GEOLOGY of the ADELAIDA QUADRANGLE, CALIFORNIA

THESIS

by

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Summary

This geological investigation covers an area lying across the southern Santa Lucia Mountains in south central California, immediately west of Paso Robles.

The land forms of this region are due to structurally controlled erosion which, in most localities, has now produced late mature physiographic surfaces. There are evidences of a Pliocene peneplain, a Pleistocene late mature surface, and vigorous erosion in the present cycle.

The sedimentary series, with an aggregate thickness of over 20,000 feet, includes the Franciscan, Knoxville, Chico, Monterey (Vaqueros and Salinas), Santa Margarita and Paso Robles formations. The sediments cover approximately nine-tenths of the area and are all marine in origin except the Paso Robles. Invertebrate fossils, including a large foraminiferal fauna, were found in the Monterey and Santa Margarita beds, but the other sediments yielded practically nothing.

Igneous rocks include peridotite altered to serpentine, granite, rhyolite, diabase, granodiorite, dacite porphyry and many basic dikes.

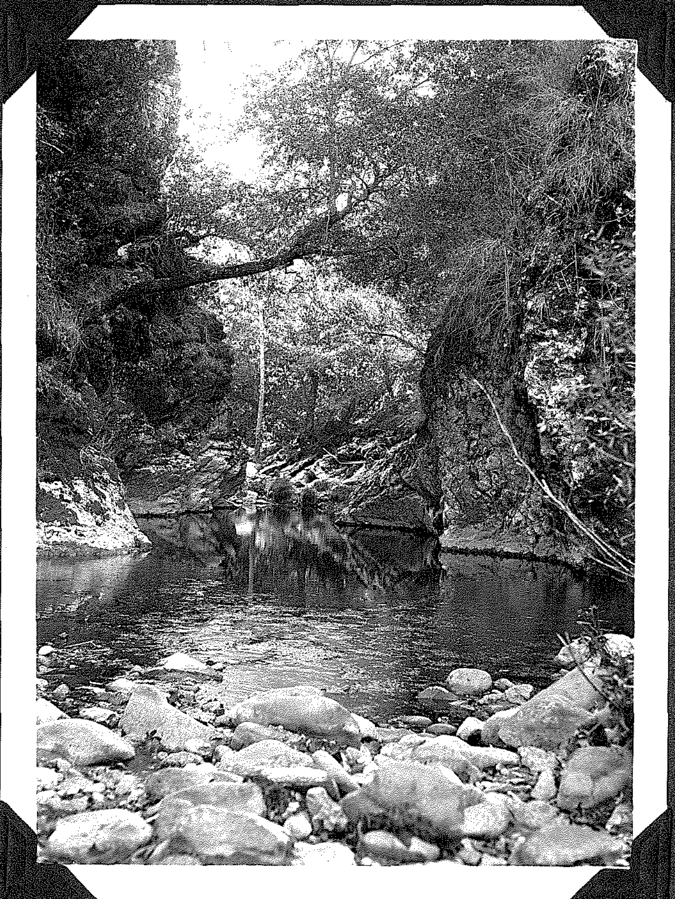
All structural lines trend northwest-southeast, paralleling the Santa Lucia Range. Three major fault zones cross the area. They are: normal faults on the west side of the range, vertical ? faults, with predominantly horizontal displacement, just east of the range, and thrust faults in the northeast part of the quadrangle. Compression

toward the northeast has caused folding, faulting, and perhaps the differential movement of blocks. Faulting is the controlling factor in the structure. A tectonic relationship between the Pacific Ocean Basin, the California Coast Ranges, the Sierra Nevadas, the Great Basin Region, the Rocky Mountains and the Mississippi Valley is suggested.

Early Pliocene deformation formed a range of mountains which were eroded to a peneplain, and later uplift (in two stages) due to faulting produced the masses from which our present mountains have been carved.

Quicksilver, in this area always associated with faults and serpentine, is the most important economic mineral product.

The ore occurs in silicified and calcitized rock or in sandstone. Other mineral resources of possible economic interest are petroleum, flagstones, lime, asbestos, and chromite.



Pool on Franklin Creek

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INTRODUCTION

Location

The area covered by this report consists of the Adelaida Quadrangle which is located in the California Coast Ranges about midway between Los Angeles and San Francisco, in northwestern San Luis Obispo county between Paso Robles and the ocean. The Salinas Valley bounds the area on the east.

Accessibility

The region is easily accessible either from east or west. The coast highway is situated two or three miles east of the district, and the Roosevelt Highway, along the beach, passes but four miles west of the area. Several good roads lead into the quadrangle from Paso Robles and Templeton, in the Salinas Valley; and one automobile road enters the area from the town of Cambria on the coast. Two roads run north and east from Cayucos across the southeastern corner of the quadrangle. A network of fairly good earth roads permits an automobile to be driven to within three or four miles of any point. There are no towns in the Adelaida Quadrangle.

Size

This area is about seventeen and one half miles long

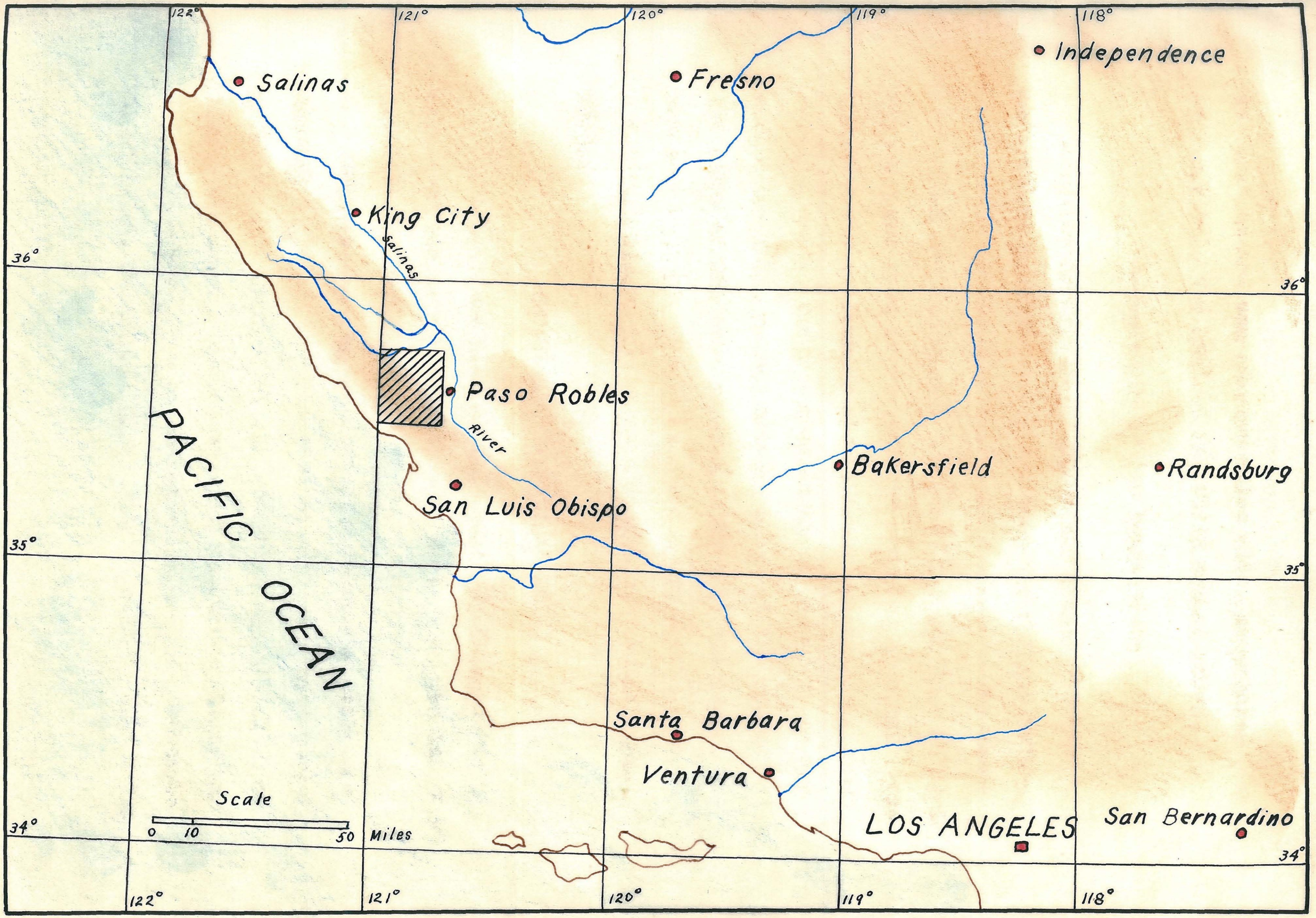


Figure 1 - Index map showing location of Adelaida Quadrangle, California

by fourteen and one quarter miles wide, comprising approximately two hundred and fifty square miles.

Occupations of the Inhabitants

Ranches are scattered about the country, being more numerous in the territory near the Salinas Valley. Much of the district is too densely covered with brush and trees and has slopes too steep for any type of agriculture, and some of it is unfit even for grazing. Two-thirds to three-fourths of the area is devoted to cattle raising, mostly for the production of beef. There are some dairy farms on the seaward slope of the range. In the hills of the east-central portion of the region are scattered almond, prune, pear and apple orchards, with a few fine vineyards and some small but fertile grain fields.

Purpose of Investigation

This work was done as a partial requirement for the degree of Doctor of Philosophy in Geology at the California Institute of Technology.

The choice of this particular area for study was determined largely by the fact that it presented varied problems in stratigraphy and structure concerning which little was known. It was thought that the training involved in working out the complex and varied structures found in the California Coast Ranges would be especially valuable, and the work interesting.

Method of Work

Field-work was done between 1927 and 1931, during which time approximately seven months were spent in the field.

Mapping was begun in the southeast corner and carried northward to the Nacimiento River, and then southward along the western half of the area. Some work was done also in adjoining quadrangles, particularly along the Nacimiento River. The geology was carefully studied during the mapping, and after the completion of the geological map, considerable time was devoted to particular problems which had developed. The field work during 1930 and 1931 consisted mainly of mapping in greater detail and the collection of additional structural data in an attempt to throw more light on the forces and mechanics involved in producing the structures of the Coast ranges.

Acknowledgment

I wish to express appreciation for the advice and help given me by Dr. J. P. Buwalda, Dr. F. L. Ransome, Dr. William Morris Davis and Dr. W. P. Woodring, all of whom were members of the teaching staff at the California Institute of Technology. Aid in the classification of the foraminifera was graciously given by Don Hughes and others of the Texas Oil Company. The kindness and cooperation of many residents of the Adelaida Quadrangle also greatly facilitated the field work. C. H. Lewis, then manager of the Oceanic Mine; L. D. Purdy, owner of the Cinnabar Mining Company property; U. L. Music, Frank Dubost, Frank W. Royer, Jack Stinchfield, W. H. Wimmer and others gave assistance for which I am grateful.

PHYSICAL CONDITIONS

Relief

Most of this district lies between one thousand and two thousand feet elevation, although the maximum relief in the area is 2800 feet. The highest elevations are found along the crest of the Santa Lucia Range, which traverses the southwestern portion of the quadrangle. Here Cypress Mountain rises to about 2925 feet above sea level. The lowest point, having an elevation of only 125 feet, lies on Villa Creek near the extreme southwest corner of the area. Valley elevations along the eastern boundary of the area average approximately 800 feet above sea level; the Nacimiento River, in the extreme north, lies at an elevation of about 650 feet. The greatest contrasts in relief are in the southwest part of the region, where the western slopes of Santa Lucia range descent abruptly to the ocean.

Topography

The topography varies from very steep ridges and canyons, through mountains and hills of moderate slope, to gently rolling hills and nearly flat country. The backbone of the Santa Lucia Range, averaging about 2000 feet in elevation, divides the region into two parts which may be designated the Salinas valley province and the coast province. Southwest from the

Looking S-E Along the Santa Lucia Range.

Looking Westward to the Pacific Ocean from Crest of Santa Lucia Mountains.

crest of the mountains the elevations decrease rapidly to about 750 feet, and the remainder of the coast province consists of rolling hills which gradually become lower toward the Pacific Ocean. Some of the hills of the coast province rise to somewhat over 1000 feet.

A view to the northeast from Cypress Mountain shows a gradual decrease of heights toward the Nacimiento and Salinas Valleys. To the northeast of the Santa Lucia range in the southern half of the quadrangle, lies another line of heights comparable to the crest of the main range and about two and one half miles distant. Thus, the Coast range here consists of two parallel ridges with a gradual descent over hilly country to the Salinas Valley.

The topographical forms are mostly of erosional origin and in stage of development, may be classed as being of late mature or early old age. The steepest slopes are on the sides of stream cut canyons rather than at fault scarps.

In general, the topography as shown on the U. S. G. S. topographical sheet is accurate. However, in localities where especially detailed geologic mapping was done, some errors werefound. For example, elevations shown on the topographical map are incorrect near the Oceanic Mine, and at a few places in the northeast corner of the area, the topographic detail was so erroneous that difficulty was experienced in representing the geology.

Nearly Flat Country East of Paso Robles.

Rock - Paso Robles.

Rolling Hills Between the Santa Lucia Range and the Salinas Valley

Drainage

In a very general way the drainage flows northeast and southwest off the Santa Lucia Range toward the Salinas Valley and the Pacific Ocean, respectively. In detail, the creeks wind about in various directions as determined by structure.

Three major water sheds exist in the Adelaida Quadrangle. The western slope of the Santa Lucia Mountains is drained by numerous creeks which flow comparatively rapidly down to the Pacific Ocean. This region west of the range comprises approximately nineteen percent of the quadrangle.

The major portion of the area, however, lies east of the range and possesses a more complicated drainage pattern. The topography in this province is subdued and many factors influence the location and direction of flow of the streams. Thirty-eight percent of the country east of the range drains eastward into the Salinas River, and forty-three percent, northward into the Nacimiento.

The Nacimiento, occupying a broad, flat, sandy river bed, is the largest river in the quadrangle and generally flows throughout the year, as do many of the smaller streams farther back in the mountains. Both the Nacimiento and the San Antonio (the large stream next north of the Nacimiento) rivers flow southeastward for many miles along weak structures, then turn eastward into the Salinas river which carries the waters back northwestward to the sea at Monterey Bay.

Climate

Climatic conditions vary considerably within the quadrangle. The air temperatures along the coast are mild throughout the year, although the ocean water is exceedingly cold for bathing purposes. Temperatures in the Salinas Valley near Paso Robles are much more variable and range from a summer maximum of 110 to 112 degrees to a winter minimum of about 10 degrees above zero. Fall and spring months are the ideal times for field work near Paso Robles. The summer weather is uncomfortably warm and most of the winter is too cold and wet.

An unusual variation in rainfall occurs in this district. Cyclonic storms move in from the ocean, strike the coast range and drop a large part of their moisture. On the valley side of the range, the precipitation decreases gradually eastward. As a consequence, the coast province enjoys a heavy rainfall, but the Salinas valley is semi-arid. The average rainfall on the coast is about thirty inches annually while the country east of the range receives a precipitation of only ten to fifteen inches.

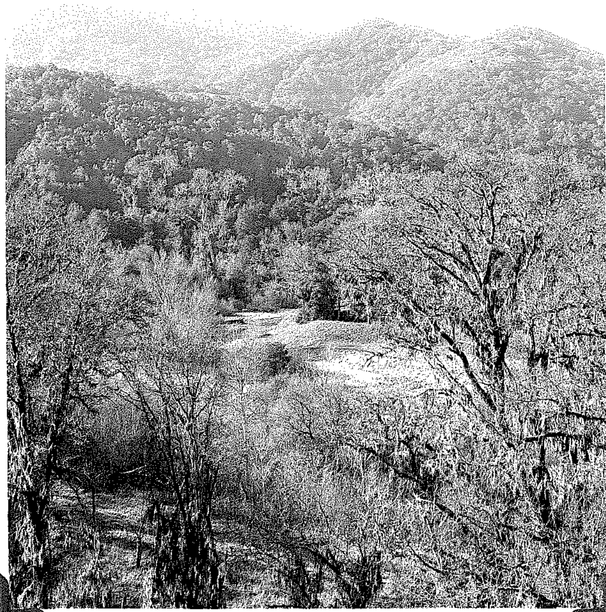
Vegetation

On viewing, from a distance, the hills and mountains west of Paso Robles, one observes a markedly patchy appearance. Some areas are nearly bare and others are thickly wooded or brush covered. Vegetation differs both as to amount and kinds. The growth present on the hills and mountains depending on three factors, namely: the amount of rainfall, the slope of the ground, and the underlying rock formation.

The most common trees are oaks, pines, cypress, madrones, and sycamores. Many canyons and hill slopes are covered by a dense brush growth of many kinds, including considerable poison oak. Some parts of the area are nearly impenetrable. The north and east slopes of the hills are usually heavily wooded, while other slopes more exposed to the sun and consequently warmer and drier, are often grass lands or are covered by brush.

The country on the west side of the mountains receives sufficient precipitation to support streams and a luxuriant flora. But due primarily to the presence of the Franciscan formation, and perhaps somewhat to the strong winds from the ocean, there is very little growth except in secluded canyons. The thickest and most luxuriant vegetation grows near the summit of the range, and on the northeast slopes of ridges, generally at rather high elevations. On the other hand, the northeast corner of the area, near San Miguel and the Salinas Valley, is hot and dry. Short grass, scattered oaks and drought resisting brush comprise most of the vegetation in this district.

The most interesting flora in the region is on Cypress Mountain, which overlooks the sea and rises to nearly 3000 feet.



Thick Vegetation on N-E Slope of Santa Lucia Mountains. Rock - Chico.

Typical Pine Trees of this Region. Rock - Vaqueros.

The southern slopes are grass lands dotted here and there with groups of trees. Near the summit, where the underlying rock is an altered peridotite or serpentine, a tall, dense growth flourishes. On the relatively flat summit is found a world entirely different from that seen anywhere else in the area. Three species of trees completely dominate the flora. A tall, ten to twenty foot shrub with red bark and small, smooth, grey-green leaves forms a dense growth on our left. On our other side is a thick forest of cypress trees towering above the shrubs, and ahead of us is a dark woods composed of cypress and pine trees.

A detailed consideration of the flora and soil, existing on each rock formation, is contained below.

Exposures

Exposures within this quadrangle are widely scattered, and in many places poor. One is forced to work out the geology from only an occasional glimpse of the underlying rock formations. Road cuts and outcrops along creek beds offer the most valuable information concerning the stratigraphy and structure. In most other places the beds are covered by a mantle of soil and vegetation. There are a few exceptions where some of the more resistant formations offer prominent outcrops as residuals of erosion.

Along the banks of the Nacimiento River, mainly north of the Adelaida Quadrangle, occur the best exposures seen in or adjacent to the area covered by this report. An unusually accurate section can be constructed from the material available along this stream, which flows across Vaqueros, Salinas, Santa Margarita and Paso Robles beds.

<u>Outline of Topography, Vegetation and Soils by Formations</u>

I. Paso Robles

A - Topography

1. Low rolling hills or nearly flat country.

B - Vegetation

1. Hills

a. Grass lands and oaks.

2. Wet slopes

b. Thicker growth, mostly oaks.

C.- Soil

1. Light colored loam, fairly productive agriculturally.

II. Salinas

A - Topography

1. May be low and rolling but characteristically consists of high, steep and nearly straight structural ridges.

B - Vegetation

1. Hills

a. Good grass land

2. Wet slopes

a. Thick vegetation of all sorts.

C - Soil

1. Black and very rich (some clay shales form a lighter colored soil).

III. Vaqueros

A - Topography

1. Sandstones

a. Moderately rugged hills

2. Argillaceous shales

a. Rounded hills and open valleys.

B - Vegetation

1. Sandstone hills

a. Brush covered.

2. Wet slopes

a. Denser growth and more trees (some pines)

3. Argillaceous shale valleys

a. Grass lands.

C - Soil

1. Brownish color, rather poor and generally coarse grained.

IV. Chico

A - Topography

1. Sandstones

a. Rather steep and rugged hills.

2. Shales

a. Form valleys

B - Vegetation

1. Hills

a. Brush

2. Wet slopes

a. All kinds of dense growth

C - Soil

1. Brownish color, fairly good.

V. Knoxville

A - Topography

1. Steep slopes and prominent, sharp ridges.

B - Vegetation

1. Very dense growth of all kinds, everywhere.

C - Soil

1. Dark brown to reddish brown, good.

VI. Franciscan

A - Topography

1. Low and rolling to decidedly hilly. Sandstone hills are well rounded.

B - Vegetation

1. Nearly all grass lands with some trees in the canyons.

C - Soil

1. Extremely variable but is often unusually rich in alluviated canyons or valleys.

VII. Granite

A - Topography

1. Smooth to rolling.

B - Vegetation

1. Brush and small oaks.

C - Soil

1. Coarse, light colored and poor.

VIII. Peridotite

A - Topography

1. Low lying country and moderately smooth ridges.

B - Vegetation

1. Exceedingly scanty when the rock has been highly serpentinized, but on Cypress Mountain a luxuriant growth is found.

C - Soil

1. Generally shallow and poor, reddish brown.

IX. Diabase

A - Topography

1. Hills

B - Vegetation

1. Brush or grass

C - Soil

1. Dirty brown color, fair.

X. Rhyolite

A - Topography

1. Very rugged.

B - Vegetation

1. Heavy growth of grass, brush and trees.

C - Soil

1. Rich.

XI. Basic Intrusives

A - Topography

1. Rounded hills

B - Vegetation

1. Grass

C - Soil

1. Good, dark colored.

Note (Franciscan cherts form prominent tors)

PHYSIOGRAPHY

Preliminary Statement

Since a complete cross-profile of a mountain range is found in the Adelaida Quadrangle, the method of physiographic treatment employed in this report could be applied to any mountain system.

The type of mountain range with which we are dealing in this paper, owes its origin to movements of the earth's crust. Large displacements along faults have brought the present range into being; this portion of the Santa Lucias therefore may be classed as a tectonic mountain.

Having postulated movements which created the mountainous elevation, we are next interested in: first, the form of the pre-uplift surface; second, the nature of the erosional processes; third, the internal structure of the block; and finally, the stage of erosion reached at the present time. All of these factors affect the physiographic development.

There is reason to believe, as will be shown in detail below, that the present cycle of erosion was initiated on an old age surface that had been elevated and tilted slightly eastward. The area being situated at a moderate elevation in a temperate climate, the chief agency of erosion has been running water in the form of large and small streams. Structural conditions of this part of the range are varied. The predominant rocks are folded sedimentaries of unequal hardness. Folds and faults trend northwest, parallel to the orientation of the range. In this area the Santa Lucia range has now progressed to a mature stage in physiographic development, only tiny remnants of the original surface remaining.

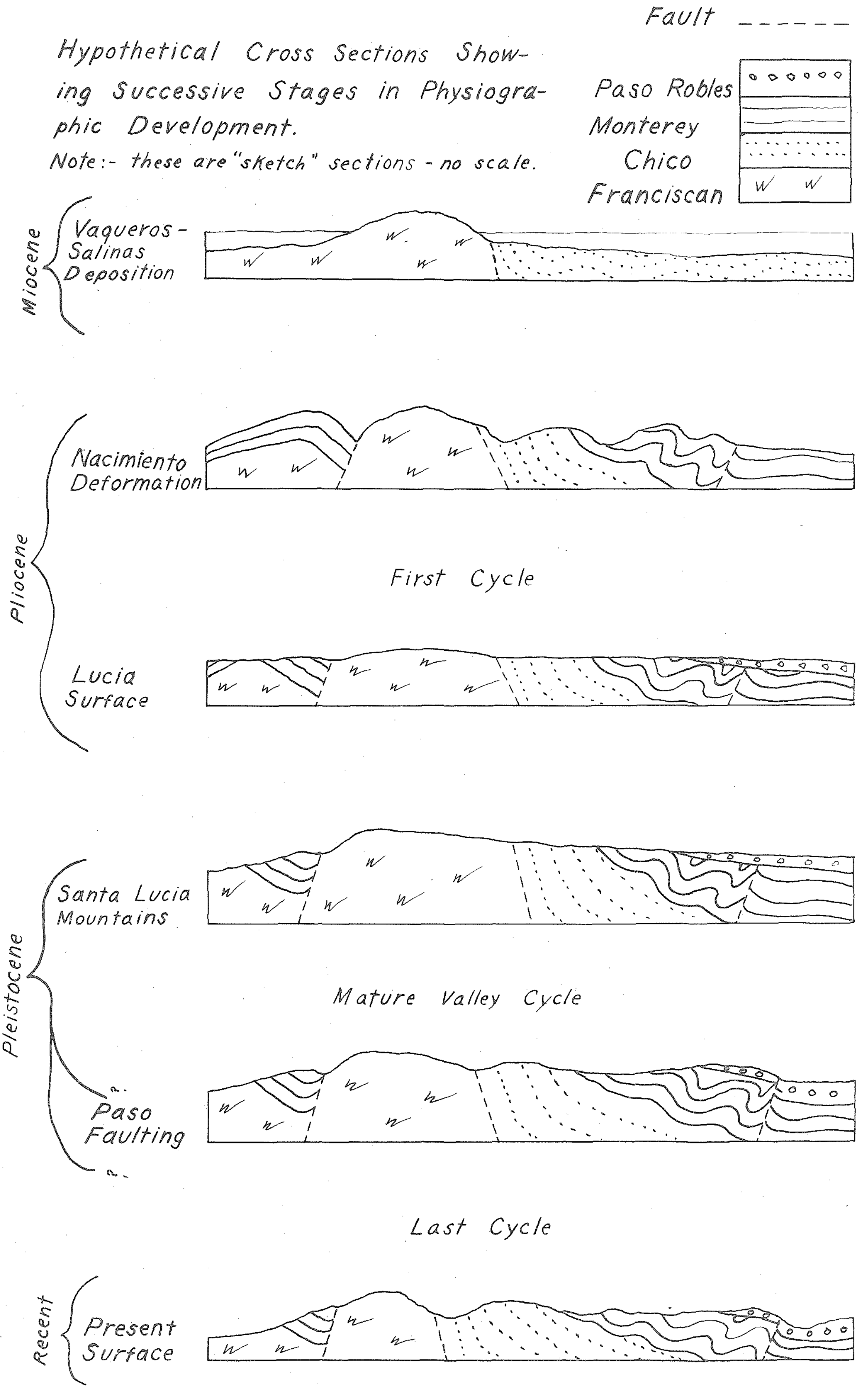
Physiographic History

A discussion of the successive events which have influenced the physiographic development of the region will aid the reader in understanding both past and present conditions, and will also provide a standard of reference in describing the existing land forms. A series of six sketches, representing different stages of development in the history of the region are included here for reference in connection with the discussion which follows. These sections are greatly generalized and are intended to illustrate only the most important features.

In Miocene time the sea covered nearly the entire area, but it is thought that a point of land extended from the northwest, into the north-west-central part of the quadrangle. Evidences that this positive area existed in Miocene time are; first, absence of Monterey beds on the block; second, presence of pre-Monterey faults on its eastern margin; third, evidence of shore line conditions in the Vaqueros (?) which lies immediately east of this block. At the end of the Miocene, or more probably

Hypothetical Cross Sections Showing Successive Stages in Physiographic Development.

Note:- these are "sketch" sections - no scale.



The line of sections is through Cypress Mt. and N-E corner of Quad.

in lower Pliocene time, mountain making forces faulted, folded and elevated the region. This disturbance, called the Nacimiento deformation, and the resulting mountains, the Nacimiento mountains,came into being following the deposition of the Santa Margarita formation. This seems to be the first appearance of a range southeast of the Cypress Mountain region, which had previously been a negative area receiving marine sediments in Knoxville, Chico, Vaqueros and Monterey time.

Extensive erosion during the Pliocene period reduced the Nacimiento Mountains to a surface of low relief and but slight elevation. This surface, designated the Lucia surface, is the one from which the present mountains were later carved.

Probably in Pleistocene time, the Lucia surface, in some places bevelling Miocene and older strata, and in other places representing the depositional surface of the Paso Robles beds, was elevated by the Santa Lucia uplift. This uplift, probably due primarily to faulting on the west side of the block, created the Santa Lucia Mountains. The Lucia surface was tilted eastward, and the processes of erosion continued their ceaseless work in cutting away material and shaping land forms.

After a considerable time, renewed faulting (called the Paso faulting) along the northeast front of the range caused an appreciable uplift which initiated a period of rapid erosion, the present cycle. This Paso faulting displaced the Paso Robles formation and the old erosion surface northeast of Chimney Rock (seemap).

Since the Paso Faulting, erosion has progressed to a late mature stage in most parts of the area, but in the northeast part of the quadrangle there are several youthful canyons. This is perhaps explained by postulating renewed movement along some of the faults. The only remnants of the Lucia surface exist on Cypress Mountain, and on the next high ridge farther east.

Present Land Forms

A relatively small area on the summit of Cypress Mountain is gently rollins. In contrast to the side slopes of the mountain, the top is nearly flat, but has a slight inclination toward the northeast. This is thought to be a remnant of the Lucia peneplain, and, at this point, is cut on Franciscan serpentine.

Two or three miles east of Cypress Mountain, and at an elevation several hundred feet lower, are several flat topped ridges. This surface, which is presumably a portion of the Lucia peneplain, here bevels Chico strata. The difference in elevation of these two remnants strengthens the hypothesis of an eastward tilt for the Lucia surface.

Along the south bank of the Nacimiento river, the Salinas-Paso Robles contact is well exposed. The Paso Robles beds lie across the edges of highly folded Salinas shale which has been bevelled by erosion. The contact is a nearly flat surface which tilts gently eastward. It is considered to represent a locality, near the western edge of Paso Robles deposition, where the continued accumulation of sediments so raised the base level that deposits were laid down on a surface which had been recently formed. Strictly speaking, the Lucia surface lies on the Paso Robles beds at this point. However, the narrow strip fringing the area of earlier Paso Robles deposition, which was first degraded as a part of the Lucia surface and then covered by detritus, (now the Salinas-Paso Robles contact at this locality) gives data concerning form attitude and age of the Lucia peneplain. See sections 2 to 4.

The cases considered above represent the only actual remnants of an old peneplain. In other parts of the Santa Lucia Range, extensive areas of the old erosion surface still exist. But due to the presence of relatively soft sedimentary rocks in this area, erosion has nearly obliterated all evidence of the Pliocene peneplain. Even crests of many of the ridges and hills, often very noticeable, suggest an old surface. The gradual decrease in elevations from the western side of the range eastward, suggests a tilting toward the east. As a decided contrast to the gentle eastward slope, we have a sudden drop, of approximately 1000 feet; on the west side of the Santa Lucia Range.

Land forms now existing in the area are due almost entirely to structurally controlled erosion, consequently, the fault scarps have been greatly subdued, and the majority of the hills have a mature form. The only steep slopes in the region are along stream cut canyons, generally where a creek passes through an area of relatively harder rocks.

In the northeast part of the quadrangle where the Paso faulting took place, we find the youngest land forms. The elevation caused rapid downcutting and many of the canyons are exceptionally steep sided, some having slopes of over 40 degrees. Some streams are flowing along the strike of Salinas shales which stand nearly vertical, and this tends to increase the steepness of the side walls.

It is in the canyons of sections, 19, 20, 29 and 30, T 25 S, R 11 E, that the last two cycles are most evident. Along the sides of these gorges are found many hanging valleys, and while the lower part of the canyon walls are steep, the upper few hundred feet are represented by broad, mature valleys. There is a sudden break between the gorge portion and the more subdued slopes near the top of the canyon walls.

The relation of the Lucia and Mature Valley surfaces to the Paso Robles formation is very significant. The latter is made up of material eroded in forming the Lucia surface. At some localities the Santa Lucia uplift was was not sufficient to enable another, distinct, and younger erosion surface to develop; the Mature Valley or Salinas surface. Consequently, near the edge of a block where there was little or no uplift, the Lucia peneplain and the mature valley surface may merge. This seems to be the case near Paso Robles, because no great amount of Paso Robles beds have been stripped off, indicating no important post-Paso Robles elevation at this locality. Landslides are common features in most of these exceptionally steep canyons. The slides have partly dammed a stream in the north-east part of the area and caused it to zig zag around the sudden obstruction.

Drainage System

A conflict for supremacy between consequent and subsequent streams has been important during the development of the present drainage system. In the case of some of the larger creeks and rivers, their courses were determined during the Lucia erosion period and they held their same position when the new cycle was begun. Other streams were first consequent on the Santa Lucia uplift, only to seek subsequent courses later. In a few instances renewed uplift induced subsequent streams to either leave their old courses and flow across structures, or allow consequent creeks to capture them.

As has been mentioned under "Drainage" and is well shown on the drainage map, the area of the quadrangle forms parts of three watersheds. The drainage map clearly illustrates a marked difference between the two divides which separate these water sheds. The Lucia divide separates the direct westward ocean drainage from the Nacimiento and Salinas systems, and the Ayers divide lies between the Nacimiento and Salinas drainage basins. The first, a structural or fault formed divide, is approximately straight. The other, which has slowly developed its present form through differential erosion, is very irregular and winding in plan. Near the eastern edge of the block, where differential erosion has not played such an important role, the divide follows a straighter course.

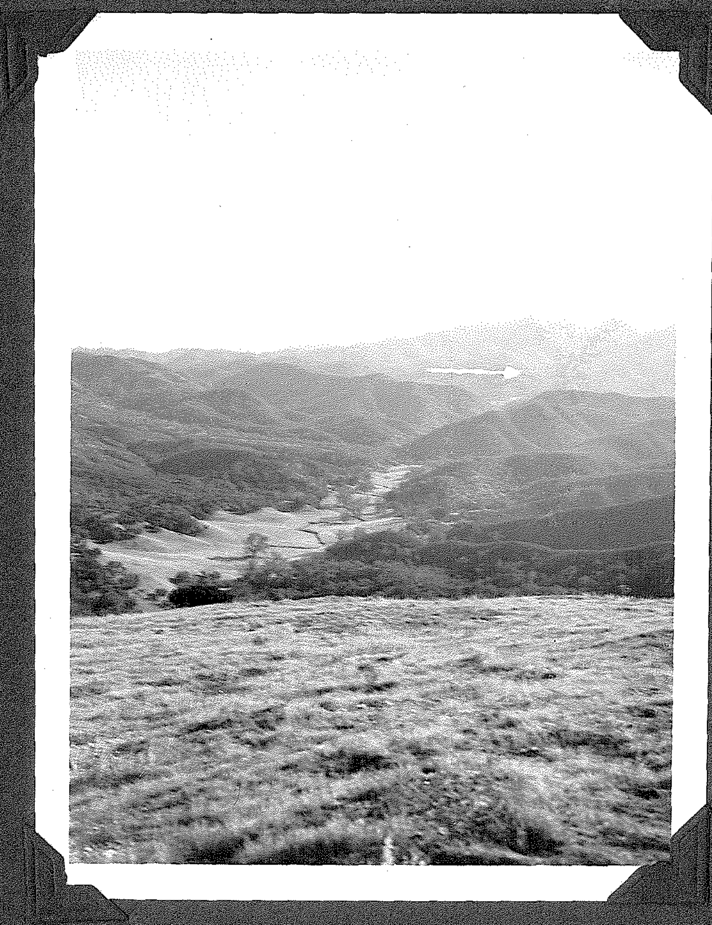
West of the Lucia divide the creeks are all consequent on the Santa Lucia uplift. In this region the present crest of the range, lying from five to ten miles from the ocean, has an elevation of nearly 3000 feet. The upper part of this steep slope represents the fault scarp on the west side of the range block. Between the steep mountain slope and the ocean, there lies a belt of territory that was uplifted, but not to such an extent as the main range. Across this surface the streams flow with sufficient velocity for degradation.

In most places, the underlying rocks are Franciscan, which have no recognizable, general structure. Whatever influence these underlying rocks might have on the development of the stream courses, would be very irregular and would not tend to give the streams any particular orientation. As a consequence, due to the steepness of slope and lack of definite structural pattern in the underlying Franciscan rocks, the streams have been able to maintain their consequent courses.

Conditions are somewhat more complicated in the Salinas basin east of the range. In the first place, during the formation of the Lucia surface, the Salinas river did not exist in this region. Paso Robles lake beds, which were deposited during this time, now extend across the present bed of the Salinas river. Streams from the west, north and south (including what is now the headwater of the Salinas river) apparently flowed into this inland depression occupied in part by the Paso Robles lake. The supposition that a lake existed over a large part of the basin is based upon the presence of thin but extensive chalk beds that contain fresh water gastropods. Probably at the time of the Santa Lucia uplift, changes in the country to the northeast opened a drainageway to the sea. The Paso Robles depression was drained and the Salinas river began to cut into the Paso Robles beds.

Santa Rita Creek is a consequent stream which maintains its course across the northwest trending structures. Jack Creek is partly consequent and partly subsequent, while the

Subsequent valleys
Parallel to strike of Salinas shale.



Consequent stream flowing across strike ridges.

→

Captured subsequent

the courses of some of its tributaries are controlled by structure and others (which flow across the strike of the beds) by the rapid downcutting of the master stream. Some of these tributaries should be classes as insequent streams. San Marcos Creek represents a strong consequent drainage, but most of its tributaries are subsequent.

The small creeks near the Salinas River, which flow on Paso Robles beds, are not influenced by the underlying rocks and are consequents. Inasmuch as the portion of the Santa Lucia Range south of the headwaters of the Santa Rita Creek was not raised to an elevation equal to that farther north, the southeast flowing streams of this locality may owe their location to a consequent slope rather than to an underlying structural control, although they do parallel the structures.

All streams north of the Ayers divide empty their waters, directly or indirectly, into the Nacimiento River. Although situated mostly to the north of the Adelaida Quadrangle, the anomalous southward flow of the Nacimiento and San Antonio Rivers invited speculation and study. It seems likely that these rivers flowed south-eastward into the Paso Robles basin during the formation of the Lucia peneplain. When the Santa Lucia uplift occurred and the Salinas River drainage was opened to the sea at Monterey, the Nacimiento and San Antonio Rivers maintained their old position, and therefore, might be classed as antecedent.

Broad, Nearly Flat Bottom of the

Nacimiento River; Late September

of a dry year.

They have maintained their southerly direction of flow in the face of regional uplift and tilting which caused the Salinas river to flow northward and begin degrading.

It seems entirely possible that Las Tablas Creek may flow in the same bed that it occupied on the Lucia surface, but it may be that the rapid cutting of the Nacimiento River in the present cycle was responsible for the location of Las Tablas Creek. The nearly straight northwest trending portion of Las Tablas Creek, and also of Franklin Creek, follows a fault line.

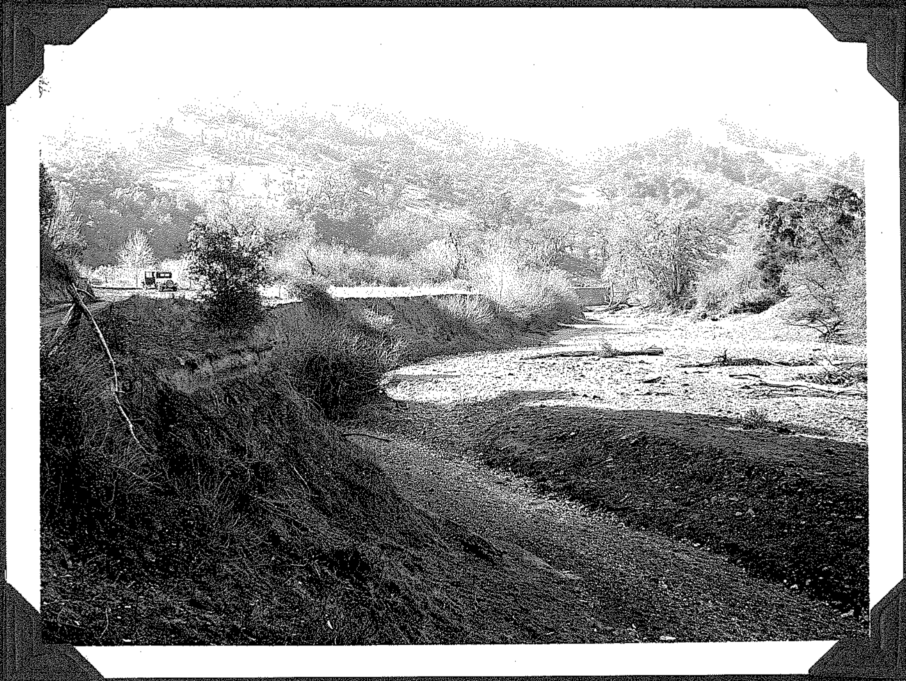
The Paso uplift must have been of appreciable magnitude in the northeast part of the area. Most of the streams now cut directly across the structure and flow toward the northeast. Some appear to have left their old subsequent valleys and run down the side of the block. The stream flowing northward in section 25 appears to have captured an old, northwest flowing subsequent drainage which roughly follows the position of the unimproved road shown on the map. This is the drainage appearing in the accompanying photograph.

River terraces have been developed by some of the larger streams, especially along the Nacimiento River and Santa Rita Creek. There is a terrace, approximately fifteen feet high, on Santa Rita Creek at the junction with its south fork. A half mile or so, farther up the creek occur both a fifteen foot and a six foot terrace. Below the forks, the Santa Rita Canyon is steep sided and the stream gradient is greater than that above the forks. The main creek above the forks flows slowly through Franciscan rocks, and then rushes through the Chico beds. It seems that the Franciscan rocks eroded more easily than the hard Chico sandstone, and the belt of outcropping Chico has acted as a partial dam or barrier to Santa Rita Creek.

The fact that a large stream cuts down much more quickly than its tributaries is demonstrated along this creek. Although, above the forks, the stream has temporarily cut down nearly as far as it can and is now flowing slowly, its tributaries are still steep and actively eroding in an attempt to become accordant with the master stream.

Three terraces occur along Santa Rita Creek where it issues into open country farther east. These may be due to lateral wanderings of the stream as it has progressively cut down.

About two miles southwest of Chimney Rock, a large anticlinal valley has formed in Vaqueros? beds. At many localities large amphitheaters and open valleys have developed in regions of soft rocks, as in the Vaqueros (?) mud shales. Oftentimes narrow canyons, trending parallel to the strike of the beds, are due to the presence of soft shales. At first glance, these prominent and straight features may easily be mistaken for fault lines.



Alluvial Terrace along Santa Rita Creek.

Open Valley Formed in Vaqueros Beds

Near the Axis of a Large Anticline.

Physiographic Correlation with Other Areas

The Lucia surface discussed in this area corresponds to Fairbank's Santa Lucia peneplain described in the San Luis Folio. These two erosion surfaces can be correlated both as to age and present position on the range. The Lucia peneplain is bevelled across the edges of Miocene (and all older) beds, and represents the original form of the present mountains before uplift. It is probably upper Pliocene in age.

As stated by Fairbanks, there are practically no indications of his Salinas peneplain in the region near Paso Robles. It may be, however, that the mature valley topography near the tops of the steep canyon walls in the northeast part of the area, is an expression of the Salinas peneplain.

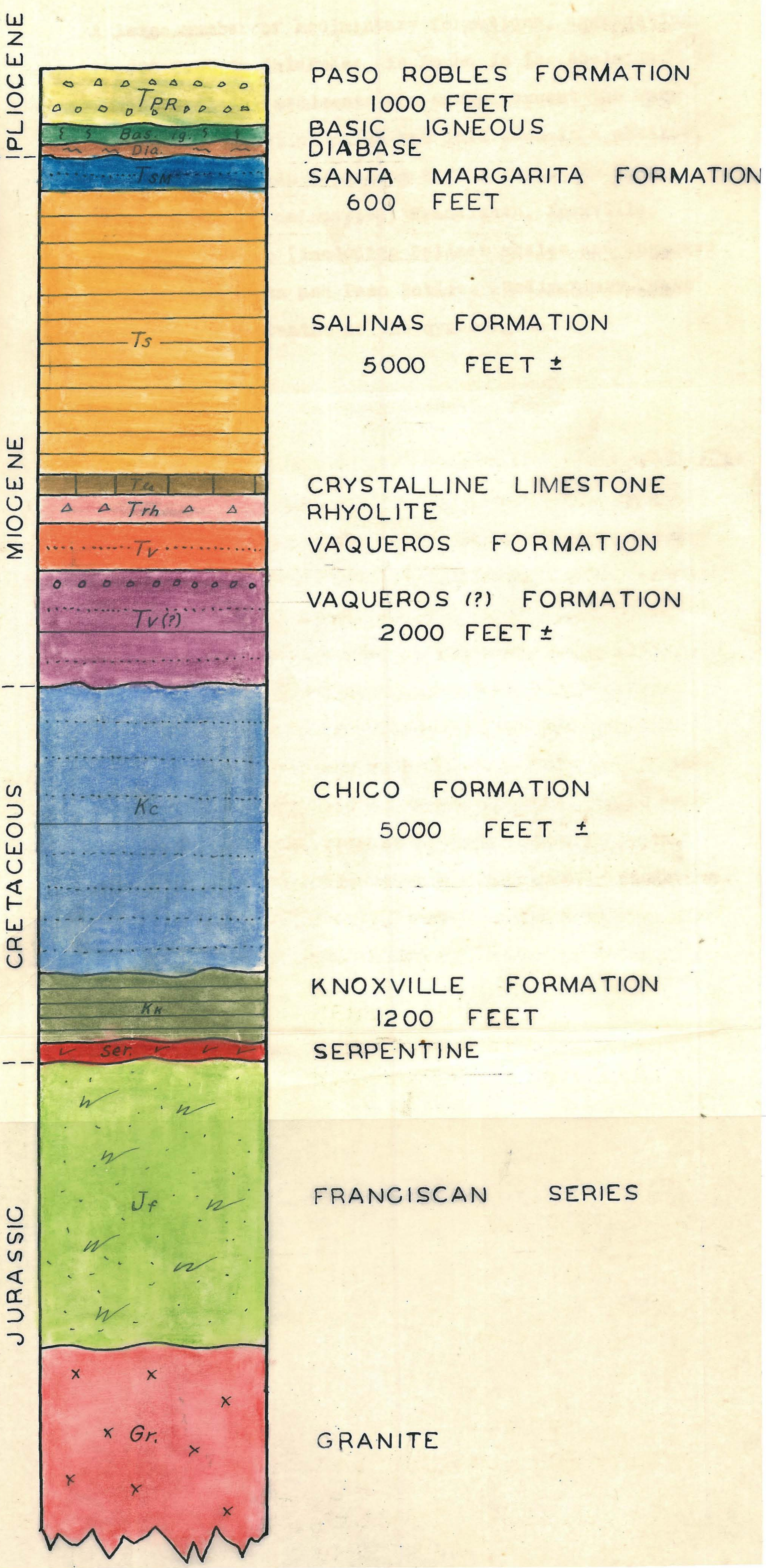
A close correlation is also possible with the work of P. D. Trask in the northern part of the Santa Lucia Range. Trask's erosion surface of low relief, formed at the end of the Pliocene, probably corresponds to the Lucia surface of this report. Trask described the last elevation as coming in two stages, as evidenced by the two faced character of the canyon sides. This two stage elevation has also been described above as occurring in the Adelaida Quadrangle.

Robin Willis also describes three cycles in the Gabilan Range. Trask seems to believe that the cycles of erosion in his area are of a somewhat younger age than those described by Willis and Fairbanks.

In general, there is a marked agreement amongst the investigators mentioned above, and also in the facts found in the Adelaida Quadrangle. Each author finds flat topped peaks, representing the oldest cycle; mature valleys, indicating a second cycle; and steep canyons formed in the third and last cycle. The mature valley surface is probably the same as the Salinas peneplain of Fairbanks.

Briefly, a statement of physiographic history which may be applied to the entire Santa Lucia Range, is as follows: Early Pliocene faulting, folding and thrusting which produced a mountainous area, was followed by erosion which developed a surface of low relief (the Lucia peneplain), at which time the Paso Robles beds were being deposited; this surface was elevated, eroded to the mature valley stage, and reelevated into our present Santa Lucia Range which has now been greatly modified by erosion.

COLUMNAR SECTION
ADELAIDA QUADRANGLE



STRATIGRAPHY

A large number of sedimentary formations, aggregating over 20,000 feet in thickness, is found in the Adelaida Quadrangle. All the sediments are marine except the Paso Robles formation, part of which was laid down in a shallow, fresh water lake. Beds belonging to the following ages have been recognized and mapped; Franciscan, Knoxville, Chico, Monterey Group (including Salinas shales and Vaqueros beds) Santa Margarita and Paso Robles. Sedimentary rocks cover at least nine-tenths of the quadrangle.

Franciscan Series

The Franciscan formation, so often found in the California Coast Ranges, occupies more than fifty square miles in the southwest portion of the quadrangle. No data concerning an age determination was obtained, so, following earlier authors, this series has been assigned to the Jurassic. Franciscan rocks cover the low country west of the Santa Lucia range, a large part of the range itself, and a considerable area east of the main range. The Franciscan landscape commonly contains hilly or mountainous grass lands, nearly devoid of trees and shrubs, dotted here and there by tors (jagged outcrops of chert) and small patches of dark intrusive rocks.

These Jurassic (?) sediments are predominantly sandstone. It is highly weathered and soft, except in the immediate vicinity of an intrusive rock. However, in some of the deep canyons east of the main divide in section 25, township 26 south, range 9 east, sandstone classed as Franciscan is extremely hard. Near this locality is a mass of even harder, blue schist, or perhaps slate, except that the rock is massive. Some shales also belong to this formation. The igneous rocks occuring in the Franciscan are: peridotite, serpentine, various basic intrusives, basalt, rhyolite and diabase. The Franciscan group is so disturbed and contains so many different types of rock that no serious attempt was made to separate individual members within the formation. No accurate estimate could be made concerning the thickness of the sediments.

The sandstones have a coarse to fine grained texture, often inequigranular. Fresh samples are very hard, but most exposures are so highly weathered that the rock is soft. Newly broken surfaces of fresh rock are blue-green. Weathering causes a change to a darker shade approaching an olive-green, and finally to brown. In a great many places these sandstones have been locally metamorphosed by intrusives. The stage of incomplete metamorphism exhibited by some sandstone samples is easily seen when studied in thin section. A section showed considerable chlorite, grains of orthoclase and plagioclase, rounded quartz grains, scattered quartz crystals and also veinlets of small, secondary quartz crystals.

Grains in the sandstone beds are subangular to well rounded, and include an unusually small proportion of quartz, less than 50% in many samples. Feldspars, dark grains, muscovite and biotite are abundant. A few particles, decidedly larger than the average grain size, of a dark basic igneous rock are often present. Quartz and calcite veinlets are commonly seen in the sandstone, which may also be rather pebbly.

Although the sandstones make up the major portion of the Franciscan sediments, there are some shales and conglomerate. Many of the shales are really thin bedded, shaly sandstones. The true shales are hard, and exhibit a dark or blue-green color, and have generally been greatly crushed and altered. The conglomerate, if fresh, is very hard, contains small, rounded pebbles of clear quartz, chert and many other kinds of rock ranging in color from white to black.

One of the most interesting rocks in the formation is a steel-blue colored schist. It is very hard, extremely fine grained, and sometimes contains large disseminated patches of chalcopyrite and some pyrite. Due to its hardness and metamorphosed condition, this schist gives an impression of being older than the surrounding rocks. It may even belong to some older formation than the Franciscan, because pebbles found in nearby sandstones, that were tentatively classed as Franciscan, appear to have been derived from this schist. Radiolarian cherts occupying certain horizons in the Franciscan have long been a matter of interest and speculation. They are typically a reddish-brown color, but may be yellow,

On Cambria - Paso Robles Road Grade,

Near Head of Santa Rosa Creek.

Rock - Franciscan Shales.

white, gray, blue, green, pink or some combination of colors in the same layer. These cherts are often perfectly bedded, each layer being a few inches in thickness, and may contain nodules that closely resemble fossils. The bedding in the cherts, and their position in the sandstones, leads to the conclusion that they are sediments deposited contemporaneously with the sandstones.

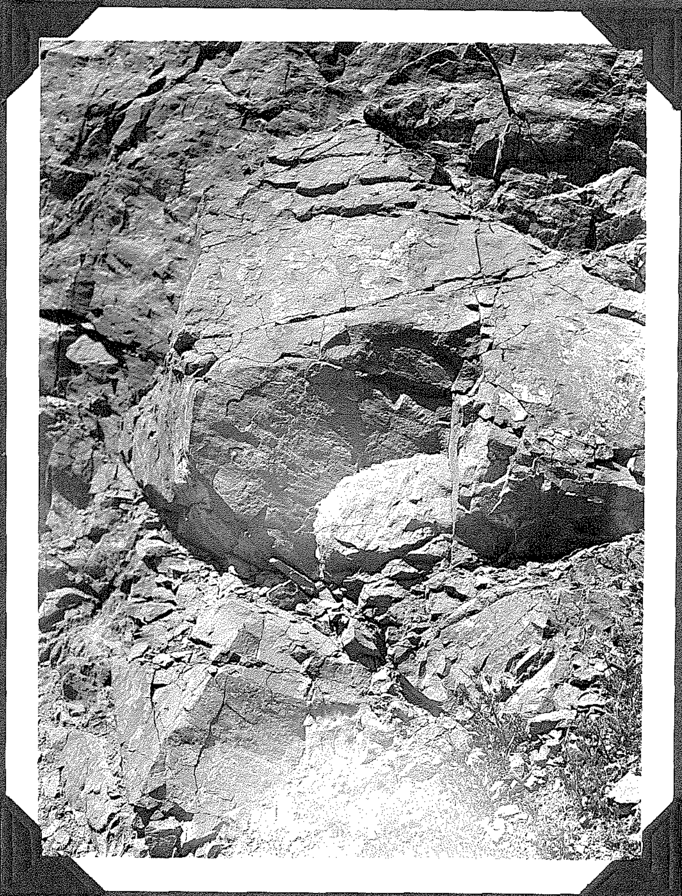
An association of other cherty masses with igneous rocks in numerous places within this area, suggests an igneous origin. It seems probable that the siliceous solutions issued from the rocks on the sea bottom in association with igneous activity in Franciscan time. This surplus silica was then laid down as a sediment on the floor of the ocean. At a few places in this area cherts have apparently replaced and entered the sandstones after their formation, but this can not be the explanation for the large chert ledges so characteristic of the Franciscan formation. I would say that the siliceous deposition took place comparatively rapidly, as suggested by their local character, igneous association, and homogeneity.

The fact that radiolaria exist in the cherts and apparently not in the nearby sandstone, may well be explained by saying that they were not preserved in the sandstone. The reddish cherts examined in thin section reveal a crypto-crystalline mass of quartz with tiny veins of secondary silica. A few round, brownish blotches that may be radiolarians were found.

Landslide in Franciscan Serpentine

Tor of
Franciscan
Chert

Franciscan
Sandstone



Knoxville
Shale

Knoxville Formation

The Knoxville formation occupies a narrow strip for a few miles along the eastern side of the Santa Lucia crests and underlies a little less than four square miles. It consists mainly of shales with some thin bedded sandstones and a very little conglomerate. Following previous work this formation has been classified as Cretaceous. Although the writer did not find Knoxville fossils in this area, these beds were traced southward into the shales from which Fairbanks collected fossils of Knoxville age.

The sandstones are thinly bedded, very hard, fine grained, exhibit a blue-green color on fresh surfaces which change to olive-green and brown when weathered. The texture is equigranular and the grains may be subangular but are usually well rounded. There are many changes from sandstone into shale, but the typical Knoxville beds of this area are composed of fine grained shale, hard but crumbly, dark colored, and often giving a burnt appearance. Fine bedding lamina in a hand specimen is rather common.

The conglomerates occur as thin, highly indurated beds with a sandstone matrix. The pebbles are well rounded and small (average $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter but may range up to a few inches). They are composed of chert, slate, quartzite, and other dark colored rocks. On being broken, the conglomerate generally does not fracture through the pebbles, but around them.

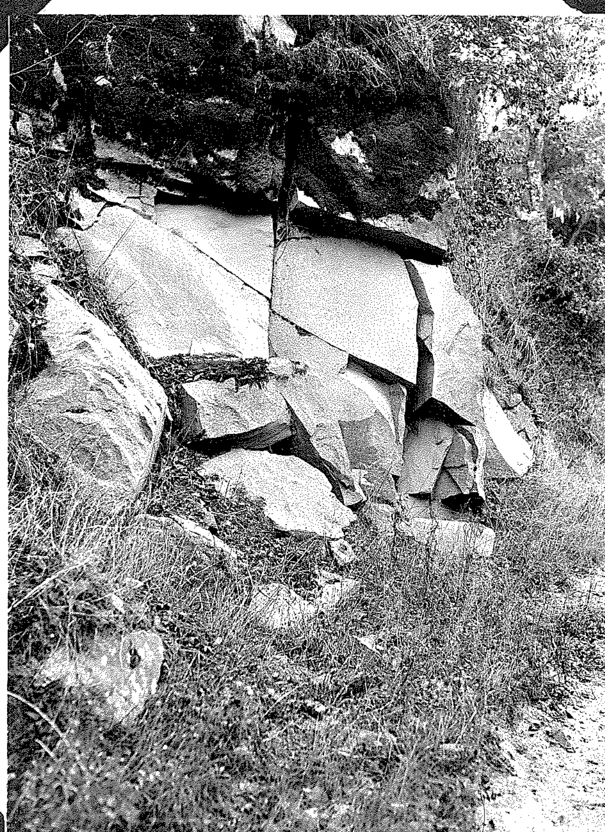
Chico Formation

Chico beds, occupying the south-central part of the area along the eastern side of the mountains, cover more than twenty square miles and total approximately 5,000 feet in thickness. The formation is composed primarily of hard, massive, greenish sandstone with some shale and a little conglomerate. Although no important fossils were found in these beds, they were tentatively classified as upper Cretaceous.

Chico sandstone, when fresh, is extremely hard. Most samples have a conchoidal fracture. In outcrops the beds appear gray, dark olive-green, yellow or brown. In the bottom of steep canyons the color is olive-green, but on the tops of hills, where weathering is more advanced, the rock is soft and has a dull yellow color. The sandstone is very massive in some localities but in other outcrops, the bedding planes are quite distinct and the rock may grade into a shaly sandstone. The texture is coarse to fine grained, but is generally equigranular and the grains are subangular to rounded. Quartz, feldspar and biotite are the major constituents, although white mica and numerous dark grains are usually present. Clay pebbles of Knoxville or Franciscan shale are found in the Chico sandstone.

Clay shales, interbedded here and there with the sandstone, are greenish-brown in color, hard but less resistant to weathering than the sandstone beds.

Chico Sandstone



White sandstone
and Conglomerate
at the Base of the
Salinas Formation.

Conglomerate occurs in the Chico formation of this region, but it comprises only a small portion of the Chico. The conglomerate is interbedded with sandstone and shale. In the conglomerate there is considerable variation from place to place in the relative percents of pebbles and matrix, some portions being practically all matrix containing but a few scattered pebbles. The matrix consists of a green, clayey material. Pebbles are subangular to rounded, and are predominantly a coarse grained, light colored, igneous rock; a light colored, fine grained, igneous rock and also colored, igneous pebbles.

Monterey Group

Taken as a whole the Monterey group comprises about two-thirds the total thickness of sediments in the area, and has an areal distribution covering nearly three-fourths of the quadrangle. This formation includes siliceous shales, mud shales, white sandstone, coarse, pebbly sandstone, limestone, conglomerate, rhyolite and many gradational phases of sediments. Figure #1 shows, as well as could be ascertained, the succession of beds in the Monterey Group. This columnar section is somewhat generalized in an attempt to include the types of sediments found throughout the area. It may be that clay shales in one place are the correlative of coarse sandstone in another part of the region.

In this report the name Salinas formation is used for the upper part of the Monterey, and the Vaqueros formation for the lower portion. Due to the perfectly conformable contact between the Salinas and Vaqueros beds, the line separating the two is quite arbitrary. An attempt has been made to include only the siliceous shale and minor interbedded thin layers of limestone and sandstone in the Salinas.

Lying conformably below the Salinas shales are massive, white sandstones in which typical Vaqueros fossils were found. The lower part of the section, still conformable to the fossiliferous Vaqueros, consists of a great thickness of pebbly sandstone interbedded with some conglomerate and shale. These beds are probably Vaqueros, but as no fossils were found in them, they were mapped separately from the beds of proven age, and are designated Vaqueros (?).

In a few cases, where the coarse beds were so thin or limited in extent that it is difficult to map them, the sandstone and conglomerate at the base of the siliceous shale have been mapped as Salinas. Rhyolite, both tuff and lava, occurs at the base of the Salinas formation. Small, black blotches of petroleum stain are often seen in the shale of the Monterey Group, in both the Vaqueros and Salinas formation.

Vaqueros (?) Formation

Different beds in the Vaqueros (?) formation vary in texture from place to place. Conglomerates range from a few feet in thickness up to 150 feet or more, the best exposure of conglomerate being at Chimney Rock on the San Marcos Creek road. The matrix of this Chimney Rock conglomerate is a pebbly sandstone, and the relative percents of matrix and pebbles change in a direction perpendicular to the bedding. The pebbles are subangular to rounded, and are composed of chert, quartz, granite and fine grained igneous rocks of a variety of colors.

Near the Paderewski Ranch on the Adelaida road is a reddish-brown exposure of Vaqueros (?) conglomerate which grades upwards and downwards into a coarse to medium grained sandstone. About three-fourths of the rock consists of subangular to well rounded pebbles, up to one foot in diameter, of blue andesite, chert, quartz, coarse igneous rock and greenish shale.

This conglomerate, which underlies the white sandstone, is continuous from Paderewski's ranch on the Adelaida road northward to the Nacimiento River, a distance of over ten miles.

Vaqueros (?) sandstone varies in texture from a fine grained, thinly bedded shaly layers, to a coarse, pebbly and massive sandstone. This sandstone is cross-bedded at some localities. The characteristic Vaqueros (?) sandstone in this area is coarse grained, inequigranular and inclined to be pebbly. The fresh rock is exceedingly hard, but at most outcrops it is sufficiently weathered to become soft. Grains are generally subangular but may be either angular or rounded, and the most common color is gray when fresh, and is a light greenish or reddish brown when weathered. The composition of the sandstone is variable but quartz always predominates; considerable feldspar may be present and also much biotite.

Vaqueros (?) shales are crumbly, tan or dark greenish in color, fine grained, thinly bedded, rather soft, and contain here and there thin beds of sandstone. An exception to the usual type occurs in bluffs where the road crosses Las Tablas Creek a short distance south of the Nacimiento River. Here the mud shales are yellow or brown, as is also a conglomeratic sandstone. These yellowish beds seem to be interbedded with typical Vaqueros (?).

Vaqueros (?) in the vicinity of the Oceanic Mine is composed of clay shales and fine grained, massive sandstone.

Vaqueros

Vaqueros fossils were found in only a relatively thin zone. Consequently, only the first few hundred feet of coarse material below the Salinas shales was conclusively proven to be Vaqueros, and mapped as such. In the northeastern part of the area, this band of white sandstone forms a conspicuous unit, which is mappable. Farther west, on the other side of the Vaqueros (?) area, it was not possible to find this same unit. At a few localities, some white sandstone was found immediately below the Salinas shales, but it could not be traced for any appreciable distance. In fact, at most points along the shale-sandstone contact, the sandstone could not be differentiated from the beds lower in the section.

Most typical of the Vaqueros is massive, white sandstone, medium to coarse grained in texture, and generally equigranular . The grains are usually rather well rounded and are composed mostly of quartz. The only colored material in the rock is small, scattered flakes of black mica, predominantly biotite. There are numerous variations from the type Vaqueros, but the outstanding characteristic of nearly all the sandstone beds is their extremely light color. They are either white, light gray or cream colored.

At some places the sandstone is very hard, at others, rather soft, and some beds are clayey in composition. The rock at most of the fossil localities contains many small, subangular pebbles, often dark colored. Some specimens are composed largely of broken shell fragments and coarse sand. The finer grained the sandstone is, the harder it seems to be. When freshly broken, this fine grained, white sandstone has a sparkling, sugary appearance.

Near the road summit just above the Asuncion Winery, and also along Santa Rita Creek, what appear to be pebbles and boulders of Chico sandstone, were found in the Vaqueros. The pebbles generally average but a few inches in diameter, and the matrix is a medium grained sandstone. Some rather thin beds of yellowish conglomerate, containing only small pebbles, occur at various places. The matrix is either a very fine grained sandstone or a yellowish clay or limey material.

On Lime Mountain, and on the hill back of the Frank Dubost home, is a considerable thickness of crystalline linestone and hard, white sandstone. The rock at many places was originally composed of small shell fragments, but is now characteristically a mass of small calcite crystals. These two areas were originally mapped as Salinas, but it is presumed that they are the correlative of Vaqueros beds occurring elsewhere in the area. They are shown on the geologic map as separate units.

Salinas

In contrast to many of the older beds, one of the outstanding features of the Salinas formation, both shales and sandstone, is its light color. Of course the great thickness of nearly uniform siliceous shale,often spoken of as Monterey shale, is the distinguishing characteristic of this series. Interbedded with the shale, and mostly at the botton of the section, are beds of white sandstone, limestone and rhyolite tuff. Calcite veins are numerous in the Salinas, sometimes being more than one foot in thickness.

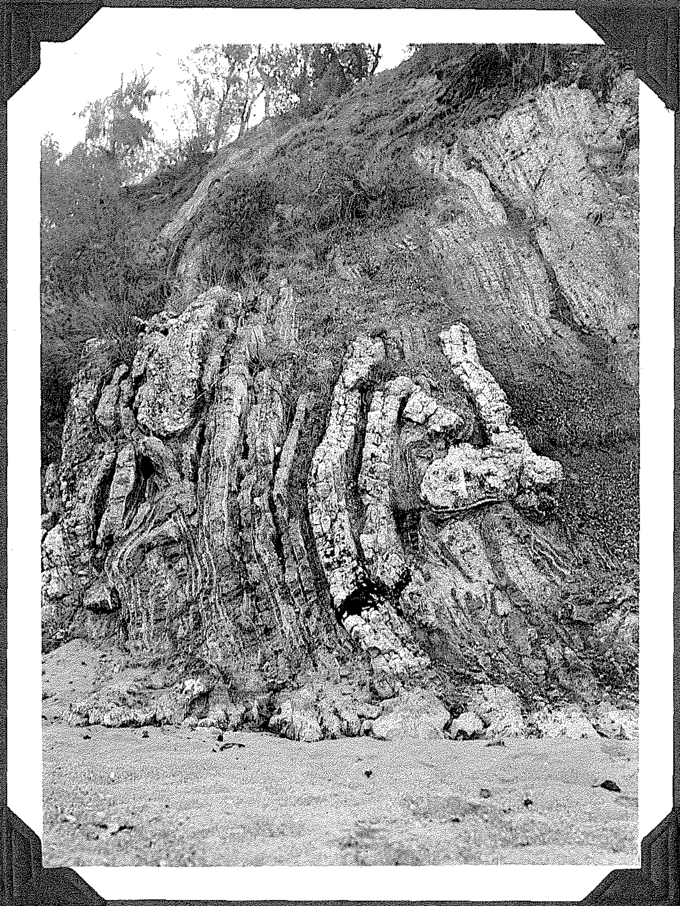
The siliceous shale is thinly bedded, each layer ranging from an inch or so up to about six inches in thickness. The shales are hard, rather brittle, very fine grained, nearly white but are stained yellow or brown on weathered surfaces.

Foraminifera, or tiny cavities from which foraminifera have been weathered, are bundant in many localities, often comprising ten percent or more of the volume of the rock. A typical sample showed 99% light colored material; 96% fine material, 1% coarse, rounded quartz grains, 2% foraminifera, a thick peppering of tiny black and reddish brown specks, and a parallel stratification or arrangement of flat grains, organic material, etc.

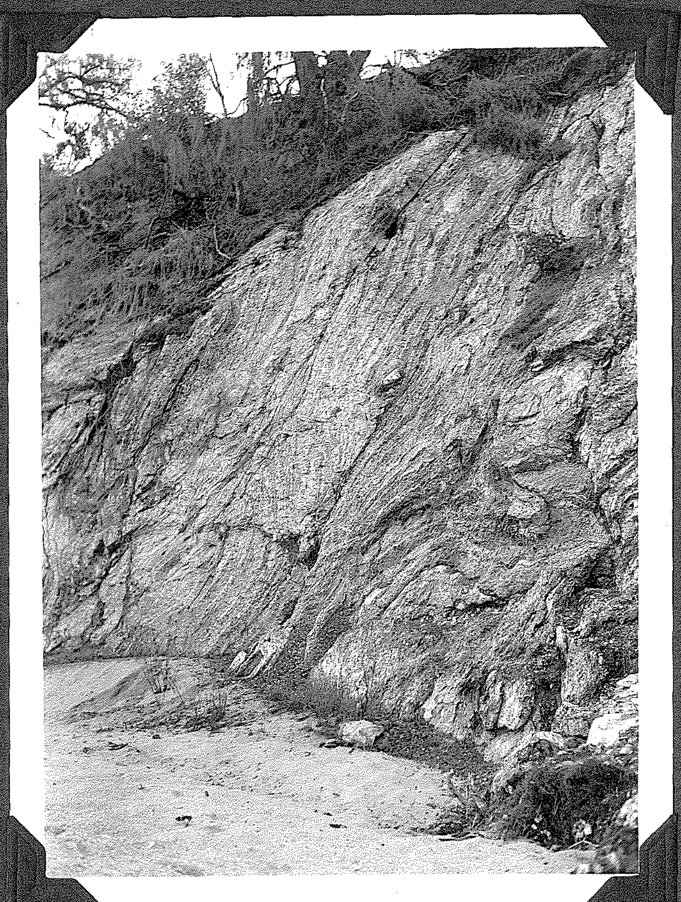
The shale often contains numerous fish scales and other brown organic material. The rock becomes extremely hard and nearly black if subjected to contact metamorphism, and if cavities from which forams have been weathered are present, a sample may closely resemble an acidic lava containing tiny vesicles. In places the shale grades into a jet black chert which still shows the original stratification lines. An interesting group of shales outcrop on the south bank of Santa Rita Creek just above the junction with the tributary that flows southward from Asuncion School. They are situated near an intrusive body, are very hard, black on fresh fracture surface, weather a light gray color, and give off a strong organic odor on being broken. In the upper part of the formation the shales become softer, more chalky, lighter in weight and contain more foraminifera.

The sandstones are exceptionally white in appearance, very hard, fine grained, equigranular, composed of well rounded grains, and the beds are usually only a few feet in

Salinas shale
crumpled around
mass of
Chert (A).



Small normal
slip in Salinas
shale near
Robles Fault.



thickness. The rock is typically composed of 90% or more of quartz and only about 1% dark grains, but there may be streaks in which lime predominates. The limestones are extremely hard, yellow in color and often have large secondary calcite veins associated with them.

Cherts found in the Salinas shale are of two types, and perhaps of two different ages. As mentioned above in the case of certain black cherts, the secondary siliceous material has replaced the original shale at some time after its formation. Also, oftentimes the typical reddish brown chalcedony is found in samples of chalky shale in such a manner as to indicate replacement. The contact between the chalcedony and shale is irregular and often obscure, the chalcedony grading into the chalky shale. On the other hand, certain large masses of chert possess a well marked contact with the surrounding shale. In the case of a particular mass of chert outcropping in the south bank of the Nacimiento River, the shales have folded and broken around the hard mass, indicating a pre-folding age for the chert. It may be that this mass of silica formed at the time the shales were being laid down.

Santa Margarita

Santa Margarita beds occupy a long, narrow strip of territory, totaling about one square mile in area, in the northeast portion of the quadrangle. This formation is only a few hundred feet thick, but is very fossiliferous and has been folded, overturned and faulted.

Farther south, and lying on the granite, are small patches of sediments, mainly soft sandstones, which are probably of Santa Margarita age. A few rather poor fossils were found here, but none of value. One of these small areas was tentatively mapped as Santa Margarita. Due to the presence of thick brush, and the small areal extent of the sandstone near the face of hills along the Salinas-granite contact, these beds were not shown as a separate unit on the geological map.

More Santa Margarita sandstone outcrops in Greene Valley, less than a half mile west of the western boundary of the Adelaida Quadrangle. These beds are massive, fossiliferous, and are predominantly soft, white sandstone interbedded with argillaceous shales. Some of the beds are yellowish and contain numerous worm tracks, other are coarse and arkosic.

Along the Nacimiento River, and at several localities a mile or two south of the river, there are excellent exposures of Santa Margarita beds. The formation is composed of sandstone varying greatly in hardness. Many of the beds are soft enough to be easily dug away with a pick, and others are so hard that a strong blow with the same implement merely leaves a small mark.

The basal member of the Santa Margarita is generally a bed of hard fossiliferous sandstone with a minimum thickness of about thirty feet. At one locality, the lowermost portion of the formation is a twenty foot bed of rather soft conglomerate which contains no Salinas shale pebbles. The most indurated beds seem to be the most fossiliferous, and frequently a major portion of the rock is composed of fossil shells. Some reefs are nearly all giant oysters, others are mainly a mass of pectens, and large accumulations of echinoids are also found.

The hard, fossiliferous, basal bed in this formation is more resistant to erosion than the rest of the Santa Margarita sandstone above it, and also the Salinas shales below. Consequently, this light colored member forms prominent bluffs that may often be seen from a distance or a mile or more.

All of the sandstone beds are light colored, usually white or gray. They vary in texture from a coarse, pebbly grain, to a fine and equigranular texture. Well rounded, clear quartz grains predominate in all samples.

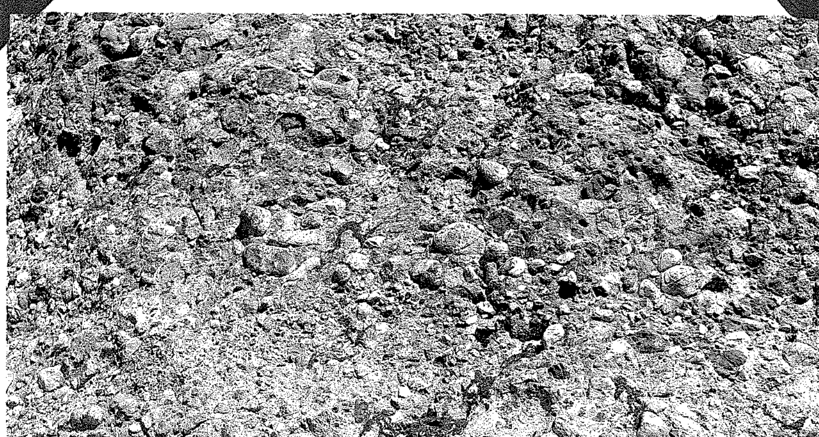
There is very little difference in appearance between some of the Santa Margarita beds and certain portions of the Paso Robles formation. In addition to the fossils, the abundance of Salinas shale pebbles in the Paso Robles, their absence from the Santa Margarita beds, and the fact that the Paso Robles beds are not folded as is the Santa Margarita formation, can be used in differentiating the two series.

Paso Robles

The Paso Robles formation, which covers between eleven and twelve square miles in this quadrangle, was deposited mainly in a shallow, freshwater lake. From the abundance of Salinas shale pebbles in these beds, one concludes that large portions of the positive areas, which furnished the material for the sediments being formed at this time, were underlain by Salinas shale. The formation is predominately a soft, chalky conglomerate and is approximately 1000 feet thick. Paso Robles beds are much more extensive in the country to the east, and cover a large part of the Paso Robles Quadrangle. No fossils were found in the territory mapped, but small, coiled, fresh water gastropods were seen near Union, about seven miles east of the town of Paso Robles.

Most typical of the Paso Robles sediments is a conglomerate consisting of rather soft, white or cream colored, chalky matrix, with angular to subangular pebbles predominately of Salinas shale. Chert or chalcedony, derived from the Salinas formation, occurs as pebbles in the Paso Robles and is somewhat translucent, has a choidal fracture and breaks forming very sharp edges. It is of many colors including, white, gray, blue-black, cream, yellow, orange, red and brown. Although the chalcedony was derived from the Salinas, no great amounts were actually found anywhere in the siliceous shales.

Paso Robles Formation



Vaqueros (?) Conglomerate

Beds of white, chalky limestone, about six to eight inches thick, are rather characteristic in some localities. At some places in the Paso Robles, occur hard, nearly white sandstone and fine conglomerate beds composed primarily of clear quartz grains, Salinas shale, and dark colored, pebbles. These beds of resistant, conglomeritic sandstone are rarely over more than one foot thick, and they form prominent outcrops along many creeks. Cross-bedding is common in the Paso Robles formation.

Several differences between the fresh water sediments of Paso Robles age and the older marine beds were noticed. Lack of complete sorting of the Paso Robles clays, sands and gravels is perhaps the most important. Nearly all samples examined are made up of grains of various sizes, and there appears to be no particular arrangement in the proportion of different sized grains present. Sometimes there is an equal amount of several different sized grains. Again, a very fine grained chalky bed often contains large, angular, Salinas shale pebbles.

The Paso Robles beds are also generally less indurated, are more varied in composition both vertically and horizontally, and vary more in hardness than the marine formations. Another point of difference is that the Paso Robles beds seldom dip more than five degrees, except in the vicinity of a fault.

Terraces

Quaternary and recent terrace gravels and soil occur at many places, the most important terraces being along the Nacimiento River and Santa Rita Creek. The composition of the gravels is varied and depends upon the source rock.

Differentiation of Non-fossiliferous Sandstones.

Due to the scarcity of fossil material, a microscopic study was made of many sandstone samples in an attempt to distinguish between different formations.

Salinas sandstone can usually be identified by its extremely light color, and its fineness and roundness of grains. Also, these sediments are very well sorted. In this case, microscopic work merely checked hand lense determinations.

Franciscan sandstones could generally be safely classed as such by their field associations and position. Where this was impossible, the remarkably small percentage of quartz in the Franciscan sandstone was used as a criterion.

Knoxville sandstone beds were always associated with the typical, hard, crumbly, incompetent, and dark Knoxville shales.

Real difficulty arose in connection with the Chico and Vaqueros (?) formations, whose sandstone beds are often very similar lithologically. Twenty samples of these sandstones, both Chico and Vaqueros (?), were labeled to permit identification later, and without knowing from what locality they came, were studied under a binocular microscope. These samples were separated into two groups, Chico and Vaqueros (?), according to certain differences which came to light in the microscopic study. The locality from which each sample had been taken was then looked up and marked Chico or Vaqueros (?) according to the laboratory determination. In practically every instance these results checked classifications made in the field on a basis of field relations and appearance of outcrops.

There were three or four distinguishing characteristics used in the laboratory classifications. The Chico sandstone contains a large percentage of biotite, is usually rather dark, contains grains of dark colored igneous rocks, and the individual grains are rather well rounded. The Vaqueros (?) samples are lighter colored, contain less biotite, and the grains are more angular. The finer Vaqueros (?) sediments appear to have been derived in larger part from granite masses than were the Chico sandstones.

Although, in certain cases as noted above, the microscopic work was helpful in classifying the different sandstone members, often no conclusive results could be reached. At a few localities it was practically impossible to say whether certain sandstone beds were Vaqueros (?), Chico or Franciscan. For this reason, there may be some minor mistakes in formation classifications, but this uncertainty exists in only a few localities and on only a small scale.

PALEONTOLOGY

Invertebrate

Excepting the Santa Margarita formation, the invertebrate fossil assemblage found within the Adelaida Quadrangle is small, although a few exceptionally fine specimens were obtained. Miocene beds are the only ones that appear to be fossiliferous to any great extent. Although large sections and many outcrops of the Franciscan and Knoxville formations were examined, no fossils were found in them, with the exception of a plant form in the Franciscan shale. At first it was thought that some invertebrate forms had been discovered in the Franciscan chert, but they proved to be only fossil-like nodules.

Chico

It was also surprising that the Chico beds yielded practically nothing, although a few small pelecypods were found. The best specimen is 28 mm. long and 15 mm. high, is decidedly inequilateral, and has a beak that overhangs about 1 mm. (on the cast). The country rock is a coarse sandstone containing clay pebbles resembling Knoxville or Franciscan shale. Another cast, having an overhanging beak, is equilateral, 30 mm. long and about 17 mm. high. The smallest form found also has a slightly overhanging beak, appears rather thick and round, and measures 12 mm. long, by 11 mm. high. A small coiled gastropod and the imprint of a very large, round ribbed form completes the assemblage from this locality, station 45.

At two other localities small, inequilateral pelecypod forms were found in beds mapped as Chico, but which were lithologically similar to the Vaqueros (?) sandstone as exposed in some parts of the region. A certain determination of these fossils is not possible.

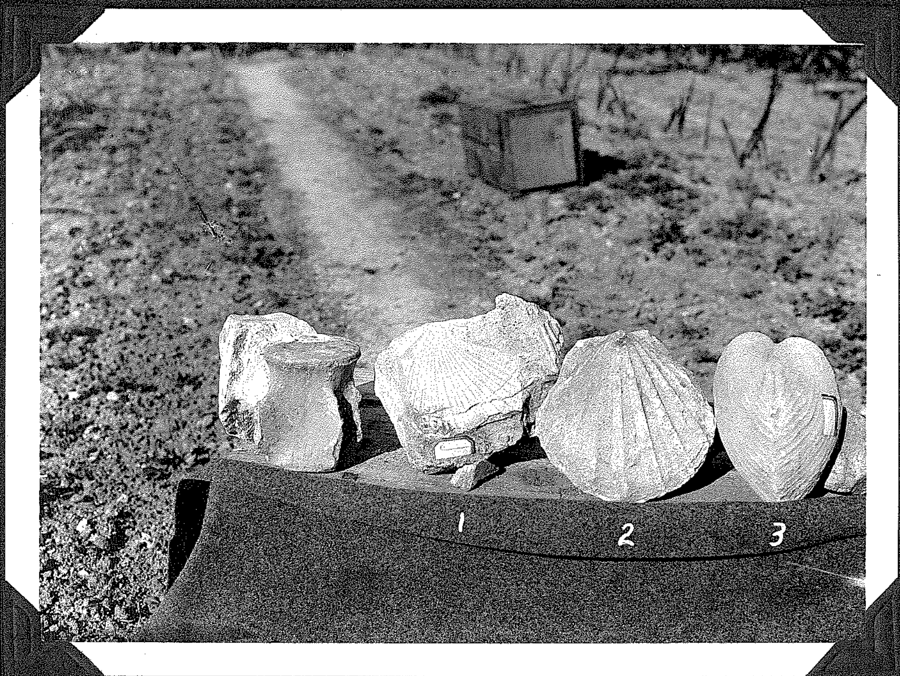
Vaqueros (?)

At no place were any determinable forms found in the lower part of the section, that designated Vaqueros (?), but always in the upper few hundred feet of sandstone.

Vaqueros

Several good fossils were found in the Vaqueros sandstone immediately below the Salinas shale. In a few cases Vaqueros fossils were found in areas mapped as Salinas due to the fact that the coarse beds at the base of the Salinas, the Vaqueros formation, did not form a large enough unit, at that locality, to be mapped separately.

The best preserved forms were found on the summit one half mile northeast from the head of Paso Robles creek. Several good specimens of Pecten magnolia Conrad were collected; the largest measuring 6 3/8 inches high, and having both ears and both valves present. The largest shell has ten easily distinguishable ribs. A very large, double valved specimen of Cardium vaqueroensis Arnold was also



Scale 0 ——— 6"

Left - Vertebra Found in Salinas Shale

Right - Vaqueros Fossils

1.- Pecten Perrini

2.- Pecten Magnolia

3.- Cardium Vaqueroensis.?

collected. The valves measure 6 5/8 inches high and about 4 1/2 inches long. This form has a large number (about 28) of small but prominent vertical ribs. A double valve specimen of Pecten perrini was also found here.

About one half mile southwest of the above locality is a fossiliferous bed at approximately the same horizon. Here the fossil shells are badly broken; Pecten perrini, a six inch oyster and small, snail-like gastropods were the only distinguishable forms.

At a large landslide one half mile southeast from the head of Old Creek, is a bed of coarse sandstone that has been grestly hardened, silicified and calcitized. This hardened layer contains thousands of Pecten perrini and apparently nothing else. Due to the metamorphosed condition of these sediments, it is difficult to remove the shells from the country rock. One exceptionally good valve was found that shows both ears. It is something over 4 1/2 inches high and 5 or more inches long.

On the ridge south of the road about one mile southeast of German Church, there were found; Pecten perrini, and a flat disc shaped mold, nearly round, that was indeterminable but may be a dosinia, perhaps ponderosa.

Salinas

The Salinas formation is not very fossiliferous, but a few forms typical of the Salinas shales were seen. Pecten (Pseudamusium) peckhami Gabb occurs in the shales or limestone at several different and widely separated localities. Also a small coiled gastropod, with prominent vertical and circular ribbing, was found along with Peckhami and the bone fragments.

A sugary white sandstone layer, interbedded with the typical siliceous shales near the eastern side of the quadrangle, is somewhat fossiliferous. It contains numerous tiny pectens, only 6 or 7 mm. in diameter, which show distinct ribbing and prominent, nearly equal ears. A larger pecten, three or four times this size, occurs nearby. A large foraminiferal fauna can be obtained just east of the eastern edge of the quadrangle. It will be discussed below.

Santa Margarita

Santa Margarita beds exposed in the northeastern part of the quadrangle are exceptionally fossiliferous. Some zones in these sandstones are literally filled with shells, many of which are well preserved. Station 108 on the Nacimiento River is a paleontoligist's paradise, there being thousands of oysters, pectens and echinoids present. The echinoids are in a bed approximately 125 feet above the basal member which contains most of the pectens and giant oysters. At this station, and the other fossil localities farther south, excellent fauna could be obtained. Only forms to identify the formation were collected when this area was mapped.

Fossiliferous, Santa Margarita sandstone at Nacimiento River.

Oysters in bed pictured above.

At station 108, many of the oysters are in almost perfect condition, but are generally bedded in rather hard sandstone. The shells of Astrodapsis antiselli are of all sizes, from tiny, smooth forms, to large mature shells which show all the different plates. These echinoids are also imbedded in a hard sandstone.

Pecten estrellanus shells comprise almost the entire assemblage at station 112, but there are plenty of them. Most shells have seventeen prominent ribs although there is sometimes as many as nineteen. The tiny ribs, lying in the spaces between the large ribs, are clearly seen on most of the specimens collected. Both valves of some of the forms were found, and many of the ears are intact.

A shell of Pecten estrellanus found at station 113 has three small ribs in the grooves between the large ribs. Of the three small ribs, the central one is largest and is sometimes double in form. Many minute growth ridges are visible between each of the outside ribs and the larger central one (all this is seen in a groove between the large prominent ribs).

Soft marine sandstone lying on the Franciscan just to the west of the quadrangle, contains two forms that lead one to believe that it is of Santa Margarita age. Ostrea titan Conrad and many mytilus shells are present. In the sandstone lying on the granite in the northeast corner of the area, are found worm tracks, medium sized clam-like pelecypods, a large pecten, and a form that may be macoma.

Paso Robles

A few fresh water gastropods, occurring seven miles east of Paso Robles, constitute the entire fauna found in the Paso Robles formation

Foraminifera

Light, soft, chalky sandstone rich in foraminifera outcrops along the Santa Rita Creek. This member lies near the top of the Salinas shales. A large foraminiferal assemblage could be obtained here, the specimens are easy to prepare and are in a fine state of preservation. From a small sample nineteen different forms were obtained. Uvigerina, Valvulineria, and Siphogenerina dominate the assemblage.

It will be noticed that these foraminifera from the upper part of the Salinas shales are very similar to Temblor assemblages, generally placed below the siliceous shales. This is not surprising inasmuch as farther south in the Nipomo Quadrangle, siliceous shales grade laterally into lenses of sand containing Temblor fossils. It looks as though so called Temblor foraminifera may be found anywhere between the Vaqueros and Santa Margarita beds. The presence of these particular foraminifera seems to be due to favorable conditions of deposition, and does not, necessarilly, indicate a narrow zone of a certain age.

INVERTEBRATE FAUNAL LIST

Foraminifera

Uvigerina californica Cushman

Uvigerina obesa Cushman

Valvulineria miocenica Cushman

Valvulinella californica Cushman

Valvulinella californica var. appressa Cushman

Bolivena advena var. ornata Cushman

Bolivena subadvena var. spissa Cushman

Siphogenerina reedi Cushman

Siphogenerina sp.

Bulliminella curta Cushman

Nonion costifera Cushman

Baggina californica Cushman

Nodosaria oblique (Linne)

Pullenia quinqueloba (Reuss)

Lenticulina miocenica (Chapman)

Cassidulina crassa d'Orbigny

Cassidulina pulchella d'Orbigny

Robulus

Rotaloid form ?

Other Invertebrates

Vaqueros

Pecten magnolia Conrad

Pecten perrini

Cardium vaqueroensis ? Arnold

Dosinia ponderosa ? Gray

Many undeterminable forms

Salinas Shale

Pecten (Pseudamusium) peckhami Gabb

Undetermined pectens and a gastropod

Santa Margarita

Ostrea titan Conrad

Ostrea titan corrugata

Pecten estrellanus Conrad

Pecten estrellanus Conrad var. terminus

Astrodapsis antiselli Conrad

Mytilus

Macoma santa margarita ?

FOSSIL LOCALITIES

Note: All stations are in the Adelaida Quadrangle unless otherwise noted.

Chico

Station # 45 - R 10 E, T28 S, in small swale on northwest slope of hill 1583.

#79 - R 9 E, T 26 S, section 22, on south slope of brushy hill about 150 feet above saddle.

#105 - R 11 E, T 27 S, section 30, in north bank of road, on spur running southeast from hill 1506.

Vaqueros

Station # 40 - R 11 E, T 28 S, on northeast edge of small canyon 50 yards southeast of road (mapped as Salinas).

47 - (pecten perrini) R 11 E, T 28 S, section 12, on spur southeast of head of Old Creek, at landslide (mapped as Salinas).

50 - R 10 E, T 27 S, section 24, near summit on northwest slope of hill 1971.

51 - R 11 E, T 27 S, on ridge 3/4 mile southeast from German Church (mapped as Salinas).

106 - R 10 E, T 27 S, section 24, near north slope of hill (approximate location)

Salinas

Station # 1 - (foraminifera) Paso Robles Quadrangle, R 12 E, T 27 S, road cut on hill, just south of S in Paso.

11 - (foraminifera) R 11 E, T 28 S, road cut at top of hill on edge of quadrangle.

16 - (foraminifera) R 11 E, T 27 S, road cut 85 yards north of cross road 982.

33 - (tiny pectens) R 11 E, T 28 S, junction of unimproved road at base of hill with Santa Rita Creek road, in small canyon east of road.

36 - (small pectens) R 11 E, T 27 S, on west bank of road 1/8 mile south of Oakdale School.

87 - R 10 E, T 26 S, section 30, just north of Dubost's barn.

91 - R 10 E, T 27 S, section 2, 100 yards north of road near old stone shack.

#100 - R 10 E, T 27 S, section 19, on Cambria road at junction with unimproved road which extends northward.

Santa Margarita

Station # 58 - R 11 E, T 26 S, section 11, road cut on east side of road near center of section.

67 - R 11 E, T 25 S, section 32, approximately 1/2 mile from mouth of deep canyon.

#104 - San Simeon Quadrangle, in Greene Valley 1/4 mile north of S in Rosa.

Station #108 - Bradley Quadrangle, along Nacimiento River in northeast corner of section 14, R 10 E.

#110 - R 11 E, T 25 S, at west-central edge of section 19.

#112 - R 11 E, T 25 S, northeast corner of section 30, on north side of first canyon south of deep gorge canyon.

#113 - R 11 E, T 25 S, section 30, on trail approximately 1/3 mile west of station 112.

#114 - R 10 E, T 25 S, northeast corner of section 24, prominent outcrops on northeast trending spur.

Vertebrate

No vertebrate fossils of importance were found in this territory. A few fish vertebrae, about .6 of an inch in diameter, were collected from a limey member in the Salinas shales near the junction of Paso Robles and Jack Creeks in the southeastern portion of the quadrangle. Some bone fragments of an ancient sea mammal? occur in a hard limestone bed of the Salinas formation on the Frank Dubost ranch, located in the east-central part of the area. These fragments were found in the same bed with Pecten (Pseudamusium) peckhami Gabb.

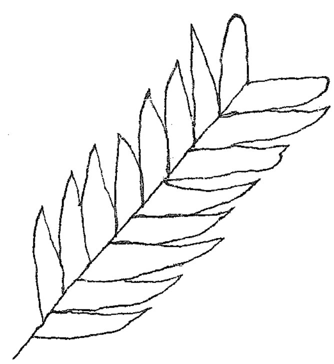
To the south in the San Luis quadrangle, about one quarter of a mile west of the main business corner in Atascadero, a large vertebra, presumably from a whale, was obtained. The specimen measures 4 1/2 inches long and about 3 1/2 inches in diameter. A smooth edged, nearly flat, pointed and somewhat crescentic tooth was imbedded in the Salinas shale along with the vertebrae.

No vertebrate material was found in the Paso Robles formation.

PALEO BOTANY

In a slab of dense, dark, Franciscan shale outcropping on the summit of the Cambria-Adelaida road grade above the Cinnabar Mining Company workings, an imprint, about one foot long of a plant was found.

Drawing of the Franciscan stem.



IGNEOUS ROCKS

Igneous rocks underlie only a small portion of the Adelaida Quadrangle. The serpentines, by far the most important, and a small mass of granite represent the only large intrusive bodies. The other rocks: diabase, rhyolite, basalt, dacite, andesite and other basic rocks occur as flows and dikes both large and small. Many of the small bodies of igneous rock are found in the Franciscan formation.

Granite

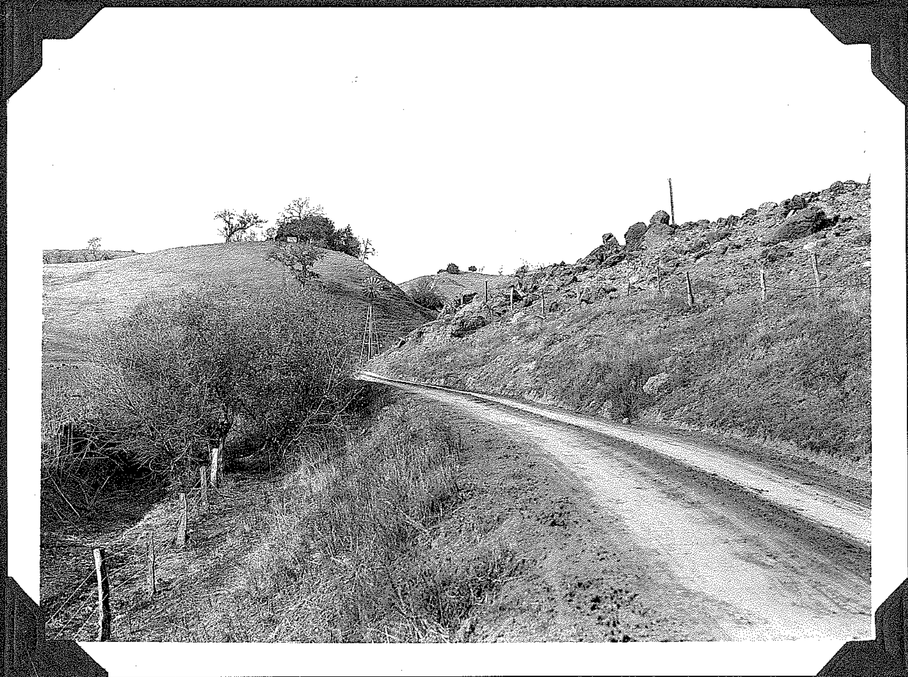
The granite, outcropping in the northeastern part of the area in the vicinity of Oak Flat, is probably the oldest rock in the region. It covers approximately one square mile, being overlapped on the north by the Paso Robles beds, and is bounded on the south and west by Salinas shale. The granite mass extends for some distance into the Paso Robles Quadrangle. The only conclusive evidence as to age is that the mass is pre-Monterey, the oldest rocks with which the granite is in contact. Nearly all outcrops are highly weathered as is the entire upper part of the granite body. Wells may be sunk for a considerable distance in the soft, disintegrated material before striking solid rock.

On a fresh surface a sample presents a decided black and white appearance, the black specks being biotite. Pink orthoclase is sometimes present. Biotite constitutes from five to ten percent of the rock, is green to brown, and was one of the first minerals to crystallize. Quartz is major constituent and in some places has replaced orthoclase. Orthoclase, also a major constituent, is very prominent and contains inclusions of apatite. A large amount of oligoclase is present, as are some iron oxide and a little muscovite. The rock should be classed as a biotite granite.

Serpentine

Serpentine forms a large part of the Franciscan and occurs also in contact with Knoxville, Chico and Monterey beds. The age of the peridotite (now serpentine) intrusives is very much in doubt. It is clear that these rocks were intruded into the Franciscan, but their relation to the later sediments is not so evident. A safe declaration as to age would be that the serpentines are Post-Franciscan and pre-Paso Robles.

A weathered outcrop of serpentine is characteristically composed of large rounded boulders, dark brown in color, and numerous patches of blue-green serpentine. The rock mass contains many fractures, prominent slickensided surfaces, considerable asbestos and a chert like form of serpentine. The typical rock, on a fresh surface, is nearly black in color.



Near Paso Robles - Cambria and Paso Robles - Cayucos Road Junction. Rock - Outcrop of Asbestos Bearing Serpentine (to right of road).

Thin sections of this intrusive are difficult to prepare due to its soft serpentinized condition. However, a study of several thin sections revealed that the original intrusive was a peridotite in some places and a pyroxenite in others. The two most outstanding characteristics are; a very coarse grain, and an almost complete alteration to the mineral serpentine.

Basic Dikes

The most common type of dike rock in the area is a dark colored, extremely basic intrusive, often resembling basalt, in the field. It has intruded the Monterey either in the form of large bodies several hundred yards across, or merely in thin layers. In places the basic dikes contain nearly round, or ellipsoidal, pillow-like forms that spall into thin layers during the process of weathering. These dikes have generally come into the Monterey parallel to the bedding planes, having hardened the beds both above and below, thus showing them to be post-Monterey in age.

Although the weathered outcrops look like basalt, a hand specimen is often rather coarsely crystalline. These rocks have nearly always, especially if in moderately large masses, entered the crust and come to the surface along lines of weakness due to faulting. These long, narrow, intrusive bodies are rather characteristic of fault zones.

Dikes at the Oceanic Mine have been referred to, by F. L. Ransome, as augite teschenite. H. W. Fairbanks described the dark, spheroidal igneous bodies near the Oceanic Mine, as analcite diabase. A thin section study, by the author, of samples taken from some dikes occurring elsewhere in the Monterey beds, showed these to be andesites, the major portion of the rock being made up of laths of labradorite. It is evident that the composition varies a great deal in the different intrusives, but is invariably basic.

Diabase

In a number of places, post-Monterey diabases have intruded both the Salinas shale and Vaqueros (?) sandstone. The rock is extremely hard and rather fine grained. These masses of diabase are extensive underground, and in some localities, are nearly always encountered in digging water wells. Magma appears to have found its way into the Vaqueros (?), and then spread out laterally beneath certain resistant sandstone beds. Vaqueros (?) sandstones have, in many localities, often been greatly hardened and altered to a blue color by this contact metamorphism. Study of thin sections of specimens, taken from the intrusives, proved them to be true diabases.

Granodiorite

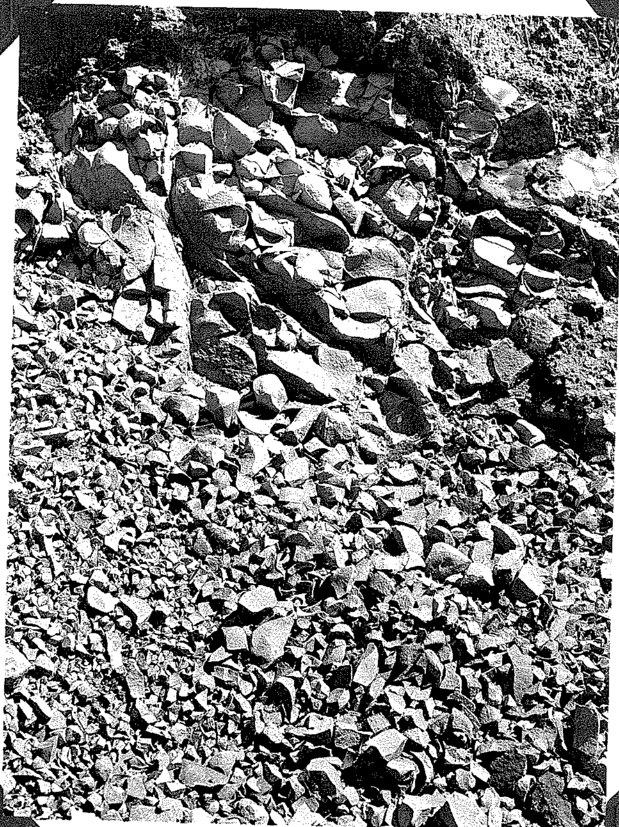
Some specimens taken from a small intrusive body, in the Franciscan, near the junction of Santa Rita Creek with its South Fork were studied in thin section. The rock contains andesine and quartz as major constituents, some orthoclase, biotite, and muscovite intergrown with biotite. This composition shows the rock to be a granodiorite.

Dacite Porphyry

Along Santa Rita Creek in the southern part of the area, one mile east of the Cayucas road, there is an unusually interesting outcrop. Apparently a small amount of magma has forced its way into a body of serpentine, near a contact with Salinas shale. The rock has a light gray color, is fine grained, and appears hard, but a pronounced tendency to part along conchoidal surfaces makes it possible to break the rock by hand into small, round pieces. It has a somewhat smooth greasy feel.

Thin sections showed the rock to be a highly altered dacite porphyry, with quartz, plagioclase and biotite phenocrysts. The gound-mass is almost glassy and shows definite flow structure. Baking of the nearby shale may be due to this small intrusive. If so, the magma found easier access upward along the serpentine-shale contact than through the Salinas shale, and is post-Salinas in age.

Dacite
Dike



Spheroidal Structure in Post-
Monterey Basic Intrusive.

Rhyolite

The summit of Black Mountain and some of the nearby slopes are composed of volcanic materials, mostly rhyolite, which are Miocene in age, being interbedded with the Monterey sediments. In places the rhyolite is very hard and forms bold bluffs that are pinkish gray in the sunlight.

Locally, the volcanic material may appear pink, reddish purple, reddish brown, white, and combinations of colors, but the pumice is usually dark colored. Some of the rhyolite tuffs have a shaly structure or bedding, indicating deposition in a water body, presumably the sea. Dark colored rock in some of the outcrops is decidedly hard, but more often it is weathered to a soft, crumbly material. A few specimens of the typical rhyolite contain nodular chert masses, also, a snow white crypto-crystalline quartz which does not resemble the common chert, jasper, etc.

These Black Mountain rhyolites were described by N. L. Taliaferro and R. E. Turner, the paper being presented at the Geological Society of America (Cordilleian Section) meeting, 1931.

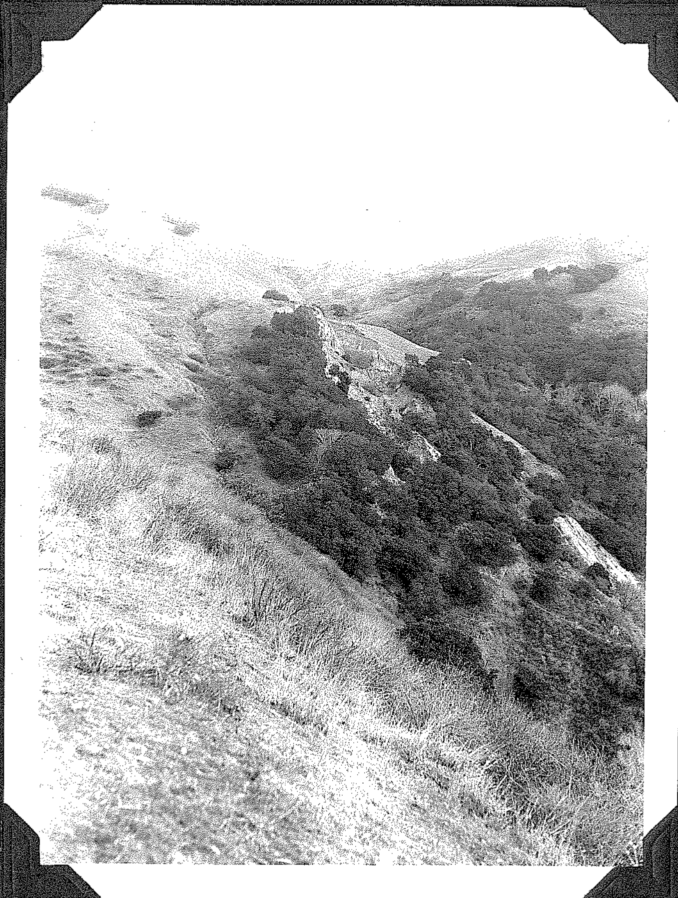
STRUCTURAL GEOLOGY

Introductory Statement

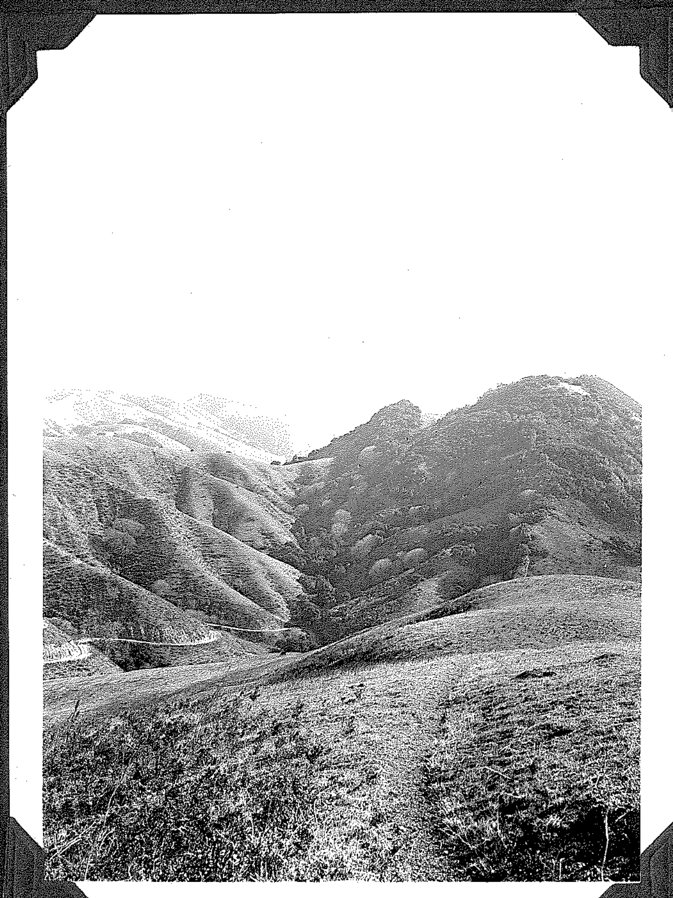
Practically all the structures in this area trend northwest. Formations of all ages, from the Franciscan to the Paso Robles, have been both folded and faulted. Along certain strips of country the faulting is predominant and decidedly the controlling factor, but over other large areas folding predominates. In a broad way, the structure of the northern portion of the quadrangle is anticlinal. The core of the Santa Lucia Range is here composed of Franciscan rocks with younger sediments on the flanks. In the southern part of the area, extensive faulting has obscured any regional folded structure. The crest of the range here is composed of Salinas shales.

The structure of the Franciscan rocks west of the Santa Lucia Range is so complex, the rocks are so weathered, and there are so few informative outcrops, that but little structural work was possible in this district.

Along the western edge of the range is a zone of heavy faulting, some faults traversing the main ridge. On the east side of this ridge there has also been faulting. It gradually diminishes towards the Salinas Valley. Another series of important fractures in the northern part of the area, occur just west of the Salinas Valley. So that passing from west to east, we have a complex belt of



Oceanic Fault Pass
Just to Left of Cut
and Continues Throu
the Notch in Distant
Ridge. Cut is the
Result of Oceanic Min
Stopes Caving to Surf



Contact Between Kno
ville Shales (grass hi
on left) and Salina
Shales (wooded hill
on right).

Franciscan rocks, intense faulting, moderate faulting, a large folded area and again a zone of faulting.

Conformities and Unconformities

In many places the relation of one formation to another is very clear; elsewhere, however, the exact relations between formations are not always discoverable.

There is plainly a great difference in age between the Franciscan formation and the younger beds. Knoxville, Chico, Vaqueros (?) and Salinas all lie unconformably above the Franciscan, unless in fault contact. The large extent, thickness, and variety of rocks found in the Franciscan indicate a great length of time during its accumulation.

The two Cretaceous formations, the Knoxville and Chico, are not in contact with each other in the Adelaida Quadrangle. If these formations were conformable, it appears probable that they would be found in contact. The marked difference in character of the Chico and Knoxville sediments also tends to indicate an unconformable relation. This criterion, however, is by no means conclusive. Unconformable relations exist between these two formations in other parts of the Coast Ranges.

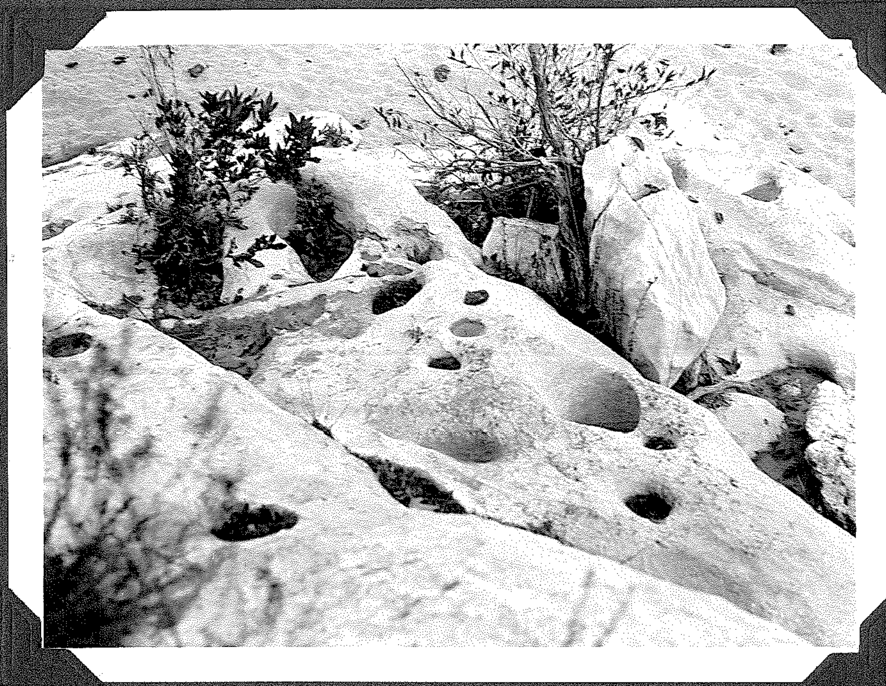
Attitudes of adjacent Chico and Vaqueros beds differ greatly. Along Jack Creek is a marked unconformity. The underlying Chico beds dip regularly about thirty or forty degrees, while the Salinas and Vaqueros sediments lie nearly flat across the bevelled edges of the Chico strata. Along Santa Rita Creek the Vaqueros (mapped here as Salinas) and Chico beds have practically the same dip and strike approximately at the contact. A disconformity must exist at that locality.

Near Klau the Salinas shale is lying nonconformably above the Chico.

Within the Monterey Group, all formations appear to be conformable. The Vaqueros(?) grades into Vaqueros which in turn grades into Salinas. The Monterey Group contains a great thickness of widely diverse sediments, but there appears to have been no break in the deposition.

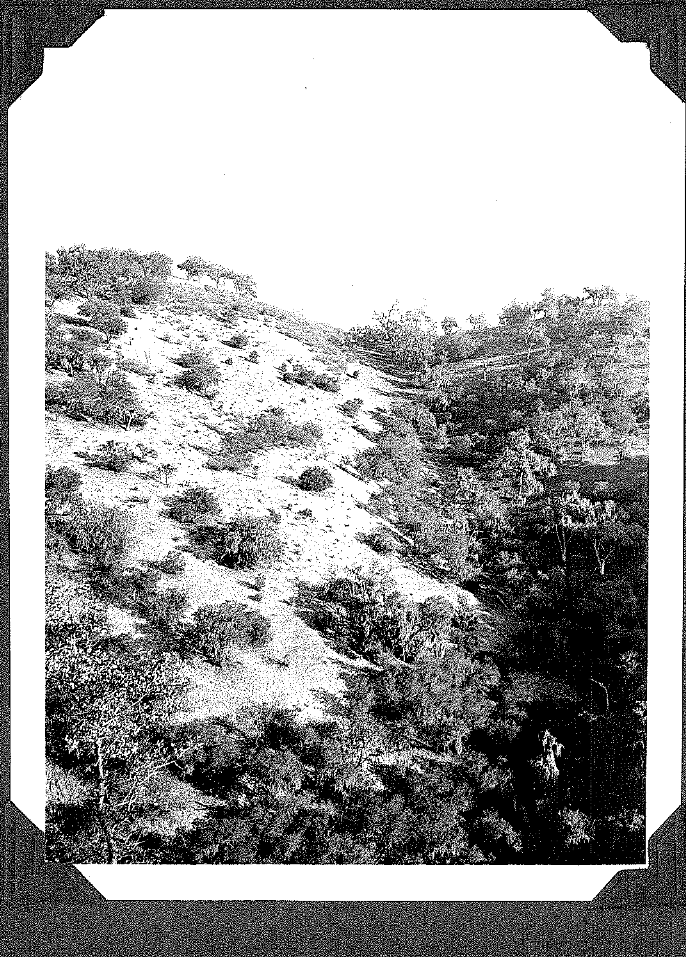
A considerable amount of discussion in the past has centered around the question as to whether the Santa Margarita sandstone is conformable or unconformable to the underlying Salinas shale. The Salinas shale has been described as highly folded while the overlying Santa Margarita generally has gentle dips. Dr. R. D. Reed concluded, from data obtained at various places in the Salinas Valley region, that the Salinas shales and Santa Margarita sandstones are conformable. This conclusion is correct. In the Adelaida Quadrangle, near the Nacimiento River, the two formations are conformable and the fossiliferous Santa Margarita sandstone has been folded in with the Salinas shale, even overturned at some localities.

Between the Miocene strata and the Paso Robles formation, is one of the most pronounced unconformities of the



Pot-holes in Santa Margarita sandstone, Nacimiento River.

Salinas - Santa Margarita (overturned, on left) contact.



area. The Paso Robles sediments lie across the bevelled edges of Salinas and Santa Margarita beds. In contrast to the intense folding common to the Miocene strata, the Paso Robles beds seldom dip over five degrees, except near a fault.

Regional Structure of the Igneous Rocks

The granite, which outcrops northwest of Paso Robles, is perhaps the oldest rock mass in the area, although the oldest rocks in contact with it, however, are Salinas shales; and all sedimentaries adjacent to the body of granite are either in fault contact with it or lie depositionally on it. Therefore, no valuable data concerning the age of the granite was obtained.

The peridotite or serpentine intrusives are generally long and narrow in localities where post-Franciscan sedimentaries are present, and trend parallel with the other structures in the range. Serpentine masses occurring in the Franciscan rock do not show this elongate form.

It is very clear that the peridotite or pyroxenite magma was intruded into the Franciscan sediments, but the relations of the intrusive to the latter formations is not so well defined. Most of the Knoxville-Serpentine contacts are faults and the Chico-Serpentine contacts have failed to furnish any valuable evidence. In some places Chico shales a few tens of feet from one of the igneous masses show no signs whatever of metamorphism.

One body of serpentine is in contact with both the Salinas and Vaqueros formations. The best exposures are east of the road summit about a mile south of the Cayucas-Cambria road junction, and near the head of Old Creek. The conditions found here are as follows:

1. At the serpentine-Monterey contact, the Monterey has been greatly changed and altered, sandstone and shale alike. These Tertiary beds have been hardened, baked and silicified along with the deposition of calcite.

2. The Monterey beds stand steeply and have various strikes.

3. The alteration is extensive and has been effective over a considerable area.

4. The serpentine body itself has been so silicified and calcitized that its original character is very obscure.

5. The serpentine appears to have intruded both the Knoxville and Monterey. It is suggested, therefore, that the serpentine may be post-Monterey in age.

In contrast to the above conclusion, a decidedly different interpretation is possible. There is a strong probability that the change in character of the Monterey beds in contact with the igneous rock may be explained on the hypothesis that the weathered and fractured serpentine merely provided an easy passageway for ascending solutions, which altered the serpentine as well as the overlying sedimentaries.

It may be of some import that these basic intrusives also occur adjacent to both crystalline limestone deposits in the Monterey. It is also very evident that the serpentine bodies, located in districts where beds younger than the Franciscan are present, trend in a northwest direction, conforming to the structural features of the range. This undoubtedly means that the intrusives came in after the present structures were formed. These points might also tend to place the age of the serpentine as post-Monterey.

The fact that the intrusives are nearly always found in the Franciscan and seldom in the younger formations, may merely be because the magma penetrated only up through the disturbed Franciscan and seldom broke through the overlying sediments. The serpentines are generally exposed only where erosion has stripped off the younger rocks, or else the later formations were never deposited at that locality.

Rhyolites, outcropping on Black Mountain in the south-eastern part of the area, are interbedded with the basal members of the Salinas formation.

In the northwest section of the quadrangle, near the Lime Mountain-Las Tablas Creek road junction, occurs a large laccolith or sill of what is probably quartz diorite. This rock extends underground for some distance to the east of Las Tablas Creek. Wells in this vicinity pass through typical Vaqueros (?) sandstone, then blue (apparently metamorphosed sediments) sandstone, and finally enter the very hard and fresh quartz diorite. The most satisfactory explanation, seemingly, is that the magma rose along some northwest zone of weakness and then spread out as a laccolith or sheet just below the massive Vaqueros (?) sandstones.

An interesting feature of the basic intrusives and dikes which are definitely post-Monterey in age, is that they occur along lines of faulting; the long axis of the intrusive body paralleling the fault. The magmas which formed these basaltic-appearing rocks sought out the lines of weakness, and then, when still in the form of molten material, forced their way upward. Sometimes these dikes cut across the strata, but more often the magma spread out along bedding planes in the Monterey formation and formed sills. The course of several faults on the west side of the range can be traced by following the occurrences of these elongate, basic bodies.

Folding

Folded structures characterize a large part of the area. Sedimentary beds of all ages have been folded to some extent, in many cases the folding becoming progressively more intense as one passes from younger to older formations.

Numerous folds exist in the Franciscan beds, but due to the poor character of outcrops and the exceedingly complex structure (which includes intrusions of several ages), it was not found practical to undertake detailed mapping in this formation. No regularity of either dip or strike was found.

Shales and thin bedded sandstone which make up the Knoxville formation, are very incompetent and have been squeezed into many small, highly compressed folds. The beds have unusually steep dips, generally ranging between fifty and ninety degrees. In the area immediately to the south, Fairbanks described the structure of the Knoxville beds, in a broad way, as being synclinal. This does not seem to be the case in the Adelaida Quadrangle. Here the attitude of the Knoxville beds and the areal relations both indicate that the Knoxville formation occupies the core of an anticline. Also, on both sides of the Knoxville is the younger Salinas formation. Faulting has complicated the structure.

Most of the dips in the Chico formation are over thirty degrees, and a large proportion of them are over fifty degrees. The beds in the northeastern part of the Chico area dip rather uniformly westward, while on the western and southern part of the Chico area the beds dip eastward. This indicates, in a rough way, that a synclinal structure exists. The synclinal axis, in the north, extends southeast for several miles and then either swings eastward under the Salinas beds near the Asuncion School, or else is cut off by the Rita fault.

Folds are best expressed in the Vaqueros (?) sandstones. The beds are competent enough to prevent crumbling and the outcrops are the best in the area. A large anticline, several miles across, occurs in the Vaqueros (?) west of Chimney Rock. Vaqueros (?) sandstones dip under Salinas shale on both flanks of the anticline, and the structure plunges southward under Salinas beds. It was found to be almost impossible to follow the structure in the more incompetent Salinas shale. This is not a simple fold. Its westward limb shows gentle westward dips and several minor folds, but the eastern limb is very steep. This unsymmetrical form of fold, a gentle west limb and a steep to overturned east limb, characterizes the structures in the northeastern part of the quadrangle.

The minor folds, which are superimposed on the major anticline just described, can be traced for several miles in the Vaqueros (?) sandstones, but are lost on entering Salinas shale. In the northwestern part of the area, numerous small folds were mapped while tracing the Salinas-Vaqueros (?) contact. Due to folding and later erosion the intersection of this contact with the surface is often a very irregular line. The location of anticlines and synclines are clearly brought out by a study of this contact, the Vaqueros (?) forming embayments in the Salinas shale areas where anticlines occur.

The large area covered by the white Vaqueros sandstones near the north central edge of the quadrangle is probably due to the presence of a gentle syncline. A syncline, which was striking in this direction, was found crossing the Nacimiento River a short distance north of the edge of the quadrangle.

A change in the strike and attitude of the beds, combined with the effects of erosion, causes the noticeable jog in the contact between the Vaqueros (?) and white Vaqueros beds, in the north central part of the quadrangle.

Several important structures were found in the Salinas shale, but due to the character of the outcrops, incompetency of the beds, and time available for field work, not many folds were mapped. These shales are generally highly folded and crumpled into small structures, but they do not usually stand steeply over any considerable area except in the vicinity of faults.

The Salinas beds on the west flank of the Santa Lucia Range dip toward the mountains, except southwest of Cypress Mountain. Here the Salinas sediments, at a distance of 300 yards southwest of the Franciscan contact, dip toward the range in the customary manner. This dip flattens northeastward and then reverses to form a syncline, probably caused by drag on the Rosa Fault.

In the south and east-central part of the area the shales have very gentle dips, and structures are not outstanding. Strikes in the district near Adelaida are northwest, but to the southeastward the beds gradually change

Fold in Salinas shale near Robles Fault.

to an east-west strike in the vicinity of German Church. Southeast of German Church, the Salinas shale exhibits a northwest strike and a comparatively steep dip only near the Chico contact. Apparently, the Nacimiento deformation did not greatly affect this particular part of the area except near the core of the range, and only in a broad way. Some east-west folds are also shown along the Peachy Canyon road south of the southern end of the large Vaqueros (?) area.

Most interesting of all the structures mapped, are the overturned folds and thrust faults in the northeastern corner of the quadrangle. Northeast of the Vaqueros (?) area the Salinas shales stand very steeply, often vertical, and at several localities, are overturned toward the northeast. Many small overturns can be seen in the shales along the south bank of the Nacimiento River. The presence of the easily distinguishable, basal bed of the Santa Margarita formation in a major overturned fold, made the unravelling of the structure possible. This fossiliferous bed of sandstone dips northeast near the northern edge of the quadrangle. By tracing it along its strike toward the southeast, it was discovered that its dip steepens, becomes vertical, and then turns westward in an overturned fold, which continues for several miles until it disappears beneath the Paso Robles sediments. The massive sandstone bed has withstood this reverse twist without much breaking.

Very gentle northeast dips are the rule in the Paso Robles formation. Variations occur in the vicinity of faults where the Paso Robles beds have been dragged into steep dips. Compression has formed a syncline in the Paso Robles just northeast of the zone of Paso faulting.

Faulting

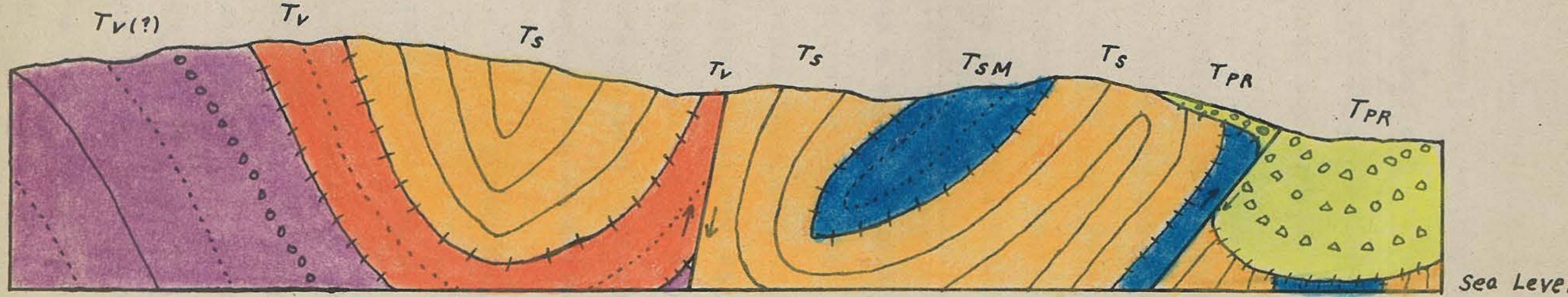
General Statement

Faulting has played a major role in the structural development of this region, in fact it appears to be of more importance than the folding. Many types of faults are found, including normal faults, thrust faults and rifts along which the largest component of movement had been horizontal. Evidence indicates that some of the faults are pre-Monterey in age, but most of them were probably formed during the disturbance which crushed and elevated the region to form the Nacimiento Mountains. Later movement along some of the fractures has caused additional uplift and displaced Paso Robles beds.

There are three zones of faulting in the quadrangle, all of which trend northwest-southeast. The Oceanic zone, from one half to a little over one mile wide consists of several normal, nearly parallel faults. It bounds the Santa Lucia Range on the west. This strip of territory has been greatly fractured and is the largest and best defined of the three fault zones.

Several important lines of movement occur at varying distances east of the crest of the Santa Lucia Range. In this zone are evidences of predominantly horizontal displacement along very steep fault planes.

Two prominent thrust faults associated with steep and overturned folds occur near the northeast corner of the area.



Section Z - Z

Scale 1" = 1000'

Illustrates (roughly) the structural relations of formations in region of thrust faulting and overturning.

With the exception of the steep west face of the main range and some subdued scarps along the Paso and Robles faults no outstanding fault scarps are found in the area. In most cases, erosion has obliterated the original scarp and the only topographical expressions of faulting are fault line features due to erosion.

Description of Individual Faults

Robles Fault

The Robles Fault, located farther to the northeast than any of the other fractures, separates, for a part of its length, Paso Robles beds on the northeast from Salinas shale on the southwest. Its length in this quadrangle is about four miles. A smaller fracture, branches off the Robles Fault about a mile south of the northern edge of the quadrangle and swings eastward into a nearly east-west strike, and is finally lost in the Paso Robles beds. The main fault enters the quadrangle near the 50' longitude line, traces a somewhat sinuous path along the face of the hills, and at its southern end, appears to swing eastward and is lost in the Paso Robles beds. These faults probably die out shortly after they change to an eastwest course.

Where the Robles Fault crosses the Nacimiento River, it is a disturbed zone characterized by overturning and thrusting in the Salinas shale. See photographs. In this zone thrusting is the dominant feature, although small normal faults exist, probably due to settling adjustments which accompanied the elevation caused by thrusting. What appears to be the most important fault surface in this zone is a thrust plane which dips about twenty degrees to the southwest. This surface is well exposed in the south bank of the Nacimiento River. The direction of dip of the fault is also very evident when one follows the fault trace southward over ridges and across canyons. Where the fault crosses a deep canyon in the southwest corner of section 28, the dip was estimated to be 52 degrees.

Judging from the position of the Paso Robles beds on both sides of the fault, 250 feet would represent the minimum vertical displacement, but the actual vertical displacement is probably somewhat greater. Since movement on the Robles Fault has displaced Paso Robles beds, it has been active in Pleistocene time. In the northeast corner of section 29, the east-west branch fault has tilted the Paso Robles beds and developed in them a strike parallel to the fault.

The subdued scarp along which the Robles Fault lies, is a composite scarp. It is due in part to movement along the fault, but still more to the erosion of the creek which flows along the base of the scarp.

Paso Fault

Nearly paralleling the Robles Fault, and lying from $\frac{1}{2}$ to $\frac{3}{4}$ of a mile west of it, is the Paso Fault. This structural

Overthrust in Salinas Shale near Robles Fault.

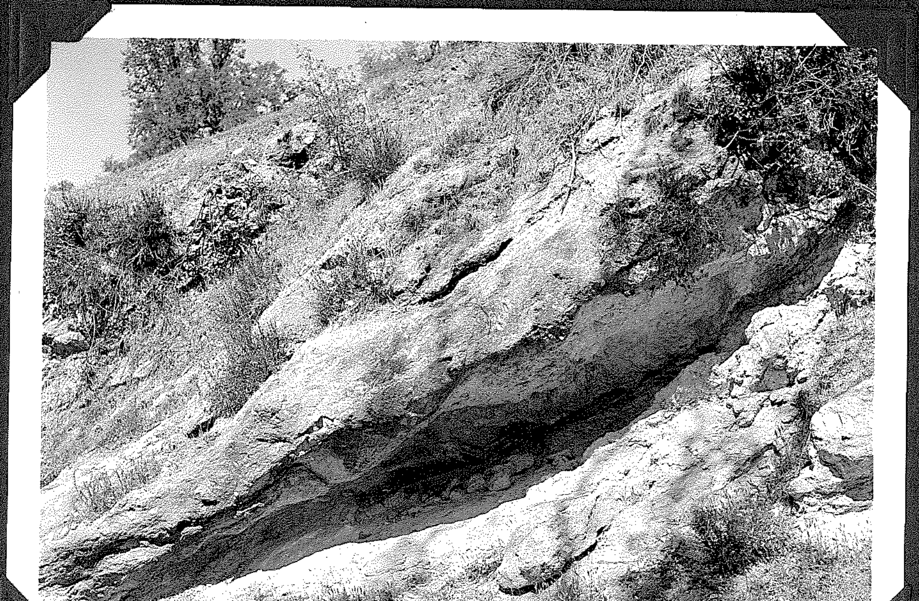
Paso Fault Scarp.

feature passes completely across the northeast corner of the quadrangle, a distance of approximately eight miles. This is also a reverse fault but appears to have a much steeper dip, at least in the north. Beds adjacent to the fault dip westward from 75 to 90 degrees, and the trace of the fault on the surface is nearly a straight line along most of its course. For the most part, the fault lies in Salinas shale, but, near the eastern edge of the map, it forms the contact between the granite and Salinas shale. The shale has been thrust northeast over the granite.

No definite evidence was obtained concerning the amount of displacement, but using what is considered to be remnants of the same surface on both sides of the fault, a minimum figure of 900 feet was obtained. The Paso Fault was probably formed during the pre-Paso Robles, Nacimiento deformation in Pliocene time, as it is associated with the folding of the Nacimiento deformation. Like the Robles Fault, its last movement was in the Pleistocene, as is evidenced by the displacement of the post-Paso Robles surface. This Pleistocene Paso faulting created the youthful valley (present) cycle. From the Chimney Rock road southeastward to the edge of the quadrangle, the fault scarp is still a rather prominent feature.

West of station 110 (see fossil localities), near the northern edge of the quadrangle, exposures indicate a great disturbance and faulting, although no actual exposure of the fault was found. Highly brecciated material was seen, and

Overthrust - Fault Gouge in Fault pictured below.



Overthrust Plane in Pasa Fault Zone. Rock - Granite.

beds change their strike 90 degrees in only a few feet.

In the north bank of San Marcos Creek, where the Salinas-granite contact crosses the stream, are some good exposures. In the granite, practically at the contact with the Salinas shale, is a thrust fault which dips west 34 degrees. The fault zone is about a foot wide and along it the granite has been ground into a gray-blue gouge. Gouging and scratching on the fault surface indicates that the west, and hanging wall, has moved up over the footwall. No shales are exposed within one hundred yards of the contact. The actual contact plane, which must be the main fault surface, may dip more steeply than does this fault in the granite.

Not Faults

There were some indications that a fault existed also on the eastern margin of the granite, but this structural feature is not a fault. The Salinas-granite contact is very irregular and is depositional. Where Salinas shale lies directly on the granite, it has been severely brecciated and is now firmly cemented into a hard breccia. This brecciation is due to crushing along the contact at times when the region was subjected to great force. The decided difference in the character of the two rocks (granite and shale) was responsible for this crushing, as each will act differently when severely strained. The shales would probably yield, move and be ground up on the surface of the granite.

The eastern contact between the Vaqueros beds and the Salinas shale north of Chimney Rock was thought at first to be a fault. It is exceptionally straight; exhibits topography that could easily be fault topography; material was found that looks like fault gouge; beds stand vertical at the contact; and the line is very prominent for miles on airplane photographs. Where this contact crosses the Nacimiento River in the Bradley Quadrangle, it appears to be a fault, but the exact relations were not discovered. At this point the conglomerates have a different strike than the overlying white beds. However, in the excellent exposures near Chimney Rock there is no indication of a fault. Also in the Adelaida Quadrangle, the beds are parallel on both sides of the contact. It was concluded that this contact is not a fault, but due to the difference in character of the adjacent beds, there has been some crushing and movement at certain points.

Tablas Fault

The Tablas Fault, probably one of the oldest in the region, bounds the Santa Lucias on the northeast near Lime Mountain. It enters the area about ½ mile south of the 40' latitude line, continues southwestward to Las Tablas Creek, follows along the Creek to Klau and then passes over the hills to somewhere in the vicinity of the Dover Canyon road west of German Church, where it appears to die out. This is a distance of approximately ten miles.

At station 116, in a small canyon near the western edge of the area, in the extreme southeast corner of section 22, the fault zone is well exposed. At this point the zone is approximately thirty feet wide and excellent examples of slickensiding, brecciation and gouge may be seen. The fault causes a hundred foot jog in the canyon bed, the stream shifting northwestward as though the northern block had moved westward, relatively. From a sight on the high saddle to the northwest, the fault contact seems to dip north about 71 degrees, in which case it would be a normal fault.

Just west of where the fault trace enters Las Tablas canyon, the fault plane stands approximately vertical. Wherever sedimentary beds are close to the Tablas Fault, their attitude is generally vertical. From the evidence secured, Tablas Fault is either vertical or has a steep north dip, and there appears to have been horizontal displacement at some localities, as evidenced by displacement of a small canyon.

This fault bounds the Franciscan formation which lies to the south, and to the north are Chico, Vaqueros (?) and Salinas beds. Tablas Fault or associated branch faults definitely bound the Franciscan, and no outcrops of this formation were found northeast of this fault system.

At one locality, a blue schist outcrops south of the fault, and angular pebbles of this schist occur in Vaqueros (?) sandstone immediately north of the fault. This would indicate that the Tablas Fault was in existence during Vaqueros (?) deposition, and perhaps bounded the land mass existing at that time. Along the fault just west of Las Tablas Canyon, slickensiding was found on post-Salinas calcite, indicating that there was a renewal of movement, probably during the Nacimiento disturbance.

No clues as to amount of displacement were found, but from the fact that the Franciscan does not cross the fault at any point, it must have been considerable. There are no scarps remaining, only a few fault line features being present.

About three miles from the western edge of the quadrangle, it seems rather certain that a branch fault leaves the Tablas and strikes through Lime Mountain. This branch fault acts as the Franciscan-Vaqueros (?) contact for a considerable distance, along part of which the Vaqueros (?) beds dip into the fault. The limestone on Lime Mountain also appears to have been faulted. The trace of the fault over Lime Mountain suggests that it is of reverse type, but the attitude is not definitely known.

Klau Fault

Considerable evidence was found to establish the existence of the Klau Fault, which leaves the Tablas Fault a little over a mile southeast of the Klau mines, and then joins the Tablas again five miles to the northwest. This is one of the old faults of the region. It has a wide gouge zone at some places, but its attitude is unknown. However, the mineralized ledges in the mine workings dip northeast, which may indicate the dip of the fault plane. This attitude would mean that it is a normal fault. Minimum vertical displacement is 800 feet.

Evidence for the Klau fault is as follows:

1. The Franciscan is at least 250 feet higher on the south wall of the canyon than on the north.

2. Chico beds on hill to the south lie at least 800 feet higher than Salinas on hill to the north.

3. Extensive Klau mineralization which follows this line.

4. Salinas beds dip steeply toward the fault.

5. Fault topography.

6. Large areas of crushed rock.

Rita Fault

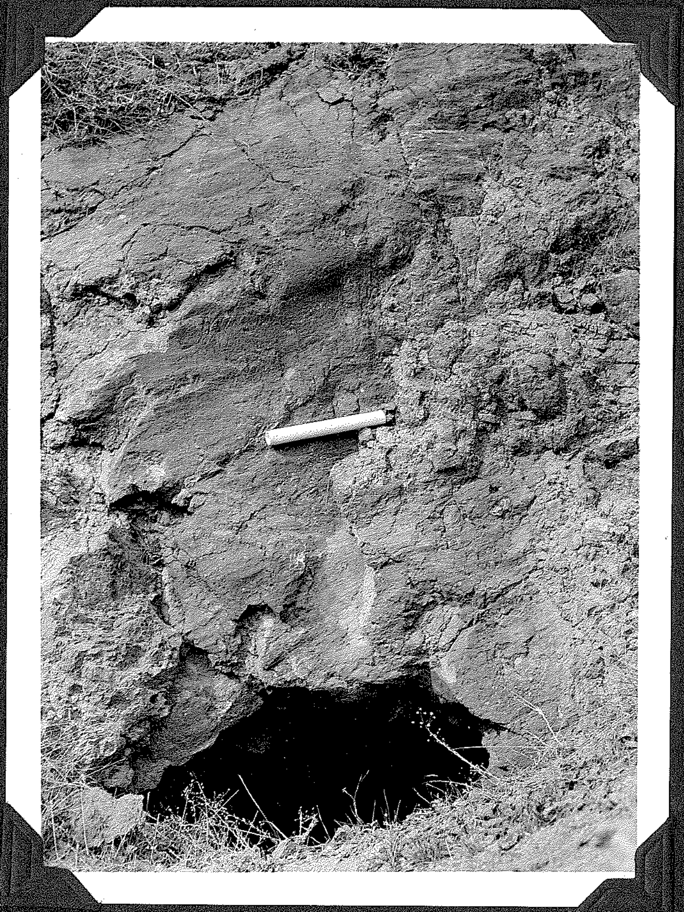
Near the southeast corner of the area, the fracture which separates Franciscan on the southwest from Chico on the northeast, has been named the Rita Fault. This fracture enters the area near the corner of the quadrangle, and trends northwest for about seven or eight miles, where its existence becomes very doubtful. It may continue and form the Franciscan-Chico contact north of the Josephine School. North of Asuncion School this fault separates Chico beds on the southwest and Vaqueros on the northeast. Just south of Santa Rita Creek the attitude of the fault plane is approximately vertical.

Steer Fault

The probable Steer Fault enters the southern edge of the quadrangle near the south fork of Santa Rita Creek, and generally speaking, bounds the Monterey beds on the north. This district is thickly covered with vegetation and the exact location and extension of the fault is not definitely known. Displacement has not been large, but the presence of many saddles, sumps and typical fault topography, indicates movement in Pleistocene or later time. A small fault surface on the line of Steer Fault, exposed in a road cut on the South Fork Santa Rita road grade, dips 49 degrees southwest. As younger beds are on the hanging wall side of the fault, it is of the normal type.

Josephine Fault

Extending for thirteen miles across the quadrangle just east of the main ridge of the Santa Lucias, the Josephine Fault is one of the most important in the region. Its plane of fracture stands nearly vertical at most localities, there has been a great deal of mineralization along it, and striations on the fault surface indicates a predominant horizontal movement. It probably joins the Tablas Fault in the north, but this is not certain. Distribution of formations might suggest that the western block moved north. The gouge zone, at places, is very wide and there



Slickensided surface in Josephine fault zone.

is a strong possibility that this rift was an important factor in the Nacimiento deformation. No evidence of later movement was found.

Sometimes the oldest beds are on one side of the fault, and sometimes on the other. Near the southern edge of the area the Josephine Fault is the contact between Knoxville on the southwest and Salinas on the northeast. Farther north Knoxville is still on its southwest side but Franciscan lies immediately northeast of the fault. Tracing it farther, the rift lies in the Franciscan, and then separates Franciscan on the southwest from Chico on the northeast.

Salinas and Knoxville beds have discordant strikes on opposite sides of the fault, the Knoxville beds striking approximately parallel to it. About 100 yards east of the summit on the Cambria-Adelaida road, mine workings have exposed a fault surface which lies in the Josephine Fault zone. This fault plane dips east 75 degrees, and striations indicate that the movement has been predominately horizontal, the west side moving north and up at an angle of about 15 degrees. Where the Josephine fault zone forms the Franciscan-Chico contact a short distance north of this point, the line of contact as traced over a high ridge dips east 80 degrees.

Oceanic Fault Zone

The Oceanic zone of faulting on the west side of the Santa Lucia Range is easily the most prominent in the area.

Six separate and distinct faults were mapped and named, and many other small fracture lines probably exist. In general, the planes of movement are normal, step faults which have dropped the Monterey, on the southwest, down against the range which is composed of Franciscan rocks. The Oceanic Fault appears to be the master break, and many of the others are branches from it.

Oceanic Fault

Nine miles of the Oceanic Fault are included in the Adelaida Quadrangle and it could probably be traced for some distance in adjoining areas. In the vicinity of the Oceanic Mine the fault separates the Franciscan formation on the north from the Monterey beds to the south. Good exposures occur in the steep canyon just west of the mine workings. The dip here is 81 degrees south, the northern block having gone up. Instead of the usual north dip of the Salinas beds, they have been bent up practically parallel to the fault plane, exposing a strip of Vaqueros adjacent to the fault.

The Oceanic Fault follows a nearly straight course along the west face of the range, lying for the most part in Salinas shale. Near the southern end of Black Mountain the fracture separates Salinas shale from the rhyolite which forms the crest of the mountain. Farther south a narrow strip of Franciscan appears on the north side of the fault. Post-Salinas basic intrusives are common along the Oceanic Fault.

The attitude of the fault plane south of Black Mountain appears to be practically vertical, and the displacement, evidenced by relative position of the same formation on different sides of the fault, must be over 1000 feet.

Other Faults in the Oceanic Zone

Somewhat south of Black Mountain, the Black Fault branches off from the Oceanic, runs along the western edge of Black Mountain near the summit, crosses the Cambria road and apparently continues through Franciscan country. It serves as a contact between several formations at different places along its course. Evidences of the faulting near the summit of Black Mountain include springs, sumps, change in dip of beds, straight contact and minor physiographic features.

Cypress Fault is a branch of Black Fault, and seems to swing back and join the larger structure again northwest of Cypress Mountain. From the trace of this line across the steep canyon in which the Cambria road lies, a south dip of 75 degrees was obtained.

The Rosa, Cottontail and Villa Faults lie to the southwest of the Oceanic. The Villa seems to be a normal step fault, as is the Rosa. Just what the nature of the Cottontail Fault is, was not ascertained. The existence of the Cottontail and Villa Faults is somewhat doubtful.

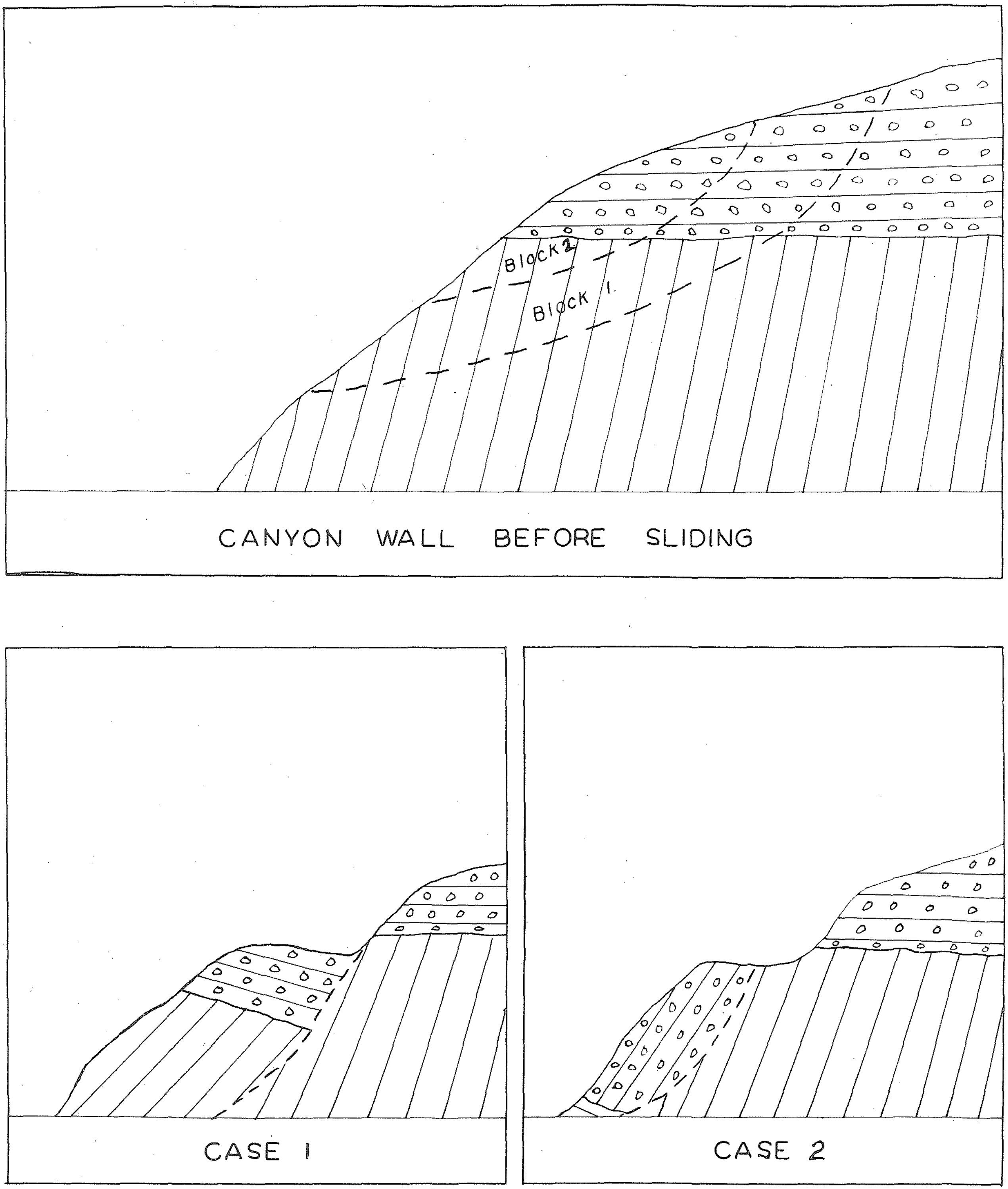
Landslides

Near the northern edge of the quadrangle, in the very deep and steep canyon just west of the Robles Fault, are some landslides which greatly confuse and complicate the detailed structure of that locality. Their effect is not particularly noticeable on the scale which the mapping was done. These landslides are interesting from a structural standpoint because two distinct types occur in this canyon.

These types can best be described with the aid of the accompanying sketches. The steep canyon wall is composed of nearly vertical Salinas shale capped by relatively flat Paso Robles beds. In case 1 the sliding block has slid off the canyon wall and tilted back, coming to rest with the Paso Robles beds dipping slightly toward the face of the hill. In case 2, the sliding block has slipped out over the edge of the canyon wall and then turned forward and slid down the wall parallel to the bedding in the Salinas. The Paso Robles beds now lie on the Salinas shale and dip 80 degrees toward the canyon as does the Salinas shale.

Decidedly different landslide conditions were discovered in the southwestern part of the area, in section 23, about two miles southwest of Cypress Mountain. At this locality, a large mass of Franciscan, mostly serpentine, has travelled approximately two miles down the slope of the range. This body of rock now protrudes across the Oceanic fault and

SKETCH SECTIONS ILLUSTRATING TWO TYPES OF LANDSLIDES DESCRIBED IN TEXT



CANYON WALL BEFORE SLIDING

CASE 1

CASE 2

overlies Monterey beds. The slide took place since there has been any movement on the Oceanic fault, but topography and tree growth after the slide indicate a fairly long lapse of time. The landslide took place, perhaps, in upper Pleistocene.

Evidence for the landslide described above:

1. The large mass of serpentine protrudes across the Oceanic fault.

2. The Monterey beds to the south dip under this mass of Franciscan material.

3. The trace of the Serpentine-Monterey contact eliminates the possibility of its being a fault.

4. Rocks in this protruding mass are the same as those on Cypress Mountain.

5. Material shows no sign of water wear, excluding alluvial deposition.

6. Topographic evidences are: a. amphitheater shape of Cypress Mountain; b. "filled" character of this canyon in contrast to all the others in the region; c. crowding of streams to each side of the fill.

STRUCTURAL MECHANICS

Structural Mechanics of the Adelaida Quadrangle

Summary of Existing Conditions

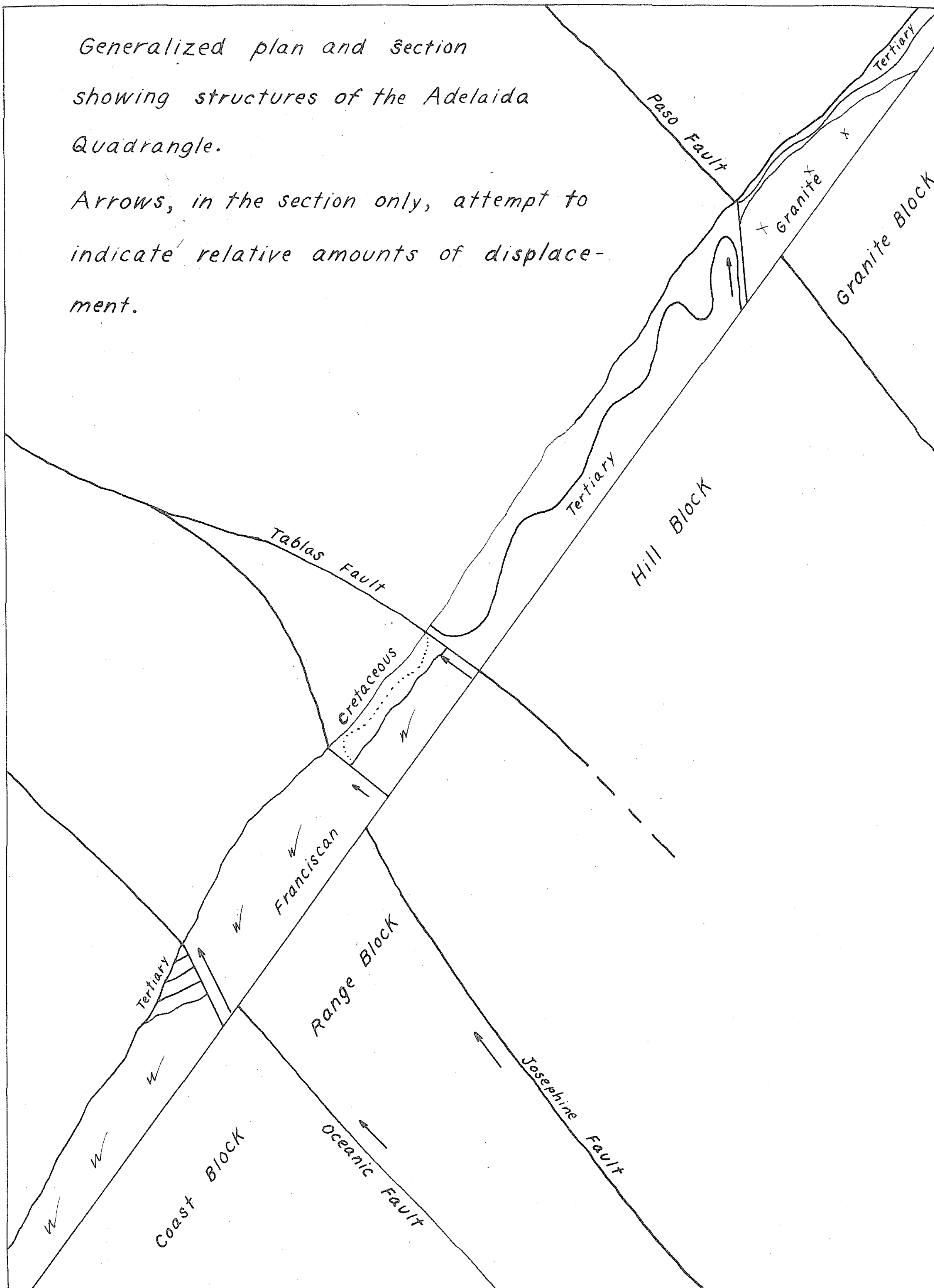
In considering the structural problems of the area the important observed facts will be presented first. With these in mind, an attempt will be made to formulate the mechanical processes which probably produced the present structure. Frequent references to the accompanying diagram will be helpful.

It has been previously shown that the area is cut by three, northwest-southeast trending fault systems. In a general way, these faults divide the quadrangle into four blocks. Enumerating them from the southwest to the north-east corner, is the coast block, the range block, the hill block and the granite block. The rocks and their attitudes on the different blocks are roughly shown on the accompanying plate.

First of importance, perhaps, is the type of faulting which characterizes each zone of movement. This is definitely known for two of the fault systems, and not so well for the third. Movement along the Oceanic Fault zone has been of the normal type, the range block going up with respect to the coast block. The relative amount of horizontal movement accompanying the uplift of the range block is not known. Well defined fault lines along which basic magma has been intruded, and wide zones of gouge are outstanding features. The presence of a large amount of intrusive material along

Generalized plan and section showing structures of the Adelaida Quadrangle.

Arrows, in the section only, attempt to indicate relative amounts of displacement.



these faults would suggest that, at some time, there was either tension or at least a sufficient relief of pressure to allow the molten rock to enter.

The Paso zone of faulting is the most northeasterly of the fault systems. The fractures in this zone are thrust faults, the thrust being toward the northeast. Of particular significance is the fact that the overturning and thrusting is most prominent near the granite area. A twist seen in Salinas beds near the Paso Fault may indicate that the hill block has also moved north relative to the granite block. Shales in the granite block several yards from the fault, strike parallel to the fault. Farther south these beds bend toward the fault through an angle of ninety degrees, suggesting drag conditions. A bend toward the east at their southern end characterizes many of the faults, especially those in the Paso system.

The character of the Josephine, Tablas and Klau Faults, which comprise the central zone of movement, is not definitely known. All evidence indicates that the fault planes are either vertical or have a very steep northeast dip. Striations, offsetting of a stream, and perhaps the distribution of formations, indicates that the predominant movement has been horizontal.

By a careful study of the folding some significant facts have been discovered. By far the most intense folding found in the hill block lies in a northeast-southwest strip between the granite and the large bend in the Josephine Fault. Also, practically all folds in the northern part of the hill block have a gently dipping western limb and a steeply dipping eastern limb. Between the Robles and Paso Faults, and also immediately west of the Paso Fault, some of the folds are overturned. Beds of all formations have much steeper dips near the faults than elsewhere. Except for some small east-west folds in the Salinas beds southeast of German Church, all beds strike approximately parallel to the lines of faulting.

Of particular interest is the fact that the overturning and thrusting in this part of the coast ranges is toward the northeast, and both to the north and south, in the Point Sur and Santa Inez regions, the thrusting is toward the south-west.

Mode of Origin of Structures

In attempting to discern the forces and mechanical processes which have been responsible for the deformation in this area, some facts are very clear, and others are not.

Most of the structure which now exists, was apparently formed during the Nacimiento Revolution. Later disturbances have been mostly in the nature of faulting, usually along fractures which had been formed during the Nacimiento de-formation.

One obvious point, as shown by the folds present on all blocks, and also the overthrusting in the northeast part of the area, is that during the Nacimiento deformation, the entire region was under compression. As evidenced by the direction of overturning and thrusting, and also the asymmetrical form of the folds throughout the northern half of the quadrangle, the compressive forces acted toward the northeast. The east-west bend at the southern end of several faults, and the evidences concerning direction of horizontal movement along the faults, also suggests that the forces acted toward the north and east.

The fact that the folds are steepest and most compressed near faults and gradually become more gentle with increased distance from the fault lines, indicates a close association between the faulting and folding. After certain large fractures occurred, continued movement along these faults would tend to cause further folding and greatly accentuate the structures near the faults.

When the compressive forces began to act in forming the Nacimiento Mountains of Pliocene time, some lines of weakness were already in existence. Evidence mentioned previously indicates that the Tablas, and perhaps the Josephine and Klau Fault was present even in Miocene time. The first pressure initiated the folding in the Miocene sediments. As the forces increased movements began to take place along the existing lines of weakness, there was more folding, new fractures formed, blocks moved against one another and the Nacimiento Mountains formed. This suggests what may have happened.

Evidence previously presented indicates some horizontal movement between the different blocks. The range block, at least in the north, appears to have moved relatively more than the others. This movement must have concentrated more strain in the Miocene beds northeast of the bulge, formed by Tablas Fault and the bend in the Josephine, than elsewhere. Due to the rather competent nature of the Vaqueros (?) sandstone, these forces, accompanied by folding in the Vaqueros (?), were transmitted to the beds near the Paso Fault. These sediments to the northeast were lying against and on a granite mass which proved to be a nearly immoveable body. As a result, the Miocene beds were overturned against the granite and thrust up over it. The granite, therefore, probably indirectly caused the overturning and thrusting in the northeast part of the quadrangle.

Later disturbances, both during the Lucia uplift and the faulting which interrupted the mature valley cycle, have been restricted almost entirely to faulting. It appears that the range and hill blocks tilted eastward due to a large vertical displacement along the Oceanic Fault zone. The only folding which has taken place since the Nacimiento deformation has been of the drag type along faults.

As to what produced the forces which acted toward the northeast, causing a northwest-southeast orientation of all structures and also apparently causing the range block to move with a predominant horizontal displacement, there is not much evidence in the Adelaida Quadrangle. This question will be discussed below in connection with California Coast Range structures in general.

Structural Mechanics of the California Coast Ranges.

Summary of Existing Structures

Despite the fact that considerable work has been done in the California Coast Ranges, and that there exists a fault map of the state which contains numerous faults, very little significant structural material is available. This became evident when an attempt was made to show on a map the location and character of the most important faults in the Coast Ranges. It is the attitude of each fault and also the direction of movement, not the mere presence of a fault, which is of prime importance in unravelling the mechanics of coast range structure. The accompanying plate shows only those faults about which we have reliable data concerning their character.

Outstanding above all else on any structural map of California, is the San Andreas Rift. This fault is now known to extend from a point in the Pacific Ocean, approximately west of the northern boundary of California, to Imperial

Valley in the extreme southeast corner of the state. The San Andreas fault zone is still active and was in existence at least in early Tertiary, and probably before. As indicated on the geomorphic map, the movement has been presumed to be predominantly horizontal, and apparently, the magnitude of displacement must be measured in terms of miles. The western block has moved northwestward, at least relatively.

Perhaps the next most noticeable feature on this geomorphic map, is how closely all smaller faults parallel the San Andreas, even where it curves. There is also a large percentage of thrust faults, along most of which the direction of thrust has been away from the Rift. The structural conditions north of Los Angeles seem to be much different than those south of this city, the typical coast range structure being best developed between Los Angeles and some point north of San Francisco.

From the work already done in the Coast Ranges, it has been learned that the region, at least during the time of major deformation, was under compression. There is considerable difference of opinion as to whether the pressure was directly responsible for the folding, or whether movement along the fault lines caused the folding in adjacent blocks. A combination of ordinary folds, overturned folds, thrust faults, and vertical or very steeply dipping normal faults are found in most areas.

Deformation has been most intense along fault lines, which tend to concentrate the zones of relief. The small structures along the San Andreas, which are due to differential movement of blocks, locally obliterate regional structures which may have been formed by general pressures. Fault zones along which there has been predominantly horizontal movement, are generally wide and are marked by large amounts of gouge.

Mode of Origin of Structures

In the California Coast Ranges as a whole, the compressive forces acted in a northeast-southwest direction. Whether the forces were directed from the northeast or from the southwest is not quite clear.

Another point of real importance, is the question as to what extent the San Andreas Rift controls the deformation and structures in the Coast Ranges. The age of the San Andreas, the amount of movement along it, the parallelism of practically all folds and faults with it strongly suggests that movement along this master rift has been directly responsible for most of our coast range structures. For instance, if the eastern block moved toward the south it would press against the western block and tend to shove the western block toward the southwest. This stress in the western block might be relieved by overthrusting toward the southwest. In this case the thrusting would tend to be away from the rift, which seems to be, generally, the case. South of the large curve in the San Andreas, where unusually strong compressive forces should exist, we find our greatest and most numerous thrust faults. Farther north, in the Santa Lucia Range near Paso Robles for instance, the compression is not so pronounced and thrusting is often due to particular local conditions. The differential movement between blocks is perhaps the most noticeable feature in this region. Even though an area is acted upon by uniform forces throughout, variations in the underlying rocks of different districts will cause a great variety in the resultant structures. This seems to be the case for a large part of the California Coast Ranges.

In further attempting to apply this hypothesis, the Rift hypothesis, assume that, relatively speaking, the eastern block moved south. While gradually working its way southward, the eastern block would exert a great pressure against the western block. This pressure would be transmitted toward the southwest and cause other rifts, folds, thrusts, etc. These forces would be transmitted almost entirely by the underlying, competent, granite mass. Under these curcumstances, what may have happened in the case of the Adelaida area is as follows: The forces acting in the granite tended to thrust this layer toward the southwest and the Miocene sediments lying against it were crumpled and shoved up over the surface of the granite. This underthrusting from the northeast would leave practically the same effects as overthrusting from the southwest.

In an alternative scheme, under the Rift hypothesis, the western block would move northward, due to pressure, acting toward the northeast.

Another possible explanation might be called the Subcrustal Flow Hypothesis. In this theory, isostatic subcrustal flow is considered as taking place from the ocean basin east north eastward to the Sierran region. This movement would bring more material under both the Coast Ranges and the Sierra, with a resulting upward pressure. The direction of flow would also probably tend to move the coastal belt northward. After the San Andreas rift was formed, this force would find relief in horizontal movement along the rift. Even according to this theory, all structures within a few miles of the rift would be due to pressures associated with the horizontal movement. If the above is true, the Sierran block should continue to rise and tilt westward.

What would be happening in the coast ranges under these conditions? As more material moved under the region, with a resulting upward pressure, fractures would occur in the crust and some blocks would be free to move. The fault planes might dip either east or west, but the block would essentially be a thrust block, even though the footwall went up, because the block would essentially be thrust or pushed up from below. However, the main subcrustal flow would be to the Sierra, so that there would be a constant sub-surface pressure toward the east or northeast. This should cause an eastward drag on the crust and the fault planes would dip or bend eastward, at least at depth. Most of the overthrusting occurs opposite the Sierra and in positions where the most underflow would be expected.

In conclusion, it should be stated that as yet we probably do not have enough data from which to explain correctly the structural conditions existing in the Coast Ranges. The Coast Range structures are both varied and complicated and no one theory is completely satisfactory. A number of forces and conditions probably exist, some of which are known and some are not. No matter what the causes, the local rock structures of each locality will produce effects peculiar to those particular conditions. As more detailed mapping continues to be done in the Coast Ranges, one may hope for more conclusive results.

The following conclusions, however, may be drawn from this work:

1. Movement along the San Andreas Rift is responsible for all structures near the rift, and probably many others.

2. The greatest period of movement and deformation was in the early Pliocene. Later disturbances are due mostly to block faulting.

3. Faulting, rather than folding, is the more important structure in the Coast Range.

4. Pressures acting approximately perpendicular to the coast line must exist.

5. There is no completely acceptable explanation for the origin of the forces which have compressed and faulted the coast range country.

6. Several different combinations of forces have probably been active in the Coast Range and no one explanation of orogeny is satisfactory, at least for all localities and all periods of disturbance.

Inter-relation of the Major Mountain Ranges of Western United States

The structural relations of the Rocky Mountains, Great Basin Region, Sierra Nevada, Coast Ranges and the Pacific Basin, if known, would be of fundamental importance. Existing conditions with regard to these features are; eastward thrusting on the east side of the Rockies, faulting (normal or thrust?) on the western edge of these mountains, tensional condition in the Great Basin, normal faulting on the east side of the Sierras, and predominant westward thrusting in the Coast Ranges.

In the central zone we have a region characterized by block faulting and extension in the earth's crust. On either side are large elevated areas, the outer edges of which show thrusting away from the Great Basin. It seems logical to conclude that the thrusting on the east side of the Rockies and in the Coast Ranges has produced the block faulting and extension in the Basin area. The Sierra is really a basin range of great magnitude. Whatever relation the Pacific Basin, on the west, has to these structures, the Mississippi Valley seems to have the same relation on the east.

Now that a hypothesis attempting to explain the conditions in the Great Basin has been presented, a cause should be found for the elevation and thrusting on each side of the Basin Range country. A hypothesis somewhat similar to the previously discussed sub-crustal flow hypothesis might explain the existing structures. Under such conditions there would be a sub-crustal flow of material from beneath the Pacific to the Sierra. This would cause an upward pressure, resulting in an elevation of that area. Due to the eastward dipping fault planes east of the Sierras, this elevation might cause a movement and compression toward the west, exemplified in the Coast Ranges. Similar conditions would also exist for the Rocky Mountains and the Mississippi Valley.

The above hypothesis sets up a constant movement of material in the form of an elongate oval flattened on both ends and sides. In the case of the western half of the system, there is sinking in the ocean basin, an eastward sub-crustal flow of material, elevation of the Sierra, and a westward migration of surface rocks by folding, faulting and erosion. These conditions should continue until this system is thrown out of operation by some greater outside forces.

Two points on which objectors to this hypothesis would have grounds for argument are; first, age of the faulting in all these regions, and second, that the Sierra and Rocky Mountains should be thrust in toward the Great Basin instead of away from it. There is no assurance, however, that the system described in this paper has not been in effect, with certain relatively quiet periods, since early in the Tertiary. Nevertheless, it must have been initiated since the period of folding in the Great Basin region. Just why the upward moving Sierra and Rocky Mountains should shove outward away from the Great Basin, can not be said.

HISTORICAL GEOLOGY

The earliest geological history, of which we have clues in this area, dates to some time in the Jurassic period. In early Jurassic the region was apparently all above sea level and was part of a large land mass, probably near the edge of the present continent. It was probably about this time that a large granite batholith intruded the region. This intrusive is now represented by a small body occurring in this quadrangle and in the Paso Robles Quadrangle, and in the larger mass farther south in the San Luis Quadrangle (described by Fairbanks). These granites probably all belong to the same batholithic mass.

Toward the close of Jurassic time the land began to sink, the sea came in and covered (unless a granite island existed) the entire country thereabouts. This initiated the period of deposition of the Franciscan formation. Due to the coarse nature of the sandstones it is thought that the water was not deep, nor was the land mass which acted as a source for the sandstone materials, far removed. This Franciscan period of deposition covered a long time during which there was tectonic and volcanic activity. Igneous intrusives came into the sediments as they were being laid down, and extensive vulcanism took place on the ocean floor. The highly siliceous solutions from the volcanic vents existing at this time are probably, responsible for the bedded

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At the close of the Jurassic the region was elevated above sea level, folded, faulted and subjected to various igneous activities. The peridotite, which is now the serpentine so frequently found in the Franciscan, may have intruded the Franciscan sediments during these post Jurassic disturbances. A long period of erosion then ensued and a large part of the Franciscan rock must have been carried away.

Sometime in the Cretaceous the sea again came in over the land, but in a different manner. It apparently did not cover the entire area, but occupied deep troughs which opened southward to the sea, and extended northward to somewhere in the vicinity of Cypress Mountain. This trough region might be named the San Luis basin of deposition. The land areas had but slight elevation, erosion was slow, and in these deep troughs the Knoxville shales were laid down. The northwest structural orientation of the coast range structures in this area, probably was initiated at this time. This deposition was followed by elevation, some folding, and probably an erosion period.

Soon, that is late in the Cretaceous period, the land sank again and received more sediments, the Chico beds. The Chico seas undoubtedly had a northwest orientation, were much larger, but do not appear to have been particularly deep, for the sediments were in the most part, rather coarse. This may have been due, however, to higher country bordering the sea, thereby causing more rapid erosion. Sandstones and some conglomerates and shales were deposited in the southeastern portion of the area.

After a rather long period of quiescence, the sea withdrew, and at the close of the Mesozoic this entire region was above sea level. It apparently continued as a positive mass on through the Eocene and Oligocene periods. This was a time of folding, probably faulting, and extensive erosion which stripped off a great amount of Chico, Knoxville and Franciscan rocks. Ever since the end of the Jurassic, part of the Santa Lucia Range extending from Cypress Mountain northward for several miles has apparently existed as a positive mass of land.

With the coming of the Miocene this portion of San Luis Obispo county suffered its greatest submergence. The sea came in from the south, perhaps also from the north, and advanced rapidly to about the latitude of Paso Robles. During the earliest deposition, the sea for some distance northwest of Paso Robles, was shallow and receiving coarse, pebbly sandstone sediments. The source was apparently to the east or northeast, and also in the Santa Lucia Range to the west. The Vaqueros beds thin appreciably toward the west and contain pebbles derived from the Franciscan beds, which comprise the main range in the northern part of the area. Blue schist pebbles are numerous in the hard Vaqueros sandstone north of Las Tablas Fault. This same schist outcrops in places immediately south of the fault. Thus it appears that this part of the Santa Lucia Range was a positive element in lower Miocene time and was bounded, perhaps, by this same fault.

Also at this time, near the old Knoxville trough and along what later was to be an extension southward of the Santa Lucia Mountains, there occurred volcanic disturbances that brought up very acidic material. This formed the rhyolites which are interbedded with sediments near the base of the Monterey.

Later in Monterey time nearly the entire area was covered by deep water for a long period and the great thickness of Salinas shale was laid down. Toward the end of Miocene deposition the Santa Lucia Range (then the Nacimiento Mountains) began to rise in this region and the Santa Margarita beds were deposited on the flanks of the range. This formation is found at several places on both sides of the mountains.

As previously suggested by Dr. R. D. Reed, in "Miocene Paleogeography in the Central Coast Ranges," the clean, granitic nature of the Santa Margarita sands suggests that a gradual uplift changed the type of sedimentation from siliceous shale to well sorted sands derived from granite masses which were raised slightly above sea level. The location of these upper Miocene beds well to the flanks of the range also tends to strenghthen the theory that the range was slowly rising in Santa Margarita time.

There then occurred a great period of elevation, folding, faulting and intrusive action which formed the backbone of the Nacimiento Range. The country southeast from Cypress Mountain was pushed up for the first time, cutting off the Paso Robles region from the sea. Thus it was in lower Pliocene that the San Luis basin of deposition first became a part of the permanent coast range. Most of the present structural lines were formed during this period. Compressive forces, pushing toward the northeast, steepened the eastern side of many folds, completely overturned others, and developed a few thrust faults.

In post-Monterey time, probably lower Pliocene, large volumes of basic magma found their way into the earth's crust along the margin of the continent. The magma apparently found the region of coast range activity a weak zone and approached the surface along this line or strip of country. At any rate, the elongate, spheroidal, basic intrusions along fault lines belong to the latter part of this period. They form many of the basic bodies often found in the Monterey and Franciscan formations. Cinnabar deposition accompanied these basic intrusions and continued for some time afterwards. The diabases, which intruded Vaqueros(?) beds in some localities, belong to this period of activity.

During a large part of the Pliocene the Nacimiento Mountains were subjected to active erosion. Part of the materials eroded away were carried to the sea, and part were deposited in the Paso Robles basin east of the range. This process continued until the mountains had been reduced to a peneplain, the Lucia peneplain, and approximately one thousand feet of sediments had been laid down to form the Paso Robles formation.

Paso Robles beds are continuous across the present bed of the Salinas River, indicating that the river was not existing there at that time, but that a large part of the area was covered by the Paso Robles Lake. The headwaters of the Salinas, where it now flows through granite, probably followed much the same course as they do now, and flowed northward into Paso Robles Lake. Streams also drained eastward and southward from the Nacimiento Mountains into the fresh water basin. It must have been at this time that the Nacimiento and San Antonio Rivers developed their present courses from north to south (approximately). In order to preserve the fresh water condition of this inland lake, there was undoubtedly some sort of outlet to the sea, perhaps a chain of low lying lakes extending northward along what is now the Salinas Valley.

Probably in early Pleistocene time, a great change took place. The Santa Lucia Range, having the Lucia peneplain as its surface, was uplifted and tilted eastward. Faulting on the west side of the mountains appears to be primarily responsible for the initiation of this new cycle. The Paso Robles basin was elevated somewhat and faulting along the Salinas Valley to the north opened an unobstructed drainage way to the sea at Monterey. The waters contained in the old Paso Robles basin drained out to the ocean and the Salinas River began to cut a channel through the lake beds. The waters of the San Antonio and Nacimiento Rivers continued to flow southward until nearing the open valley country, where they turned eastward to the Salinas River, and then flowed northward. They still follow this peculiar course.

During the Pleistocene we have record of another long period of erosion, but of considerably less duration than the one which produced the Lucia peneplain in Pliocene time. The land forms show evidence of having progressed to a stage of late maturity, now indicated by the high level, mature valleys. The exact history out in the Paso Robles basin is difficult to decipher, but the region was probably undergoing slow degradation.

Later in the Pleistocene this mature valley cycle was interrupted, and the coast range was further elevated to make the mountains from which the present forms have been shaped. Extensive faulting, the Paso Faulting, took place near the Salinas Valley, and perhaps also along both sides of the Santa Lucias. The Paso Robles beds were tilted and displaced while the mature valley surface was elevated and broken. Paso faulting introduced the present cycle, now represented by steep walled canyons which are still being rapidly cut away.

The present relatively flat country south of Estrella is due partly to the nearly flat attitude of the Paso Robles beds, and is not an old peneplain. It is approximately a surface of deposition. This surface has, however, been somewhat altered by erosion, but it has never been elevated much above its present position.

Many minor changes have occurred in comparatively recent time. First a subsidence of the land took place, now evidenced by the deeply filled valleys; the fill extending to below sea level in some places. The land came up again, causing the cutting of a series of terraces along the coast. It may be the effects of this Quaternary elevation, finally reaching around through the Salinas Valley, which has caused renewed intrenchment and stream erosion in the vicinity of Paso Robles. The Estrella River, and other tributaries of the Salinas east of Paso Robles, have continued this cutting into recent time. These streams are now very slowly degrading.

ECONOMIC GEOLOGY

QUICKSILVER

The production of quicksilver is the most important mining industry in the Adelaida Quadrangle. San Luis Obispo county has been one of the important quicksilver producing districts in the state since the early seventies, and most of this production has come from the Oceanic and Klau mines in the Adelaida Quadrangle, although a dozen or so smaller mines have contributed to the total.

History of Mining

It is said that cinnabar from the Santa Lucia Mountains was used by Indians for pigment long before any mining was done. The first prospecting began in 1861, locations being made the following year. The Little Bonanza Mine, originally the Josephine, was located in 1862 and was the first quicksilver mine worked in the county. A great deal of prospecting, developing, and considerable production took place at various localities during the next few years, and a number of old, tumble down furnaces record this former activity.

The patent for the Oceanic mining claims, signed by President Lincoln, was granted in 1865. The location of the Klau mine was made in 1868. Considerable work was done in the next few years and the high price of mercury in 1874 stimulated both mines to heavy production. No records of output are available until those of 1876, when the Oceanic produced 2358 flasks and the Klau 1590 flasks. This activity continued, with a gradual diminution, until 1879 when nearly all work was suspended.

The slight rise in the price of quicksilver about the year 1900 brought renewed activity. In 1902, with 3300 flasks, the Klau was the leading mine in the county and the fourth largest producer in the state. The Oceanic was re-opened the same year and continued work more steadily than any other mine in the district, being one of the largest producers in the state from 1906 to 1908. Total recorded production of the mines to the end of 1917 was; Oceanic 23251 flasks, and the Klau 14213 flasks.

The high prices prevailing during the war again started important work, but the district soon lapsed into semi-idleness. The present high price of quicksilver, with the apparent favorable regulation of the market by Spanish and Italian interests, has brought new operators and miners into nearly all the old camps. During the summer of 1929 the Oceanic produced 384 flasks from April through August at an operating cost of $1.70 per ton on ore running about .18% mercury. This amounts to a cost of $35 to $36 a flask, which is creditable in view of the grade of ore being worked.

Trend of Production in California

The accompanying graph shows clearly the influence of price on the production of quicksilver in California. Every peak in the price curve is followed, in from three to six years, by a maximum in the production curve. During the war period, the price and production curves rise simultaneously. Any price peak, rising to $45 or more a flask, has greatly stimulated mining activities. By far the largest production of mercury took place for a few years around 1877 following the high prices of 1873, '74 and '75. If the minor irregularities be disregarded, the quicksilver output has shown a steady decrease from 1877 to the present, although there has been a slight increase since 1921. Since 1877 the response of the production curve to advances in price has become more and more feeble. This indicates that large quantities of quicksilver are not as readily available as in the past. It is true that in most of the mines the richest ore has been worked out during boom periods and the lower grade rock is now being extracted in a more painstaking manner. The present high price of this metal should definitely bring to light the condition of California's quicksilver resources.

Geology

The rocks found in the vicinity of the ore deposites are: the Franciscan series consisting of sandstone, chert, and some shales; the Monterey group containing sandstone and

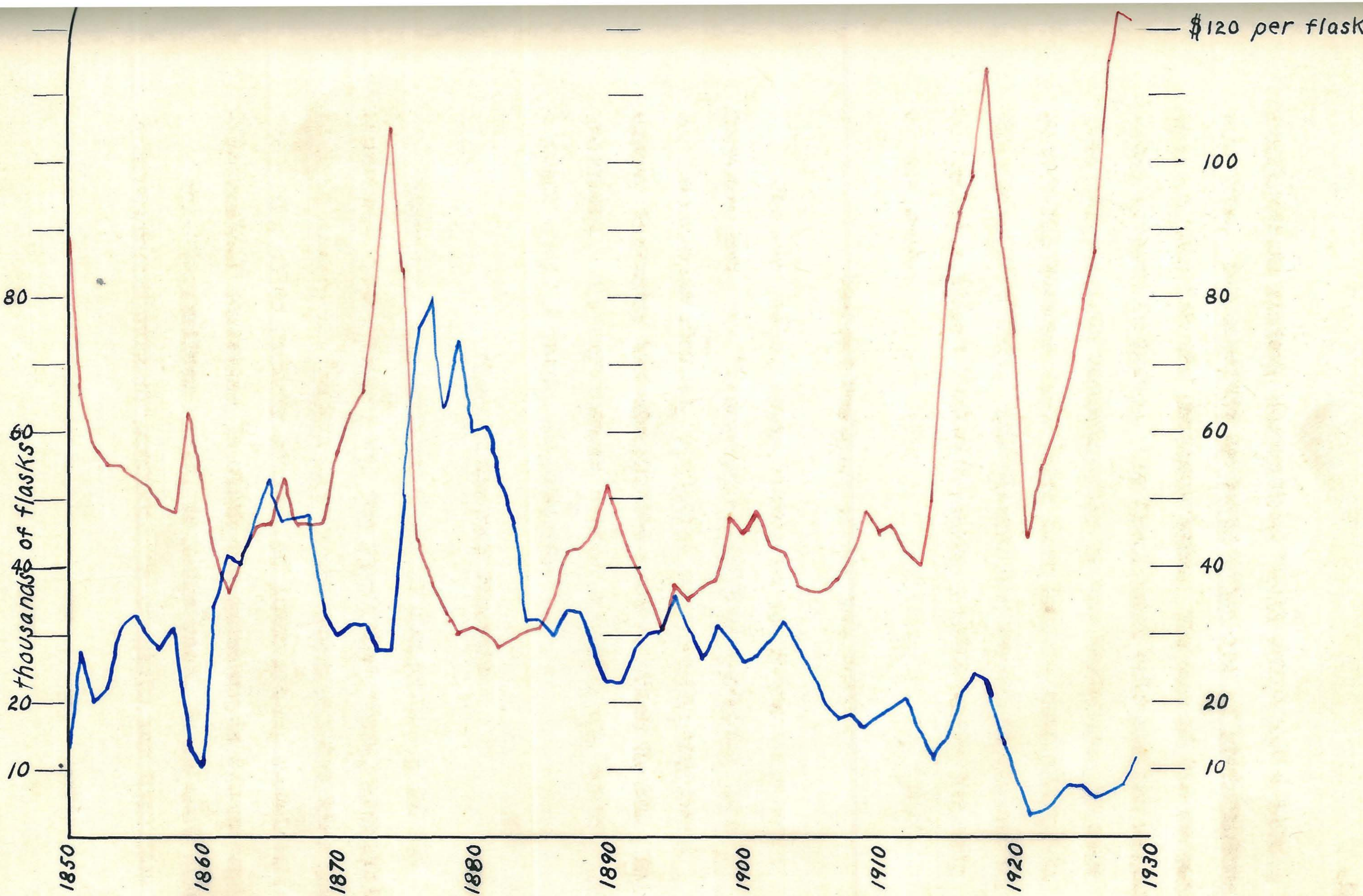


Figure - Graph showing production (blue) and price (red) of quicksilver in California.

argillaceous shales; serpentine; basic dikes and a little rhyolite. The basaltic or basic dikes are of post-Monterey age, as they cut the Monterey beds. The age of the serpentines is much in doubt. The Franciscan beds and the serpentine are overlain unconformably by the Monterey. In some places the Miocene rocks have been faulted down alongside the older formation. The mineralized region is dislocated by numerous normal faults trending parallel with the axis of the range.

General Features of the Ore Bodies

The ore bodies occur either in the Franciscan or in the Monterey near the Franciscan - Monterey contact. At all the localities studied, bodies of serpentine were found either bordering the mineralized zone or close to it. In practically all occurrences a large fault zone, containing a great deal of gouge, is present.

Type of Ore and Minerals

There are two distinct types of ore existing in the district. The richest, and the first kind mined, consisted of hard ledges of "quicksilver rock" which yielded high grade ore. The other variety of ore, of lower grade, consists of fine grained sandstone in which the cinnabar is disseminated.

The "quicksilver rock", or ledge rock, is in most places a thorough replacement product. So complete has been the transformation that the identity of the original rock has in most places been completely obliterated. These hard ledges are made up of crystalline quartz, chert or chalcedonic material, calcite, pyrite, cinnabar, and various other minor constituents. These ledges stand out prominently due to their superior hardness, and are profusely stained with streaks of iron oxide giving them generally an ocher-yellow color. In some places the ledges appear to be replacements of serpentine, and in others, replacements of sandstone.

The cinnabar-bearing sandstone is massive, fine grained, and rather hard, the cinnabar occurring as small, red specks and spots. Cinnabar is the only ore mineral of the district and is found coating fracture surfaces, as disseminated specks or spots, and as small veins or stringers, but distinct crystals are rare.

Only meager data was obtained concerning the order of deposition of the various minerals. The probable sequence was; quartz, chert, pyrite, cinnabar, and, finally, calcite. The cinnabar was seen in fissures cutting chert, and in places calcite veins cut across the cinnabar.

Immediate Geological Environment

The country rock is sandstone or serpentine, or fault gouge, some basic dikes are found near the ore bodies. Most of the sandstone belongs to the Franciscan formation and weathers with very characteristic streaks of ocherous yellow.

The coarse beds are generally barren. At the Oceanic mine, fine grained sandstone belonging to the Vaqueros formation occurs both as ore and country rock.

In nearly all the mines are found large masses of what was originally a fine grained shale of Franciscan age, but which has been so disturbed as to present the appearance of fault gouge. This dark gouge contains numerous slickensided surfaces, evidences of movement, and appears rather impervious. There are, however, boulders of sandstone (often resembling lenses) which have apprently been dragged into the fault zone. These boulders have been largely replaced and mineralized, and many of them are completely altered to a white kaolin-like material which sometimes contains cinnabar. The zones of fault gouge generally bound the ore bodies.

All deposites examined occur along large faults which may be old or may or may not have been active in recent times. The ore deposites are clearly connected with faults and bodies of serpentine. The ledge rock is regarded as a replacement of a highly brecciated rock mass of both serpentine and sandstone.

Form and Shape of Ore Bodies

The ore bodies occur as irregular masses relatively near the surface. The hard ledge rock averages from 10 to 15 feet in width and rarely extends deeper than a few hundred feet, often pinching out at a depth of about a hundred feet. The ledges undoubtedly represent replacement bodies that have formed near the surface. The sandstone ore bodies are also irregular, but are larger, extending deeper, and their boundaries may be marked merely by a gradual decrease in the amount of cinnabar present.

Origin and Age of the Deposits

These ore bodies represent normal, epithermal deposits laid down by hot, ascending solutions. The minerals were probably released as the solutions cooled, came in contact with other waters, and migrated into relatively open zones with a consequent release of pressure. Two interesting questions arise. Are the deposites related to any igneous rock, and if so what rock? Also of what age are the ore bodies?

The following facts appear to be indicative of the mode of origin. In the first place, the cinnabar mineralization has occurred adjacent to, or in, large fault zones. Secondly, the only igneous rock invariably present immediately adjacent to, or near the ore bodies, is serpentine. From the evidence gathered, a logical conclusion is that the mercury bearing solutions emanated from a basic magma, basaltic or peridotite in nature, and found their way upward along lines of faulting. Although there has been movement in rather recent times along some of the faults, evidence indicates their existence in late Miocene time.

The question of age is a more difficult one. There are, as far as known, no hot springs or solutions still depositing cinnabar in this district at the present time. There are also no Pliocene or younger rocks containing ore deposits. There are, however, practically no post-Miocene beds present in any of the quicksilver localities. Cinnabar was found in a basic, post-Monterey dike in the Esperanza tunnel at the Oceanic mine. The youngest beds in which mineralization was found are the Vaqueros sandstones. That narrows the possible time of deposition down to post-Monterey (post-Miocene) and pre-recent time.

There is a possibility that the ore deposits are related to the basic intrusives that cut the Monterey. The main difficulty is that basic dikes or bodies are not always found associated with the ore bodies. A large dike of this nature occurs at the Oceanic mine near the ore body, but none was found at either the Klau or Cinnabar Mining Company workings. On the other hand, an attempt to correlate the quicksilver deposits with the serpentines, which are always present in the vicinity of the ore bodies, brings up the question of age of the serpentines. If the peridotite intrusives gave off cinnabar bearing solutions at the time of their intrusion, and are the source of the quicksilver, they must be post-Monterey in age. Although this youthful age for the serpentine was suggested in this report, it seems most impossible.

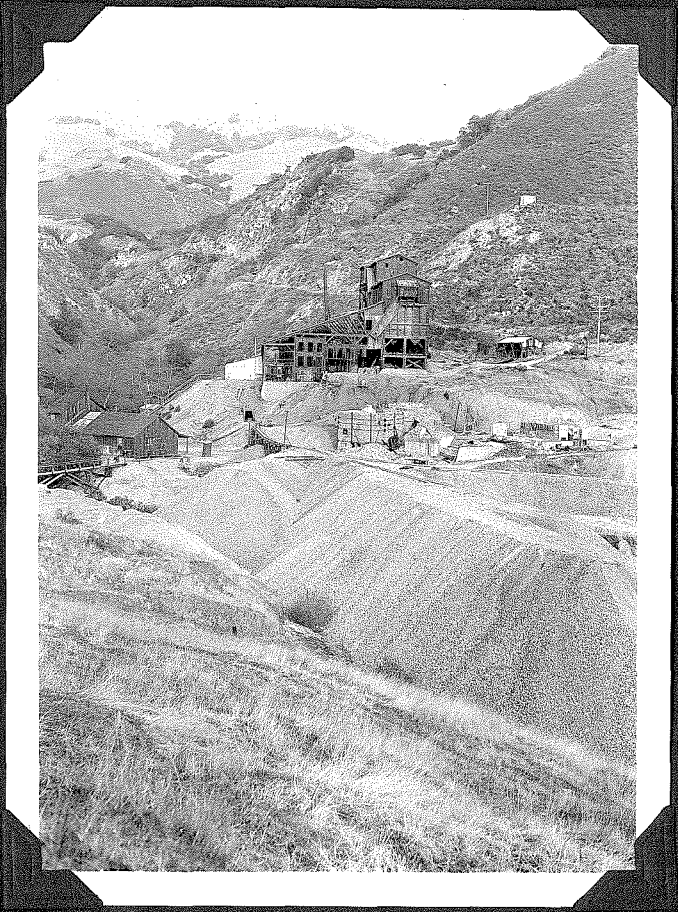
It may be that hot solutions rising through the serpentine picked up the mercury already present in the basic rocks, carried it into the surface rocks and then redeposited it as cinnabar. If the deposition of the cinnabar is related to either the serpentine or basic dike intrusives, it must be recognized that the deposition continued for some time following the igneous intrusions.

In conclusion it may be said that the quicksilver bearing solutions migrated upward and deposited their contents along faults. There also may be some relation between the cinnabar and the serpentine, but the magma which formed the post-Monterey basic dikes was probably the source of the mercury.

Mines and Prospects

Only two localities were studied in detail, the Oceanic mine and the Cinnabar Mining Company prospect. C. H. Lewis, at that time manager of the Oceanic mine, and L. D. Purdy, owner of the Cinnabar Mining Company holdings, extended every possible courtesy and help while the geology of the two mines was being studied.

The Oceanic Mine is just off the Santa Rosa Creek road about five miles east of Cambria. The rocks exposed on a traverse running from north to south are; Franciscan cherts, Franciscan sandstone, serpentine, sandstone, ledge rock, fine grained Vaqueros sandstone, a basic dike and Vaqueros mud shales. A fairly coarse grained diabase or gabbro dike, containing inclusions of Franciscan sandstone and shale, has been intruded into the Franciscan. A short distance



Furnace and Dump at Oceanic Mine.

down the canyon a large ellipsoidal, basaltic sill about 200 feet thick has come into the Vaqueros. This basaltic rock contains still younger quartz-calcite veins. The shales both above and below the dike have been baked and hardened. The Vaqueros series dips north, becoming steeper near the large fault which separates the Vaqueros and Franciscan.

This Oceanic Fault is one of the largest in the region and may be traced entirely across the southwestern part of the quadrangle. In the canyon just west of the mine, exposures show that the fault dips south 81 degrees. This fault zone is 10 to 20 feet wide and is generally filled with impervious gouge. The gouge and serpentine mark the northern boundary of the ore body. The serpentine contains small veins of cross fiber asbestos.

In the early days, some rich ore was extracted from a small ledge near the surface, but most of the ore came from comparatively coarse sandstone immediately south of the fault gouge. The richer ore was exhausted about the year 1911 and at the present time fine grained sandstone farther from the fault is contributing large quantities of low grade ore. Cinnabar was found in the basic dike of Esperanza Hill, in the Vaqueros sandstone, and in the hard ledge rock. This places the mineralization in post-Miocene time, and indicates a source from ascending solutions later than either the basic dike or peridotite intrusive epoch.

The Cinnabar Mining Company prospect is situated at the summit of the Cambria-Adelaida road. A small amount of good ore occurs in a mineralized ledge outcropping on the summit of the ridge. This ledge apparently extends northward down the canyon but pinches out within a short distance to the south. The ledge rock dies out in depth, for a tunnel running directly under the outcrop, approximately 200 feet below, failed to pick up the mineralized zone. Instead, a fault gouge containing sandstone boulders, altered to a kaolin-like material containing cinnabar, was found. The rocks in the vicinity of this mine are all Franciscan, mostly coarse, iron stained sandstone. A body of serpentine outcrops in the swale just south of the mine.

PETROLEUM PROSPECTS

There is a strong possibility of large, new oil fields being discovered in San Luis Obispo county. The systematic search for oil by the large companies is gradually working farther and farther north both in the San Joaquin Valley and along the coast. The country immediately east of Paso Robles looks especially favorable for oil prospecting. There occur thousands of feet of Salinas shales, a possible source rock for the petroleum, and also a thick section of Vaqueros, and in some localities, considerable Santa Margarita sandstone. Both of these last named formations contain beds that would make excellent reservoir rocks under suitable structural conditions.

Much of the country near Paso Robles is covered by the nearly flat-lying, fresh-water, Paso Robles formation which effectively masks the underground structure. This will undoubtedly necessitate a large amount of wildcatting before a producing field is found. A few oil seeps and water wells containing oil showings indicate the presence of petroleum in the region.

Prospects in the Adelaida Quadrangle proper are not so bright. There is practically no chance for oil in economic quantities on the coast side of the Santa Lucia Range. Although there are a thousand or two thousand feet of Monterey beds on this slope of the range, the country is greatly cut up by faults, there are numerous post-Miocene intrusive bodies, and no favorable structures were found. These points combined with the fact that the Franciscan formation lies immediately below the Monterey group of sediments, would seem to rule out all possibilities of petroleum occurring in any quantity.

The country on the Salinas Valley side of the coast range contains more favorable indications, but even here there is not much chance that a potential oil field exists. The best territory lies in the northeastern corner of the quadrangle. A large thickness of Vaqueros sandstone occurs in the upper half of the quadrangle and thins out southward until the coarse beds directly beneath the Salinas shales practically disappear. This thinning out of possible reservoir rock in the southern half of the area makes the accumulation of oil highly improbable.

It is possible that folding and faulting may have produced a suitable trap for oil somewhere in the northeastern part of the quadrangle, for numerous anticlines and a few faults are present in the Monterey. To the west, the Salinas shales have been stripped off the Vaqueros which is the surface rock over a large area. The exposed Vaqueros shows no signs of petroleum. Some asphaltic beds occur in highly folded Salinas shales indicating past seepages. Careful mapping of the Vaqueros-Salinas contact is very helpful in bringing out anticlines and synclines, for the two formations are perfectly conformable.

In the portion of the area north of Adelaida numerous anticlines in the Vaqueros may be traced into and under the Salinas shales but signs of petroleum are not present. Farther northeast, beyond a fault, oil seepages in steeply dipping Salinas shales are rather common. The oil has migrated upward, much of it having been dissipated at the surface some time in the past. These conditions exist for several miles to the north where considerable leasing and drilling has been done resulting in numerous indications of oil but no commercial production. The district in which there exists the highest probability of finding oil lies north of San Marcos Creek and east of the Salinas-Paso Robles contact. The most adverse condition existing here is the high probability of finding the underlying Salinas beds greatly contorted and standing vertical. A well sunk in this locality should penetrate Paso Robles, Santa Margarita, Salinas and Vaqueros beds. The Continental Oil Company is drilling here now (January 1931).

At the time this field work was done a well was also being drilled in the southeastern portion of the Quadrangle, about three-fourths of a mile south of the Oakdale School. The well had penetrated nearly 3000 feet of what was supposed to be Salinas beds and the operators were hoping to reach Vaqueros sandstone. The Salinas-Chico contact lies about a mile to the southwest. Two points make the success of the project look very doubtful. In the first place, the presence of a favorable structure is exceedingly doubtful. Secondly, the chance of finding suitable Vaqueros beds, in this particular locality, is poor. The lower Miocene member of the Monterey, the sandstones, seem to have thinned out here almost to the disappearing point. The well cores show that the direction of drilling is practically perpendicular to the attitude of the beds.

FLAGSTONES

There are, in the area, two rather productive flagstone quarries where slabs of Salinas shale are mined. The largest quarry is situated on top of the ridge extending northwest from the summit of the Santa Rita Creek road grade. It lies at an elevation of 1800 feet, from which point one looks down steep canyons to Morro Bay and the ocean.

Salinas Shale Quarr
on Crest of Santa
Lucia Range.

Slabs of Shale Ready for Shipment (location as above).

The rock consists of large slabs of Salinas shales from about two inches to a foot thick. It is white, gray, or cream colored, sometimes massive within a slab, but more often showing white and cream colored streaks parallel to the bedding. The beds strike north 50 to 80 degrees west and dip from 30 to 60 degrees to the southwest. The bedding planes, or rift planes, are very helpful in the quarrying; while the grain fracture breaks the slabs into workable sizes varying from 1' by 1' to 5' by 5' blocks. All work is done in open cuts 5 to 30 feet deep, generally on the side or top of a narrow ridge. The rock is unusually hard and heavy for shale.

The stones are hauled to Templeton and then shipped to Los Angeles, Santa Barbara and Pasadena to be used as stepping stones in gardens, etc. The total production amounts to over twenty five carloads.

A smaller but similar Salinas shale quarry is situated on Santa Rosa Creek about eight miles from the coast. The rocks dip from 60 to 80 degrees northward and are mined from a steep face on the south side of the road. The slabs obtained here were used on the grounds of the Hearst estate, near San Simeon.

Some of the Chico and Vaqueros sandstone exposed in creek bottoms appears suitable for certain building purposes. Some of the rhyolites of Black Mountain might be used as decorating stones.

LIME

There are three occurrences within the area of good grade limestone. The largest and purest body is on Lime Mountain near the western edge of the mapped area. The other limestone beds are on the hill just west of the Dubost ranch house, and a half mile farther west extending down to Franklin Creek. These last two sets of beds may be continuous or nearly so. At all localities the limestone seems to be the lowermost member of the Salinas formation.

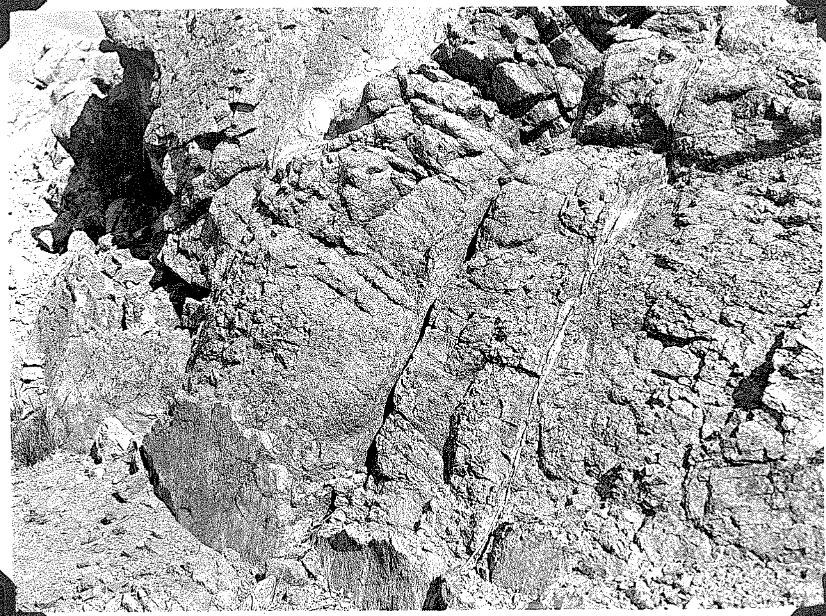
The limestone at the Lime Mountain locality forms a capping for the main mountain mass which is composed of Vaqueros and Franciscan rocks. The limestone beds are now crystalline, but contain many shell fragments. A fresh surface shows a pinkish cream color but outcrops are a blue-gray. A fair automobile road extends to within less than a mile of the beds.

The limestones near Dubost's are adjacent to an old road which is still passable. There are two old limestone kilns here; one near the Dubost home was built in about the year 1890; the other one, over the hill and down the creek, was built in 1894. The lime used in the construction of the Paso Robles Hotel came from these kilns, and they were last used in the year 1912. These deposits represent a large resource of lime.

ASBESTOS

Some of the serpentine intrusives contain numerous seams of asbestos, especially those near the junction of the Cayucos-Paso Robles road and the Cambria road. The country rock was originally a very basic intrusive, probably a peridotite, but has now been altered almost entirely to serpentine. It outcrops in the form of large, rounded, dark boulders and patches of blue-green material. The weathered surfaces appear reddish-brown but a fresh surface exhibits a dark greenish or brownish black color, and is often coarsely crystalline.

The rock contains many veins of cross-fiber, chrysotile asbestos of fair quality. The seams are either in the serpentine or in a light colored gray-green rock, (a chert-like appearing form of serpentine), and are in part filling and in part replacements in and along the fractures. The asbestos may occur alone in a fracture, but often it has formed interlayered with this cherty looking type of serpentine; or the fractures may have been filled entirely by this amorphous serpentine. The asbestos and chert-like material belong to the same period of deposition for in some samples the asbestos occupies the center of the fracture, and the chert-like filling, the sides; while in others, the relative positions of the two are reversed. Generally, however, the asbestos was deposited first. The asbestos is green and noticeably shiny. In some places several veins occur in a two foot width of country rock. There are many sizes of veins ranging from those barely visible up to fibers .4 of



Serpentine

Asbestos seams in Serpentine

an inch long.

The seams of asbestos bring out clearly the fracture pattern in the rocks. In some cases two sets of tiny fractures are practically at right angles to each other. Some samples show a decidedly irregular, replacement contact between the cross fiber asbestos and the surrounding, coarse grained serpentine. In most specimens the asbestos is cut off sharply along the edges of the fracture and the contact shows no sign of replacement of the surrounding rock. The contact between the asbestos and the chert-like serpentine is also a sharp one. Some samples show a division line along the center of the vein. In one specimen the hard, chert-like serpentine shows a tendency toward the formation of cross fibers.

A history of deposition is as follows. Intrusion of the peridotites, complete solidification, serpenization, weathering and fracturing, and then came solutions depositing asbestos and later, due to some change of conditions, the solutions deposited the serpentine in the light colored, chert-like form. There was some overlap in the periods of deposition. The hot, ascending solutions dissolved parts of the serpentine country rock and then under different conditions, dropped their load, depositing the serpentine in a new form.

Due to the short length of the fibers and irregularity of the seams, it is doubtful if the deposits are of any economic value.

CHROME IRON ORE

A few chromite deposits of minor importance are scattered about in the basic igneous rocks of the Franciscan formation. The chromite masses occur as irregular bodies in peridotite or serpentine. The samples of rock studied showed a large percentage of hematite present with the chromite. The chromite is in crystalline form while the hematite fills in around the crystals of chromite. There has been practically no production of ore in the quadrangle but considerable prospecting and some development was done during the war.

ROAD MATERIAL

A number of different rocks are used for road material within the area. There being but little sand or gravel in the region, other materials are spread over the earth roads in an attempt to make them passable in wet weather. Some stream gravels in the Paso Robles formation, chert, and Salinas shales are used. They break up into suitable sizes on excavation and may be spread on the roads without further treatment.

CHARCOAL

Another resource utilized in this region, but not strictly geological, is the small oak tree from which charcoal is produced. The oak wood is cut into three to four foot lengths and something less than a foot in diameter, and burnt in earth covered furnaces. The charcoal logs are then cooled, sacked and shipped away. The industry is carried on by Japanese who have camps in several different localities.

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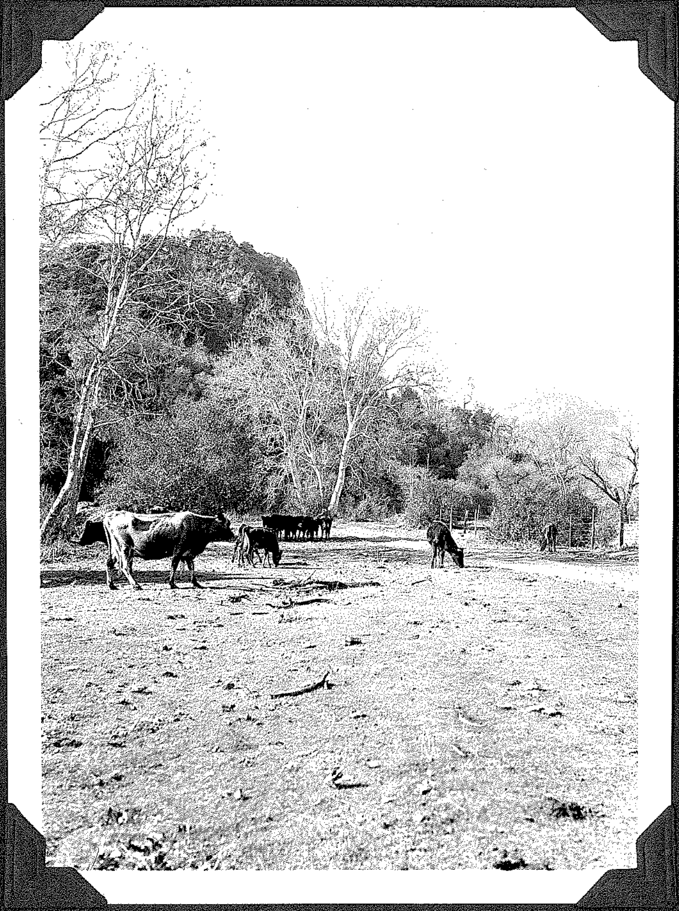

Beauty and Contentment