# GEOLOGY

# OF A

# PART OF SEMINOLE QUADRANGLE

# Los Angeles County

# California

by

Donald H. Kupfer

and

David J. Varnes.

## ABSTRACT.

A small area in the Central Santa Monica Mountains was mapped. Two formations, a series of interbedded basalts and pyroclastics of Topanga age and some Modelo shales and sandstones, were mapped and an angular unconformity was found between them. The region is one of broad folds with axes trending generally east-west.

## INTRODUCTION.

Seminole Quadrangle lies just west of Calabasas, California, on the east side of the Central Santa Monica Mountains. (See index map.) Seminole Hot Springs and Malibu Lake are both located in this quadrangle. The area mapped, about twelve square miles, is bounded by Ventura Boulevard (north), Medea Creek (west), Latitude 34 6' S. (south), and Las Virgenes Creek (east). The region is in the mature stage of the erosional cycle and consists mainly of rolling, brush-covered hills and broad, alluvium-filled valleys. The maximum relief is about 1,000 feet. Outcrops are plentiful in the smaller valleys and can occasionally be found on the hillsides. The soil cover is thin. The brush is very thick in the basalt and sandstone but thins out in the pyroclastics and shale.

The base map is a photographic enlargement (x2) of the 1932 edition of the U.S.G.S. Seminole Quadrangle Map. The topography was surveyed by C. W. H. Nessler in 1929. The geologic mapping was done by Brunton Compass and was completed in May 1940.

| SYSTEM | SERIES | GROUP | FORMATION | SYMBOL | COLUMNAR SECTION 4/5"=1000' | AVERAGE THICKNESS (feet) | DESCRIPTION OF ROCKS |
|---|---|---|---|---|---|---|---|
| QUAT. | RECENT | | Alluvium | | | | Recent alluvium in the larger stream valleys. |
| | | | UNCONFORMITY | | ? | | |
| TERTIARY | MIOCENE | MODELO | Modelo Shales | Tsh | | Over 1000 | Silty, cherty, siliceous, and diatomaceous shales; interbedded fine grained sandstones. |
| | | | | Tss | | 400 | Sandstn. with interbedded sh. & cg. |
| | | | | Tsh | | 600 | Silty and cherty shale. |
| | | | UNCONFORMITY | | | | |
| | | TOPANGA | Basalt and Medea Creek | Tb | | 1270 | Basalt. |
| | | | | Tb & Tmc | | 800 | Interbedded pyroclastics and basalt. Ash, tuff, and agglomerate. |
| | | | | Tb | | 500 | Basalt. |
| | | | | Tb & Tmc | ? | over 1000 | Interbedded pyroclastics (ash, tuff, and agglomerate) and basalt. |

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Columnar Section - Seminole Quadrangle California.

## STRATIGRAPHY.

Besides the Quaternary alluvium in the larger stream valleys only two formations are present in the area mapped. The older, the Topanga formation, is a series of basalt flows and interbedded pyroclastics. The Topanga is nonconformably overlain by the second formation, the Modelo Shale. The thickness of these two formations totals over 6,000 feet. The Topanga Volcanoes were deposited in middle Topanga time and the Modelo Shale in upper Modelo time. These ages were determined by H. W. Hoots[1] and E. K. Soper[2], who worked in this region.

The Topanga formation occupies the western part of the area. It is divided into two parts: the basalt flows and the Medea Creek Pyroclastics. The basalt flows vary in thickness from a few feet to several hundred feet. Although these are called flows, there may be and probably are sills and dikes in the series; an accurate check was not made. Interbedded with the basalt are the Medea Creek Pyroclastics.

The Medea Creek Pyroclastics were named by Fredric Oder[3]. They consist of volcanic agglomerates and tuffs, sedimentary conglomerates and sandstones, and gradations between these. The agglomerates are rare. The tuffs and

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1- Hoots, H.W., Geology of the Eastern Part of the Santa Monica Mountains, Los Angeles County, California: U.S.G.S., P.P., 165-C, 1931.

2- Soper, E.K., Geology of the Central Santa Monica Mountains, Los Angeles County: Cal. Jour. Mines and Geology, vol. 134, no. 2, 1938.

3- Oder, F.C.E., Geology of a Portion of the Seminole Quadrangle: Senior Thesis no. 2, Calif.Inst.of Tech., 1940.

sandstones constitute about half of the Medea Creek formation, are difficult to distinguish from each other, and are often intermixed. The tuffs and sandstones grade up into the conglomerates which constitute the other half of the formation. The conglomerages are composed of cobbles of lava ranging from one inch to ten inches in diameter. The cobbles are well rounded and lie in a groundmass of ash and sand.

During Topanga time the Seminole Quadrangle was covered by a shallow sea of fluctuating depth. A near-by source of volcanic activity was supplying the area with volcanic material at the same time that ordinary erosional processes were supplying the area with sediments from near-by mountains. Thus pyroclastic and sedimentary materials were both interbedded with each other and deposited simultaneously.

Some of the basalt flows contain pillow structure and were probably deposited under water. Other basalt flows, that show no pillow structure and are highly vesiculated on their upper surfaces, were probably laid down on land. This alternation of subarial and submarine conditions of deposition was probably taking place during the deposition of the Medea Creek Pyroclastics as well as during the deposition of the basalt flows.

In this quadrangle the basalts and pyroclastics may attain a thickness of over 3,500 feet, although the actual thickness was not determined since the structure is incompletely known. (See "Structure in the Topanga" p. 6.)

The basalt erodes much faster than the pyroclastics and as a result the pyroclastics form the long, sharp ridges characteristic of the northern and southern parts of the area. The Medea Creek Pyroclastics do not support a heavy growth of brush like the basalt does. Therefore, in many cases where it was almost impossible to trace a Medea Creek and Basalt contact by walking it, the contact could be traced quite accurately by going to a near-by hill and mapping the change in brush.

<u>The Modelo Shale</u>. Following the deposition of the Topanga Volcanics, the Seminole region was subjected to compression, uplift, erosion, and subsidence. The erosion left an irregular surface (evidence from trend of contacts) on which the Modelo Shale was deposited nonconformably. Parts of the Modelo Shale were deposited with an initial dip due to the irregularity of the surface on which they were deposited.

The Modelo Shale is made up of soft shales, diatomaceous shales, and cherty shales. The formation contains a middle member of about 400 feet of semi-arkosic sandstones, interbedded shales, and lenses of conglomerate.

About 1,800 feet of Modelo is exposed in the area mapped, but this is not a complete section since the top of the Modelo does not lie within the area mapped.

## GEOLOGIC STRUCTURE.

The dominant structures in both the Topanga and Modelo formations of the Seminole Quadrangle are folds. The strike of the axes of the folds is N. 70° W. The folds in the Topanga formation have been more severely flexed than the folds in the overlying Modelo formation and, therefore, the Topanga folds have been subjected to an earlier deformation to which the Modelo folds were not subjected. The structures in the Topanga formation have, therefore, had a different history than the structures in the Modelo and will be considered separately.

Structures in the Topanga formation. The Topanga basalts and pyroclastics are exposed along the western side of the mapped area. The exposure was mapped in detail around Malibu Lake (in the south) and around Ventura Boulevard (in the north) but the area between these two was only done by reconnaissance. Much of the structure in the Topanga is, therefore, inferred.

Around Malibu Lake and around Ventura Boulevard the Topanga strikes N. 70° W. and dips 40°-60° N. If this dip and strike were constant over the whole exposure of the Topanga from Malibu Lake to Ventura Boulevard, the Topanga volcanics would have a thickness of over 12,000 feet. However, Soper[4] found 4,000 feet of volcanics in the area east of Seminole and Kelly[5] found 4,000 feet of volcanics in the area west of

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4- Soper, E.K., op. cit.

5- Kelly, V.C., Master's Thesis: Calif.Inst. of Tech.

Seminole. Therefore, it is assumed that there is repetition of the Topanga volcanics by either folding or faulting.

There is some direct evidence for folding, but none for faulting. First, the Modelo Shale which was deposited after the Topanga volcanics has been folded into a broad syncline, Therefore, the older Topanga volcanics must also have been folded. Second, under the word "Monica" of "Santa Monica Mountains" is a small east-west valley. In this valley are several south-dipping pyroclastic beds. If a syncline and an anticline are assumed in the volcanics between Mailbu Lake and Ventura Boulevard, then these south-dipping pyroclastic beds would form the north limb of the syncline and the south limb of the anticline. Third, if one stands on Cornell Road, near the words "Cornell" on the map, and looks westward along the axis of the assumed syncline, one is looking up a valley which appears to be formed by dip slopes in the volcanics. The north side of the valley is a south-dipping dip slope and the south side is a north-dipping dip slope. Therefore, from the above evidence, I conclude that a syncline and an anticline (with axes striking about N. 70° W.) exist in the Topanga volcanics between Malibu Lake and Ventura Boulevard.

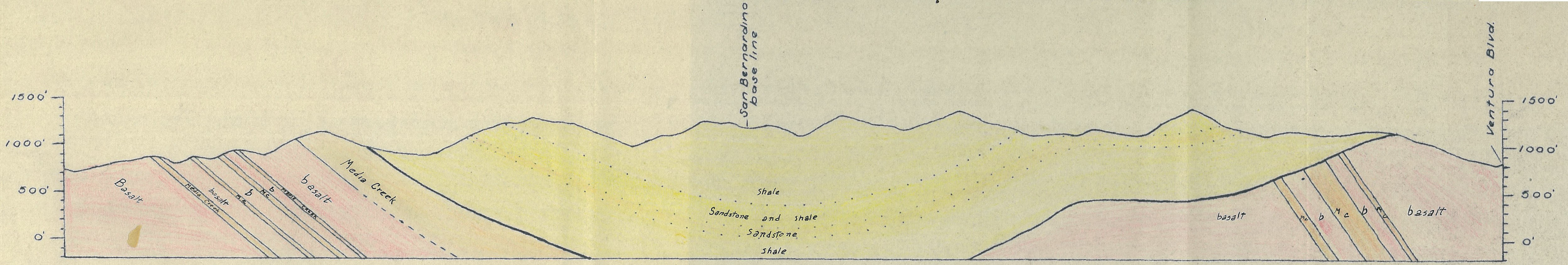
There are two minor faults in the pyroclastics above Agoura. The resultant displacement is not known, but from mapping the fault plane is found to strike about N.45° E. and dip 72° SE. The north sides have moved either up or northeast (or both). The stratigraphic displacement of the eastern fault is about 150 feet and of the western fault about 120 feet.

<u>Structure in the Modelo Shale.</u> The Modelo shales are very incompetent beds and as a result the formation contains many very complex minor structures. The dips and strikes on the map, although indicating complex structure, are actually a simplification of the existing structures since most of the dips and strikes were plotted to show general trends rather than every minor structure. A few of the more important *minor* structures are shown on the map, but these are only a few of the large number actually in the area.

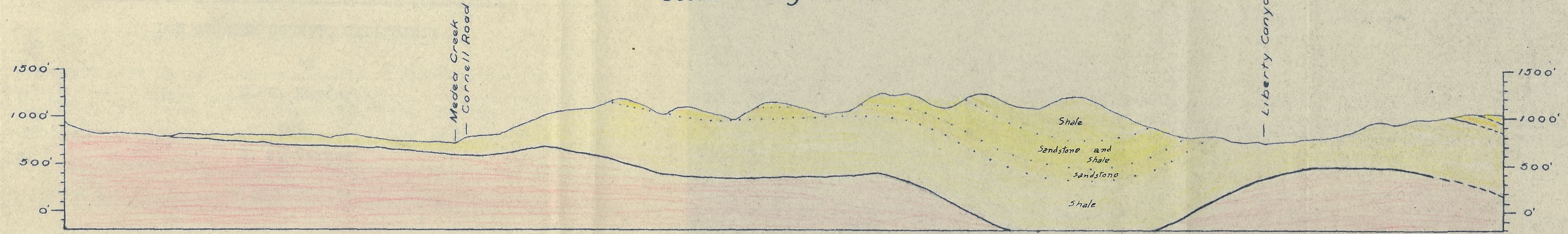
The only major structure involving the Modelo is the broad, east-west syncline near the San Bernardino Base Line. The evidemce for this structure was derived from the outcrops of the more competent sandstome beds and from the Topanga-Modelo contact. This syncline has a 16 degree plunge to the east. (Data from map and structure section A - A'.)

## GEOLOGIC HISTORY.

| | |
|---|---|
| (1) Middle Topanga | Deposition of basalt flows and Medea Creek Pyroclastics in a shallow sea of variable depth. |
| (2) Upper Topanga to middle Modelo | Uplift of region and first deformation of Topanga volcanics. Subsequent erosion. Submergence. |
| (3) Upper Modelo | Deposition of the Modelo shales and sandstones. |
| (4) Post-Modelo | Uplift of region and deformation of the sediments. The folds in the Topanga were tightened. A broad syncline was formed in the Modelo and many minor folds and faults were formed on the flanks of the syncline. |
| (5) After the second uplift to Recent | Erosion of the mountains and valleys and deposition of Quaternary alluvium in the valleys. |




Section along line A-A'



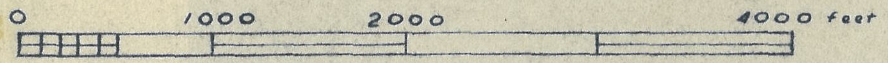

Section along line B-B'

# GEOLOGY OF A PART OF THE SEMINOLE QUADRANGLE

## STRUCTURE SECTIONS

Scale 1" = 1000'

See main map for legend



# GEOLOGY OF A PART OF THE SEMINOLE QUADRANGLE
# LOS ANGELES COUNTY, CALIFORNIA

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D. H. Kupfer

and

D. J. Varnes

Calif. Inst. of Tech. D. J. Varnes
Adv. Field Geology
June, 1940

# GEOLOGY OF A PART OF THE SEMINOLE QUADRANGLE LOS ANGELES COUNTY, CALIFORNIA

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By D. H. Kupfer and D. J. Varnes

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## Abstract

A small area on the northern slopes of the central part of the Santa Monica Mountains was mapped during April and May of 1940. Middle Miocene Topanga basalts, pyroclastics, and conglomerates are overlain unconformably by upper Miocene Modelo shales and sandstones. Both formations have been folded into broad anticlines and synclines trending WNW-ESE.

## Introduction

The mapping of this area was undertaken as a problem in field geology by the author and his co-worker, D. H. Kupfer, from April to late May, 1940. Mapping was done with Brunton compass on a 2x enlargement of a part of the U.S.G.S. topographic map of the Seminole Quadrangle.

The author wishes to acknowledge indebtedness to Dr. F. D. Bode of Caltech for his suggestions and criticisms concerning the work, and to Mr. Oder, also of Caltech, for suggestions concerning the area mapped.

## Geography

The region mapped is roughly square shaped and about 12 square miles in size. It lies south of the main Los Angeles-Ventura Highway about 30 miles west of Los Angeles. It is bounded on the north by Ventura Blvd.; on the east by Las Virgenes Valley; on the south by latitude 34 degrees 6 minutes North; and on the west by longitude 118 degrees 46 minutes West.

Relief is about 800 feet and the topography mature. The valleys run north and south, draining southward. The ridges, when of shale, usually trend N-S; when of conglomerate of the underlying formation, they are dip-slopes trending WNW. Vegetation is sparse in the broader valleys. Brush is often thick on the ridges and in the ravines, and is controlled in part by the rock types. Exposures are fair.

## Stratigraphy

Two main stratigraphic units occur in this region. The older is a series of basalt flows, pyroclastics, conglomerates, and sandstones. The younger is a series of shales and sandstones which overly the basalts with a high angle unconformity.

By a comparison of the rock types and relationships in this area with those in the area mapped by H. W. Hoots (1) in the eastern Santa Monica Mountains, the age of the basalt is placed as middle Miocene Topanga, and that of the overlying shale as equivalent to the lower Modelo of the upper Miocene.

The shales and sandstones, together with the underlying basalts and pyroclastics, have been folded into broad synclines and anticlines trending WNW-ESE, and gently plunging ESE.

1. Basalts and associated rocks.

Age. Middle Miocene Topanga.

Distribution and trend. This conformable series of basalts, tuffs, agglomerates, conglomerates, and sandstones is widely exposed in the western part of the area mapped, but is covered by shales and sandstones in most of the region east of Cornell Road. Mapping of the basalts and associated rocks was confined largely to the far northern and to the far southern parts of the area in which these rocks outcrop. In both regions the series dips about 50 degrees north with a strike of north 60-70 degrees west. Dips are variable and uncertain in the region between the far northern outcrops just south of Ventura Blvd. and the far southern outcrops around Malibu Lake. Lack of time prevented working out the detailed structure of this middle section.

Thickness. The total thickness of the basalt and associated rocks is unknown. Thicknesses of the individual members of the basalt, pyroclastic, and conglomerate series are variable. Usually the tuff beds are less than ten feet thick; the sandstone beds are ten or twenty feet thick; while the conglomerates and agglomerates may attain thicknesses of three or four hundred feet.

Lithology. The basalt members are flows, usually vesicular, and quite often amygdaloidal. Natrolite amygdules up to the size of one inch are locally common, while infillings of chalcedony (agate) and crystalline quartz are very common in the western part of the area mapped. Fresh basalt is very rare; usually the outcrops are weathered to a deep red or brown. Locally, pillow structure is shown, suggesting extrusion under water.

The conglomerates are well cemented and usually composed of rounded basalt cobbles up to several inches in diameter imbedded in a matrix of sand or ash. Sandstone beds are common within the conglomerate.

Agglomerates composed of angular lava fragments are also common. In some, the fragments are only .1 or .2 inches in diameter and cemented by ash. Other agglomerates contain angular blocks a foot or so in diameter. Tuffs outcrop sporadically and usually in narrow beds less than 10 feet thick. They are often lighter than the surrounding rock in color, and contrast with the red basalt and gray-brown conglomerate.

Map symbols. The symbol "Tb" has been used to represent the basalt flows on the map. To the pyroclastics and sediments interbedded with the basalt, Mr.Oder has applied the name "Medea Creek Formation", from the type locality in Medea Creek valley just south of Ventura Blvd. Since they occur so abundantly throughout the basalt, the writer will not refer them to a formation but will reserve the symbol "Tmc" as a convient indicator for this material on the maps and structure sections.

2. Modelo Shale.

Age. Upper Miocene. As mentioned before, the age of this formation has been only tentatively placed on the basis of comparison with the Modelo shale described by H. W. Hoots (1).

Distribution. The entire central and eastern part of the area mapped is composed of shales with interbedded sandstones.

Lithology. Shales of the region are either soft or hard and siliceous. The usual colors are brown, tan, or white, but small patches of black shale are present on the southeast slopes of hill 1436. The shale is thin-bedded with laminae a fraction of an inch to two or three inches thick. The hard white siliceous shale breaks into rectangular plates.

A zone of interbedded sandstone and shale has been recognized within the main body of the shale, and its boundaries have been partly mapped (see map). At the bottom of this zone there are massive beds of white sandstone which have a total thickness of about 125 feet. This massive white sandstone lies 650 feet stratigraphically above the basalt.

Deposition. The Modelo shale was probably laid down in a shallow sea near the coast, where currents were steady enough to sort the material well and allow undisturbed deposition. Occasional sandstone beds and rare conglomerate indicate times of more rapid deposition, but these too are well sorted.

Fossils. Fossil fish and leaves are rather common in some localities.

## Geologic Structures

Folds.

Evidence given by dips and strikes, trends of marker beds, and by the behavoir of the basalt-shale contact was all used in an attempt to work out the structure of the shale.

In the central part of the area mapped the trend of the folds is WNW with the anticlines and synclines plunging gently to the ESE. (See structure section). The major syncline shown in the structure section A-A' and represented on the map by the synclinal axis $S_1$-$S_2$, plunges ESE at an angle of 14 degrees. Anticline $F_1$-$F_2$ plunges ESE at an angle of 17 degrees, as computed from structure section A-A' and the position of the lava-shale contact at the prolongation of the anticlinal axis.

Sufficient outcrops are lacking in Liberty Canyon and eastward to work out the structure, but the trend on the west side of Liberty Canyon seems to be N-S rather than ESE.

Minor folds are common throughout the shale. Some of these have been indicated by short axial lines on the map.

Scattered observations indicate that dips are variable in the basalt of the west central part of the area, and that it has been deformed to some degree. Also, if one stands on Cornell Road where "Cornell" is printed on the map and looks westward, at sunset, there appears to be a prolongation of the syncline with dip-slopes in the basalt northward on the south side of the depression, and southward on the north side.

## Faults.

Only two faults were found in the area. Both occur in the ridge of conglomerate a quarter of a mile south of Ventura Blvd.. Both are very steep and both strike NE. In each case the west side has moved northeastward relative to the east side. The conglomerate has been displaced horizontally about forty feet by the western fault, and about eighty feet by the eastern fault.

## Unconformity.

A high-angle uncomformity exists between the Topanga basalts and the overlying Modelo shales. It represents the period of time involving the deformation and erosion of the Topanga basalt and the subsequent subsidence preceeding the deposition of the Modelo shale.

Geologically speaking, the unconformity does not represent a long period of time -- only the interval between middle Miocene Topanga and upper Miocene Modelo. It does represent a relatively short period of strong deformation and erosion.

## Geologic History

| | |
|---|---|
| Middle Miocene | 1. Extrusion of basalt, with contemporaneous deposition of tuff and conglomerate. |
| | 2. Deformation and uplift, with erosion |
| | 3. Subsidence |
| Upper Miocene | 4. Deposition of Modelo shale |
| Late Pliocene (1) | 5. Violent deformation and uplift; crumpling of the shales in many places and further deformation of the basalt. |
| Late Pliocene to the present | 6. Erosion. Proceeding now with deposition of alluvium in the valleys. |

<u>Note:-</u>

Many of the valleys are partially covered with Quaternary alluvium. This has been left unmapped.

## Economic Considerations

There is an abandoned oil well in Liberty Canyon which shows a trace of oil and gas at the top of the casing. It was drilled to a depth of 750 feet but never gave any production of oil. The casing is now filled with water. Aside from this well, no indications of oil were found in the area mapped.

Respectfully submitted,

David J. Varnes

David J. Varnes

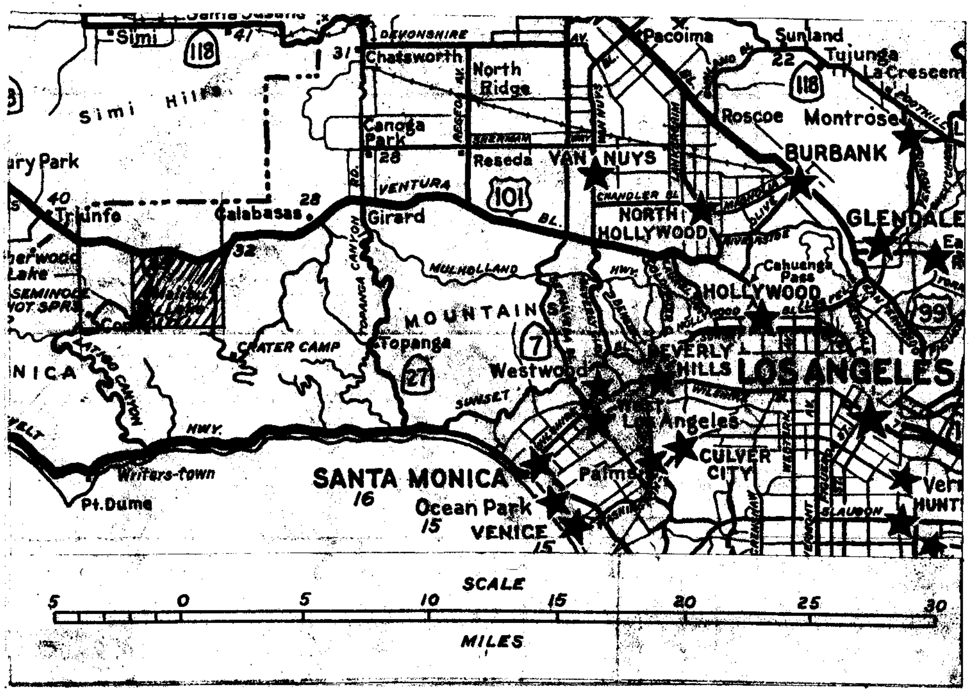
## Reference

(1). Hoots, H. W.

Geology of the Eastern Part of the Santa Monica Mountains

Los Angeles County, California

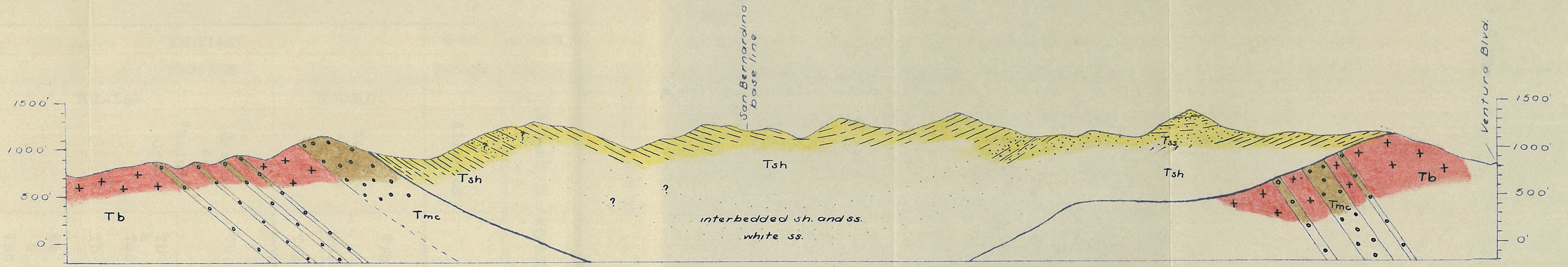
U.S.G.S. Professional Paper 165-C



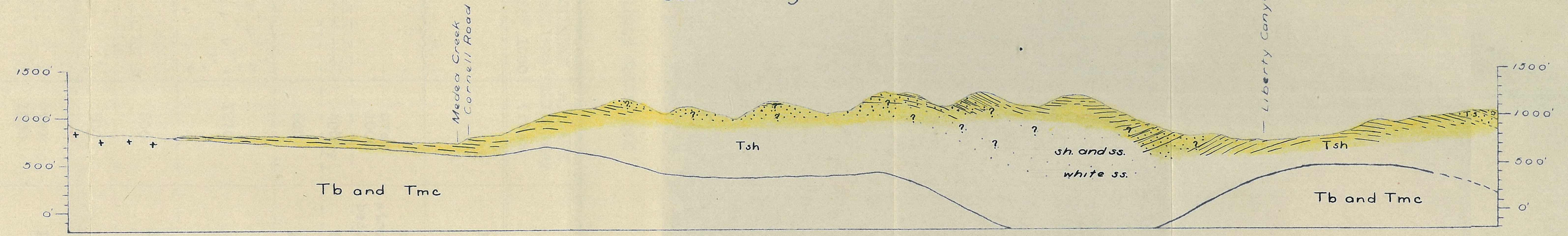

INDEX MAP FOR SEMINOLE AREA

Seminole Quadrangle is outlined

Area examined is ruled




Section along line A-A'




Section along line B-B'

# GEOLOGY OF A PART OF THE SEMINOLE QUADRANGLE

## STRUCTURE SECTIONS

Scale 1" = 1000'

See main map for legend


D.J. Varnes

COLUMNAR SECTION -- SEMINOLE QUADRANGLE

| SYSTEM | SERIES | GROUP | FORMATION | SYMBOL | COLUMNAR SECTION 4/5" 1000' | AVERAGE THICKNESS (feet) | DESCRIPTION OF ROCKS |
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| | | | | Tss | | 400 ? | Sandstn. with interbedded sh. and cg. |
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| | | | | UNCONFORMITY | | | |
| | | TOPANGA | Basalt and "Medea Creek" | Tb | | 1270 | Basalt |
| | | | | Tb & Tmc | | 800 | Interbedded pyroclastics & basalt Ash, tuff, agglomerate, cg., ss. |
| | | | | Tb | | 500 | Basalt |
| | | | | Tb & Tmc | ? | over 1000 | Interbedded basalt and pyroclastics tuff, ss, cg., agglomerate |

DHK

# GEOLOGY OF THE BLUFF COVE REGION
# PALOS VERDES SOUTHERN CALIFORNIA

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D. H. Kupfer

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Advanced Field Geol.
June 1940

# GEOLOGY OF THE BLUFF COVE REGION
# PALOS VERDES SOUTHERN CALIFORNIA

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By D. H. Kupfer and D. J. Varnes

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## Abstract

About two miles of sea cliffs were examined at the west end of the Palos Verdes Hills, in southern California. Middle and lower upper Miocene breccia, sandstone, and shale have been intruded by sills of basalt. Faulting and minor folding have taken place since the intrusion. Successive terraces indicate repeated uplift in Pleistocene time.

## Introduction

This area was mapped as a problem in field geology by the author and his co-worker D. H. Kupfer, both of Caltech, during January and February of 1940. The area is located on the coast of southern California about twenty miles southwest of Los Angeles, where the west slopes of the Palos Verdes Hills meet the sea. Mapping was done with Brunton compass on a U.S.G.S. topographic map, and confined largely to the sea cliffs. The cliffs were mapped for a distance of one and two-thirds miles, beginning about one-fourth of a mile northeast of Flat Rock Point and extending southward and westward along the shore.

The author wishes to acknowledge the work of his partner Mr. Kupfer whose contributions to this problem more than equal his own. He also acknowledges indebtedness to Dr. F. D. Bode of Caltech for his suggestions and criticisms as the work progressed.

## Topography

The west coast of the Palos Verdes Hills trends generally southwestward in this region, and is indented occasionally by small bays extending up to half a mile inland. On the slopes of the hills terraces have been cut. The lowest and broadest of these ends abruptly at the sea with a steep slope two or three hundred feet high. The upper part of this slope is often a sheer cliff twenty to a hundred feet high which gives excellent exposures, while the lower part of the slope is often covered with talus or landslide material. In some places the waves have produced dip-slope reefs which jut out from the shore. (See Photo. 5). These give geologic information only at low tide.

## Stratigraphy

The sequence of rocks exposed in the area, in order of decreasing age, is as follows:

| | |
|---|---|
| 1. The Green Breccia | middle Miocene? |
| 2. Altamira shales and sandstones with basalt sills. | lower upper Miocene see(1) |
| 3. Terrace cover | Pleistocene see (1) and (2) |

### 1. The Green Breccia

This is thought to be the oldest exposed rock in the area, but its position relative to the other strata is uncertain. It has but one outcrop 400-175 feet wide, running down the cliff perpendicular to the shore at the southeast corner of Bluff Cove. Its boundaries on either side are obscured by talus and landslide, while a terrace truncates its top surface and beach rubble hides its foot.

The breccia is bluish green and composed of boulders of glaucophane shist and gneiss up to several feet in diameter, together with smaller fragments of quartzite, all embedded in a soft, green, silty matrix. Fragments are usually angular and show no sign of sorting.

A possible source of the material would be the Franciscan shist within the Palos Verdes Hills. Perhaps, more probably, its source was an offshore highland to the west of the basin in which the breccia was deposited, similar to the source postulated for the very similar San Onofre Breccia. (3).

The thickness of the breccia could not be measured. Sandstones and shales to the north show considerable variation in dip, while slickensides and slumping within the breccia indicate internal movement. See Photo. 3.

Woodring, Bramlette, and Kleinpell (1) refer the breccia to the base of the Altamira shale and thus to middle Miocene or lower upper Miocene age.

The writer believes that the breccia has been brought to the surface by faulting or folding or both.

2. Altamira Shale

This formation makes up much of the sea cliff and, if minor folds are neglected, it generally dips at low angles SSE into a cliff running SW.

The shale is gray, buff, or brown, and is siliceous, silty, sandy, or diatomaceous. Woodring (1) reports phosphatic shale in some localities. Bedding ranges from a fraction of an inch to a few feet in the case of the interbedded sandstones.

The total thickness of the shale is unknown, for neither the top nor bottom is exposed in the area studied. A thickness of 138 feet, plus or minus 5 feet, was measured for the shale member between the upper and lower basalts at Flat Rock Point.

According to Woodring (1), foram assemblages from the lower part of the Altamira are of shallow to medium depth types. He found the Altamira to be at least 1045 feet thick in Altamira Canyon on the south slope of the Palos Verdes Hills, but there also its lower limit was not exposed.

The shale is intruded at two or more levels by basalt. Extensive brecciation with deposition of quartz and calcite stringers in the breccia accompanied the intrusion. The extensive brecciation suggests that the rock was not well consolidated at the time of intrusion.

The age of the Altamira, based on micropaleontology, has been placed tentatively by Woodring at lower upper Miocene (1). No megafossils were found by the writer in the Altamira formation except a single small cast of a mollusc at X"

3. Basalt

Three main outcrops of basalt occur in the region (see map), the southernmost of which may represent an extension of either of the others.

Evidences that the basalts are sills are: hardening, blackening, brecciation, and mineralization of the surrounding shale, together with the presence of large angular xenoliths of shale within basalt flows. These xenoliths are well shown in the deep roadcut on the

the main highway at the southeast corner of Bluff Cove.

The basalt is more resistant to marine erosion than is the shale, and forms promintories where it outcrops on the shore. See Photos 1 and 2. On the other hand, weathering has affected the basalt more than the shale so that the basalt has been reduced to a red, tan, or nearly colorless powder in many places.

The thicknesses of the basalt sills are:

(a). Lower member, Flat Rock Point ------ 130 feet

(b). Upper member, Flat Rock Point ------ 150 feet

(c). Basalt member, "Sea Bowl"
one-half mile **SW** of Bluff Cove ---- 107 feet

These thicknesses were measured by clinometer.

The basalt is fine to medium grained with visible feldspar laths sometimes several millimeters long. A fresh surface is blue-gray. Amygdules filled with quartz and calcite are rather common and are not confined to particular horizons. Their average diameter is that of a pea.

4. Terrace cover

A series of remarkably well developed terraces have been cut on the slopes back of the sea cliff, and the sea is at present cutting into the lowest and most prominent of these. At least eleven distinct terraces have been recognized in the Palos Verdes Hills (2), but only two or three are represented in the area mapped.

Fairly well sorted sub-angular to rounded pebbles and boulders, interbedded with lenses of pure sand, make up the terrace deposits. The boulders range up to eight or ten inches in diameter, but are usually much smaller. (See Photo 4).

The thickness of the terrace deposits varys from a foot or two to a maximum of 45 feet in the cliff east of Bluff Cove. The terrace material is waste which was deposited near shore as the sea cut back into the hills at each uplift of the land. Shale, basalt, and breccia are all overlain unconformably by the terrace deposits. The lower layers of the deposits at Bluff Cove are richly fossiliferous. Woodring and others, (1) and (2), have placed the age of the terrace deposits as Pleistocene on the basis of faunal assemblages. Lucinacea are abundant at $X^1$ where also a complete set of plates of a large chiton was found. Gastropods are very common at $X^3$.

### Landslide

A large landslide involving ten or eleven acres and movements up to one or two hundred feet has covered many of the contacts (see map and Photos 1 and 2). Since the landslide prevented the tracing of marker beds, the author was obliged to construct the structure section on the basis of dips and strikes alone. For this reason the structure section is likely to be inaccurate.

## Geologic Structure

(see also structure section)

### Folding

The regional dip of the shale is gentle and to the SSE. In addition to this major structure, there are many smaller anticlines and synclines which were probably formed at the same time that the regional dip was given to the area. Around Bluff Cove, and especially near the breccia, the folding is more intense than it is farther to the south. In the southern part of the region mapped, the folds are small and only a small stratigraphic range is exposed in the sea cliffs. Photo 5 shows one of these small anticlines.

Faulting

Aside from the movement on the landslide, vertical displacement has probably occurred on a fault forming the northern boundary of the Green Breccia. If faulting has occurred, the south side has gone up relative to the north side. In this way the Green Breccia, which is older than the shales on either side (1), has been brought to the surface. Below is tabulated the evidence for this fault.

1. Abrupt change in lithology.
2. Slickensides within the Green Breccia.
3. Intense folding of the shale to the north.
4. Presence of breccia composed of shale alone 50 yards north of the Green Breccia.
5. The structure section indicates displacement.

## Geologic History

1. Submergence
2. Deposition of shales and sandstones in shallow seas. --- lower upper Miocene
3. Intrusion of basalt --- upper Miocene?
4. Deformation --- post intrusion
5. Intermittent uplifts continued from late Miocene? until the present with cutting of terraces and deposition of terrace sands and gravels.

Respectfully submitted,

David J. Varnes

David J. Varnes

References

(1). Woodring, W. P., Bramlette, M. V., and Kleinpell, R. N.

Miocene Stratigraphy and Paleontology of the Palos Verdes Hills, California: Am. Assoc. Petroleum Geologists Bull., Vol. 20, pp. 125-159.

(2). Woodring, W. P.

Fossils from the Marine Pleistocene Terraces of the San Pedro Hills, California: Am. Jour. Sci., Series 5, Vol. 29, pp. 292-305, 1935.

(3). Woodford, A. O.

The San Onofre Breccia: California Univ., Dept. Geol. Sci., Bull., Vol. 15, No. 7, (1925), pp. 182-205.

PHOTO 1.

View of Bluff Cove from the south. Note sea cliff, landslide, promintories, and terraces.

PHOTO 2.

View of the north shore of Bluff Cove, showing resistance of the basalt to wave erosion.

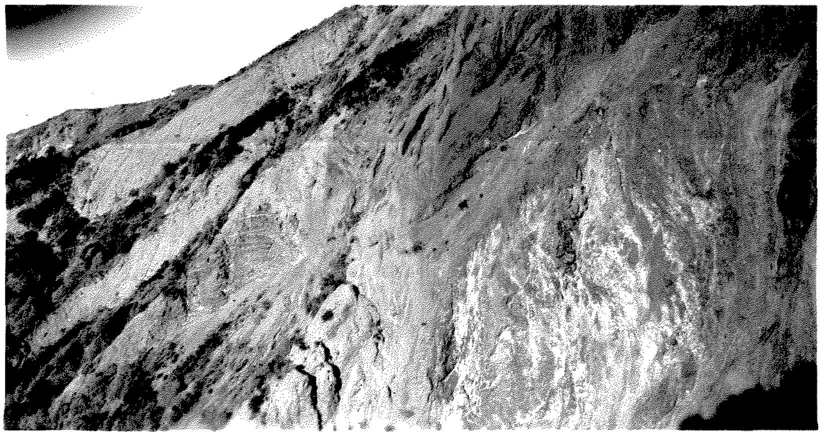


PHOTO 3.

View looking northeast from middle of green breccia. Note the breccia on the right and the folded shale on the left.

PHOTO 4.

Terrace lying unconformably on breccia. Terrace is about 30 feet thick here.

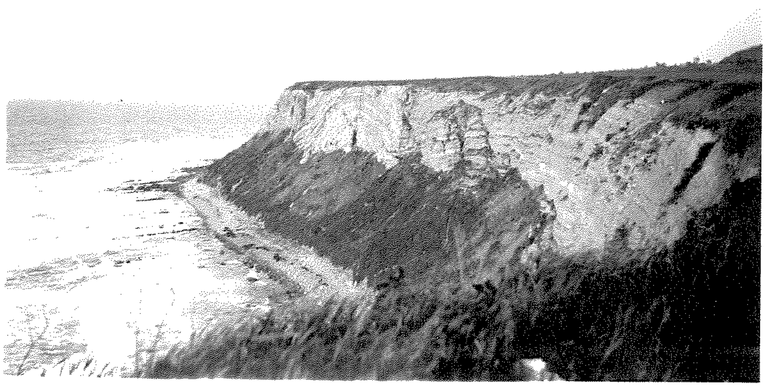
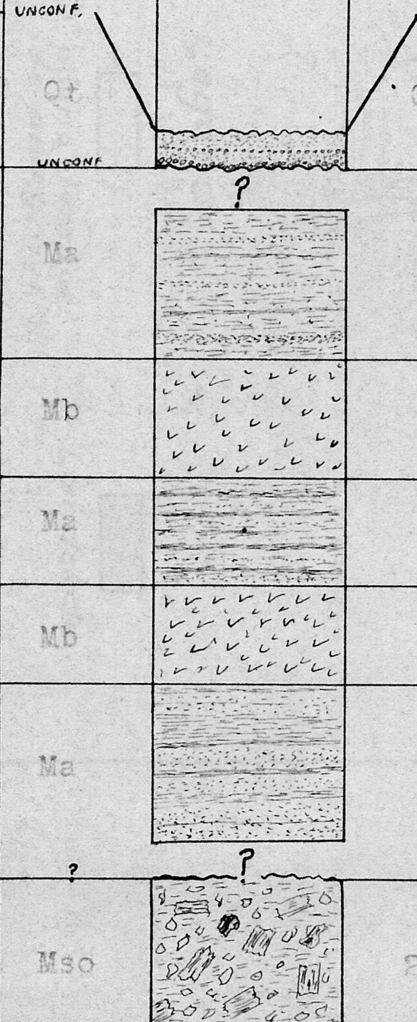


PHOTO 5.

Looking northward from a point $1\frac{1}{4}$ miles southwest of Bluff Cove. Note the small anticline and the generally low dip of the shale as it outcrops on the cliff.

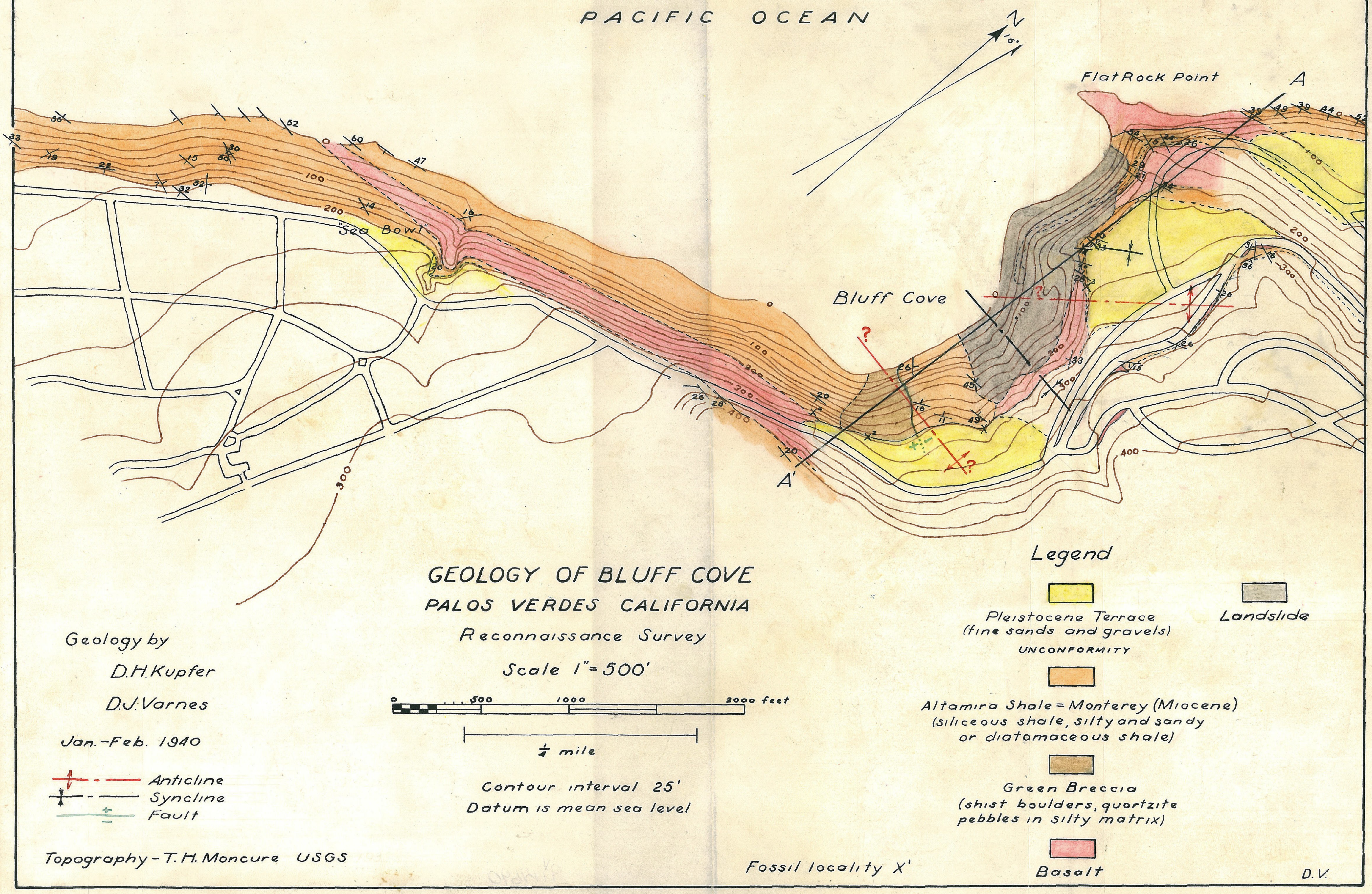

INDEX MAP FOR BLUFF COVE AREA

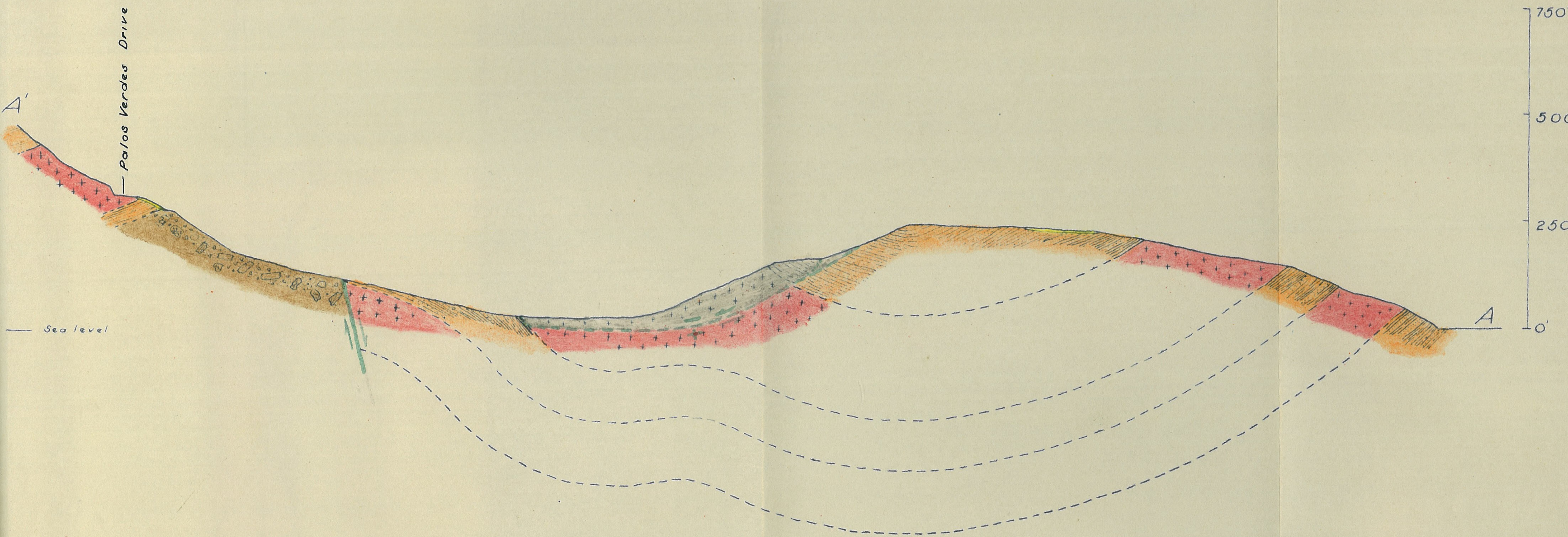



| SYSTEM | SERIES | GROUP | FORMATION | SYMBOL | COLUMNAR SECTION | AVERAGE THICKNESS (feet) | DESCRIPTION OF THE ROCK |
|---|---|---|---|---|---|---|---|
| QUATERNARY | RECENT | | ALLUVIUM | Qls | | | Surface soil and landslide material. |
| | PLEIS-TOCENE | | TERRACE | Qt | | 0-50 | Clay, sand, and pebbles. FOSSILS |
| TERTIARY | MIOCENE | MONTEREY | ALTAMIRA | Ma | | ? | Siliceous sh., diatomaceous sh., silty sh., fine ss., lms. |
| | | | | Mb | | 150 | Basalt |
| | | | | Ma | | 140 | Diatomaceous & silty shale, ss. |
| | | | | Mb | | 130 | Basalt |
| | | | | Ma | | ? | Sh. & ss. |
| | | ? | BRECCIA | Mso | | 200 ? | Breccia of quartzite, gneiss, glaucophane schist, etc. in a clay matrix. |

DHK

PLATE THREE Columnar Section


PACIFIC OCEAN
N
Flat Rock Point
A
"Sea Bowl"
Bluff Cove
A'
GEOLOGY OF BLUFF COVE
PALOS VERDES CALIFORNIA
Reconnaissance Survey
Scale 1" = 500'
0 500 1000 2000 feet
1/4 mile
Contour interval 25'
Datum is mean sea level
Geology by
D.H.Kupfer
D.J.Varnes
Jan.-Feb. 1940
Anticline
Syncline
Fault
Topography - T.H. Moncure USGS
Fossil locality X'
Legend
Pleistocene Terrace (fine sands and gravels)
Landslide
UNCONFORMITY
Altamira Shale = Monterey (Miocene) (siliceous shale, silty and sandy or diatomaceous shale)
Green Breccia (shist boulders, quartzite pebbles in silty matrix)
Basalt
D.V.




## BLUFF COVE

## STRUCTURE SECTION A-A'

Scale 1" = 250'

See main map for legend

0 250 500 1000 feet

D. J. Varnes