THE GEOLOGY OF A PORTION OF THE SAN PEDRO HILLS

by

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&

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Report by Hampton Smith.

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INTRODUCTION

The San Pedro Hills represent a line of heights adjacent to the sea coast, and extending in a northwesterly direction from the town of San Pedro to Santa Monica Bay, a distance of about ten miles. The width of the hills is about four miles. The highest point is San Pedro Hill, which rises to an elevation of 1480 feet.

The area investigated by this survey comprises about the eastern half of these Hills, and includes about twenty square miles. Most of this territory is included in the "San Pedro Hills" quadrangle, but the eastern quarter of it lies in the "Wilmington" quadrangle. The town of San Pedro covers a portion of the eastern third of the area, and the consequent cultivation there renders mapping rather difficult, although several road cuts and excavations expose some excellent sections. The remainder of the area is more or less free from habitations, except for some ranches devoted to the cultivation of beans and hay. The exposures are as a whole rather poor, except in road cuts and on canyon walls. The area is well cut up by good roads, and an automobile can be used to advantage in mapping.

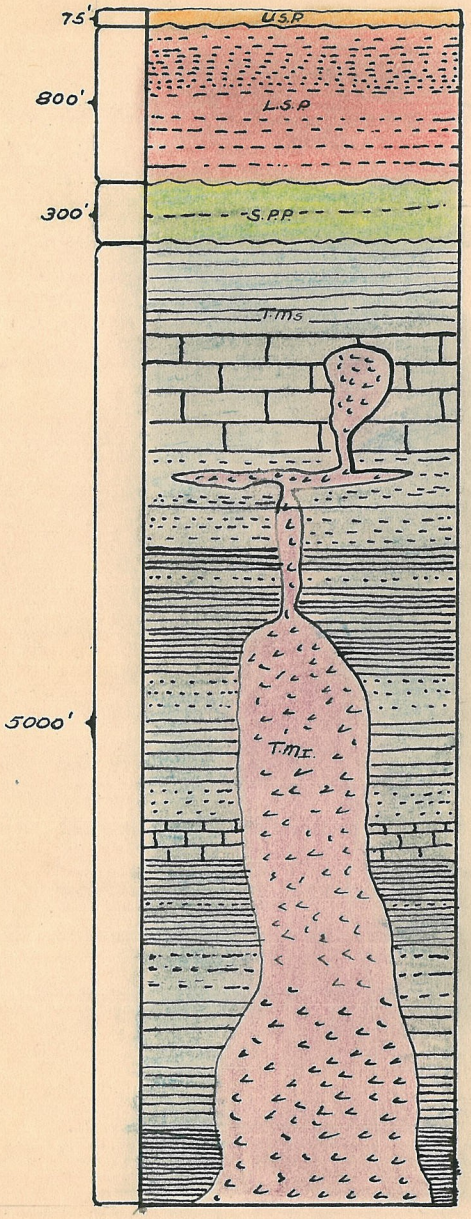
Practically the only work published on this area was done by Ralph Arnold, whose work included the paleontological study of Dead Man's Island, and a section along the west shore of San Pedro Bay. Arnold's work, though now questioned by later investigators, has been accepted by the writer in the age determination of the different formations.

The survey made by the writer and Mr Bell, as a senior

thesis for the California Institute, was done during the winter of 1927 and the spring of 1928, and included the mapping of the formations as defined by Arnold, and an investigation of the structure and physiography of the area. The paleontological work done by this survey was limited to an investigation of the foraminifera from Timm's Point.

STRATIGRAPHY.

According to Arnold, the formations represented on Dead Man's Island, and along the west shore of San Pedro Bay, are: the "Modelo" Miocene, the so-called "San Pedro Pliocene", and two Pleistocene formations called the "Lower" and "Upper San Pedro" respectively. Arnold considered that Dead Man's Island gave a type section of the deposits in the San Pedro basin, excluding the "Modelo". However, more extensive work on the mainland indicates that although the complete section may be represented on Dead Man's Island, considered from a paleontological viewpoint, there are certainly many facies of the Upper and Lower San Pedro on the mainland which are not present on the now rapidly disappearing island. The other formations represented on the mainland and not on the island, are: an igneous rock, probably dolerite, occurring in sills, necks, and irregular intrusive masses in the "Modelo"; and a formation which was not mapped, but which appears to be unconformable with the



UPPER SAN PEDRO - PLEISTOCENE

LOWER SAN PEDRO - PLEISTOCENE

SAN PEDRO PLIOCENE - PLIOCENE

"MODELO" - UPPER MIOCENE

COLUMNAR SECTION

Erase pencil guidelines
Label intrusive

Modelo shales on Point Fermin, and will be termed for convenience the "Upper Modelo". The formations then, in chronological order are: "Modelo", "Upper Modelo", San Pedro Pliocene, Lower San Pedro, and Upper San Pedro.

"Modelo" - Upper Miocene.

In the area studied, no locality was found where the base of this formation was exposed, so that its total thickness cannot be stated, nor its relationship to underlying strata. However, it might be stated that several miles farther west along the coast if lies on a series of glaucophane schists.

Due to the severe distortion which the strata has everywhere suffered, even a minimum thickness is difficult to obtain, but judging from the south end of Cross Section A - B, it must be at least four or five thousand feet, and may very possibly be several times this.

As far as areal extent is concerned, the "Modelo" is by far the most important formation in the area. It makes up all of San Pedro Hill, and extends from the sea coast northward to within about two miles of Redondo Boulevard. Only along the east and north sides of San Pedro Hill is it overlain to any extent by subsequent deposits.

In general, the "Modelo" is composed of more or less siliceous shales, but there are so many other facies of it exposed in the area that some of the most important will be briefly described.

The siliceous shales vary in color from almost pure

white to yellowish brown, and in general do not alter their color appreciably due to weathering. The darker colors seem to be associated with the presence of a greater or less amount of kaolin. The degree of consolidation also varies within rather wide limits; but as a rule the white shales are rather cherty, and very hard, while the yellow and brown shales may be much less consolidated. It might be mentioned here that many of the rocks in the Modelo are impregnated with gypsum, and when so, seem especially liable to be rather badly disintegrated. The "Modelo" at Timm's Point is a good example of this; the shales here are rich in gypsum, and are so earthy that they can easily be dug into with the bare hands.

Some of the shales are exceedingly rich in diatoms; a sample examined by Mr. Kenneth Lohman was reported to consist practically entirely of these organisms. These shales have a very low specific gravity, are quite porous, and rather well laminated.

The siliceous shales are often accompanied by arenaceous shales, mudstones and sandstones. The latter are quite often lenticular and massive. They are usually dull gray in color and composed of fairly well rounded quartz particles.

More important than the sandstones in the Modelo, however, are the cherts and limestones, and the rather common mixtures of the two. The cherts vary from black to light brown in color, but inclined toward the former. They frequently exhibit an unusually good conchoidal fracture. The limestones are generally a dull grayish black, and are a very resistant rock. The cherty limestones seem to be frequently made up of alternating, paper thin sheets of limestone and chert. Solution in HCl dissolves the limestone

and leaves fine projecting ridges of chert. Arenaceous limestones of dark reddish brown to black color are also common, and are generally rather well laminated, though occasionally massive.

The age of this formation is considered by Arnold to be Upper Miocene.

"Upper Modelo."

As noted above, the cliffs below Pt. Fermin seem to show a slight angular unconformity between the "Modelo" and an overlying formation. The "Modelo" is here made up almost entirely of cherty, finely bedded siliceous shales, and dips about 18° eastward with a strike of about N. 60 E. Directly above these shales is a series of conglomeratic sandstones having an attitude of N. 75 W. 12°S. These conglomeratic sandstones are totally unlike anything noted elsewhere in the "Modelo", but on going further up in the section they are replaced, without an observable unconformity, by shales and cherts which seem to be identical with those of the "Modelo".

The conglomeratic sandstones are of a dull rather dark gray color, and are well consolidated. They are composed almost entirely of particles of glaucophane schist, which are sometimes quite well rounded, but as a rule are subangular to angular. Some fragments of glaucophane schist several feet in diameter apparently show no water wear at all. Intercalated between bands of these sandstones and conglomerates are thin sheets of bluish-black mud shales.

This formation was not observed except on Point Fermin, and due to the poor character of the exposures just north of there,

the contact could not be closed. The fact that it grades upward into strata indistinguishable from the rest of the "Modelo" may indicate that it represents a contemporaneous continental or sea cliff deposit. At any rate it was included, prehaps unfortunately, with the rest of the "Modelo", on the map.

A formation which strikingly resembles this conglomeratic sandstone except that its fragments are in general prehaps slightly more angular, is the San Onofre Breccia, as exposed south of the town of San Onofre along the Los Angeles - San Diego Highway. The San Onofre Breccia is considered to be of the same age as the Vaqueros, which is older than the "Modelo"; but the striking similarity of the constituent particles, suggests a possible relationship of sources which might be interesting to investigate.

The only fossils found in the "Upper Modelo" were some fish and eel skeletons preserved in a light brown shale, about 200 feet above the contact of the conglomeratic sandstone with the siliceous shale.

Intrusive.

As mentioned above, this rock occurs as sills and irregular intrusive masses in the "Modelo". It crops out in several places along the Palos Verde Coast Road on the east side of the Hill, and again on the south west side of the Hills back of Portugese Bend. Also it occurs in the form of thin sheets between shale members in the reefs at White's Point.

With prehaps one exception, all the samples of this rock from various parts of the several exposures seem to be dolerite.

The major elements are olivine and augite, with plagioclase occuring sometimes as a major, and sometimes as a minor element. Hornblende is also present in varying amounts, but in general is subordinate to augite. In places the rock is vesicular for a short distance near the contact, and the vesicles are occasionally filled with quartz and natrolite.

Exposures of the rock are typically a medium dark brown, and occasionally a somewhat darker greenish brown. It is rarely that specimens of the fresh rock can be obtained, but when so, they have a dark olive green to black color.

The one exception to the rock's being a dolerite is along the northern contact of the intrusive with the shales in the exposure back of Portugese Bend. In this locality, in about the center of the exposure in an E-W direction, the rock is decidedly more acidic than elsewhere. It is made up primarily of phenocrysts of feldspar, both orthoclase and plagioclase; with a rather salic ground-mass containing some femic minerals. In a north-south direction this body is separated from the dolerite by fifty feet of shale, but seems to grade into it in a east-west direction. (See Cross-Section C-D).

Exposures of this rock are markedly less decomposed than the dolarite, and rise steeply as cliff faces in the canyon bottoms. The characteristic color is a light brown when weathered, and a light brownish to light greenish gray color when fresh.

Nowhere is the dolerite observed in contact with formations other than the "Modelo", which fact, however, in view of the rather limited extent of the other formations, is only contributory evidence for assuming the intrusion to be of Upper Miocene age.

San Pedro Pliocene.

On Dead Man's Island, and at Timm's Point, the so-called San Pedro Pliocene is separated by a marked angular unconformity from the underlying "Modelo". (See Figures 1 & 2).

On the island this formation is composed of about 40 feet of soft, rather poorly consolidated, clayey sandstones, which have, in general, a peculiar grayish yellow color. The formation is highly fossiliferous, and contains numerous species of gastropods, plecepods and bryozoa. At Timm's Point, the formation referred to the Pliocene has the same general aspect as on the island, but is more poorly stratified. In fact no bedding planes whatsoever could be found on the mainland Pliocene, and the 38° dip attributed to it there is really the dip of the contact plane with the "Modelo".

The areal extent of this formation as mapped, is limited to a narrow strip extending from Timm's Point to near the center of the town of San Pedro. It should be mentioned, however, that at a point just west of the Tank farm having 8 tanks, a formation is exposed which seems to be lithologically indistinguishable from the Timm's Point Pliocene, but it is almost certainly continuous with the Lower San Pedro Pleistocene. Such a relationship between the two formations is of course possible, but due to the marked angular discordance on Dead Man's Island, and the impossibility of making a paleontological differentiation at this locality, the strata near the Tank farm were considered to be Lower San Pedro. The possibility that the bedding planes in the mainland Pliocene are not parallel to the contact plane with the "Modelo", might permit the assumption that there is no

SKETCHES

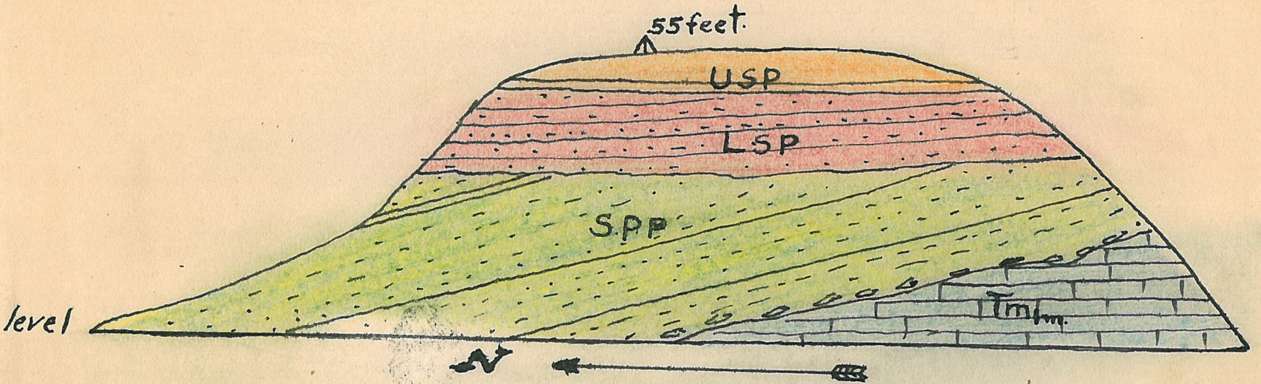


Fig 1.
Dead Man's Island

USP — Upper San Pedro
LSP — Lower San Pedro
SPP — San Pedro Pliocene
Tm — "Modelo" Miocene

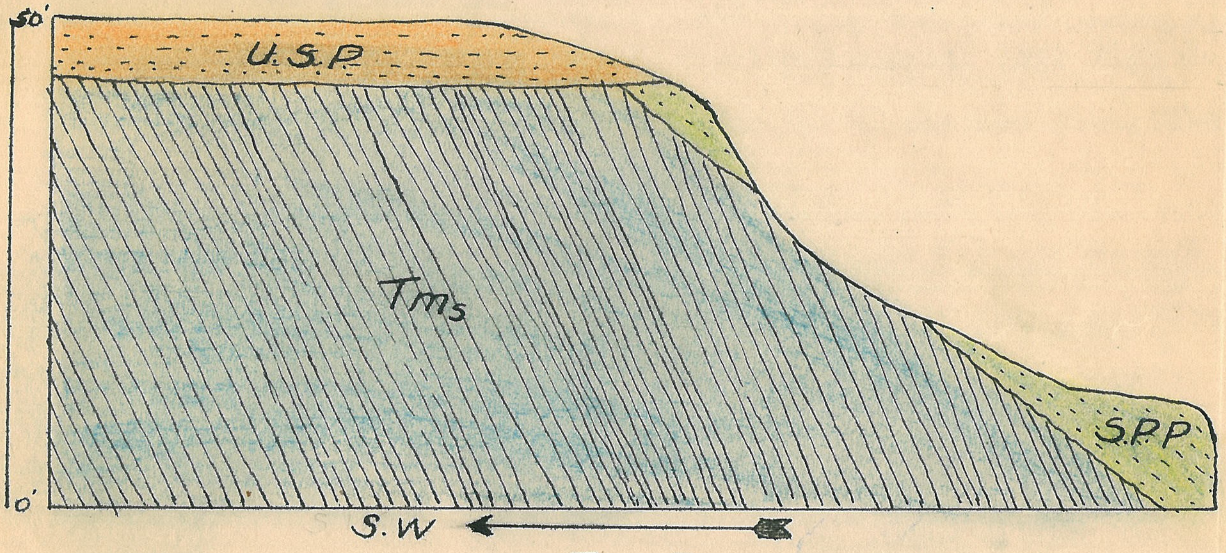


Fig. 2.
Timm's Point

Desirable to use legend for sed types, as Conglom ∘∘∘∘
SS
Sh
LS
Etc

Not necessary then to use solid lines except as formation or member boundaries.

unconformity between the San Pedro Pliocene and the Lower San Pedro on the mainland. The writer, however, is inclined toward the opinion that the two formations are separated on the mainland as on Dead Man's Island by an angular unconformity.

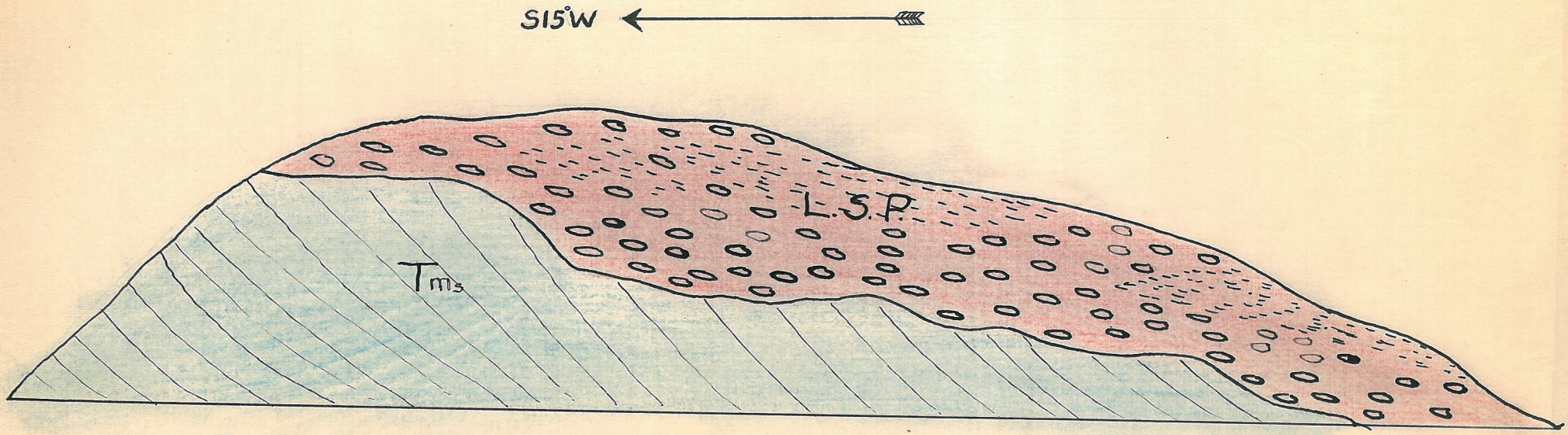
The formation is much thicker on the mainland than on the island, and may attain a thickness of 500 feet.

Lower San Pedro.

As exposed on Dead Man's Island the Lower San Pedro is composed of about 20 feet of massive, poorly bedded, and fairly well consolidated sandstone. The color is almost pure white when fresh, and somewhat grayer when weathered. The particles are almost entirely quartz and feldspar. This formation is also highly fossiliferous, and on the basis of extinct fossils is called Lower Pleistocene by Arnold. The unconformity with the Pliocene is marked on the island and shows not only angular discordance but several good examples of an old erosion surface. (See Fig. 1.).

On the mainland the formation is exposed along the water front, north of Timm's Point, and is in general the formation in contact with the "Modelo" around the north-east edge of San Pedro Hill. The thickness may attain 800 feet, and the formation on the mainland is characterized by a great number of facies, including clean white almost unconsolidated sands, brownish yellow, argillaceous sandstones, and calcareous beds composed almost entirely of pelecypods shells. The relation of this formation on the mainland to the Pliocene has already been discussed.

Color even more faintly.



Sketch showing the unconformity between the "Modelo Shales" and the "Lower San Pedro" exposed in a road cut on the Palos Verdes Coast Road about 1½ miles south of Redondo Blvd.

Fig 5.

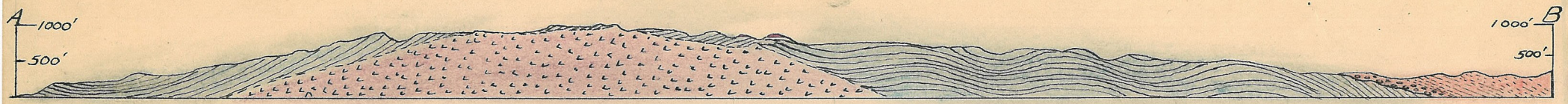
Upper San Pedro.

On Dead Man's Island this formation is about 13 feet thick; the lower 3 feet being a shell bed consisting almost entirely of pelecepod and gastropod shells, cemented with a white calcareous sandstone. The upper 10 feet is a rather resistant clayey sandstone, grayish brown when weathered and a rich reddish brown when fresh. It exhibits no stratification and the uppermost foot of it is rich in wonderfully preserved pecten shells. These, however, may possibly represent a kitchen midden deposit rather than a truly marine facies. On the island the contact with the Lower San Pedro seems to be marked by an erosional surface, but no angular discordance was observed.

On the mainland the two facies just described are also present, but are accompanied by thick beds of rather soft yellowish sands, so that the total thickness may attain 75 feet.

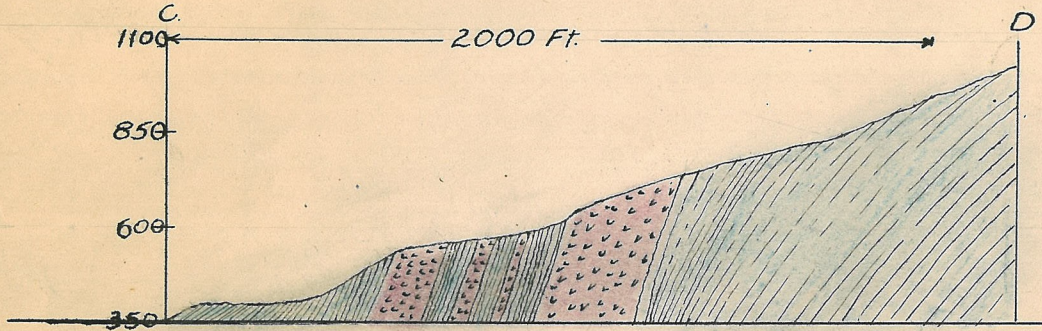
The unconformity with the Lower San Pedro is very marked at several places in the town of San Pedro, where excavations have beautifully displayed the relations of the two series. (See Cross-Section E - F).

The Upper San Pedro seems to always lie nearly horizontally, although sometimes attaining dips of about 4° east. It covers the Lower San Pedro in a considerable portion of the town, and also overlies it as far north as Redondo Boulevard.



N 8°30'E

Scale 2000' = 1"



N 26°E.

Note: Most northerly sill is acidic.

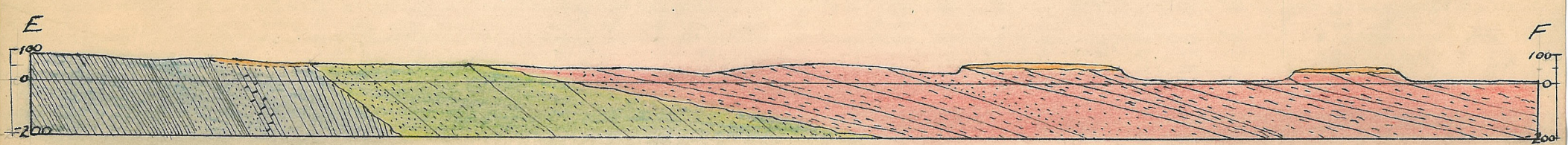
U.S.P. Upper San Pedro-Pleist.

L.S.P. Lower San Pedro-Pleist.

S.P.P. San Pedro Pliocene

Tmx "Modelo" Intrusive

Tms "Modelo" - Up. Miocene



N 40°E

Scale 500 feet = 1 inch

STRUCTURE

Considered as a whole, the area is prehaps not so interesting structurally, as lithologically and physiographically. There are, however, several features of interest, and a more detailed study of certain portions of the area might prove worth while from a structural viewpoint.

Folding .

The folding which has occurred in the area has apparently been almost confined mainly to the "Modelo". The subsequent later formations are tilted, but in general the attitudes of their strata are rather persistant and do not show much distortion. The "Modelo", however, is a veritable "hodge podge" of small folds. The smallness of these features makes an accurate determination of their axes and extent a difficult matter; because, due to the poor character of the exposures except along road cuts, it is an easy matter to miss several changes in dip altogether. Moreover, the fact that few if any of these folds have any topographic expression, adds to the difficulties in mapping them.

The only folds which were mapped to any extent, and the persistence of these through any great distance is doubtful, are a series of anticlines and synclines along the coast from White's Point to Portugese Bend. In this stretch of coast there are four anticlines and as many synclines, all of which trend in a NW-SE direction and ~~dip~~ plunge southward into the sea. They seem to be practically symmetrical, and the flanks seldom dip more than 15° away from the axes. As stated above the persistence of these folds is doubtful.

Along the Palos Verdes Coast Road north of Seventh Street there seem to be at least four anticlines developed. These vary considerably in their trend, but as a rule the axes seem to run somewhat north of east. They plunge eastward.

The two examples just cited are probably of little value in themselves, since neither set of the folds were followed along their axes; but they are of value in showing that, in spite of minor distortions of the strata, the general dip of all the "Modelo" is away from San Pedro Hill. The possible significance of this will be discussed in the following section under Intrusion.

Intrusion.

As noted under Stratigraphy the dolerite occurs as sills, necks and irregular intrusive masses; all of these, however, have a composition which is practically identical.

Along the reefs at White's Point the dolerite occurs as sheets, not exceeding 3 feet in thickness, intercalated with beds of shale and sandstone. No vesicularity was observed, and little baking of the adjacent sediments.

North and somewhat east of this, along the Palos Verde Coast Road, above the San Pedro Golf Course, there is a small neck, which contains several inclusions of shale. (See Fig. 3). It is exposed at an elevation of 750 feet.

The large intrusion west of Seventh Street seems to be of no particular simple type. In places it lies on the shale like a sill, but more often cuts through it at varying angles. Within the igneous mass there is an island of shale several hundred feet in diameter. In general the shale at the contact shows

Fig 3.

PHOTOGRAPH SHOWING CONTACT BETWEEN INTRUSIVE NECK (CENTER) AND SHALE (RIGHT AND LEFT)

Fig 4.

PHOTOGRAPH SHOWING CONTACT BETWEEN DOLERITE (LEFT) AND "MODELO" SHALE (RIGHT) NEAR INTERSECTION OF 7th. STREET AND PALOS VERDE COAST ROAD

considerable baking, and the dolerite occasionally exhibits some vesicularity. This mass is exposed between the elevations of 525 and 1000 feet.

The smaller intrusion north of this is predominately a sill, but ends against distorted strata.

The large intrusion north of Portugese Bend is in places a series of sills (See Cross Section C - D), 20 to 250 feet in thickness, and separated from each other by bands of shale up to 50 feet thick. Elsewhere the intervening shale members seem to disappear leaving one thick sill. In the canyon at the western edge of this intrusion this sill is exposed as a 100 foot cliff. It exhibits laminations parallel to the overlying shale, which laminations get finer as one approaches the contact. It also exhibits pillowstructure to a remarkable degree. This intrusion occurs between elevations of 500 and 800 feet.

The rather wide area over which the dolerite occurs, the different levels, and the persistance of the same type of rock, all seem to indicate a magmatic source of considerable proportions. Moreover, the fact that the highest outcrops are not sills, but large intrusive bodies, tends to show that the main body of the magma rose to a considerable height in the shale series, and did not merely send out thin sills from feeder necks.

Assuming then, that the dolerite is of near - batholithic proportions, it appears possible that its intrusion might be responsible for some of the distortion of the shales. Such an intrusion, centered prehaps in San Pedro Hill, could conceivably give the surrounding strata dips away from the Hill. Wether, however,

it could produce a series of near - parallel folds with their axes running into the Hill, as exists along the coast between Portugese Bend and White's Point seems doubtful. Nevertheless, in view of the unknown persistance of these folds and the probability that they are not extensive, it seems reasonable to give batholithic intrusion credit for the development of some of the folds in the "Modelo". The fact that some of the sills end against distorted strata, however, would prehaps indicate that there had been some faulting and distortion previous to the igneous activity.

Faulting.

Faulting on a large scale is conspicuous by its absence in this area. Numerous small faults of several feet displacement were observed in the "Modelo", but all these seem to be old and inactive, and have absolutely no topographic expression.

A long straight scarp, twenty five to fifty feet high, extending north-west from Point Fermin for about three miles, was considered to be a possible fault scarp; but investigation along its course failed to reveal any substantiating evidence for a fault hypothesis, other than a small fault of about 10 feet displacement, which is exposed on the sea cliffs east of the Point Fermin Light House. The scarp, however, does seem to be unusually long and straight to have been developed by terrace erosion, and a more detailed study might lead to the conclusion that it was developed by faulting. For want of such evidence, however, it is regarded by the writer as an erosional feature.

PHYSIOGRAPHY

The San Pedro Hills are perhaps most noted fro their wonderful terrace development. These terraces were not, however, investigated in great detail by this survey, and only their main characteristics will be cited.

There are from six to nine sets of these terraces developed along the seaward face of San Pedro Hills, with approximately the same vertical distance between them, namely from 100 - 200 feet. The lowest terrace is 170 feet above the present sea level; the highest is the flat top of San Pedro Hill. The terraces are not continuous, being broken up by subsequent erosion and landsliding. There is apparently no relation between the terraces and the structure of the shales; highly distorted and vertical strata yielding the same flat surfaces as horizontal beds. Almost certainly the, these marine terraces owe their existence to the intermittent uplift of a block which includes the whole of the Palos Verdes Hills. That this uplift occurred entirely during the Pleistocene is shown by the marine deposits of that age upon the highest terraces.

In line with the development of terraces irrespective of underlying structure, it holds true for the whole area that the physiography is almost entirely the result of erosion, and has no structural significance.

PALEONTOLOGY

A great quantity of fossils were collected from the area,

especially from the Pliocene & Pleistocene formations. The limited time however, did not permit making a complete list of the forms from any locality. The following list represents the species of foraminifera occuring in the Pliocene at Timm's Point, as determined by Mr. Bell.

FORAMINIFERA FROM San Pedro Pliocene ~~DEMERMOST SAUGUS BEDS~~ TIMM'S POINT

Collected by Frank Bell.

Biloculina bradyi Schlumberger
Bulimina sp.
Cassidulina several species, undetermined
Cibicides lobatus (d'Orbigny)
Cibicides fletcheri Galloway and Wissler
Cibicides tenuimargo Brady
Cibicides sp.
Globergerina sp.
Globorotalia grandis Galloway and Wissler
Lagena sp.
Nonion incisa Cushman
Nonion scapha (Fitchel and Moll)
Nonion sp.
Nonionella auris d'Orbigny
Orbulina universa d'Orbigny
Polymorphina sp.
Quinquiloculina vulgaris d'Orbigny
Quinquiloculina ankeriana d'Orbigny
Quinquloculina sp.
Rotalia subtenera Galloway and Wissler
Sigmolina sp.
Textullaria barettii Jones and Parker
Textularia gramen d'Orbigny
Themon crispus (Linne)
Triloculina several species undetermined
Uvigerina farinosa Hankten
Uvigernia peregrina Cushman
Virgulina sp.
Several other undetermined genera and species

HISTORY

The history of the region as deduced from stratigraphic and structural relations is briefly as follows:

1. Deposition of the "Modelo" in the Upper Miocene.
2. Folding - with or without emergence.
3. Intrusion of dolerites producing additional distortion.
4. Uplift and erosion in latest Miocene or early Pliocene.
5. Subsidence and deposition of San Pedro Pliocene.
6. Uplift, tilting and erosion in late Pliocene or early Pleistocene.
7. Subsidence and deposition of Lower San Pedro in lower Pleistocene.
8. Uplift, tilting and erosion in middle Pleistocene.
9. Subsidence, and deposition of Upper San Pedro in late Pleistocene.
10. Intermittent uplift, without appreciable tilting, continuing until the present day.

ECONOMIC POSSIBILITIES

Although probably not containing any precious metals, the economic possibilities of the area are not altogether insignificant. The dolerite intrusions are being quarried at two localities for road bed material. The first of these localities is just opposite the intersection of Seventh Street and the Palos Verdes Coast Road. The dolerite here is very badly weathered and is easily quarried with a steam shovel. The second quarry is back of Portugese Bend. The rock here is much harder and more difficult to quarry, but considerable work has been done in the past at this locality.

Two other economic possibilities are the exploitation of the thick barite seams, so common in the "Modelo" and the exploitation of some of the diatomaceous shale beds. The latter are very rich in diatoms, and if found in sizable deposits would be valuable as filtering material for oil.

The possibilities for oil have apparently not found favor in the eyes of the oil geologists, although one "wild-cat" well was drilled on Point Fermin. It is possible that the intrusion of the dolerite has had an unfortunate effect on the accumulation of oil along the coast, or the structure may not be favorable. However, this may be, the writer has observed considerable thickness of strata in the "Modelo" which are well saturated with petroleum.