GEOLOGY OF A SECTION
OF THE
PALOS VERDES SEA COAST

A Senior Thesis report in fulfillment of Caltech Geology Department requirements.

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Submitted by:

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TABLE OF CONTENTS

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INTRODUCTION

The area in which this work was done is located in the San Pedro Hills Quadrangle. It can be reached by following the Roosevelt Highway south from Redondo, California, then following the branch off this highway along the coast. The area begins about one eighth mile south of the San Vincente Lighthouse at Long Point, extends southeast for a little over four miles along the coast.

The area includes the sea cliffs along the ocean. It does not constitute a true area because no extension back from the coast was studied.

The area was investigated on foot, there being only two places accessible by car, one at Abalone Cove and the other at Portuguese Bend.

GENERAL DESCRIPTION

The sea cliffs in the area are from 100 to 150 feet high. Inland from the cliffs lie a series of terraces, about ten or eleven distinct terrace profiles existing from the top of the sea cliffs to the top of the San Pedro Hills. The terraces are irregular and broken. The upper terraces lie near the top of the hills, with the highest ranging from 1200 to 1400 feet above sea level.

The center of the region contains a slide area about two miles long. Here the cliffs are broken and crumbled, and in some places completely lacking.

Long Point, the most southerly point of the west part of the quadrangle, is a broad, rounded point with well developed vertical cliffs. One half mile east along the shore from Long Point is a small point which is very narrow and sharply pointed. In the face of the cliff at the end of this point is a large sea cave, due to differential erosion. The point is the expression of a fault zone.

Abalone Cove extends eastward from this point, forming a crescent-shaped bay about one mile across its outer margin. Good cliffs are found in the west and east ends of Abalone Cove. In the center of the Cove is an extensive expression of the large slide area.

Portuguese Point lies at the eastern end of Abalone Cove.

It is about 200 yards wide, rectangular-shaped. Its vertical cliffs, running north-south, show well exposed shale beds and igneous sill. This north-south exposure is helpful in giving the regional dip and strike and also aid in getting a three dimensional picture of the area's structure. Portuguese Point has a flat top, the expression of the latest terrace.

To the east of Portuguese Point lies a small deep cove about 200 yards wide. The large landslide area is again encountered along the interior side of this cove. The cove is bound on the east by Inspiration Point which is flat topped, one hundred yards wide, has good cliffs, and is very similar in appearance to Portuguese Point.

Eastward from Inspiration Point lies broadly curving Portuguese Bend, which is about one and one half miles long. The west and center portions are landslide areas, but good cliffs are exposed in the eastern part of the Bend. A point terminating the southeast end of the cove constitutes the eastern boundary of the area mapped.

All along the coast are low, irregular reefs, composed of igneous rock. The drainage system cuts through the cliffs in minor gullies carrying waters only during torrential rains in the winter.

In mapping the area contacts were not carried back inland from the sea cliffs, mainly because this area is covered with cultivated alluvium lying on top of the terraces, and covering the contacts. The exposures for this mapping were found entirely in the cliffs.

STRATIGRAPHY

For convience' sake the region can be divided into three main stratigraphic zones: 1) Lower Shale; 2) Basaltic Sill; 3) and Upper Shale. Actually the shales are the same, but are only divided or separated by the basalt.

Lower Shales

The lower shales are a grey, usually sandy, finely laminated rock. They are irregularly bedded, moderately to well consolidated, and occur in layers or laminations from 1/32" to 6" thick. The shales contain some fish scales, indicating a marine origin. Beds of volcanic ash about 6" to 3' thick are scattered irregularly in the shales. Fish scales in the ash indicate marine deposition near shore. The ash is very fine grained, poorly consolidated, and grey colored.

In the west end of the area are found veins in the siliceous shale which contain barite. The veins are near the shale-igneous contact.

Igneous Sill

The igneous sill occurs throughout the area, separating the Lower Shales from the Upper Shales. The sill is composed of a dark fine grained rock with small light colored phenocrysts which appear to be plagioclase and sanadine. The rock shows little flow structure, is vesicular in places and well consolidated in others. It is irregularly jointed, and the joints are filled with calcite and a lighter intrusive, more resistant to weathering. The basalt alters to a reddish color in the cliffs, although it is a black color when near water level and unaltered. It alters readily in sea water and weathers faster than the shales of the area, mainly due to chemical action. The basalt occurs interruptedly all along the coast of the area. Most reefs are of basalt, probably because they are better consolidated than the shales and do not crack and shatter so easily, although they weather faster as a whole. Because of its rapid alteration, good specimens of this rock are hard to find.

Upper Shale

The Upper Shales are much the same as the Lower Shales, although in some cases they show a greater percent of silica. These siliceous shales are very hard, light grey, and fine grained. They withstand weathering better than any other rock in the area. They are so well consolidated that they tend to shatter like and igneous rock, giving a conchoidal, smooth fracture surface.

However both the Upper and Lower shale members seem to be characterized generally as siliceous shales. Their bedding is irregular and lensed. As a result, correlation of beds cannot be carried for a very great distance.

Both the Upper and Lower shale beds have interbedded calcite and gypsum. The calcite is abundant near the fault zone just east of Long Point.

GEOLOGIC STRUCTURE

The general regional dip is from 10 to 20 south, the strike about N85 W. The area has been affected by faulting, folding, intrusion, landsliding and terracing, during an apparently periodic gradual uplift. The shales have been intruded by a basaltic sill which varies in thickness from thirty to ninety feet. The sill is generally conformable to the regional dip, although it may break irregularly through one bed to another in some places. Good exposures of shale beds caving and stoping into the sill are shown in the cliffs. The caving beds bend downward then break off, and in some cases, show free fragments below in the sill.

The shales were laid down near shore as marine deposits. A thickness of about three hundred feet of these shales is exposed in the area. Throughout the area the general character of the shales is much the same both horizontally and vertically.

The igneous intrusion caused much minor folding but did not form many tongues into the shales. Therefore it was not injected at very high pressures and did not greatly affect the structure of the region. The shales are severely folded in minor areas, but this folding is due to the same stresses which caused the faulting rather than to the intrusion of the sill.

Faults cut the cliffs in about five places. One large fault cuts Long Point. Its location is inferred from the brecciation of the shales here, and their silicification, which seems to accompany most of the larger faults of the area. An actural face or trace of the fault was not found, and hence its strike, direction of movement, and displacement are unknown.

Another large fault tending N-S is found at the finger-like point just east of Long Point. This point here is purely an expression and result of the fault. It is composed of consolidated silicic shale breccia and extends in a sharp projection into the ocean. The area of brecciation is about sixty feet wide. Some excellent slickensides are exposed here which show that the movement along the fault was in a horizontal direction. Here it seems probable, from the relations of the shale to the igneous sill, that the western block moved north relative to the eastern block. The Basalt-Lower Shale contact bears an odd relation to the fault face here because at the southern tip of the point the contact dips about 55 to the east instead of maintaining the regional dip of 20 south. This relation suggests either strong vertical movement which took place before the horizontal movement, or strong horizontal compressional forces at nearly right angles to the face of the fault. The latter forces were possibly responsible for the fault by having their component parallel to the fault cause its movement. This problem infers that the structure of the area is really quite complex when studied in detail.

Two hundreds east of the above fault is a minor fault tending N40 E. It shows as a slickensides exposure in the cliffs. Its movement was horizontal.

Two other faults lie on the inner side of Abalone Cove. Both seem to be of minor importance, and their exposures are so poor that no data could be taken from them.

A large fault zone in silicic shale occurs at the eastern end of the area. This zone is similar to the one at the western end of the area.

In the center of Portuguese Bend is a syncline which trends nearly E-W. The syncline is three or four hundred feet wide and has gently sloping limbs. South of this syncline lies an anticline of about the same dimensions. This structure is further treated in a separate paper as a special problem.* (Enclosed with this report.)

* Reynolds, "Structure of the Folded Shales in Portuguese Bend"

HISTORY

Not much regional history can be inferred from the area studied. Marine deposition first took place while the area underwent slow submergence. The region was supplied with fine, sandy material from the north. With this material was formed a siliceous ooze which was a result of organisms living in a sub-salic sea. The ooze later consolidated with the silts to form the silicic shales.

The sill was then injected between the shales, probably while the shales were still submerged, at a depth which amounted only to a few hundred feet.

The faulting and folding of the area probably took place during the same geologic period as the basalt intrusion, and before.

Emergence then began in periodic movements which formed the terraces. Each time the movement slowed or ceased, the sea would cut a bench, then when it was raised it became another terrace.

Recently the wave cutting has proceeded a t a more rapid rate than elevation to form the high sea cliffs of the present coast line.

STRUCTURE OF THE FOLDED SHALES
IN PORTUGUESE BEND

The area of the accompanying map and diagram is located at the intersection of the coast with a line S85E from the tip of Inspiration Pt. The mapping of this deatiled section was made in order to determine the exact nature of the folds in this area and the reason for the non-recurrence of the ingeous bed immediately up ~~to~~ the coast to the northwest.

Dips and strikes were taken about every forty feet except where the beds continued in the same attitude over a larger area, and at closer intervals where deemed necessary because of more complex structure. Great effort was taken to try correlating some particular bed from one side of the structures to the other, but only in the case of the anti-cline at D could this be done. The line AE represents not the coast line but the approximate line of exposed structure. Just NE of this line the structure is covered by loose rocks and beach gravel.

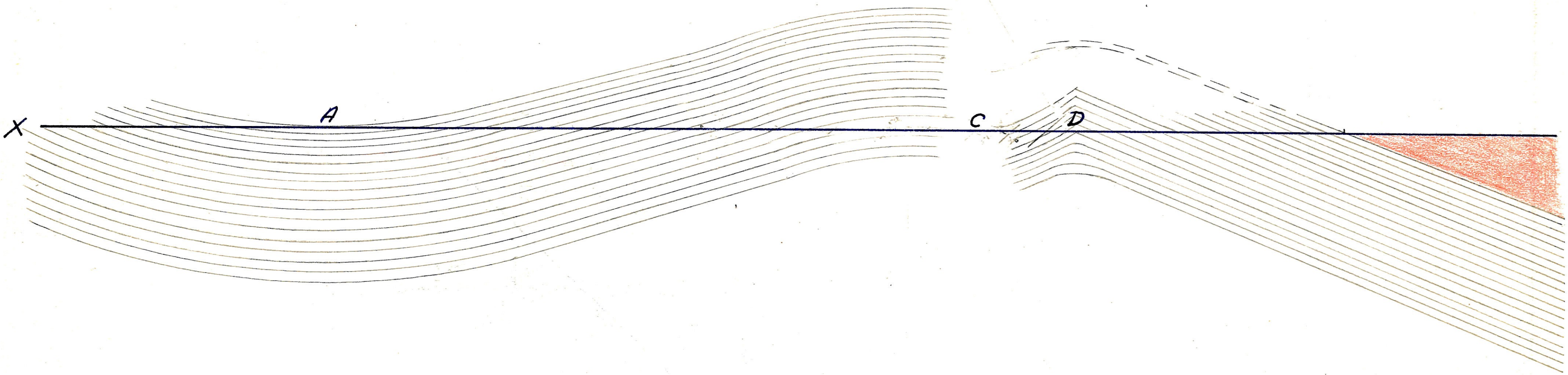
In the northernmost part of the area are shales dipping S 20° striking N85W in accordance with the regional dip. The next exposure is 200' SE along the coast, with shale dipping N 20° striking nearly W. Between these two exposures are no exposed strata, and since no bed can be traced from one side to the other, the syncline can reasonably be placed at A, as can be seen from the vertical section. The shales then form the limb of an anticline lying to the south. At B is an anticline, apparently of minor importance, probably only a slight flexure of the limb. It plunges westward, but no dips or strikes of it were available near the line of the vertical section because of a small bay of water. However it was assumed that this minor structure continued westward and intersected the vertical section. This area of flat strata is terminated on the south by shales dipping 40° and 50° N. There is a small gap of two feet along this E-W "contact", along which no correlation from one side to the other could be found, nor any evidence for the relation of the two sides. At the east end of this small trough of the "contact" there is a sharp bend through about 40° of a radius of about 10 feet, which would eliminate the possibility of a fault unless it were entirely vertical in displacement. If this were a fault, it might explain the mashed anticline at D, which would then be the result possibly of drag. The anticline at D, however, is not merely due to drag but is a true anticline. The fault would only have caused the breaking of the beds at the crest of the anticline. South of the anticline the beds resume the regional dip and run into the shale-igneous contact.

At F are some beds dipping 70° SE, the explanation of which can not be found. At E is a minor anticline plunging west which probably does not extend even as far as the vertical section plane.

The green and brown lines on the map represent correlated shale beds and represent the outcropping of these beds. They clearly show the nature of this minor anticline.

As seen in the vertical section, if the beds could be correlated across C, it might be possible for the igneous shale contact to pass above the surface at A. However, the beds do not line up from B to D very well and the complete lack of outcropping beds in this narrow area would not permit a positive postulation for any structure here.

This vertical section would infer a syncline tending N85S, Bounded on the south by an anticline which then is bounded on the south by the regional dip, but conclusive evidence for this structure would have to be sought elsewhere. The probability for a fault at C is very slight.

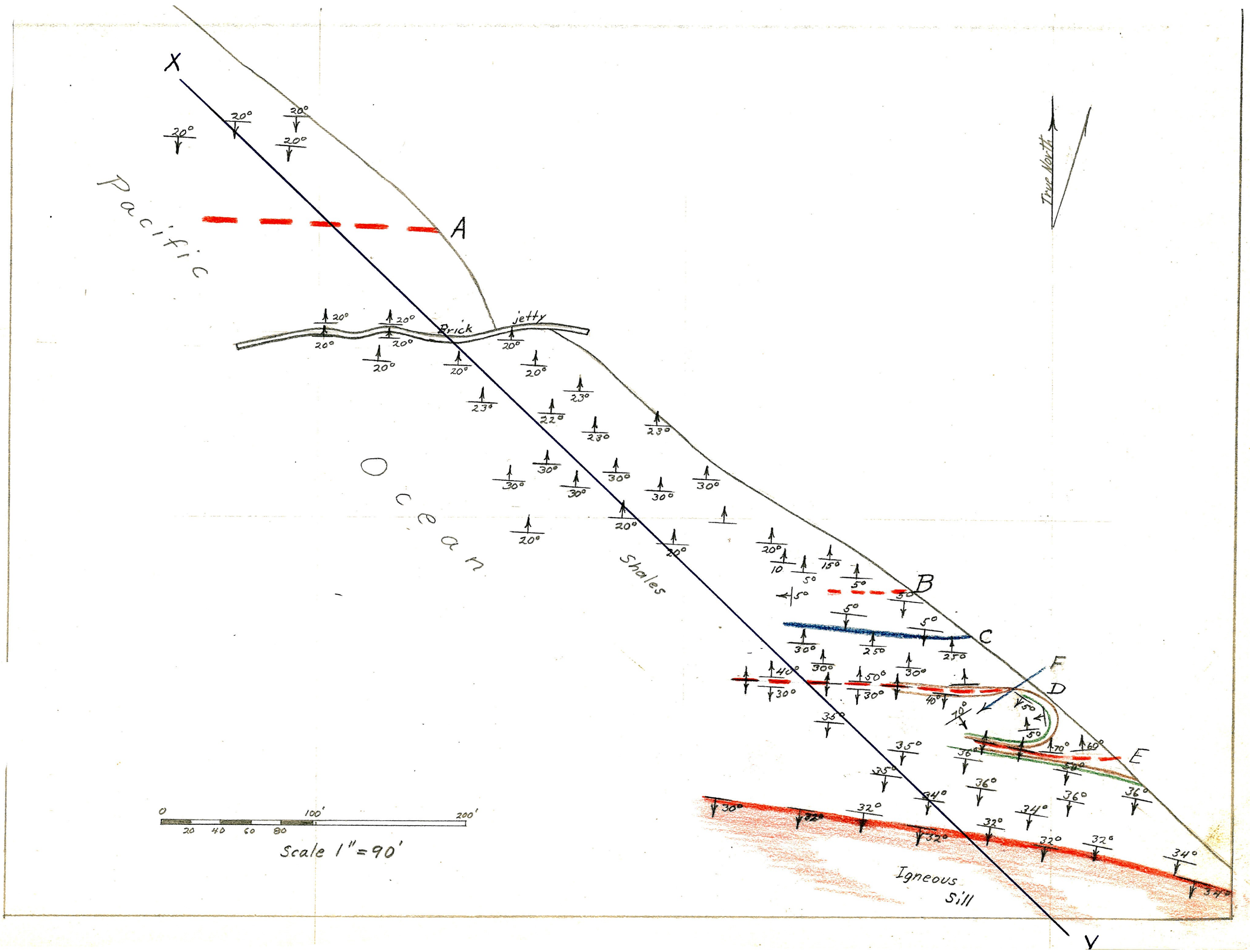


Vertical and horizont. scales are equal.

Vertical Section of strata

Y to X is N 42°W

The dips and strikes have been reduced by a factor in such a way that the dips and strikes of this section represent the actual intersection of them with a vertical plane N 42°W.



True North
X
Y
A
B
C
D
E
F
Pacific Ocean
Brick jetty
Shales
Igneous Sill
0 20 40 60 80 100' 200'
Scale 1" = 90'

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of the

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A Senior Thesis

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CALIFORNIA INSTITUTE OF TECHNOLOGY

TABLE OF CONTENTS

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GEOLOGY OF A PORTION OF THE ADELANTO HILLS

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ABSTRACT

The Adelanto Hills are a low range of folded limestone hills, situated about five miles northwest of Adelanto, California. The limestone is a dark blue, finely crystalline banded type, which has been hydrothermally altered in places to a white crystalline limestone, or to a fine-grained, highly altered brown limestone. The alteration is indistinctly associated with faulting and minor intrusions in the area. The main igneous body in the area is a large granodiorite body that apparently has been faulted into its present position. A complementary association of a fine-grained dark intrusion and numerous pegmatite dikes occur in the northwestern part of the area. Several large, light colored acidic dikes intrude the limestone, and their relationships to the other intrusions cannot be determined. The area is cut by a large fault trending N65 W and by numerous smaller faults trending about N20 W. The structure on either side of the main fault is roughly parallel. Mineralization of the area is mainly a contact-metamorphic type, containing lead, zinc, and silver. Considerable oxidation in the area has occurred, resulting in some secondary enrichment, especially of silver. Some scheelite is mined at the present time from a contact zone between porphyry and limestone.

INTRODUCTION

The area covered by this report comprises about forty acres, located across the center of a low range of hills, approximately five miles northwest of Adelanto, San Bernardino County, California. These hills have been named by the authors of this report the Adelanto Hills.

An outcrop map was prepared by means of a plane table survey on a scale of fifty feet to the inch. No topography was included in the map. The work was done in conjunction with the Field Geology course at the California Institute of Technology by Howard Reynolds, Richard Wasem, and Bernhard Haffner. This report was prepared as a Senior Thesis.

STRATIGRAPHY

The Adelanto Hills are a low, roughly lenticular range of folded limestone, intruded by a few moderate-sized igneous bodies of hypabyssal character and cut by numerous dikes, including pegmatite, aplite, and acid types.

Limestone

The limestone is mainly a dark blue, finely crystalline, roughly banded variety. The banding is probably a remnant of the original bedding of the limestone and contains a greater percent of carbonaceous material than the unbanded rock. The banded parts resist erosion better than the unbanded parts and give the limestone a ribbed appearance on weathered surfaces.

Two main types of blue limestone alteration occur, which will be considered under the heading of White Limestone and Brown Limestone.

White Limestone

The white limestone is a white to light brown variety, usually fine-grained, but sometimes quite coarsely crystalline. It is an alteration of the blue limestone which retains none of the banding or structure of the blue limestone.

Although the contact between the white and the blue is often sharp, it actually grades into the blue. In many places the contact is indeterminable because of interfingering of white and blue bands. No definite relation between the white limestone and the faults and intrusions could be found.

Brown Limestone

This variety of limestone is of infrequent occurrence. It occurs mainly in thin stringers and narrow zones, usually localized along faults or shears, or next to intrusives. It is a highly altered fine-grained rock and seems to be associated more closely with the white limestone than with the blue. It may be a further alteration of the white limestone rather than a different type of alteration.

Breccia

The breccia is a limestone fault breccia locallized along a well defined fault trending N65°W in the western part of the area. The limestone has been well fractured and broken up into small angular fragments. The breccia has been solidly cemented by silica. Both white and blue limestone fragments make up the breccia, with a predominance of white particles near the white limestone and blue particles near the blue limestone.

Fine-grained Granodiorite

In the northeastern and eastern part of the area are several large intrusive outcrops. This rock is a fine-grained, holocrystalline, dark hypabyssal intrusive. The contact between the granodiorite and the limestone seems to be of an intrusive nature. The contact is somewhat complicated by the presence of altered zones in the limestone along the contact in some places and a lack of this alteration in other places. This is especially well illustrated along the boundaries of the large outcrop of this granodiorite in the extreme northern part of the area.

Coarse-grained Granodiorite

This is a distinctly different type of intrusive and its outcrop is confined to the extreme southwestern part of the area. The rock is granitic in appearance, medium coarse-grained, and rather light colored. It seems almost certain that the contact between this granodiorite and the limestone is a fault contact. This conclusion is based mainly on the fact that there is no alteration of the limestone along the contact. This rock is the main igneous rock of the area.

Pegmatite

The pegmatite is granitic in type, containing few dark minerals. It is only moderately coarse-grained. It occurs as thin dikes averaging four feet in width and in larger irregular patches. The pegmatite is largely confined to the northern part of the area. One large outcrop is found just south of the center of the area. In the northern section it extensively cuts the fine-grained granodiorite. The pegmatites were probably very closely associated with the intrusion of this fine-grained granodiorite.

Acid Dikes

Many rather large and fairly continuous silicic, fine-grained to cryptocrystalline dikes cut through the area. Four or five slightly different types of dikes occur, although some may be only slightly different facies of the same rock. The dikes are confined to the limestone and in no place cut the fine-grained granodiorite. Their relations with the larger intrusive bodies could not be determined.

STRUCTURE

The limestone in the area is very tightly folded. The main axial trend seems to be northwesterly with some local variations. Dips range from 65° to vertical, generally in a southerly or westerly direction. The strikes are generally in a northwesterly direction.

The dark granodiorite in the area is probably post-folding in age. The nature of the outcrop outline and the fine-grained texture of the rock suggests that it was a close-to-the-surface intrusion and was intruded into its present position rather than having been faulted into place as was the coarse-grained granodiorite.

The pegmatite dikes throughout the area were intruded shortly after the emplacement of the fine-grained granodiorite and probably represent an end phase of this intrusion. This is borne out by the fact that the pegmatites are located around this fine-grained granodiorite or cut through it.

There is no clearly defined connection between the alteration of the blue limestone to white limestone and intrusion or faulting. It was observed that, in general, white limestone always occurs in close association with the dikes. On the other hand, white limestone also occurs where no dikes are to be found. It is certainly probable that the hydrothermal alteration of the blue limestone to white limestone is connected, at least in part, to the cutting of the area by these numerous acid dikes. The areas not immediately adjacent to dikes may have been altered by these same dike solutions which came up along fracture planes in the limestone.

The probable fault relationship of the coarse-grained granodiorite to the blue limestone has already been mentioned in a previous paragraph. The absolute lack of alteration of the blue limestone around such a coarse-grained igneous body is an almost conclusive argument against an intrusive relationship.

The area is roughly divided into two parts by a fault zone that trends N65°W and which is characterized by a fairly thick band of breccia which has been discussed in a previous paragraph. The breccia is best exposed in the western part of the area, and in the east traces of the fault become discontinuous. In the area to the east of the mapped area further evidence of shearing lines up well with a continuation of this fault zone.

In the extreme northwestern portion of the area another well defined fault was mapped. Along this fault is a narrow zone of brecciation, averaging a foot in width and characterized by a distinct jasper cement. The trend of the fault is about N20°W. This trend is the same as that of several small subsidiary faults or fractures on the south side of the main fault. The small faults are cut off by the main fault.

ECONOMIC CONSIDERATIONS

The mineralization of this area is definitely that of a contact metamorphic type. The Adelanto Hills have been pretty well prospected for a number of years, and there has been some small production. The primary mineralization is mostly galena, sphalerite, and silver in limestone contact zones. Igneous rock is not always apparent where these minerals are found, and the mineralized areas are often localized along shear zones which show a sort of alteration characterized by garnet, epidote and the like. There has been some hydrothermal mineralization along shears, which are said to show good gold values. Alteration has modified the lead-zinc localities, leaving secondarily enriched ore and forming, in places, secondary deposits of hydrozincite which as yet have not proved to be of commercial value. Galena is very scarce in the ore, and no secondary deposits of galena have been found, although there is a little calamine in places.

The latest development work in the area has exposed some scheelite. The scheelite occurs, apparently, in a small upfaulted block, which has brought to the surface the contact between limestone and an altered porphyry. The scheelite occurs in disseminated grains in both the limestone and the porphyry along the contact. The porphyry does not outcrop elsewhere in the area.