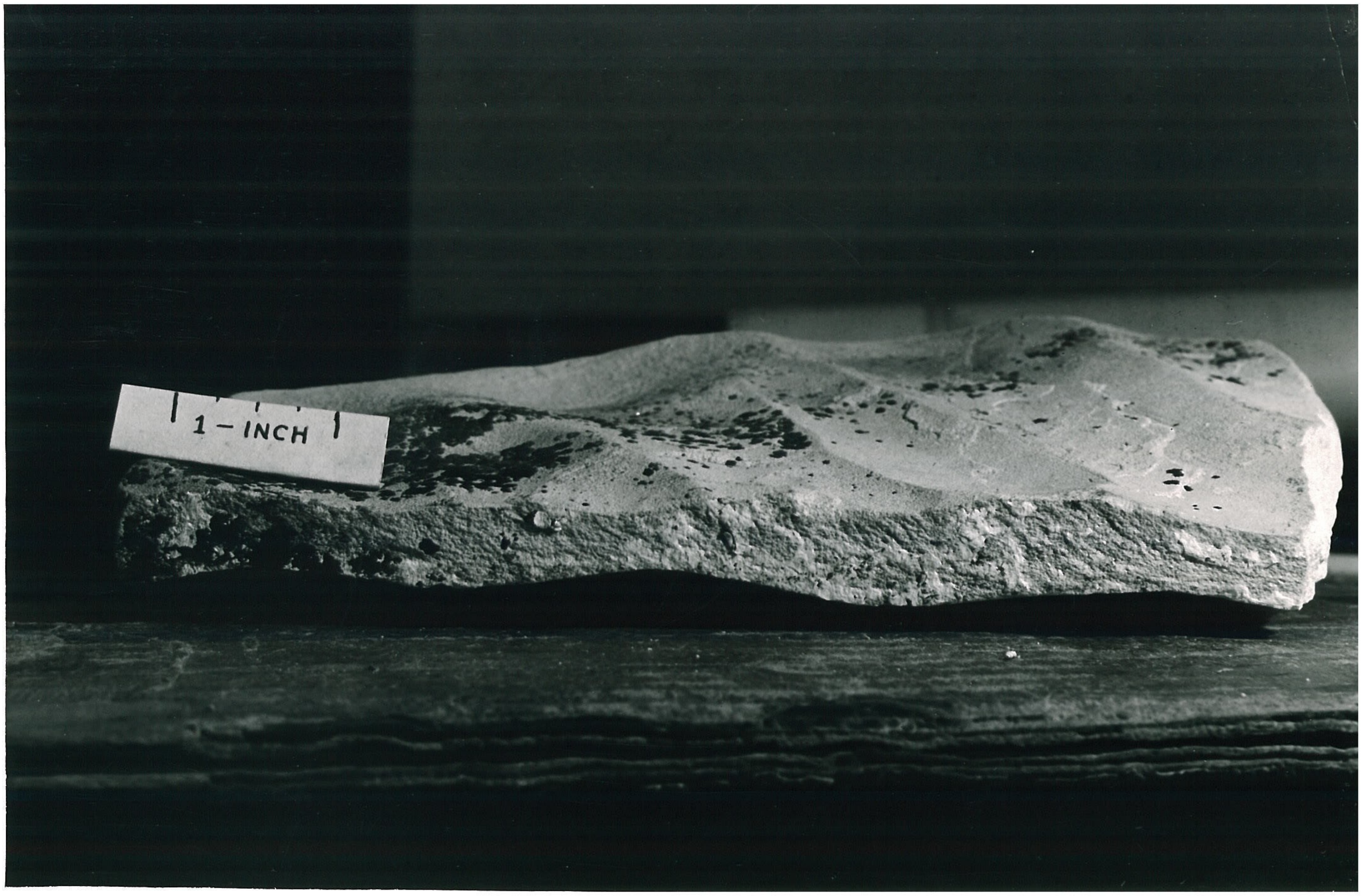
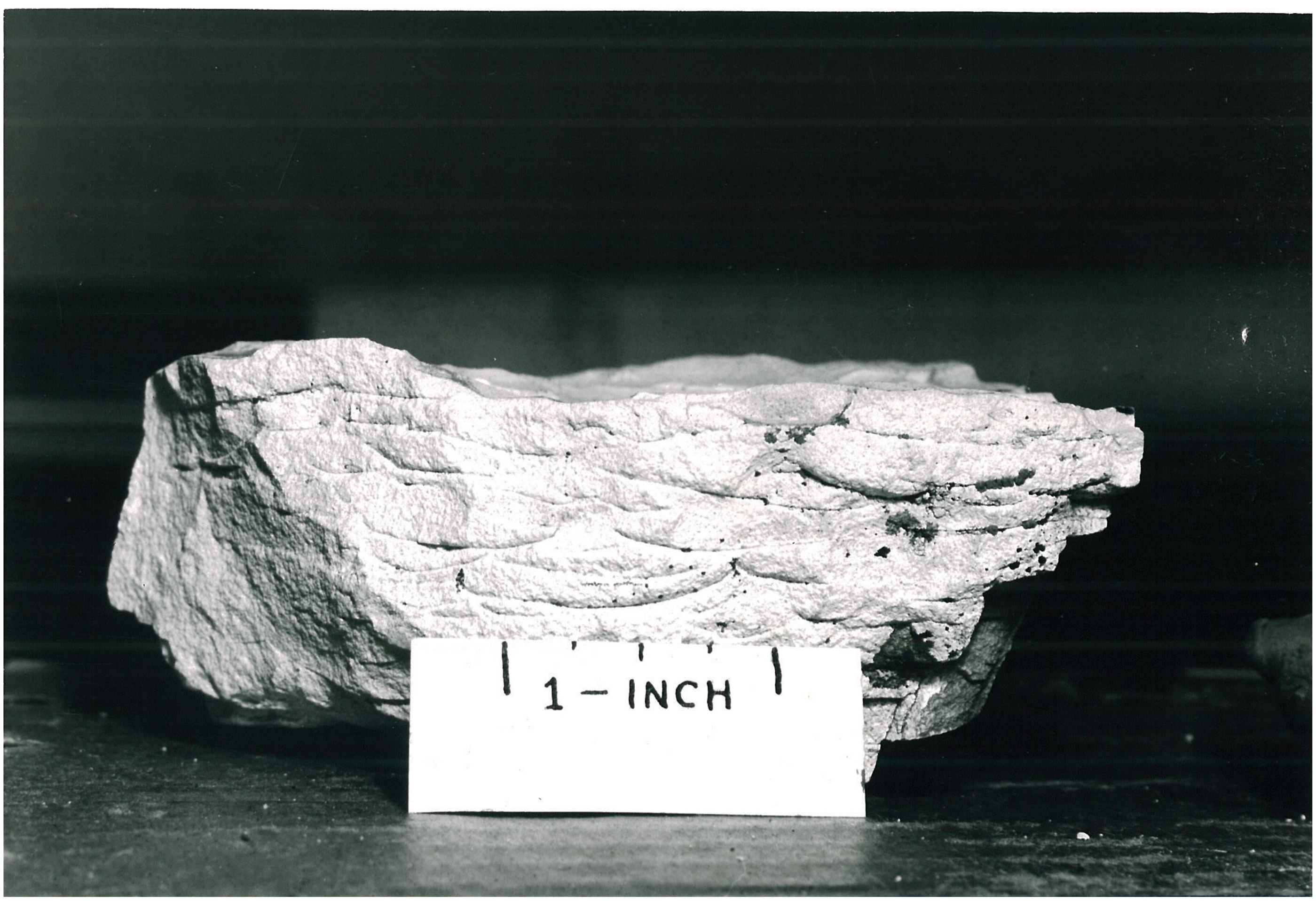

1 - INCH

Fig. 40. North area. Oscillation ripple marks from top of tuff bed "H" near Vasquez Canyon.

Fig. 41. North area. Oscillation ripple marks from top of tuff bed "K" east of Bouquet Canyon.


1 - INCH


1 - INCH

Geologic Structure

General

Since the volcanic tuff beds are the most distinctive beds in the Mint Canyon formation, it is not unusual that the mapping of their distribution should bring out some interesting structural features of the Mint Canyon basin.

The main structure of the Mint Canyon area is a broad synclinal trough roughly eight miles in width, and pitching in a direction slightly south of west at an angle of about 10° to 20°. There are complications within the main structure, but generally speaking, the dips on the flanks of the basin range between 15° and 30°.

There are two separate areas of tuff outcrop occurring on opposite borders of the syncline as though the water system in which they were deposited had a greater north-south extent, across the strike of the synclinal axis, than in an east-west direction. These two areas were mapped separately. It so happens that these areas have a complicated structure as compared to many areas in the basin. Overturned folds and considerable faulting occur in both sections. The overturning in the north area is to the north, while in the south area it is to the south. There are fairly extensive areas toward the center of the Mint Canyon trough, however, in which the dips and strikes are relatively constant, or at most vary only to conform with the large synclinal structure. The generalized picture then, that has been obtained from working with the tuff beds plus some general reconnaissance work over other parts of the area is one of a broad, gently pitching syncline with a few rather restricted sections near either edge, complicated by folds and faults.

Since only the distribution of the tuff beds was mapped, however, it must be realized that the structural picture can not be actually complete. In the north area, the distribution of the tuff beds is such that a fairly continuous and complete picture of that area is obtained, but the patchy nature of the tuff beds in the south area, results in only a limited picture of the structure there. Even though the data is incomplete, certain generalizations concerning the structure seem to be warranted.

North Area

Folding

In the north area, the major folding includes a series of four folds, two anticlines and two synclines, trending east-west and sometimes south or west. The southernmost syncline is overturned to the north in its eastern part. Its axial plane dips southeast at about 40° near the mouth of Vasquez Canyon. About a mile west of the Bouquet Canyon road, this syncline becomes open and symmetrical.

Structure section B - B' shows the nature of the folding west of Bouquet Canyon, and one of the anticlines is well exposed in a cliff as shown in fig. 42. The nature of the folding is interesting in that the flexing takes place in a restricted region at the axis of the folds, leaving each flank with a relatively homoclinal aspect. Other folds of this nature, though of small scale, may be seen in road cuts on the west side of Bouquet Canyon Road between the Vasquez Canyon Road and Texas Canyon.

Of particular interest is the manner in which the beds involved, having relatively constant orientations as they enter this section, suddenly break into a series of folds and then quite as suddenly return to to their original orientations. This localized nature of the folding is discussed further under the summary of structure.

There is other folding in the area, but it is not as prominent as that so far mentioned. A broad syncline whose axis strikes southwest, cuts the bad lands cliff just south of Puckett Ranch east of the mouth of Vasquez Canyon. Small undulations are apparent in many areas. For example, there is considerable folding on a small scale west of Bouquet Canyon and slightly south of Texas Canyon. These small folds tend to follow the southwesterly pitch of the more prominent folds.

Still another system of folds, appears to trend more or less transversely to the southwesterly pitching folding. It manifests itself in an undulating nature of the axes of the other folds. It is quite difficult to map any individual folds in this system, however.

Faulting

A moderate amount of faulting is present in the north area. There appear to be two major systems of faulting, one with faults striking in a northwest-southeast direction, and a second with faults striking east-west. Some of the small faults in the area may be referable to landsliding.

The east-west trending system is the oldest, cut in many cases by northwest-southeast faults. For the most part they are small faults with vertical components most prominent. Displacements usually do not exceed 75 feet and most commonly are much less. On those that could be determined the faulting was normal.

The younger, northwest trending faults are of greater magnitude in most cases. The movements are larger and the faults are more continuous for greater distances. There is a very good agreement in the motion of these faults. The northeast side, in all the faults of this system that were mapped, was the down-thrown, and/or the southwest, the moving side. Since no fault planes were seen and since no suitable data was obtained from areal mapping, the component directions of motion could not be calculated definitely. The main fault displacing tuff bed "L", west of Bouquet Canyon, shows definite dip-slip movement and only possible strike-slip movement. On any of the other faults, dip-slip movement alone could have accomplished any of the relationships observed.

The movements on these faults, though larger than those displayed on the east-west faults, is still not of great magnitude, being of the order of only 100 to 200 feet in the vertical component.

South Area

Folding

Folding in the south area is similar to that in the north area in that the folds are confined to a fairly restricted area, and that they grade from upright folds into overturned folds within relatively short distances. The folds strike northwest-southeast, and pitch to the northwest. They occur on the southwest flank of a northwest trending branch of the main Mint Canyon syncline. This branch is similar to the main synclinal structure in that it is a broad gentle flexure as compared to the local patches of overturned folds.

This area of overturning lies about a mile southwest of the town of Humphreys.

There are two main synclines and two anticlines, though several small branches from the main structures were noted. There is uncertainty in the interpretation of some of the minor features due to brush and insufficient exposures, but the main features seem to be as mapped.

In one instance, a tuff bed can be traced along its strike and be found to grade from 65° south dip to an 80° overturned north dip inside of about 1000 feet.

This extremely localized flexing is also apparent in that these folds die out quite rapidly to the southeast and don't affect a tuff bed occurring lower in the section and exposed about a mile southeast of the overturned part.

Faulting

The trend of the faults of the south area which were mapped varies from a nearly northwest trend to a more east-west trend. The northwest sides of the faults are usually the up-thrown sides. The amount of strike-slip motion can not be determined with the data on hand. Kew[1] mapped a fault cutting the lower tuff bed, "I", near the mouth of Reynier Canyon as post-Modelo and pre-Pico. This fault according to Kew has a minimum vertical displacement of over 1,000 feet as indicated by the thickness of Modelo removed. The tuff bed is offset, but apparently not enough to account for 1,000 feet of vertical movement. There possibly has been, therefore, strike-slip movement, the southwest side moving northwest as in the San Gabriel fault, thereby partially closing the offset caused by the vertical movement.

Kew, W. S. W., U. S. G. S., Bull. No. 753, pp.   , 1924

The movement of the northwest sides of the faults, the upthrown sides, is opposite to that of the Placerita fault[1] which branches from the San Gabriel fault near the mouth of Los Pinetos Canyon, but is compatible with that on the San Gabriel fault itself.

The dating of folding and faulting can be done at least tentatively by correlation with those divisions of movement indicated by Kew.[2] The large synclinal structure was probably started directly after the end of the Mint Canyon stage. The overturned folds probably followed this immediately or were contemporaneous with it, since the overlying Modelo is only slightly affected. The east-west faulting of the north area is apparently later than the folding and can possibly be considered as post-Modelo. Kew has shown that a large fault in the south area is post-Modelo and pre-Pico. Since the other faults mapped in the south area are comparable to Kew's larger fault, both in orientation and nature of movement, they are probably also of the same date. The northwest trending fault system of the north area is possibly Pleistocene or post-Saugus pre-Quaternary terrace, since it displaces the east-west fault system and yet does not displace

---

1. Kew, W. S. W., & Brown, A. B., A. A. P. G., Vol. / XVI, pg. 780, 1932
2. Kew, W. S. W., U. S. G. S., Bull. No. 753, pp. ,1924

the Quaternary terrace deposits. There is also post-Saugus folding, though it is not extremely sharp in the areas mapped or observed.

As has been indicated previously, the restricted extent of the sharply folded beds is peculiar. It does not seem possible that the overturned folds can be directly related to the broad synclinal folding. It seems more likely that these local areas are merèly expressions of movements in the basement complex in the incompetent sediments of the Mint Canyon. The flexures being so sharp, it seems likely that thrust faulting is responsible.

Fig. 42. North area. Anticline exposed west of Bouquet Canyon. Tuff beds "L" and "M" are exposed in cliff.

Fig. 43. North area. This view overlaps the left edge of the photograph above, and shows the adjoining syncline.

Mode of Deposition

There are several questions which immediately arise when one considers the various possibilities as to the conditions of deposition of the tuff beds.

First of all, are the tuff beds deposited sub-aerially or sub-aqueously? The evidence appears to be one-sided in favor of a sub-aqueous deposition. Some fairly conclusive evidence is as follows: presence of,

1. Aqueous oscillation ripple marks
2. Aqueous type cross-laminations
3. Water rounded conglomerates and poorly sorted sediments in general
4. A type of lenticular distribution of tuff beds most possible in water-laid deposits.

Though no evidence of wind action was recorded, it seems likely that in a semi-arid climate such as is indicated by the plant record, most bodies of water of the small size indicated by the extent of the tuff beds would be to some extent ephemeral and that wind action would, therefore, play an important part.

Since the beds appear to be chiefly water-laid, are they, then, marine or fresh-water deposits? Evidence seems to indicate a fresh-water origin.

Fresh-water invertebrates and plants, the presence of a good representation of land vertebrates, and the presence of fanglomerates point toward land deposition.

If they are terrestrial deposits, are they river flood plain deposits, lake deposits,or fresh-water estuarine deposits? The major deposition of the tuff beds is apparently in nearly still bodies of water as indicated by the fineness of the ash and silts deposited and the presence of many oscillation ripple marks.

The deposits have been described previously as lacustrine deposits and there are many points favoring this view. Some of the more important are listed as follows:

1. Presence of and abundance of mainly one form of fresh water gastropod, which is typical of lake conditions; and presence of fresh-water plants.
2. Thin, regular, lenticular nature of tuff beds, typically lake-like in character.
3. Fineness of sediments.
4. Lack of any indication of strong stream action through area of deposition.

The main difficulty with postulating an inland lake is the fact that the Mint Canyon sediments were deposited very near the sea with no apparent barrier to cayse a basin. The lack of any playa-like salt deposits in the sediments is also against an enclosed basin. For these reasons the hypotheses of river flood plain and fresh-water estuarine conditions are suggested as alternate hypotheses and are tested with the evidence on hand.

Favoring a river flood plain deposition as compared to a lake hypothesis, the following features can be listed:

1. Possible elongate nature of deposit with a limited east-west extent of only one or two miles, and a north-south extent of 10 to 12 miles.
2. Presence of stream worn conglomerates. These, however, are confined chiefly to the edges of the body of water.
3. Lack of evidence for a barrier between Miocene sea and area of deposition to account for lake basin.

Contradicting the river hypothesis are the following points:

1. No channelways or prominent cut and fill features distinguishable in any part of the section to indicate stream action.
2. No evidence of currents such as current ripple

marks.

3. Lack of certainty regarding elongate distribution of tuff beds.

In favor of fresh-water estuarine deposition are the following points:

1. No necessity of a massive land barrier between sea and area of deposition.
2. Proximity of area of Mint Canyon sediments to marine sediments of supposedly the same age.

Against the hypothesis of estuarine deposition are the following points:

1. Fauna is limited in number of forms, but the few present are abundant. This distribution is more typical of lake conditions.
2. There is no evidence for a large stream which would keep the area dominantly fresh-water if of marine estuarine nature. This is especially pertinent when it is noted that the floral record indicates semi-arid conditions which would include the suggestion of intermittent stream flow.
3. No bed of barrier bar type has been observed.

Of these three hypotheses, the lacustrine mode of deposition has apparently the least serious objections and more evidence in its favor.

The next problem, then, is to determine the nature of the basin of deposition and especially the type of barrier to seaward which would cause a lake system to form at this point. The fact that some 4,000 feet[1] of sediments have accumulated indicates that the basin was due to some fairly prominent feature.

The possibilities seem to divide themselves into two groups: namely, tectonic and physiographic.

Several physiographic possibilities arise. The lakes may have formed as lagoons behind marine barrier bars or beach dunes. It is conceivable that fresh-water conditions would be possible and that the depression would be of an elongate nature. The thickness, however, of sediments present seems very unlikely to have accumulated in such a manner.

Maxson[2] has suggested the possibility of a large alluvial fan being formed across the Miocene Santa Clara Valley thus isolating this eastern portion. The picture would be somewhat similar to the Salton Sea - Imperial Valley section. This could account for the great thicknesses of sediment, and much of the Mint

---

1. Jahns, R.H., Am. Jr. of Sci., Vol. , pp.818-825, 1939
2. Maxson, J. H., Oral communication, April, 1940

Canyon formation is fanglomerate. The fact that there are no large salt deposits in the formation, however, indicates that the lakes were not playa in nature but were drained at intervals. This is compatible with a fan hypothesis, since a fan would cause only a gradual rise of base level for the streams from the east, and the basin, therefore, would not be deep at any one time and overflow would be very likely.

In considering a source of such a fan, no evidence is known to indicate a possibility. Study of the distribution of the fanglomerates of the formation would undoubtedly throw light on this matter.

Of folding and faulting, the latter seems to be the most likely possibility in this region. The major folding in the Santa Clara Valley has apparently been nearly parallel to the valley and would not produce a barrier as easily as would faulting. Tilting to the east of the block on which the sediments occur could cause a basin, but, if this were a gradual process as indicated by the probability of the basin draining at times, one would expect the oldest beds to be tilted considerably more than the younger ones. If a block to the west of a fault crossing the valley were elevated gradually, an inland basin would be formed. If aggradation in the basin were at such a speed as to keep the basin nearly filled, the conditions indicated previously could be met. It seems that some down-dropping of the block of deposition would be necessary, however, to accomodate 4,000 feet of sediments. Otherwise one must postulate a great elevations of the mountains surrounding the basin. Since tectonic activity has been great in the area during much of the Tertiary, it seems possible that the necessary conditions could be fulfilled.

Summary

The lake system in which the tuff beds were deposited appears to be of fresh-water nature and was apparently drained at intervals. Semi-arid conditions indicated by the flora, plus the thinness of individual units, plus the nature of the ripple marks, suggests that these lakes were shallow and possibly ephemeral.

The most plausible explanations of the lake basins at present seems to be that they are due to a transverse alluvial fan or vertical movement on a transverse fault, either of which would separate the upper end of the Miocene Santa Clara Valley from the ocean.

The extremely fine, well-defined units of tuff suggest that they were deposited from ash falls directly into the lake. Other units have typical water transported characters. For example, some units show perfect gradation from coarse material at the base, which is certainly transported by water, to extremely fine ash at the top.

Origin of the Pyroclastic Material

Simpson[1] reports rhyolitic tuffs, pumaceous material and dacite flows in the Rosamond series of the Mojave Desert. Merriam[2] assigned some vertebrates that were collected from the upper part of the Rosamond series to the Upper Miocene, near a Barstow age. Simpson[1], however, tentatively correlated the Rosamond with the Escondido or Vasquez formation which was of questionable Middle Miocene age. Maxson[3] and Jahns[4] beleeve the Vasquez formation to be Lower Miocene or Oligocene, and that the Rosamond and Vasquez can not be correlated. Maxson has suggested that the Mint Canyon formation and the Rosamond formation cover approximately the same time range, and that the tuffs of the Mint Canyon formation are correlatives of the tuffs of the Rosamond formation.

The tuffs of the Rosamond formation are apparently similar in composition to the tuffs of the Mint Canyon,

---

1. Simpson, E. C., Calif. State Min. Bureau, 13th Report, pp. 400-401, 1934.
2. Merriam, J. C., Univ. of Calif. Pub., Dept. of Geol. Bull., vol. 11, pp. 438-585, 1919.
3. Jahns, R. H., Amer. Jr. of Sci., vol. 237, pp. 823, 1939.
4. Maxson, J. H., Personal communication.

and if they are correlatives, represent a much coarser phase, possibly nearer the point of origin.

The nearest area of outcrop of Rosamond flows and tuffs is at Antelope Buttes about 30 miles airline from the Mint Canyon region.

The Rosamond area, therefore, would appear to be the most likely origin of the acidic tuffs forming the Mint Canyon tuff beds.

Economic Aspects

Tuff Beds

The economic use of the tuff beds at present is limited to two things; first, as road material; and second, as surfacing material for various types of roofing.

Tuff bed "I" in Placerita and Reynier Canyons is being quarried at present and the material used by the Pioneer Division of The Flintkote Company.[1] It is burned at a temperature of from 1800° to 1900° at which temperature it turns red due to the oxidation of the iron content. The burned material is ground and classified by screens and is used as a surfacing material on asphalt shingles and certain types of roll roofing.

Tuff bed "L" was quarried some years ago west of Bouquet Canyon and was burned in an oven at that location.

It is used as road material only locally. It is not too resistant and does not stand up very well under any hard wear.

---

1. Harkins, F. S., Mgr., Bldg. Mtls. Division, The Flintkote Co., written communication.

Tuff beds "L" and "M" are nearly pure volcanic glass as indicated previously. The size of the glass fragments ranges from about 1/6 mm. down. It seems that such material should be useful as a rough abrasive. The author, however, found no record of any of the tuff material having been used in such a way.