GEOLOGY OF THE SOLEDAD QUADRANGLE, CENTRAL CALIFORNIA

Thesis by

Frank A. Nickell

In Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy,

California Institute of Technology,
Pasadena, California

1931

Frontispiece

Panorama of the King City fault scarp and the Salinas valley.

INDEX

INDEX (continued)

INDEX (continued)

List of Illustrations

Photomicrographs

Plates

ABSTRACT

The area studied is located in the central Coast Ranges of California and about 40 miles inland southeast of Monterey on the Pacific coast. It is nearly 100 miles south of San Francisco. It includes portions of the Santa Lucia and Gabilan Ranges and of the intervening Salinas valley.

The pre-Cretaceous basement is divisible into three units, the Santa Lucia granite, the Santa Lucia quartz diorite series, which is the latest intrusive, and the Sur Series (?) of metamorphics. Tertiary and Quaternary formations are found within the Salinas valley and chiefly along the western side. The aggregate thickness of middle Miocene, Pliocene, and Quaternary rocks is approximately 12,000 feet. Pre-Quaternary formations are folded into a composite syncline.

Faulting occurred in both the Pliocene and the Pleistocene. In the Pliocene the sediments west of the valley were folded and overthrust. Compressive forces acted from the south and west.

The early Pleistocene normal faulting along northwest lines divided the area into two blocks, the Gabilan block to the east and the King City block. The movement tilted the Gabilan block southwestward, interrupted the Pleistocene cycle of erosion which had produced the Salinas old age surface, and tilted the King City block towards the west. The displacement of about 4000 feet formed a scarp now somewhat dissected along the western side of the Salinas valley. At the same time movement occurred along several other normal faults within the blocks.

SUMMARY

The Soledad Quadrangle, an area of 254 square miles, is situated in the central Coast Ranges of California 40 miles inland from the Pacific ocean at Monterey and about 100 miles south of San Francisco. The area includes three major topographic and structural units. The Santa Lucia Range in the southwestern half of the area includes both sedimentary and crystalline rocks. The crystalline rocks of the Gabilan Range are exposed to the northeast. The two ranges are separated by the Salinas valley, which is nearly seven miles wide in this area.

Physiography.- The youthful composite topography contains large areas of a modified Pleistocene old age surface, the Salinas surface, which slopes southwestward on the Gabilan Range and westward on Palo Escrito ridge of the Santa Lucia Range. Recent features include the aggraded surface, fans, and terraces of the down-faulted Salinas valley, and a mature surface on the sedimentary rocks west of the Salinas depression. Most of the streams are subsequent or consequent.

Stratigraphy.- Pre-Cretaceous rocks in this area include the Santa Lucia granite in the Gabilan and Santa Lucia Ranges, the Santa Lucia quartz diorite series of quartz diorite, quartz monzonite and granodiorite of the Santa Lucia Range and intrusive into the granite of the Gabilan Range; and the Sur

Series (?) of metamorphics, partly of sedimentary origin, largely micaceous quartz orthogneisses and shists composing Palo Escrito ridge.

The area of marine sediments west of the Salinas depression is about 10,000 feet thick, and contains Temblor sandstone and Salinas shale of middle Miocene age, upper Miocene Santa Margarita sandstone, and possibly lower Pliocene Etchegoin shale. The Paso Robles formation (upper Pliocene, lower Pleistocene) of continental origin is 1100 feet thick in the Salinas valley.

The Quaternary deposits, chiefly in the Salinas valley, include recent alluvium, fans, and terraces totalling about 1700 feet in thickness.

Structure.- Major diastrophic movements occurred in the late Pliocene and in the early Pleistocene. In the Pliocene the sediments were folded into a composite syncline, while the quartz diorite series west of the Salinas depression was thrust from the south over Salinas shale. Minor faulting took place in the Salinas valley intermediate to the Pliocene and the Pleistocene movements.

Normal faulting in the early Pleistocene divided the area into two northwest trending blocks, the Gabilan block to the east and the King City block to the west. An approximate displacement of 4000 feet on the King City fault along the western side of the Salinas depression tilted the Gabilan block towards the southwest forming the present range and the Salinas depression, interrupted the Salinas cycle of erosion, considerably elevated the Santa Lucia Range and formed the now dissected scarp facing the Salinas valley on the west. Several normal faults within the blocks were formed during the same period.

History.--As seen from the stratigraphic record this area was a portion of a comparatively stable land mass in pre-middle Miocene time. Gradual submergence occurred during the middle Miocene with the deposition of the Temblor sandstone and Salinas shale. During oscillatory, though gradual uplift, the Santa Margarita sandstone and possibly Etchegoin shale were deposited in the upper Miocene and lower Pliocene.

After the withdrawal of the sea, the land was elevated and the sediments were folded and overthrust in the Pliocene by forces acting from the south and west. In the erosional period that followed, the fresh water Paso Robles formation was deposited in the Salinas depression. Following a slight elevation a second period of erosion produced the Salinas old age surface which was tilted and faulted in the early Pleistocene period of normal faulting.

During late Quaternary and Recent times, the region has risen although oscillations probably did occur.

Economic resources.- One small cinnabar claim was operated during the war in the southwestern part of the area. Mineralizing solutions ascended the thrust in that locality. Paraiso Springs west of the Salinas valley is the site of hot mineral springs and a resort. Although there are some indications of oil in the Salinas shale, it is improbable that there is any accumulation of economic value.

INTRODUCTION

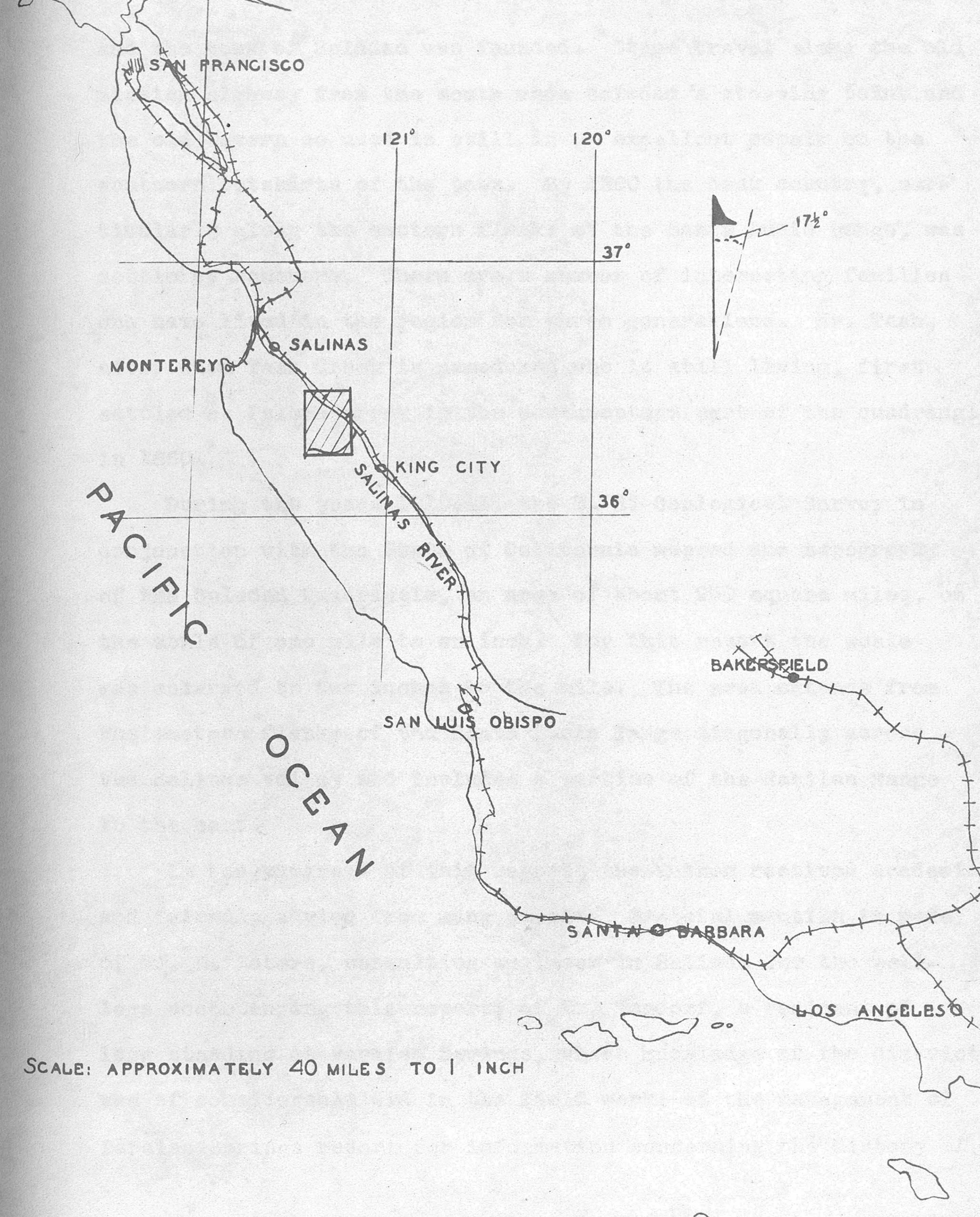
The little town of Soledad lies in the center of the Salinas valley of central California, 40 miles inland from the ocean at Monterey, and 100 miles south of San Francisco. The Salinas valley itself, trending approximately northwest, is a wide depression nearly 100 miles long, lying between the Santa Lucia Range to the west and the Gabilan Range to the east.

The settling of this region is intimately connected with the history of early California and the Spanish missions. The missions were constructed at intervals of a days travel on foot. Besides the Mission at Monterey, there are three others in the Salinas valley, the Mission 'de la Soledad', or the Mission of Our Lady of Solitude, built in 1791 just north of the present town, the Mission San Antonio at King City, and the Mission at San Miguel considerably to the south. Of the Soledad Mission only crumbling walls now remain.

The fathers at the Soledad Mission knew and made use of the Paraiso Hot mineral Springs. Crude stone implements of the Indians who lived around the springs are still to be found in the first canyon north of the resort, while one can occasionally find spear and arrow heads on the alluvial slopes of the fans on either side of the valley.

Following the Mission period, in the middle of the past century, ranchers began to settle around the old mission site

Ill. 1



INDEX MAP SHOWING LOCATION OF SOLEDAD QUADRANGLE and the town of Soledad was founded. Stage travel along the old mission highway from the south made Soledad a stopping point and the old tavern so used is still in excellent repair on the southern outskirts of the town. By 1860 the back country, particularly along the eastern flanks of the Santa Lucia Range, was settledby ranchers. There are a number of interesting families who have lived in the region for three generations. Mr. Tash, after whom Tash Creek is named and who is still living, first settled on Paloma creek in the southwestern part of the quadrangle in 1860.

During the years 1910-13, the U. S. Geological Survey in conjunction with the State of California mapped the topography of the Soledad Quadrangle, an area of about 250 square miles, on the scale of one mile to an inch. For this report the scale was enlarged to two inches to the mile. The area extends from the eastern flanks of the Santa Lucia Range diagonally across the Salinas valley and includes a portion of the Gabilan Range to the east.

In the progress of this report, the author received academic and friendly advice from many people. Grateful mention is made of Mr. H. Peters, consulting engineer in Salinas for the well-logs accompanying this report; of Mr. Tondorf, a resident of long standing at Paraiso Springs, whose knowledge of the district was of considerable aid in the field work; of the management of Paraiso Springs resort for information concerning the history of

these hot springs; and of Mr. Don Hughes of the Texas Company of Los Angeles for confirmation of foraminiferal determinations. Grateful mention is made of the members of the geological staff of the California Institute of Technology for advice in the preparation of this report. The problem was carried out under the direction of Dr. J. P. Buwalda. Dr. W. P. Woodring reviewed fossil determinations; Petrographical work was done under the supervision of Mr. Rene Engel; Dr. W. M. Davis criticized the chapter on physiography.

Previous studies in the region

General information on this area can be found in several earlier reports. The Salinas valley and its stratigraphy were briefly mentioned in the U.S. Explorations for a Railroad to the Pacific Coast (1853-56, pp. 38-41). Fairbanks, in an annual report to the state Mining Bureau (1894, 516-20) discussed some of the rocks of the Santa Lucia Range accompanied by a geologic section from the mouth of the Arroyo Seco in this area across the range to the ocean on the west. Between the years 1903-06 various reports on the surface drainage published in U.S. Water Supply Papers, mention streams in this area. Hamlin (1904) reported on possible damsites along the Arroyo Seco and incidentally named the type section of the Vaqueros formation south of this stream. During the past decade several valuable papers on regional geology have appeared. Among these are to be noted those by Kerr and Schenck (1926, 465-94), R. Willis (1925, 641-78), and P.D. Trask (1926, 119-86), as well as many others of more specific and local importance. Unavailable material on this region includes various plane table surveys of oil companies on areas of sedimentary rocks and the reports of summer camps of the University of California held immediately south of this quadrangle.

GEOGRAPHY

Both the coast highway between Los Angeles and San Francisco and the Southern Pacific Railroad follow the Salinas valley and afford easy access to the area. From the highway, branching roads along the major streams and finally trails lead to the more remote sections.

Most of the population is in the towns of Soledad and Greenfield within the Salinas valley, and on nearby dairy ranches. A few ranches are scattered along the chief streams, principally in the Santa Lucia Range.

The rainfall decreases rapidly inland from the ocean so that the climate at Soledad is semi-arid. During the rainy season from November to March some snow falls in the higher regions. The total percipitation is increased in the summer months by heavy morning fogs in the Salinas valley. Earlier reports discussing the Salinas river and its tributaries show that the average rainfall at Soledad during the years of 1902-05 was about 9 inches.I

I) Water Supply Papers 81, 89, 100, 177

In 1929 the total rainfall was 10 inches.

During the summer, the temperature often exceeds 100 degrees. On summer afternoons winds sweep up the Salinas valley from the ocean and reduce the mid-day heat. These winds attain velocities of 30-40 miles an hour and sometimes carry huge clouds of dust.

The Salinas river drains a larger area than any other stream in the Coast Ranges. Most of its flow is underground in this district. The Arroyo Seco draining the eastern flanks of the Santa Lucia Range is its largest tributary in this vicinity.

The lowest elevation, 105 feet, is in the Salinas valley. The highest point is Palo Escrito peak, 4465 feet, one mile to the west on Palo Escrito ridge.[I] The maximum relief of 4360 feet far exceeds the average relief of about 1000 feet. The maximum relief is related to recent earth movements while the average relief is an expression of erosional activity. Nearly all of the stream channels, with the exception of the Salinas river are deeply incised.

I) Reed, R.D.-Post-Monterey Disturbance in the Salinas Valley, Calif., Journ. Geol., v33: pp 580-607:1925

PHYSIOGRAPHY[1]

General discussion

Little has been written on the physiography of the central Coast Ranges. It is difficult to correlate surfaces in one area with those of another with any degree of certainty. This problem becomes more apparent, the older the features under consideration.

The data presented are compiled from (1) personal observation in this and other areas within the Salinas valley, (2) from reports by R. Willis (1925) and P.D. Trask (1926), (3) and from oral communication with various people.

The discussion concerns three major units in the central Coast Ranges. The Santa Lucia Range to the west extends from the coast at Monterey southward to the vicinity of San Luis Obispo. The Gabilan Range to the east has a comparable length. The Salinas valley between the two ranges extends over one hundred miles southeast from Monterey.

1) The reader who may be unfamiliar with the terminology used, is referred to: Cotton, C.A.- The Geomorphology of New Zealand, Part I, Systematic, 1926

SURFACES

Three surfaces can be recognized in the vicinity of the Salinas valley, two of which are earlier than the one now being developed. In order of age of formation these are the Summit surface, the Salinas surface, and the present surface. Fairbanks early recognized the same features at the southern end of the Salinas valley.[1]

Summit surface.- At the southern end of the Santa Lucia Range, Fairbanks identified an old surface upon the crest. This surface becomes less distinct towards the north. It is not present in the vicinity of Soledad.

Trask[2] thought the Summit surface could be recognized at the northern end of the Santa Lucia Range. Correlation could not be made because faulting has disturbed the relations.

In and to the north of the area worked by Fairbanks the youngest rocks cut by the Summit surface are middle Miocene, so that the age of this surface is post Miocene.[3]

1) Fairbanks, H.W.-San Luis Obispo Folio 101

2) Trask, P.D.-Geomorphogeny of the Northern Part of the Santa Lucia Coast Range, Calif.-Amer. Journ, Science: v12: pp. 293-300: 1926

3) Stanton, W.L.-Oral Communication

Salinas surface

A striking feature in the Salinas depression is the old age Salinas surface, which extends from the southern end of the valley over a hundred miles northward to the vicinity of Soledad. The greater portion of the surface is cut across sedimentary rocks of varying hardness. In the vicinity of Soledad, the Salinas surface is cut across the crystalline rocks of both the Santa Lucia and Gabilan Ranges. This surface on the sedimentary rocks was comparatively smooth. The relief is more pronounced in the crystalline rocks to the north.

Deformative forces have disturbed the position and continuity of the Salinas surface. Near Soledad, the surface has a definite southwesterly tilt which gradually diminishes towards the south. Local faulting has greatly displaced sections of this surface in some places.

The Salinas surface was formed after the Summit surface had been uplifted several hundred feet. Even in the regions where the Summit surface can not be recognized, the crest of the Santa Lucia Range lies considerably above any possible projection of the Salinas surface.

The youngest rocks cut by the Salinas surface belong to the Paso Robles formation (upper Pliocene, lower Pleistocene). In view of evidence to be discussed later, the surface is definitely early Pleistocene. It was cut after the greater portion of the folding and thrusting which is seen in the Coast Ranges, and after the erosion cycle which produced the Summit Surface. Subsequently the Salinas surface was disturbed by the normal faulting which produced the recent topography.

Conclusions about older surfaces

Since early Pliocene time the central Coast Ranges have passed through two cycles of erosion in each of which an old age surface was produced. The oldest surface is the Summit surface which can be identified in the southern part of Santa Lucia range. The topography of the present range has been produced by Quaternary faulting and the dissection of the Summit surface. The younger of the two old age surfaces is the Salinas surface, produced in early Pleistocene time and lying several hundred feet below the Summit surface.

Recent cycle

The interruption of the erosion cycle which produced the Pleistocene Salinas surface involved both regional uplift and local deformation. The present features, relief, and the fraction of the original area of the Salinas surface remaining undissected are related to the underlying rocks, position above base level, spacing of streams, and structure of individual blocks. The contrast in surface forms is especially marked between areas of crystalline and sedimentary rocks and between regions of steeply tilted beds and those in which the strata approximate a horizontal position. In the areas of sedimentary rocks the trunk streams flow in broad alluviated valleys with interstream ridges both rounded and sharp depending on the spacing of the streams. In the crystalline rocks the trunk streams flow in narrow steep canyons.

The agents of erosion differ somewhat in various portions of the central Coast Ranges. Besides streams and weathering, the Salinas valley region is perceptibly influenced by the effect of high winds which strip the soil from the windward side and deposit it on the leeward side modifying the irregularities.[1] Districts along the coast are subject to the active cutting of ocean waves. Reports of various authors[2] as Lawson (1893, pp. 1-59), Willis, B (1900, pp. 424-36), Fairbanks (1904), and Trask, P.D. (1926, pp. 119-86) describe well preserved marine terraces at different localities along the coast. These surfaces are the result of regional uplift which probably is reflected on the interior by a series of stream terraces in sedimentary rocks.

Soledad Quadrangle

The Soledad Quadrangle has a composite topography of considerable relief with a large part of the Salinas surface still

1) Reed, R.D.-Effect of the Wind in San Joaquin and Salinas Valleys (abstract): G.S.A Bull.: v37: pp214-5: 1926

2) See bibliography

preserved. The physiographic divisions in this area are intimately related to structural units. The Salinas surface has been preserved in the areas underlain by crystalline rocks while it was destroyed elsewhere. As a consequence the modified Salinas surface extends across the Gabilan Range in this area and is also present on the eastern flanks of the Santa Lucia Range on Palo Escrito ridge.

Salinas surface

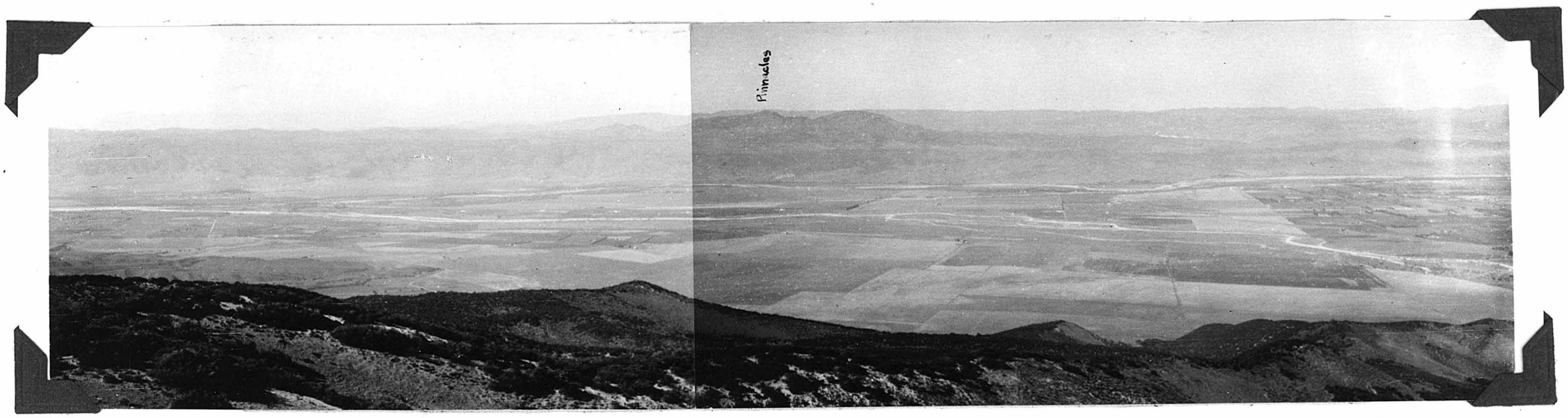
This post Pliocene old age surface is well developed on the Gabilan Range to the east of the Salinas valley. As seen from the Santa Lucia Range, the surface is nearly a plane which slopes gently southwesterly and disappears under the alluvium of the Salinas valley.

In a paper on the physiography of the Coast Ranges, Robin Willis[1] discussed in detail the land forms found in the Gabilan Range, a range which he considers to be an excellent example of the arch uplift type of mountain. Willis found two cycles of erosion manifested by surface remnants. The oldest, Willis believes to be represented by the flat top of Mt. Johnson, the highest peak of the range. (This may correspond to the Summit surface of the Santa Lucia Range).

The high valley cycle, as seen by Willis, is the extended

1) Willis, R.- Physiography of the California Coast Ranges; Geol. Soc. Am. Bull.: 36: 641-78: 1925

Ill. 2



The Gabilan range as seen from the western side of the Salinas depression. The even crest-line is a portion of the Salinas old age surface. The depression has a width of over four miles at this point.

old age surface upon the Gabilan Highlands. In the Soledad quadrangle the relief of this surface is only two or three hundred feet. Greater relief elsewhere is the result of the accumulation of volcanic agglomerates and of differential movement.

The southern flanks of the Gabilan Range are covered with Tertiary sediments across which the Salinas surface extends without perceptible change. Just what angular relation exists between the Salinas surface and the surface upon which the sediments were deposited is not known. The Salinas surface at the time of its formation, must have had a slope towards the west since all of the open valleys of former streams have a westerly course. The margins of such streams as Stonewall and Bryant Creeks are deeply incised on the Salinas valley side as a result of rejuvenation through uplift. The change in gradient along any stream is noticeable in passing from the valley margin to the upland regions which are as yet unaffected by headward erosion.

Since the Salinas surface has little relief, it must have been formed near base level. The ocean is now 40 miles from the vicinity of Soledad so that the Salinas old age surface must have been formed when the region was only two or three hundred feet above sea level. Willis states a figure of 2000 feet as the elevation of the Salinas surface at the time of formation. This could not be correct since the streams would have a gradient of 40 feet to the mile, or that of a youthful stream. (see Willis, pp. 668).

The high valley cycle, or the Salinas surface, (Willis, pp. 678), was traced continuously to the north into San Benito and Tres Pinos valleys where it passes into a surface of low relief cut on Pliocene sediments. The age determination as post-Pliocene agrees with the age determination of faulting activity in this area which interrupted the Salinas cycle of erosion and initiated the recent. All data in the central Coast Ranges confirm a post-Pliocene age for the Salinas surface.

On the topographic map the Salinas surface upon Palo Escrito ridge is in great contrast to the fault scarp along the western side of the Salinas valley. The streams on the western side of Palo Escrito ridge have a low gradient near the crest. West of the crest, the streams cross the Middle fault in sharply entrenched canyons. The eastern limit of the Salinas surface on the Palo Escrito ridge is the upper edge of the abrupt and dissected fault scarp along the western side of Salinas valley. The divide between the two surfaces is approximately a straight line parallel to the Salinas valley.

The streams on Palo Escrito ridge, like those on the surface of the Gabilan Range, are not consequent on the latest tilting of the surface, but have been rejuvenated and are gradually destroying the original channels by headward erosion. The Salinas surface on Palo Escrito ridge also sloped towards the west since the streams all flow westward.

The Tertiary rocks west of Palo Escrito ridge lie on a

Ill. 3

Mature surface on the Salinas shale series south of the Arroyo Seco.

surface cut across crystalline rocks. The projection of this buried surface eastward would meet the summit surface on the ridge at a small angle. In view of the fineness of the material near the contact, the sediments probably did cover part or all of the ridge.

The Salinas depression in this area has a width of about five miles between crystalline rock outcrops so that the two portions of the Salinas surface upon the Gabilan Range and upon Palo Escrito ridge, are not more than eight miles apart. The physiographic correlation of the two surfaces is evident from field relations. They are both cut on rocks of comparable hardness, granite in the Gabilan Range and metamorphics and granodiorites in Palo Escrito ridge. Both are evidently limited by the same fault on a mutual side, a fault which has disturbed upper Pliocene sediments. For the preceding reasons the surface on Palo Escrito ridge is considered a former portion of the Salinas surface since it would be impossible to have erosional surfaces of approximately the same low relief, cut across crystalline rocks of comparable hardness, and separated by a structural depression of eight miles width, without their being parts of one and the same surface.

No trace of the Salinas surface is seen on the Tertiary rocks west of Salinas valley since the interstream ridges have sharp crests. There are numerous examples of old stream channels, particularly along Piney Creek, which stand at elevations

Ill. 4

Stream terracing near the head of Piney Creek. As a result of regional uplift and change in base level for the Salinas river, terracing is commonly seen along the streams channels in Salinas shale.

from 75 to 150 feet above the present stream and which may represent drainage channels on the Salinas surface. But regional uplift and rejuvenation through lowering of local base level could explain these features.

The granite of the Santa Lucia Range in the southwestern part of this sheet stands above the projection of any portion of the Salinas surface and it must have done so during the development of that old landscape.

Recent cycle

The interruption of the Salinas cycle of erosion resulted from Quaternary faulting. The uplifted blocks west of the Salinas valley have been actively dissected in the recent cycle so that no trace of the Salinas surface is left on the softer sediments. Downthrown areas such as the Salinas valley depression have been aggraded for some miles inland from the ocean as a result of rise of relative base-level of the streams.

The Salinas depression is a feature whose topographic expression has been greatly emphasized by the faulting which initiated the recent cycle and by consequent erosion. As mentioned before, the river has entrenched itself in the prefaulting sediments near its head while the lower portions of the stream near the ocean have been aggraded. The topographic forms along the stream and near its mouth show a hurried and complicated history in Quaternary time. Extensive remnants of stream terraces are found in the vicinity of King City and to the south as well as intermittently in the portions of the depression nearer to the ocean. There are three terraces near King City. The portions on both sides of the stream can be correlated so that these surfaces are not residual terraces formed in the normal cycle of an active, though wandering stream.

Although there is no record of the matching of river terraces with marine terraces at the mouth of the Salinas river, it is probable that the regional uplift which is responsible for the production of the marine terraces along the coast finds its expression inland by terraces along various streams. An inference to be drawn from this conclusion is that alluvium in the Salinas depression was once much greater than now. This is also a conclusion from evidence found in the Soledad Quadrangle. At the mouth of the Arroyo Seco within the Salinas valley there is a small boulder field at an elevation of 1250 and 800 feet above the river. The terraces are not disturbed by faulting so this remnant must have been recently a part of a higher valley floor. In the northern part of the valley the ridges along the western side have flat shoulders or benches which are accordant at an elevation of approximately 1200 feet. The boulder field and the benches are features which were formed when the valley floor was much higher. The facets on the ridge ends to the north were buried under alluvium at this higher level and subsequently have been exposed. The unprotected scarp above the benches in this earlier period retreated from the fault line.

Fans formed during this earlier stage were subsequently wholly or largely removed. The new alluvial cone at the mouth of the Arroyo Seco has forced the Salinas river to the eastern side of the depression and has protected the fans lying immediately to the north of it, so that their fanheads now stand at approximately 1250 feet. The size of the fans is also dependent upon the position of the Salinas river in the depression.

The Salinas river empties into the bay at Monterey. A striking feature of this bay is a submarine channel at right angles to the coast in approximate continuation of the Salinas river. A short distance from shore this cleft is 200 fathoms (1200 feet) deep. Recent soundings have shown that this feature continues to the bottom of the steep front of the continental shelf at a depth of nearly 2000 fathoms.

Le Conte[1] believed that this channel represented the coastal extension of the Salinas river at a time when the region stood much higher. The trend of the depression at right angles to the shore would be the normal path of the Salinas river in case the region was elevated above the present position.

1) Le Conte, S.--Tertiary and Post-Tertiary Changes of the Atlantic and Pacific Coast. Geol. Soc. Amer. Bul: No2-326: 1891

Lawson[1], among others, is of the opinion that the depression has a structural origin. This view is more consistent with fact since the feature continues to the base of front of the continental shelf, below the possible action of the stream, even in advent of great uplift. However, the Salinas river would follow the same path on the coastal plain and may have done so in recent periods of uplift.

Although the sequence is not clear, the marine and stream terraces, residual boulder fields, exhumed scarps and possibly the submarine channel in Monterey Bay have been formed during recent depression and uplift of this portion of the Coast Ranges.

The first two terraces above the Arroyo Seco are continuous with surfaces within the Salinas valley and have not been displaced by the faults which they cross. The Salinas old age surface has been tilted by movement along these faults and now is covered by the alluvium in the valley. Consequently, the stream terraces are younger than this old age terrain. It is improbable that the marine terraces along the coast could have persisted through the period necessary to cut the Salinas surface and consequently they are also younger than it.

1) Lawson, A.C.--The Continental Shelf of the Coast of California: Nat. Research Council: V8: pt 2: 15: April 1924. Also-Geology of Carmelo Bay: Univ. Cal. Pub. Geol. Series: V1: 1-59: 1893

Ill. 5

Terracing along the Arroyo Seco. Looking eastward at the surfaces near the mouth of the Arroyo Seco. The stream channel is cut in steeply dipping Salinas shale and records four separate terrace levels in this view.

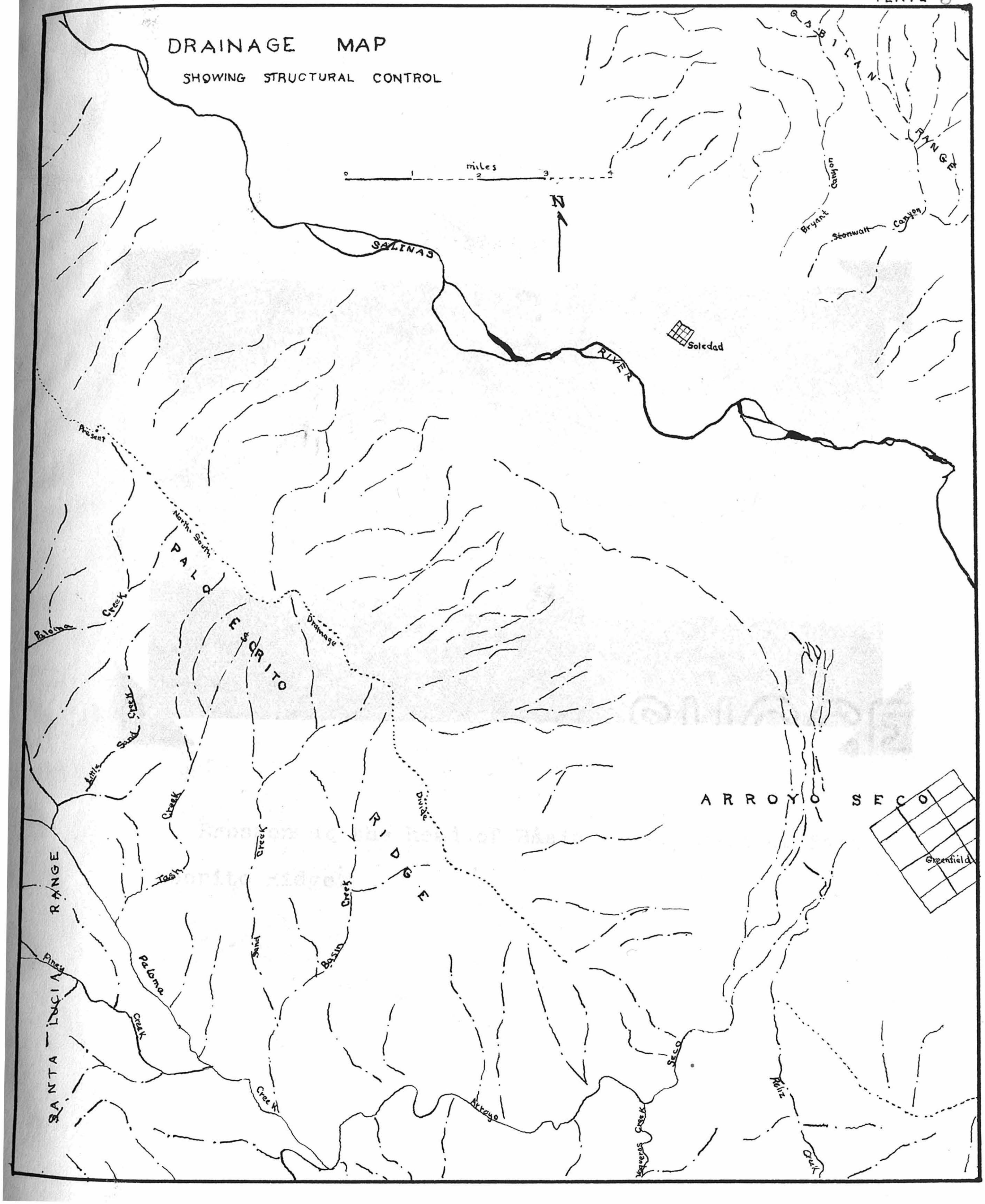
The terraces along the Arroyo Seco show that regional uplift was not a continuous process. The four terraces, widely separated at the mouth, converge upstream. Accumulation of stream boulders on each of these terraces near the mouth shows that the Arroyo Seco always joined the Salinas river at grade. Since the two lower terraces are continuous with the Salinas river terraces developed during regional uplift, and are not cut by faults, they are the result of the lowering of the level of the trunk stream through regional uplift. With the same volume of water and drainage basin, and with erosion proceeding in identical rocks, the decrease in width of valley with successive terraces is evidence of progressively shorter intervals during each stage.

Types of streams

In the Soledad Quadrangle the streams are of three types, consequent, subsequent, and superposed. Although the Salinas river near its head is an antecedent stream where it is deeply intrenched in granite[1], it may be a consequent stream upon the downfaulted valley block in the vicinity of Soledad. Most of the streams, those on the Gabilan and Santa Lucia Ranges are persistent, intrenched consequents. Paloma creek is a subsequent stream where it follows the Tash Creek Thrust and a strike valley. Reliz creek, a subsequent stream, follows a

1) Fairbanks, H.W.-U.S.G.S. Folio 101

PLATE 3


DRAINAGE MAP
SHOWING STRUCTURAL CONTROL
miles
0 1 2 3 4
N
GABILAN RANGE
Bryant Canyon
Stonwall Canyon
SALINAS RIVER
Soledad
Present North-South Drainage Divide
PALO ESCRITO RIDGE
Paloma Creek
Little Sand Creek
Tash Creek
Sand Creek
Basin Creek
SANTA LUCIA RANGE
Piney
Paloma Creek
Arroyo Seco
ARROYO SECO
Greenfield
Vaqueros Creek
Reliz Creek

Ill. 6

Erosion at the head of Basin Creek, west of Palo Escrito Ridge.

fault and the contact of three formations near its mouth.

Interesting streams, tributary to Paloma creek, flow down the western slope of Palo Escrito ridge. Their heads lie in crystalline rocks. They cross a block of sediments and cut another mass of upfaulted crystalline rocks before joining Paloma creek. Since these creeks maintain their direction across the upfaulted block of crystalline rock, they are superposed.

Consequent streams flow down the fault scarp along the western side of Salinas valley. Through their activity the scarp has been maturely dissected with the formation of deep ravines.

Fans

Great alluvial fans extend into the Salinas valley on both sides. Since the most abrupt slope is the fault scarp along the western side, the fans there are much larger than those from the Gabilan Range to the east. The fanheads on the western side gradually rise from north to south. Most of them lie within the canyons cut in the crystalline rocks of the Palo Escrito ridge.

In general, the slope of the fans on the western side is $4\text{-}6\frac{1}{2}^{\circ}$, although it is much greater near their heads. The fans at the base of the Santa Lucia Range have an average length of two miles. Those along the Gabilan Range to the east, with gentler slope, have a maximum length of over three miles.

The growth of the fans into the valley seems to have little influence in determining the position of the Salinas river. Although it has a gradient of only 6 inches to a mile in this area, the stream is able to maintain its position. The alluvial cone at the mouth of the Arroyo Seco has forced the Salinas river to the eastern side of the depression.

In passing it should be mentioned that the fans on the western side of the depression are not broken by any faults which they may conceal.

Fault scarps

King City Scarp

The most distinctive feature in the Salinas valley is the dissected King City fault scarp along the western side. The present crest on Palo Escrito ridge is nearly 3500 feet above, and about a mile and a half from the fanheads at the base.

The King City scarp may have been formed in one of three ways, by faulting, erosion, or doming. If formed by faulting, the fault plane is effectively masked by recent alluvial and fan deposits.

On the western side of the Salinas valley, in the vicinity of the Arroyo Seco, the Tertiary and Quaternary rocks approximate 14000 feet and dip eastward towards the depression. Their deposition was probably accompanied by a gradual subsidence. The absence of any sediment upon the Gabilan Range in the Soledad Quadrangle, on the opposite side of the Salinas depression from this section, is evidence of a fault somewhere in the valley.

The triangular facets on the spur ends, as previously mentioned, have been formed by faulting at the base of the King City scarp. These features are separated from the Salinas river by an alluvial apron nearly a mile long and are not related to stream cutting. The bases of the faces are also aligned.

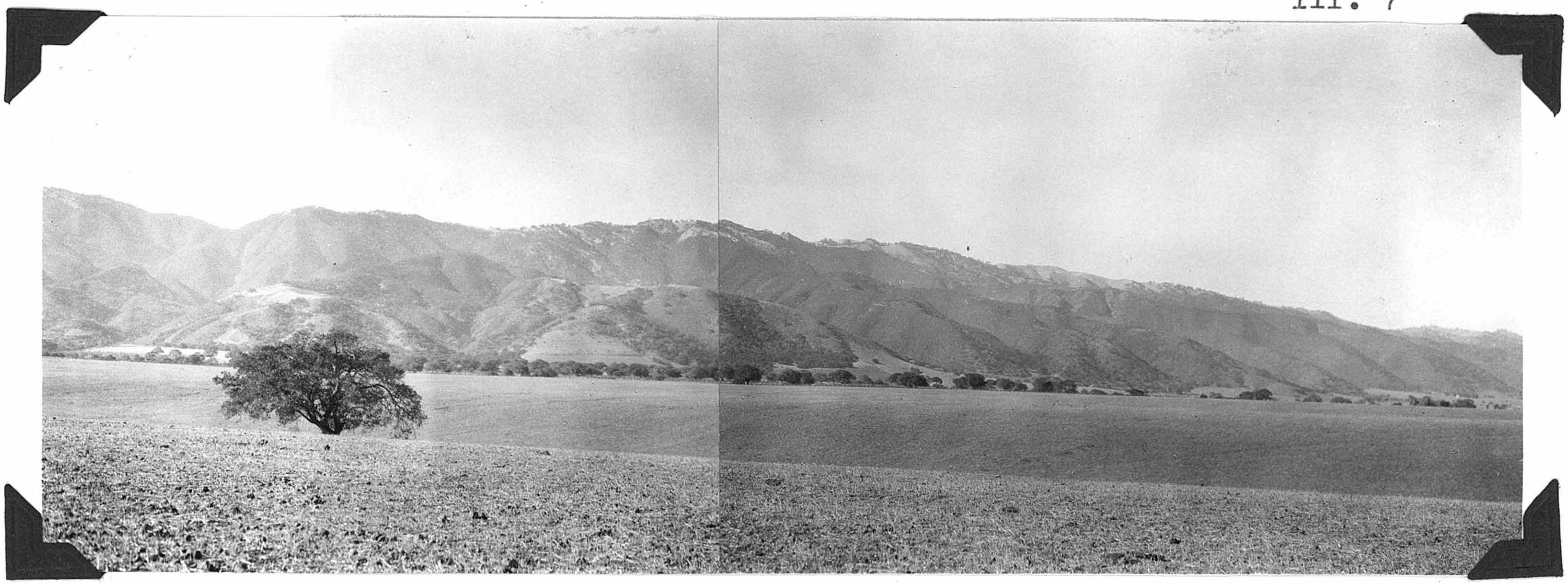
The strongest evidence for a fault origin of the King City scarp is the offset of the Salinas, early Pleistocene, surface on the Gabilan Range and Palo Escrito ridge.

Nor has the activity of the Salinas river been responsible for either the depression or the scarp. The valley is much larger than necessary to accommodate this stream. Normally, a stream-cut feature is constricted in passing through crystalline rocks as compared to the width in softer sediments. The Salinas valley increases greatly from head to mouth irrespective of the distribution of harder rocks.

The structure in the sedimentary series is not consistent with doming. The majority of the folds are at right angles to the trend of the scarp and do not show cross-folding in its vicinity.

In recapitulation of the evidence for faulting along the King City scarp the following facts are cited. The scarp and size of the depression are not consistent with the erosional ability of the river. The Salinas surface has been displaced several thousand feet to its position upon Palo Escrito ridge. The faceted spurs and aligned bases at the foot of the scarp are unrelated.to stream cutting and could be formed only by faulting. The alluvium is greatest near the scarp, a condition which would not occur in a stream cut valley. Furthermore,

Ill. 7



Accordant benches and aligned spur-end facets along the King City scarp to the north.

faults which can be seen or established by stratigraphic discordances, such as the Reliz Creek fault, join this scarp at small angles and, in part, are responsible for it.

The King City scarp is a fault scarp, although the basal portion has been exposed by erosion. As previously discussed, the alluvium in the depression, at one time, was much thicker and concealed the lower part of the present face. However, the fault is older than the alluvium in the valley and the accumulation and removal of this detritus are only incidents in the ultimate reduction of the scarp.

Scarp of the Middle fault

Movement on the Middle fault near the western margin of Palo Escrito ridge has displaced the Salinas surface and has produced a scarp increasing in size towards the north. The streams, flowing westerly upon Palo Escrito ridge, cross this fault in sharp canyons and with occasional falls. Small subsequent tributaries follow the fault line near its southern extremity.

STRATIGRAPHY

Regional

The Central Coast Ranges contain formations whose ages range from Paleozoic to Recent time. The earliest sediments are metamorphosed members of the basement complex and undoubtedly are older than Jurassic and possibly are of late Paleozoic age. In the Mesozoic, the Franciscan (Jurassic?) series and lower and upper Cretaceous formations were deposited. Small areas of Martinez (Paleocene) lie along the flanks and the crest of the Santa Lucia Range. Oligocene formations have not been found. Sediments of Miocene or later age are widely distributed in the Central Coast Ranges. The basement complex also can be divided into a number of units.

Basement complex

Crystalline and metamorphic rocks occupy nearly 100 square miles of the Soledad Quadrangle. These rocks, with practically continuous exposure, extend from the vicinity of Santa Cruz and Monterey near the ocean on the north to Priest valley and the Mouth of the Nacimiento on the south. They undoubtedly are related to crystalline rocks east of San Luis Obispo and to similar rocks in the Tehachapi mountains.

The intrusive rocks of the Central Coast Ranges belong to several classes, more or less related in composition. The series from the head of the Salinas valley northward to the vicinity of Monterey on the coast includes granite, quartz monzonite, granodiorite, and quartz diorite. Quartz diorite porphyry, granite, and granite porphyry appear along the coast near Carmel and Monterey. The rock of the Gabilan Range, east of the Salinas depression, is chiefly a true granite, although quartz diorite porphyry appears at the northern end, near Santa Cruz.

The metamorphic rocks of the Central Coast Ranges are similar to those found in the Tehachapi mountains. In the southern portion of the Gabilan Range and the northern part of the Santa Lucia Range this series is composed of primary and secondary micaceous shists and gneisses associated with areas of limestone.

The age of the intrusive rocks of the Coast Ranges can not be determined as satisfactorily as that of similar intrusives in the Sierra Nevadas in which sediments of known age were metamorphosed during intrusion. The last batholithic intrusion in the Sierra Nevadas was post-Mariposa slates (Jurassic) and pre-Cretaceous in age.

In the Coast Ranges, the basal beds of the Franciscan (Jurassic) formation contain boulders of rocks metamorphosed during intrusion[1]. From this evidence the intrusive rocks of the Coast Ranges are pre-Jurassic and older than the Jurassic intrusives of the Sierra Nevadas. Fairbanks[1] thought the in-

1) Fairbanks, H.W.-Review of our Knowledge of the Geology of the Calif. Coast Ranges-G.S.A.Bul:v6:71-102:1894; pp81

trusive rocks of the coastal belt were as old as the Carboniferous. Diller[1] stated the same age for the intrusives of both the Coast Ranges and the Sierra Nevadas.

Local
Basement complex

Sur Series(?) pre-Cretaceous

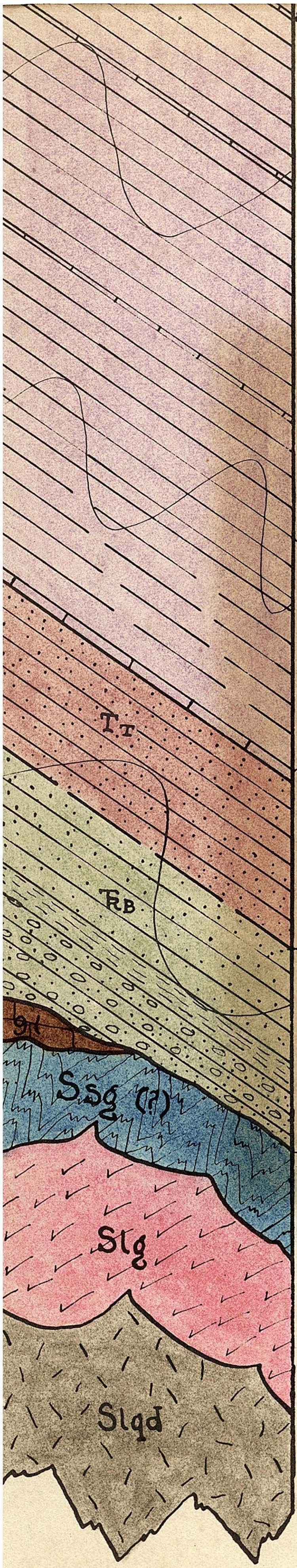
The oldest rocks in this region are a series of orthogneisses and quartzose micaceous shists comprising most of Palo Escrito ridge. The northern end of this ridge near Salinas is formed of granite[2]. Quartz diorite, quartz monzonite, and granodiorite are exposed to its west.

P. D. Trask[3] in studying the Pt. Sur Quadrangle at the northern end of the Santa Lucia Range, proposed a formational name for the metamorphic rocks. The Pt. Sur section is considered as the type for this district. Although the metamorphic rocks in the Soledad Quadrangle differ somewhat from those at the type section, correlation is based on stratigraphic position, regional proximity to the type section, and correspondence of salient features.

1) Diller, J.S.-The Geology of Northern Calif.-U.S.G.S. Bul.: v33:21:1886

2) Fairbanks, H.W.-Geology of N. Ventura, San Luis Obispo, Santa Barbara, Monterey and San Benito Counties: 12th report-Calif. State Mining Bureau.

3) Trask, P.D.-Geology of Pt. Sur Quad., Calif.-U.C. Pub. Geol. Ser.:v16: 116-186: 1926



8000'

Lower calcareous shale. This is similar in appearance to the upper member. Portions of the lower member are rich in formanifera.

Basal Limestone. This is a brown limestone member from about five to twenty feet thick. It frequently carries Pecten (pseudameusium) peckhami Gabb

TEMBLOR SANDSTONE - MARINE

1100'± Essentially a fine to coarse-grained, white arkosic sandstone series. Along Tash Creek, to the west, it is a massively bedded, brown, sugar sandstone. Mega forms include Turritella ocoyaña.

BASAL RED BEDS - MARINE

Series at Paraiso Springs, largely well-sorted conglomerates with metamorphic boulders, red, coarse grained sandstone matrix, interbedded dark shales and white sandstones. Non-fossiliferous. Conformible and grades into overlying Temblor. 1800'±

UNCONFORMITY, Pre-CRETACEOUS BASEMENT

SUR SERIES (?)

A metamorphic series of ortho-gneisses, biotitic-quartzose shists and gneisses; Sedimentary(?) in part. One small area of associated, fine grained limestone (gl)

INTRUSIVE CONTACT

SANTA LUCIA GRANITE

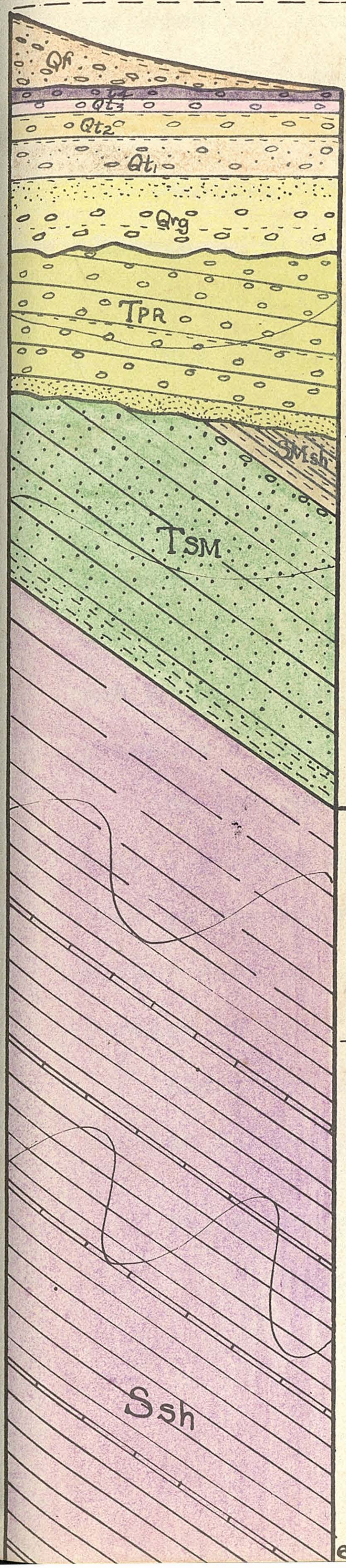
A homogeneous fine to coarse-grained binary granite with little ferro-magnesium minerals. Intruded by the Santa Lucia granodiorite-quartz Diorite Series in the Gabilan Range.

INTRUSIVE CONTACT

SANTA LUCIA QUARTZ DIORITE

A series, largely granodiorite with quartz monzonitic and dioritic facies.

COLUMNAR SECTION IN THE SOLEDAD QUADRANGLE, CALIFORNIA — Plate 4



QUATERNARY ALLUVIUM

500'± Fans composed of material swept in from crystalline rocks on either side of Salinas valley. Greatest thicknesses on western side of valley.

QUATERNARY TERRACES, ALLUVIUM, VALLEY-FILL

1200'± Terraces in the Salinas valley and in the Arroyo Seco. Sequence from the terraces at the mouth of the Arroyo Seco. Thickness only appreciable in the Salinas Valley as fill. (Qrg), besides fill, represents recent alluvium.

UNCONFORMITY

PASO ROBLES FORMATION, (Upper Pliocene, Lower Pleistocene).

1100' A series of thick bedded conglomerates with cobbles of Salinas shale, thin shale seams, and basal sandstone with cross-bedding. - TERRESTRIAL.

UNCONFORMITY

SANTA MARGARITA SANDSTONE (Upper Miocene)

1815'+ A series of massively bedded white sandstones locally with some conglomerate. Brown shale member forming upper portion of section west of Reliz Creek. Series is transitional to, or disconformable upon, underlying Salinas shale. MARINE.

MONTEREY SERIES (Middle Miocene)

SALINAS SHALE - MARINE

Upper calcareous shale member. Characterised as white shale series which appears in the northern part of the Miocene basin of deposition.

Siliceous shale. The brown and cream sandy shale forms the bulk of the SALINAS shale series. The upper portion of this series is characterized by numerous beds of brown impure limestone from one to six feet thick. Locally fossiliferous with distorted casts of ARCA common.

6000'

At the type section, the Sur Series has an estimated thickness of 5000 feet, chiefly of metamorphosed sediments, injection gneisses and associated and interbedded limestones. It is preponderately a quartzose micaceous shist recognizably of sedimentary origin. The age of the Sur Series, at the type section and in the Santa Cruz Quadrangle[1], is considered only as pre-Cretaceous. Metamorphism was the result of the intrusion of quartz diorite on a large scale.

The metamorphic rocks in the Soledad Quadrangle are uniformly micaceous in character. The degree of metamorphism diminishes from the crest of Palo Escrito ridge eastward to the base of the King City scarp. The micaceous shists along the crest contain innumerable thin seams of quartz which are accordant. Veins of quartz up to ten feet have been found. The series is irregularly cut by aplite dikes. Weathered outcrops are characterized by the presence of many angular fragments of quartz.

On the crest of Palo Escrito ridge the planes of shistosity have a general dip of from 40-60^{0} south, opposite in direction to that at the type section. The strike varies several degrees either side of an average EW direction. The gneisses in the lower portion of the King City scarp are, in places, badly contorted.

Along the crest, near the southern limit of this ridge above Paraiso Springs, a small circular area of limestone is in nearly

1) Branner, J.C., Newsom, J.F., and Arnold, R.-U.S.G. S. Santa Cruz folio 163: ppl,2: 1909

horizontal contact with the underlying shists. Since the limestone is fine grained and comparatively pure, it was included in the Sur Series (?). The Tertiary formations in this region have a number of impure limey members which do not resemble the rock at this exposure. Subsequent work of a reconnaisance nature in the Salinas Quadrangle has disclosed extensive areas of pure limestone definitely associated with the metamorphic rocks of that area.

Petrographic description

The shists and gneisses of the Sur Series (?) have a suite of minerals which characterise it in this area and from which local departures are not considerable. In general, the series is a fine to medium grained rock which, under the microscope, exhibits a mosaic texture in the shists and a porphyroblastic texture in the gneisses. The sections contain, in order of importance, quartz up to 50%, generally of two or more generation, orthoclase and oligoclase in nearly equal amounts up to 40% of the section and biotite as the principal accessory. Oligoclase varies from aligclase-andesine ($ab_{75}an_{25}$) to oligoclase ($ab_{90}an_{10}$). In one section from the head of Tash creek, the plagioclase is andesine ($ab_{60}an_{40}$). The proportion of quartz, potash and sodic felspars may vary any one predominating. The quartz always shows undulatory extinction.

Of the accessory minerals, biotite is the most important. It is reddish in basal section, giving color to the rock, while other sections have a yellowish cast. In order of importance after biotite occur magnetite, generally as irregular masses, euhedral crystals of olivine, forming at times an important accessory mineral, and occasionally fibrous diopside. Pyroxenes and amphiboles are generally not present. Occasional accessories include needles of apatite in biotite, sillimanite, topaz, some titanite, fayalite and secondary muscovite. Weathering is manifested by iron stains and alteration products of the feldspars.

Origin of Sur Series (?)

The greater portion of the 3000 feet exposed is composed of orthogneisses. The processes to which they were subjected include both thermal and dynamic metamorphism.

The quartzose-micaceous shists are mineralogically similar to the gneisses. However, they seem to preserve a hint of bedding in their regularity which, together with the area of limestone, shows a sedimentary origin for a part of the series.

The bulk of the section must be regarded as igneous in origin. The petrographic relations indicate that the original rock varied between a quartz monzonite and a granodiorite. Similar rocks are exposed on the western flanks of the ridge and have there a sinuous contact with the Sur Series (?). The origin of the metamorphic series is believed to be due to contact metamorphism on the border of a large intrusion, as borne out both by field relation and the intense biotitization and the presence of manganese minerals[1].

Detritus containing boulders and weathered grains from the Sur Series (?) is found in the base of the oldest sediments in this area, the basal Temblor Red Beds at Paraiso Springs. The sedimentary record is much too fragmentary to approximate the age. Correlation with the type section as pre-Cretaceous consequently is used.

1) Lindgren, W.--Mineral Deposits-1926

Santa Lucia Granite (pre-Cretaceous)

The oldest intrusive rock in the Central Coast Ranges is the Santa Lucia granite. The name was first applied by Lawson to the granitic series at Carmelo Bay near Monterey[1], and later was expanded to include all the granites in the Central Coast Ranges.

Portions of the northern Santa Lucia Range, large areas in the Gabilan Range, as well as isolated areas farther to the south, are formed of this rock. Over wide areas the granite has been the basement upon which later sediments were deposited and has furnished much of the detrital material composing them.

Gabilan Range

The largest area of the Santa Lucia granite in the Soledad Quadrangle is in the Gabilan Range. In this small section of the entire range, the composition and texture are generally uniform. Slight variations are found, however.

In the northeastern portion the rock is a holocrystalline, coarse grained rock, either a muscovite or binary granite. The major elements are quartz and orthoclase. Both microcline and oligoclase ($ab_{80}an_{20}$) occur together or individually as major or minor elements in amounts never equalling that of orthoclase.

1) Lawson, A.W.--Geology of Carmelo Bay-U.C. Pub. Geol. Ser. vI:1893

Accessory minerals are biotite, occasionally muscovite, magnetite and apatite.

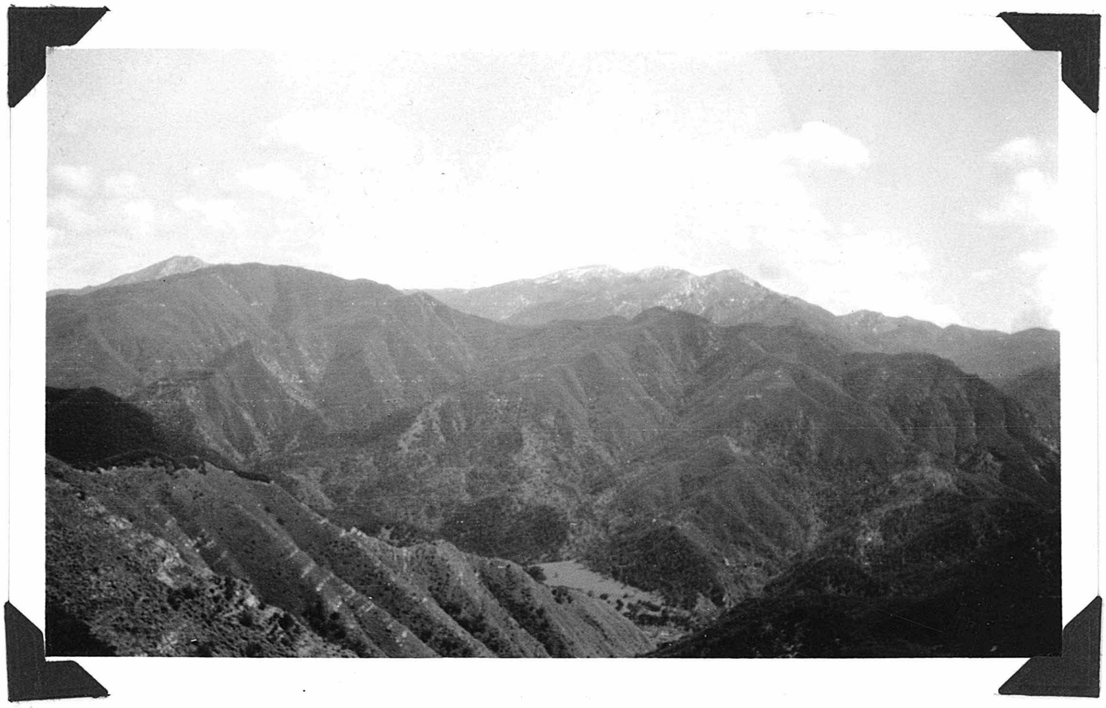
In areas to the east, oligoclase is generally a minor element while microcline is always major. Specimens from this locality frequently show micrographic intergrowth. The major elements are microcline, quartz, orthoclase and minor amounts of oligoclase ($ab_{75}an_{25}$) to ($ab_{80}an_{20}$). Accessories include biotite (one or two generations), magnetite and occasionally muscovite, apatite, hornblende, and titanite. Diopside was present in one section. The felspars are always more or less altered.

In the southeastern portion near the Salinas river, a number of horizontal pegmatitic dikes, rich in orthoclase have intruded the main body of granite. As is discussed later, the Santa Lucia quartz diorite and related dike rocks are intrusive into the granite between Bryant and Stonewall canyons with the production of gneissic structure in both rocks.

Santa Lucia Range

A small area of granite is in depositional contact with Miocene sediments on the eastern flanks of the Santa Lucia Range. There are some differences between this rock and the granite of the Gabilan Range. In the few sections examined from the Santa Lucia Range, the rock is a spinel binary granite. Oligoclase is always a major element. Major constituents are quartz equal to orthoclase and oligoclase, and orthoclase equal to or greater

Ill. 8



Looking southward across the Arroyo Seco near its head at the higher portions of the Santa Lucia Range and the dip facets developed in the Tertiary rocks in the center of the picture. The lower left portion shows Salinas shale dipping eastward.

than oligoclase ($ab_{85}an_{15}$) to ($ab_{90}an_{10}$). The quartz and felspars are sometimes in micrographic intergrowth. Minor elements are biotite, magnetite, spinel, apatite and occasionally muscovite and hornblende.

Associated with the granite of the Santa Lucia Range are dikes of dacite closely allied in composition to a quartz diorite and thus are either intrusions from the rest magma of the granite or, more likely, accompanied the intrusion of the Santa Lucia quartz diorite. The dacite is a fine to medium grained holocrystalline rock with euhedral crystals of hornblende and aegirite-augite. Other major constituents are quartz and orthoclase in nearly equal amounts to that of labordorite ($ab_{30}an_{70}$). The only minor mineral is apatite.

Age relations

The Santa Lucia granite is the oldest intrusive rock of the Central Coast Ranges. It has been intruded by the Santa Lucia quartz diorite series between Stonewall and Bryant Canyons, and is consequently older than that rock. It is probably of pre-Jurassic age since conglomerates derived from the granite are found in the Franciscan (Jurassic?) formation, as was previously mentioned. Indeed, as was already cited, Fairbanks and Diller believed the granite to be at least as old as Carboniferous. In various regions in which it is exposed, the granite is the basement upon which the Chico (upper Cretaceous) formation was deposited.

The granitic areas in the northern central Coast Ranges have stood high during the greater portion of sedimentary history and have furnished a considerable amount of the detrital material composing the Tertiary sandstones. It is not definitely known whether the Santa Lucia granite in the Santa Lucia and the Gabilan Ranges was covered by sediment or not. The dip of the contact plane between the sediments and the granite of the Santa Lucia Range, indicates the probability that Miocene sediments covered all or, at least, a large portion of the present range.

Santa Lucia Quartz Diorite and Related Rocks

Santa Lucia Range

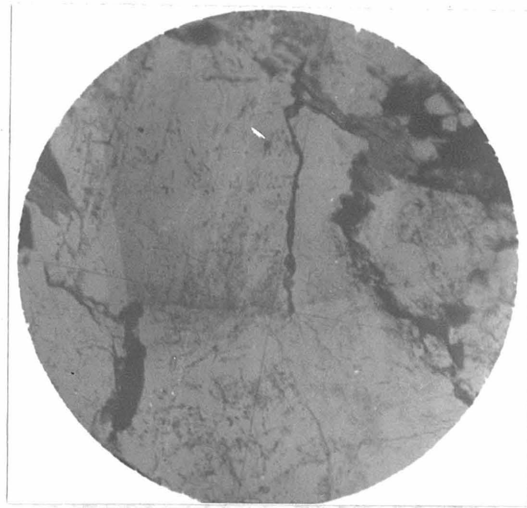
Medium grained intrusive rocks, varying between a quartz diorite and a granodiorite, appear on the western flanks of Palo Escrito ridge in contact with both the Sur Series (?) and Miocene sediments. They are exposed by upfaulting and stream-cutting along Basin, Sand, Tash and Paloma creeks. Detritus from them is recognized in the basal members of the Miocene sediments in this district. Along Sand and Basin creeks the granodiorite is a gray speckled rock. The quartz monzonite east and north of this locality contains large euhedral crystals of orthoclase which give it a pinkish cast.

The granodiorite is composed of quartz up to 40% and oligoclase with a composition similar to that in the quartz monzonite ($ab_{75}an_{25}$) to ($ab_{90}an_{10}$), mostly, however, ($ab_{85}an_{15}$). The granodiorite at the head of Tash creek contains albite ($ab_{95}an_{5}$). Orthoclase is nearly equal to plagioclase in some specimens and is a minor mineral in others. Common accessories are magnetite, biotite, muscovite, and rutile, A complete absence of pyroxenes or amphiboles is characteristic.

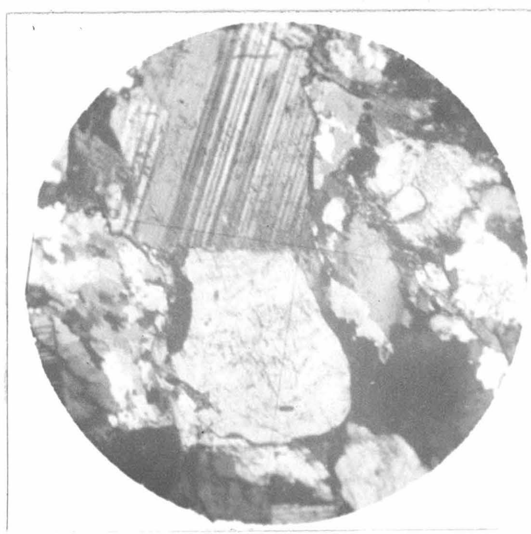
The quartz monzonite facies has essentially the same constituents. Orthoclase is equal to, or greater than, either quartz or oligoclase. Occasional accessory minerals include brown hornblende, magnetite, olivine, apatite and some titanite.

Sta. 39-- Quartz monzonite near the contact with the Sur Series (?) on Paloma creek, Santa Lucia range. x80
Holocrystalline, medium-grained, seriate porphyry;
Major elements: orthoclase, albite, quartz, biotite;
Minor elements: hornblende, magnetite, olivine, apatite, secondary biotite in hornblende

Ill. 9



Ordinary light x85



Crossed nicols x70

Quartz diorite outcrops near the junction of Paloma and Little Sand creeks. The mineral components are andesine, ($ab_{60}an_{40}$) to ($ab_{70}an_{30}$), exceeding both quartz and orthoclase. Minor elements are biotite, magnetite and occasionally secondary quartz and apatite.

Gabilan Range

The quartz-diorite-quartz monzonite series has intruded the Santa Lucia granite between Stonewall and Bryant Canyons metamorphosing both rocks. The contact between the two series is not visible. At the mouth of Bryant Canyon the quartz diorite is a medium grained holocrystalline rock containing quartz, andesine ($ab_{70}an_{30}$), and orthoclase in order of abundance. The accessory minerals are magnetite, olivine and apatite. One mile upstream the quartz diorite is replaced by quartz monzonite composed of equal amounts of orthoclase and oligoclase ($ab_{90}an_{10}$) both exceeding quartz. Minor minerals are biotite, muscovite, magnetite and apatite.

A comparable change in composition occurs in Stonewall Canyon. At the mouth, the quartz diorite is composed of andesine ($ab_{65}an_{35}$) preponderating over quartz. Accessories are hornblende, augite hornblende, orthoclase and magnetite, as well as occasionally secondary quartz with undulating extinction. Upstream, a mile and a half, the quartz diorite is replaced by a quartz monzonite with equal amounts of oligoclase ($ab_{75}an_{25}$) and

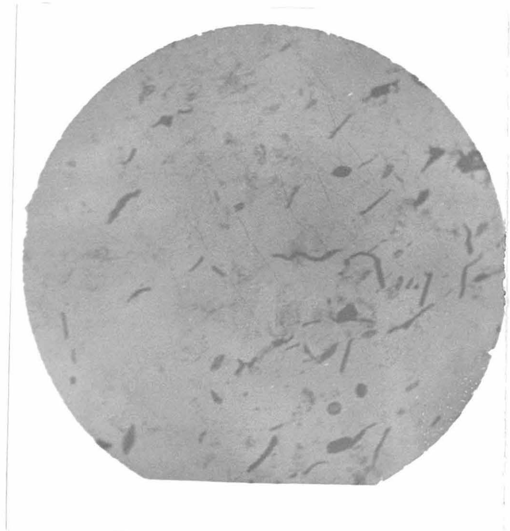
Sta. 80-- Quartz diorite near the mouth of Bryant Canyon in the Gabilan range. x27

Hypocrystalline, percrystalline, fine-grained, hiatal persemic;

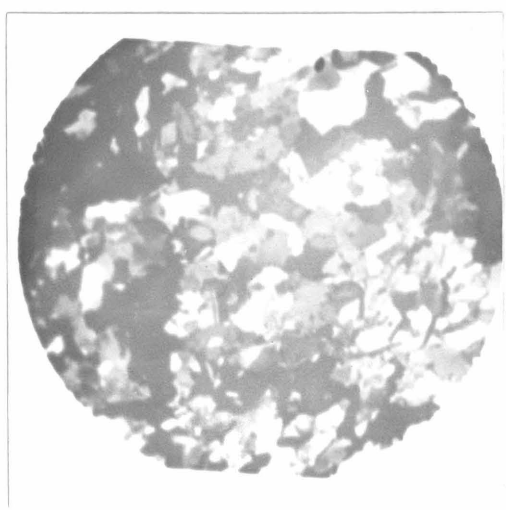
Major elements: quartz, orthoclase equal to andesine ($ab_{70}an_{30}$);

Minor elements: magnetite, olivine, and apatite.

Ill. 10



Ordinary light x27



Crossed nicols x27

orthoclase each subordinate to quartz. Biotite is the only accessory. All salic minerals show strain shadows.

Dikes

The intrusion of the quartz diorite-quartz monzonite-granodiorite series was accompanied by and is associated with various dikes. The prominent ones are more basic than the rocks intruded and show, in their chilled borders, an elapse of time between major and minor intrusion.

Dikes are not numerous on the western side of the Salinas valley. Aplitic dikes near the quartz monzonite-Sur Series (?) contact cut the metamorphic series. A holocrystalline, fine grained hornblende andesite on Basin Creek contains hornblende as a major element preponderating over labordorite (ab_5an_{95}) with magnetite and zircon as accessories.

In the Gabilan Range the largest dike, a dacite porphyry, has a length of over a mile near Stonewall Canyon. Several other dikes have the same composition. Weathered fragments and the surface outcrops of this rock resemble a compact arkosic sandstone.

The smaller dikes near the mouth of Stonewall Canyon are fine grained hypocrystalline (largely) hornblende andesites. Major elements include hornblende, labordorite ($ab_{30}an_{70}$), and augite with minor amounts of biotite, magnetite, olivine, quartz, orthoclase and apatite.

Sta. 128-- Dacite porphry, a dike rock in Stonewall Canyon in the Gabilan range. x25

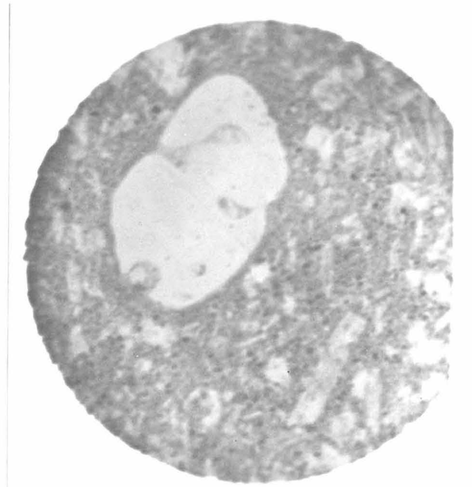
Hypocrystalline, hyalacrystalline, fine to medium-grained, hiatal porphyritic, sempatic;

Major elements: oligoclase, orthoclase, quartz, occasionally phenocrysts of quartz, oligoclase ($ab_{80}an_{20}$), carbonates, glass, and magnetite.

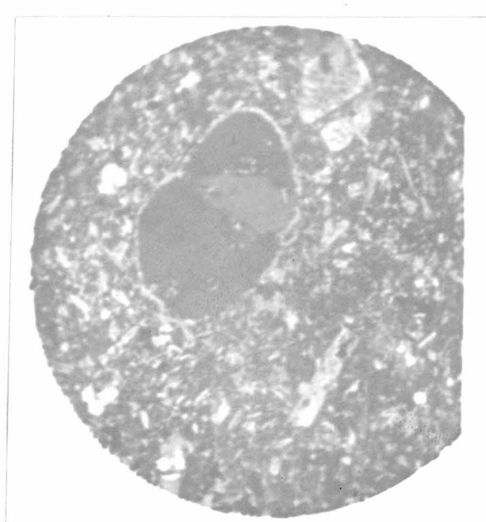
Minor elements: sometimes leucoxene

Remarks: Some alteration of earlier formed phenocrysts accompanied by a rim of carbonate.

Ill. 11



Ordinary light x25



Crossed nicols x25

The large dike of dacite porphyry contains phenocrysts which are both rounded and angular crystals of quartz or oligoclase ($ab_{80}an_{20}$). These earlier crystals are surrounded by rims formed by a carbonate. Major elements are oligoclase, orthoclase, quartz, magnetite, and interstitial glass and carbonates. Leucoxene is the only minor mineral.

Age and correlation

The quartz diorite series was formerly considered as a variant of the Santa Lucia granite of the Coast Ranges. This name was originally applied by Lawson[1] to a porphoritic granite near Carmelo. Trask believes the porphoritic granite to be a differentiate of a much more extensive intrusion of quartz diorite which appears in large areas in the Santa Cruz Quadrangle[2] as well as in the Point Sur Quadrangle[3]. Consequently Trask proposed the name of Santa Lucia Quartz Diorite to include rocks of this series, reserving the term of Santa Lucia granite for the granites of the Santa Lucia and Gabilan Ranges.

In spite of the fact that the name is applied in the Soledad Quadrangle to a series of rocks which include quartz diorite, monzonite, to a granodiorite, it is felt this may logically be

1) Lawson, A.W.-op. cit.

2) Branner, J.C.-Newsom, J.F., Arnold, R.--op. cit.

3) Trask, P.D.-op. cit.

done since Trask used the name for a series containing both quartz diorite and porphoritic granite.

The quartz diorite in the Santa Cruz Quadrangle metamorphosed pre-Franciscan (Jurassic?) sediments during its intrusion. Consequently its age must be pre-Jurassic. In the Soledad area the quartz diorite series evidently has intruded the Santa Lucia granite of the Gabilan Range and is post granite for that reason.

Sedimentary Rocks

General

The sedimentary history of the coastal region is a record of a series of oscillations of the coastline during the past. From the composition and distribution of many of the formations of this region, portions of the central Coast Ranges have been stable over much of Tertiary time. The oscillations must have been accompanied by extreme deformation of the earths crust. Some blocks have received several thousand feet of sediment while adjacent localities received little or none. As mentioned previously, deposition took place in the central Coast Ranges at irregular intervals through the Mesozoic and Tertiary. During this time the Franciscan (Jurassic?), Chico (upper Cretaceous), Martinez (Eocene) and numerous Miocene and later formations were laid down.

The absence of pre-Miocene sediments over a considerable portion of the central Coast Ranges is an indication of extensive land masses during that time or, at least, of only shallow submergence. This region, as well as most of the area west of the Sierra Nevadas in southern California, was submerged during the Miocene with the deposition of enormous thicknesses of sediments. In the central Coast Ranges this submergence is evidenced by the great distribution of Miocene sediment which, if the contact with the crystalline rocks was projected, would pass over and cover all, or the greater portion, of the existing peaks. The fineness of the Salinas shale series (middle Miocene) and its uniformity over great thicknesses and areas is an evidence of widespread submergence.

The sedimentary section is much larger on the western side of the Salinas valley than on the eastern. Consequently, submergence took place unequally. A section of several hundred feet of Martinez south of the Soledad Quadrangle shows that this interior basin was present through most of the Tertiary. The sedimentary record is more complete towards the south and submergence probably proceeded from that direction.

During parts of the Miocene, there was an archipelago of islands and a great inland sea in the present Salinas depression. Shallow seas during Vaqueros and Temblor times washed the then low-lying Gabilan Range to the east and the Santa Lucia Range north and west of the Salinas basin. This inland body of water was connected with the ocean along Paloma creek in lower middle Miocene time since sediments of this age are found there which reflect the near-by land in the texture of the sandstones.

Gradual and complete emergence extending from the upper Miocene into the Pliocene brought about the withdrawal of this inland sea. In its place was left a broad depression with scattered fresh water lakes and torrential streams. The continental Paso Robles formation (upper Pliocene, lower Pleistocene) formation was deposited in many sections of this basin. As previously mentioned, regional uplift, with slight oscillations, has continued to the present time.

Soledad Quadrangle

Inland seas occupied portions of the basin during Paleocene and lower Miocene times. During the same intervals the Soledad Quadrangle stood high and was first partially submerged in the lower middle Miocene when the Temblor formation was deposited. In the continued period of depression from the middle Miocene into the Pliocene, over ten thousand feet of marine sediments were laid down on the western side of the Salinas valley. Any emergence, which may have taken place during this interval, was of minor importance since the formations are accordant with one another and each is composed of material of uniform size.

The Miocene basin had a greater depth southward. This is shown by the increasing fineness of detritus in that direction. A shallow connection with the ocean to the north existed along the present line of Paloma creek. Portions of Palo Escrito ridge, of the Santa Lucia Range, and probably of the Gabilan Highlands, were elevated during lower middle Miocene and upper Miocene, or were swept by currents in shallow water. The sands of the Temblor and the Santa Margarita (upper Miocene) formations show the proximity of land in their sorting and composition.

Temblor sandstone (lower middle Miocene)

The Vaqueros sandstone (lower Miocene), at the type locality

Ill. 12

Looking northwest in Sand Creek at white calcareous Salinas shale lying on an erosion surface cut across the Santa Lucia Quartz Diorite. The canyon at this point is straight-walled and nearly one hundred feet deep.

along Vaqueros creek south of the Arroyo Seco was not deposited in the Soledad Quadrangle although both districts are in the same basin. The period of Vaqueros deposition is represented in this area by an interval of erosion which produced the rock-cut surface upon which the Temblor formation was deposited.

The Temblor sandstone, an arkosic detritus of consistent composition was derived from local sources. The variation in size indicates the relative position with respect to old shore lines.

The basin, during this period, lay between the present Santa Lucia Range and Palo Escrito ridge. From the decrease in size of particles, the depth was greater towards the center and to the south. The exposures west of Palo Escrito ridge are continuous with a large area of sandstone in the Salinas valley, south of Paraiso Springs. One small outcrop appears on Piney Creek where the stream has cut through the overlying Salinas shale.

Initial irregularities were present in the Temblor basin. Consequently some sections are greater than others. West of Palo Escrito ridge the section gradually increases towards Paloma Creek and has a minimum thickness in the vicinity of Basin Creek. The section in the Salinas valley, south of Paraiso Springs, is about 1100 feet thick. The basal red beds in the Salinas depression probably belong to the same formation.

West of Palo Escrito ridge the maximum thickness is 200 feet. Along Tash Creek the Temblor sandstone is 50 feet thick. A mile and a half south of Tash creek, on Sand Creek, this is reduced to 20 feet, and on Basin Creek, two miles to the south, only thin outcrops are found.

Lithology

The Temblor formation, characteristically, is a white arkosic sandstone. The cement includes both calcite and iron oxides. The degree of induration is variable. Along Tash Creek the Temblor beds are massively bedded and jointed. The brown color at this locality is due to the large amount of iron oxide present.

Rounding of the grains is a function of the distance from the original shoreline. The only exception to this occurs in the upper beds of the section in the Salinas valley. Near-shore phases are sub-angular to angular and those off-shore are round to sub-angular.

The Temblor sands include quartz, oligoclase ($ab_{80}an_{20}$), some orthoclase and minor amounts of biotite, magnetite, ilmenite and traces of leucoxene, chlorite and hematite. Quartz and felspars compose at least 90% of the rock with quartz either predominating over or subordinate to felspar, depending upon position in the basin. The felspars commonly are greatly altered.

The dependence of composition upon position within the basin is clearly shown by analyses. Off-shore, as along Tash and upper Sand Creeks, quartz greatly predominates as much as 30%, over felspar. Only traces of femic minerals are to be found. Samples collected near to former shore-lines contain nearly equal amounts

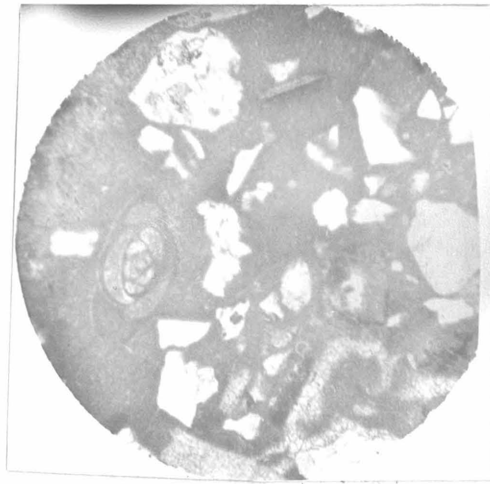
Sta.7-- Temblor sandstone x25

Medium-grained, angular;
Major elements: calcareous cement, quartz;
Minor elements: orthoclase, oligoclase ($ab_{90}an_{10}$), hornblende, magnetite, and microcline.

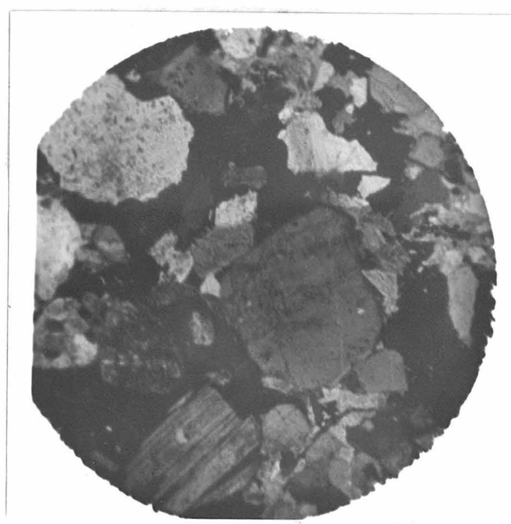
Sta. 25-- Temblor sandstone from Gilleylen's cinnabar claim. x27

Medium-grained, sub-angular to angular;
Major elements: calcareous cement, quartz;
Minor elements: orthoclase, oligoclase ($ab_{75}an_{25}$), magnetite, hornblende, and foraminifera.

Ill. 13

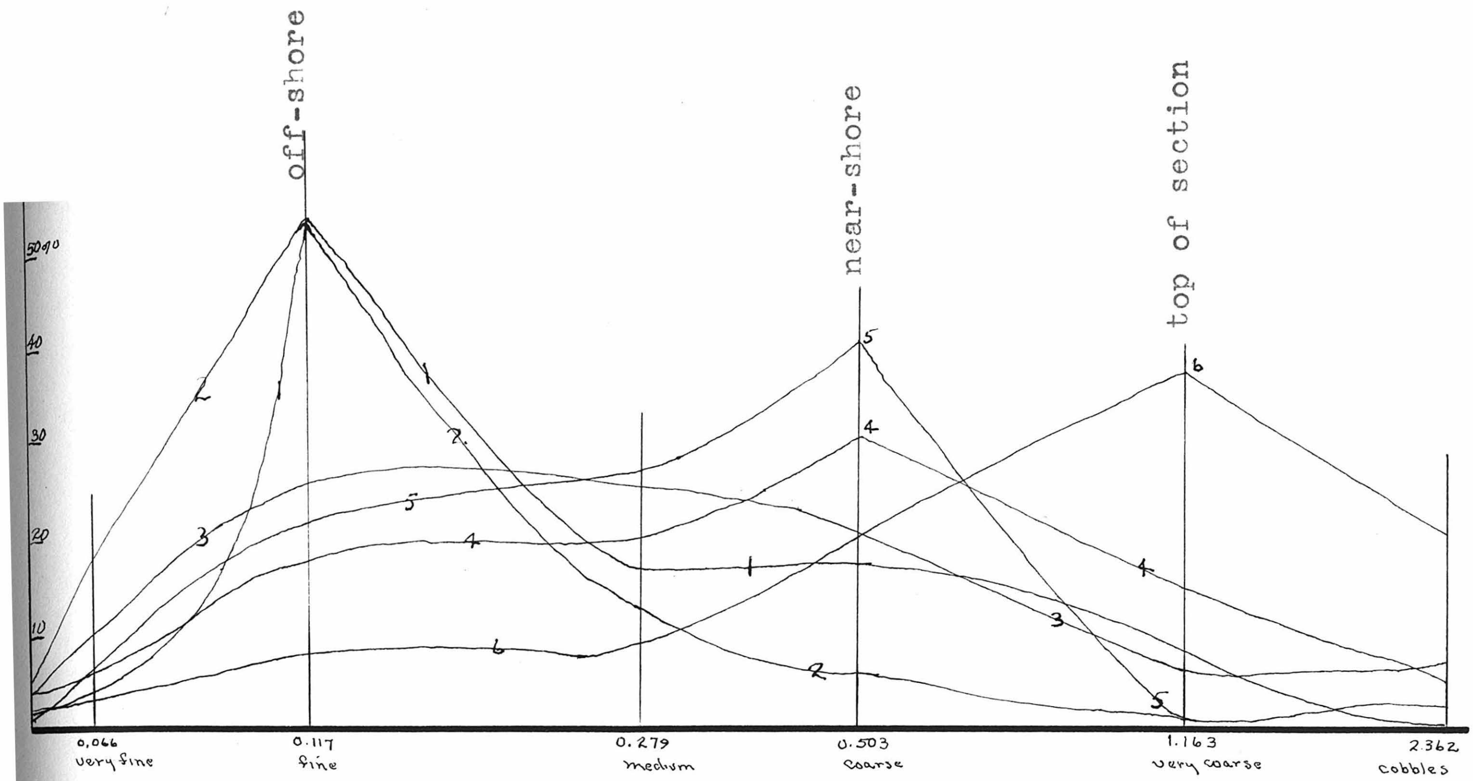


Ordinary light x 25



Crossed nicols x 27

Mechanical Analysis of Temblor Sands



Logarithm of size in mm are plotted against percentage composition

Location of samples

1). On Little Sand creek near upper contact with basement.

2). In Tash creek near Paloma creek.

3). Head of Basin creek--a green sandstone.

4). Between Middle and North faults, west of (3).

5). On Palo Excrito ridge west of Paraiso Springs.

6). West of Riliz creek fault and south of Paraiso Springs.

The average is a medium-grained sand. Determination of position is based on size of grain and location in the field.

of quartz and felspar while biotite and other accessories compose about 10% of the rock. The composition of near-shore sands also corresponds closely to that of the source rock and include pebbles from nearby crystalline rocks.

Conditions at the time of deposition

Since the Temblor formation is entirely sandstone with no shale, the sea during deposition must have been comparatively shallow. This is emphasized by the variations in texture.

Silicified fragments of wood are found occasionally in the Temblor formation. The largest piece seen by the author was a section of a tree one foot in diameter. These fragments probably are indicative of a temperate climate during Temblor time.

Paleontology

Fossils occur at a number of localities west of Palo Escrito ridge. The original material is well preserved in the calcic cement of the rock. Casts of large bi-valves were found in the 'sugar' sandstone near the mouth of Tash creek. Several foraminiferal localities are present west of Basin creek. The collection from the Temblor formation in the Soledad Quadrangle includes:

Turitella ocoyana
Scutella merriami
Cardium sp?
Pecten sp? (13-14 ribs)
Mytilus near Mathewsoni Gabb var. expansus Arnold
Spisula sp?
Calcareous algae

Foraminifera

Siphogenerina kleinpelli
Siphogenerina collomi
Bolivina conica
Bolivina advena
Baggina californica Cushman
Valvulineria californica
Nonion sp?
Robulus sp?
Cristellaria beali
Nodosaria obliqua (Linnê)
Pullenia sp?

Relation of the Temblor formation in the Soledad Quadrangle to other sections

The foraminifera, collected in the Soledad Quadrangle near the base of the Temblor formation west of Basin Creek, correspond closely to a group obtained by W. L. Stanton in the Adelaida Quadrangle, about 70 miles to the south. The forms from the Adelaida Quadrangle are slightly more advanced and include one more diagnostic genus.

In comparison it was found that the collection made by Mr. Stanton came from above the siliceous shale (Salinas formation). The determinations on both collections were checked by Mr. Don Hughes of the Texas Company, Los Angeles.

Mr. Hughes previously had collected from a section along Reliz Creek, south of the Soledad Quadrangle and below the siliceous (Salinas) shale. The group from Reliz Creek is somewhat older than the forms from the Soledad Quadrangle. The Adelaida collection is the youngest, corresponding in age to a section near Crestion in the southern portion of the Salinas valley.

Mr. Hughes had compiled a chart of generic occurrences of foraminifera along the coast. In this chart two divisions are recognized with distinct faunal changes at 1730 feet above the Vaqueros contact. The 1730 feet above the Vaqueros formation is occupied by the molluscan assemblage from the Temblor which is characterized by Turitella ocoyana. The division above this group is based entirely on foraminiferal evidence. The collection from the Soledad Quadrangle lies in the middle of the upper zone.

Red Beds (basal Temblor formation?)

In the vicinity of Paraiso Springs, conformably underlying, and grading into the typical white sandstone of the Temblor formation, is a thick section of red conglomerates, interbedded sandstones, dark shales, and two massive beds of white sandstone. The contact of this series with the basement is a fault whose presence is inferred from the dip of the strata into the crystalline rocks. Where the dip is away from the crystalline rocks, the red beds are fine sandstones and do not reflect in their composition the presence of a strong topographic break at the time of deposition. The base of the section can not be definitely established. The formation grades imperceptibly into the overlying Temblor.

Without fossil evidence, it is not known whether the series represents basal Temblor, the Vaqueros (lower Miocene) formation or the continental Sespe (Oligocene?) formation.

This section is similar to one found by Trask (pp145)[1] near the coast. Both have an indefinite upper contact and interbedded white sandstone members. The Red Beds do not have the same composition as the typical Temblor in this region.

This formation is easily distinguished in the field on the basis of color. The strata have an average thickness of three

1) Trask, P.D.- Pt. Sur Quadrangle

feet. The section is, for the greater part, a conglomerate with a red sandstone matrix. The largest cobbles are six inches in diameter and are well sorted. The majority of these boulders were derived from the metamorphic rocks of the Sur Series (?). Alteration has not advanced sufficiently in them to color the formation.

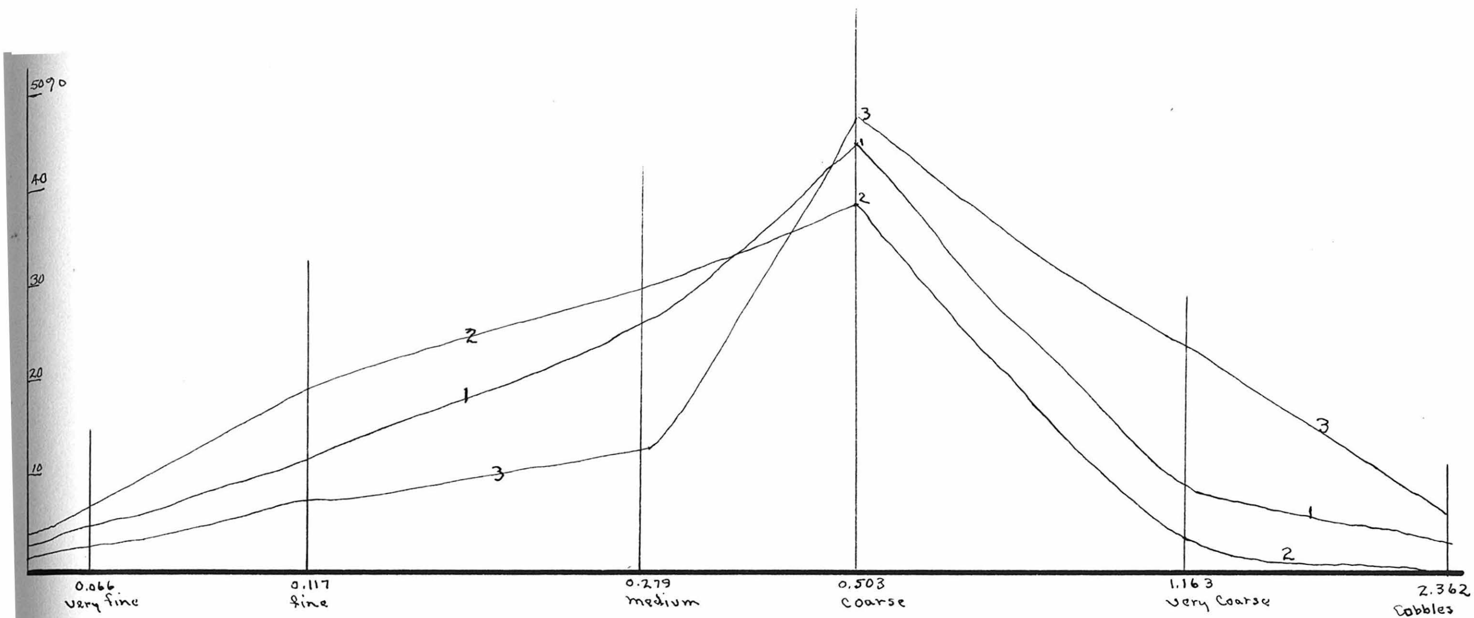
A distinguishing feature between the Red Beds and the overlying Temblor sandstone is the presence of rounded, scoriaceous, boulders of andesite with a maximum diameter of three inches. The interbedded sandstone members are similar in composition to the matrix of the conglomerates. The dark shales are in the upper portion of the section.

The Red Beds are considered as basal Temblor although they might be of Vaqueros age since strata of this period are also conformable to the Temblor formation. Kerr and Schenck[1] assigned a lower Miocene age to similar beds which appear, overlying lava flows, in San Benito county. In that locality, however, the strata show by crossbedding that they are of torrential origin.

1) Kerr, P.F. and Schenck, H.G.-Active Thrust-faults in San Benito County, Calif.-G.S.A.Bul.v36:pp465-494:1925

The Red Beds do not belong to the Sespe (Oligocene?) formation since they are conformable to, and grade into, the overlying Temblor sandstone. As far as is known, Oligocene formations are not present in this region.

MECHANICAL ANALYSIS OF RED BEDS



Logarithm of size in mm plotted against percentage composition

Location of Samples

1). Red sandstone matrix north of Paraiso Springs

2). Interbedded white sandstones near locality (1)

3). Red sandstone matrix one mile east of Paraiso Springs

The curves show that all sands in the Red Beds are coarse-grained. Furthermore, samples (1) and (2) are finer than (3) although they were taken from localities closer to the basement contact, a fault. They were deposited during a slight change in conditions, or are higher in the section.

Lithology

The red sandstone varies in composition with the distance from the basement contact. The color is imparted to the series by particles of hematite which may equal 10% of the matrix. In the vicinity of Paraiso Springs, the composition is quartz 60%, albite and oligoclase 20%, biotite 10%, hematite 10% and minor amounts of chlorite and magnetite. One mile east of the basement, a sample, which, through faulting may be higher or lower in the section than the previous analysis, contains quartz 30%, oligoclase-albite 60%, hematite 10%, and minor amounts of ilmenite with leucoxene, magnetite, and biotite.

The interbedded white sandstone at Paraiso Springs differs in composition from the two previous analyses and does not contain hematite. In it quartz is equal to felspar, 45%, and ilmenite, magnetite, and biotite compose 10% of the sample.

Origin

The Red Beds are believed to be of marine origin. They are better sorted and bedded than strata deposited under torrential or fluviatile conditions. The color possibly resulted from oxidation in a moist climate where the relief was small. This character gradually would change with continued deposition.

Thickness

The maximum thickness of the Red Beds can not be stated since they are in fault contact with the basement and have a gradational contact with the overlying Temblor formation. The maximum section exposed is approximately 1800 feet.

Salinas Shale (middle Miocene)

Submergence was at a maximum during the middle Miocene during which time organic and sandy shale, sandstone and limestone were deposited. Formations of this age are found in many parts of central and southern California. Covered by water of moderate depth, the basins of deposition sank under accumulating load until tremendous thicknesses were laid down. These rocks have been of considerable economic importance in California as the source of much of the petroleum.

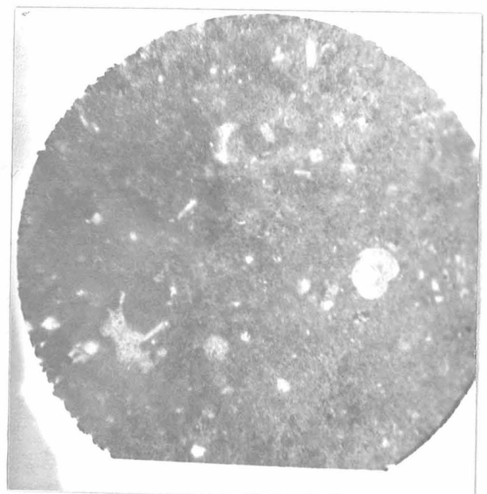
The type section at Monterey is composed largely of sandy shale with basal and upper calcareous shale members and a capping of diatomite. Salinas shale outcrops along the western side of the Salinas valley almost continuously from Monterey to the vicinity of Paso Robles. South of King City the shales are folded into a syncline and pass continuously under the valley and upon the flanks of the Gabilan Range.

The Salinas shale section in the Soledad Quadrangle is composed of a lower calcareous member, a great thickness of sandy shale and interbedded impure limestone, and a small upper calcareous member.

The base of the Salinas shale series in this and adjacent areas is always indicated by a limestone stratum of varying thickness. In the Soledad Quadrangle this member is a yellow, impure, sandy limestone varying in thickness from a few feet to 20 feet, richly sprinkled with foraminifera and most character-

Sta. 4-- Basal, impure limestone in Salinas shale x28
Very fine-grained
Major elements: impure calcite;
Minor elements: quartz, andesine ($ab_{70}an_{30}$), biotite, magnetite, and foraminifera.

Ill. 14



Ordinary light x 28

istically accompanied by a small pecten, Pecten (pseudameusium) peckhami Gabb. The overlying brown, laminar, calcareous shales also carry casts and original material of foraminifera.

Under the binoculars the sandy shales in the greater portion of the section,with a cream or buff color, appear to be fine ocean sands, largely quartz grains with minute flakes of biotite. In weathering, the shale breaks into angular fragments.

Limestone strata, which frequently occur in the middle and upper portions of the section are impure brown limestone similar to that at the base of the section, however, without being fossiliferous. Their thickness is from one to six feet. It is not known whether the limestone strata are lenticular or not.

Oil seeps and sulphur springs are present in the Salinas shale series along the Arroyo Seco. There is little organic or bituminous matter in most of the formation.

Thickness

Intricate crumpling and folding of the shales complicate measurements. The sections differ greatly in various parts of the area.

The greatest thickness west of Palo Escrito ridge is a few hundred feet. At the mouth of the Arroyo Seco a section across the north limb of Herbert's syncline has a maximum thickness of nearly 8000 feet. This figure probably is exaggerated by duplication in crumpling, tight folding, and minor variations in dip.

Dr. Edwards[1], in a plane table survey of possible oil territory, computed a maximum thickness of about 5000 feet. This is a minimum figure.

Stalder[2], made a recent plane table survey of a section of Salinas shale in Pine Canyon near King City, 20 miles to the south. The thickness measured was 4900 feet, which, with portions unexposed towards the Salinas valley, might be increased to 6250 feet. Stalder found 35 beds of impure limestone in the upper 1200 feet. The section at the mouth of the Arroyo Seco is at least equal to that in Pine Canyon.

Conditions of deposition

The uniformity and great thickness of the Salinas shale in this area are indications of deposition under more or less constant conditions. It is unlikely that a basin over 8000 feet deep could exist during deposition and it is probable that gradual subsidence occurred with increasing load.

The Salinas shale in this area and, as far as is known, in this region, does not show lithologic or textural variations depending on position relative to the present outcrops of the basement rock. At the contact with the granite of the Santa Lucia

1) Geological staff, Shell Company of Calif., Oral communication.

2) Stalder, W.-A section of the Monterey (Salinas) Shales in Pine Canyon, Monterey Co., Calif.-A.A.P.G.Bul. v8:pp55:1924

Ill. 15

Looking northward near the head of Piney Creek at the depositional contact between Salinas shale on the right and the granite of the Santa Lucia Range on the left.

Range the dip is 40 degrees off of the basement. If the sediments were projected, they would pass entirely over the Santa Lucia Range. Little evidence exists that the Salinas shale did or did not cover most of the Santa Lucia and Gabilan Ranges at one time.

One mile south of this area, near the base of the Salinas shales, there is a section of pure limestones several hundred feet thick. Pure limestones, according to Twenhofel[1], pp. 215,

> .....are usually shallow water or only moderately deep water deposits,......There is little positive evidence of deposition of limestones in very deep water.

It is probable that the deposition of the Salinas shale took place in comparitively shallow water.

The Santa Margarita formation (upper Miocene) overlies and is accordant to the Salinas shale. A fact, generally borne out in the field, is that the Salinas shale was not eroded to any extent prior to Santa Margarita deposition[2]. The Santa Margarita formation overlaps the Salinas shale upon the Gabilan Range, and could not do so, unless preceded by extensive erosion, if Salinas shale was once deposited everywhere in a period of general submergence. It is impossible to state the source of the Salinas shale from the evidence available in the Soledad Quadrangle.

1) Twenhofel, W.H.-Treatise on Sedimentation:1926

2) Reed, R.D.-Post-Monterey Disturbance in the Salinas Valley, Calif.-Journ.Geol.: v33:Pg 588-607:1925

Paleontology

The porous condition of the siliceous shale is unfavorable for the preservation of fossils. Casts of shells, which occur in abundance are difficult to determine. The lower limestone member and some of the argillaceous members preserve the original material. Macro and micro forms collected in this area are:

Arca montereyana Osmont
Arca near perdisparis Wiedley
Pecten (pseudameusium) peckhami Gabb
Calyptrea costalada Conrad
Macoma sp?
Cardium sp?
Leda sp?
Semele sp?
Pandora sp?
Spisula sp?
Echinoid spine
Small fish skeletons

Foraminifera

Bolivina advena
Bulimina ovula d'Orbigny
Valvulineria californica
Cristellaria miocenica Chapman
Nodosaria obliqua (Linné)
Nonion sp?

The most frequent fossil in the Salinas shale is the Arca. Most of the casts have been distorted by compressive forces.

Santa Margarita (upper Miocene) formation

After the deposition of the Salinas shale, the sea withdrew in part. With but slight erosion of the Salinas shale, the Santa Margarita sandstone was accordantly deposited. This formation, one of the important units in the Salinas depression, derives its name from the town of Santa Margarita in the southern part of the valley.

The Santa Margarita formation is one of the lower members of the San Pablo group. In the Salinas valley as elsewhere it is conformable with the upper members, the Etchegoin and Jacalitos formations, lower Pliocene. This series is found in many parts of central and southern California.

The Santa Margarita formerly was considered as resting unconformably on the Salinas shale. The present view is the Santa Margarita accordantly overlies the shales and that any possible unconformity is small.[1] In the Soledad Quadrangle the transition between the two formations is represented by a small period of erosion and the reworking of a portion of the shale during the deposition of the basal Santa Margarita. In a plane table survey, Dr. Edwards[2] used small erosional gutters in the shale to mark the contact between formations west of Reliz creek. The Santa

1) Reed, R.D.-op.cit.

2) Shell Oil Company, Oral communication

Margarita sandstone was folded with the Salinas shale in this vicinity.

Areal distribution

Some of the exposures of the Santa Margarita sandstone indicate the presence of nearby land and are near the northern limit of deposition in the Salinas valley. These beds outcrop continuously southward from the point of maximum thickness at the mouth of the Arroyo Seco and rim Herbert's syncline. Two isolated outcrops, one 4 miles west of the mouth of the Arroyo Seco and the other one mile north, have a capping of conglomerate.

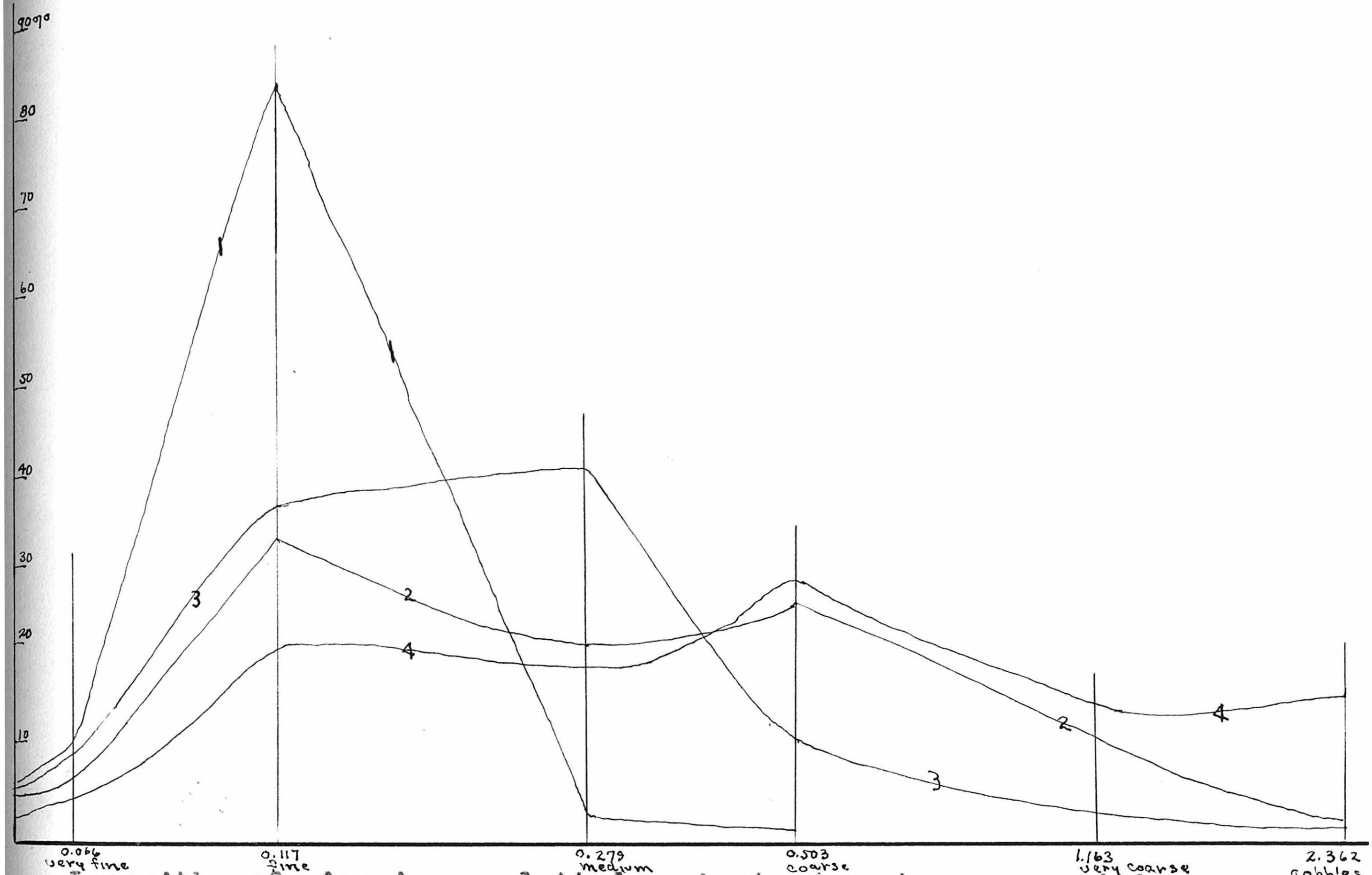
Conditions of deposition

Sandstone from this formation is uniformly fine and well sorted. The texture and the massive character of the beds indicate that deposition occurred in water of moderate depth. The grains are much smaller towards the south and it is probable, in conjunction with the greatest areal distribution, that the Santa Margarita basin had a greater depth in that direction. The upper portion of the section is considerably coarser grained than the rest and marks the return of shallow water conditions.

The thickness varies considerably. The western exposure 4 miles from the mouth of the Arroyo Seco, is over a hundred feet thick. It is composed of gently southward dipping, white sandstone capped by a conglomerate some tens of feet thick. The conglomerate contains granitic and quartzitic pebbles in a coarse sandstone matrix. The northern exposure, one mile from the mouth of the Arroyo Seco, is about a hundred feet thick and is overlain by a similar conglomerate member. At this point the series dips steeply towards the Salinas valley and is in fault contact with the underlying Salinas shale. Exposures along Reliz Creek and Herbert's syncline have a maximum thickness of 300 or 400 feet.

The maximum section of 1815 feet at the mouth of the Arroyo Seco, is composed of fine white sandstone in massive beds which dip uniformly $35^{O}E$ towards the valley. The upper and lower limits are not definite. The basal portion is transitional from the underlying Salinas shale and is partly reworked material. The contact was drawn at the first appearance of sandstone above shale. The succeeding hundred or so feet are alternate beds of sandstone, up to ten feet thick, and shale. In these are found several large concretions. The remaining 1500 feet is composed of massive, uniform, soft, white sandstone in beds up to 40 feet. The top of the section is covered by recent alluvium.

MECHANICAL ANALYSIS OF THE SANTA MARGARITA FORMATION



Logarithm of size in mm plotted against percentage composition

Location of samples

1). At shale contact-SE edge of sheet, east of Reliz creek

2). At shale contact west of Reliz creek in Herbert's syncline

3). Half way up in section at the mouth of Arroyo Seco

4). Top of section along Arroyo Seco

(1) shows an exceptionally well sorted sand of probable deep water origin. (2), in the same vicinity as (1), shows decrease in depth towards the west in the increased coarseness and less complete sorting. (4) shows current or shallow water conditions near the close of the Santa Margarita.

Lithology

The individual grains in the Santa Margarita formation are rounded to sub-angular. A generalized list of component minerals includes quartz and felspar in nearly equal amounts and minor quantities, with a maximum of 10%, of biotite, magnetite, ilmenite, some muscovite, leucoxene, limonite, siderite, hematite and calcite. The felspar is commonly oligoclase occasionally with andesine and orthoclase.

In Herbert's syncline the Santa Margarita appears different from other exposures. In this district it often has a greenish color resulting from alteration products. The beds in this locality are never over 6 feet thick compared to 40 feet at the mouth of the Arroyo Seco.

Shale member

West of Reliz creek, on the north limb of Herbert's syncline, a small area of dark colored shale with one interbedded layer of impure yellow limestone is exposed. The contact between the shale member and the underlying sandstone is not clear although apparently the two are conformible.

Classes in summer camps from the University of California reported fossils from this shale which were determined as Etchegoin (lower Pliocene). Etchegoin beds are exposed south of this locality. No diagnostic material was found which would warrant a division and the shale was included in the upper part of the Santa Margarita formation.

Paleontology

A number of fossils were found in a cliff exposure north of the mouth of the Arroyo Seco one mile. (TI8S, R5E, section 4). Most of the forms occur near the contact between the underlying white, massive sandstone with the overlying conglomerate. The species identified are:

Macoma vanvlecki
Macoma sp?
Metis sp?
Belanus sp?
Solen perrini
Panopea generosa
Pecten (Patinopecten) propatulus Conrad
Pecten crassicardo Conrad (?)
Pecten (Lyropecten) estrellanus Conrad
Lunatia lewisii
Trophon Belcheri avitum
Turitella vanvlecki

The forms, in part, are characteristic of the Santa Margarita series while others are not diagnostic. A number of the forms also appear in the overlying Etchegoin in other localities.

Paso Robles formation (upper Pliocene, lower Pleistocene)

General

A non-marine series, the Paso Robles formation, covers a large portion of the Salinas depression and derives its name from the town of Paso Robles in the southern end of the valley. These beds are also exposed in the vicinity of the coast and in San Benito valley. The sequence includes detritus deposited on fans, in streams and in small bodies of fresh water. The lake deposits in the vicinity of Paso Robles include homogeneous beds of limestone, marl and shale in which are found various fresh water forms.

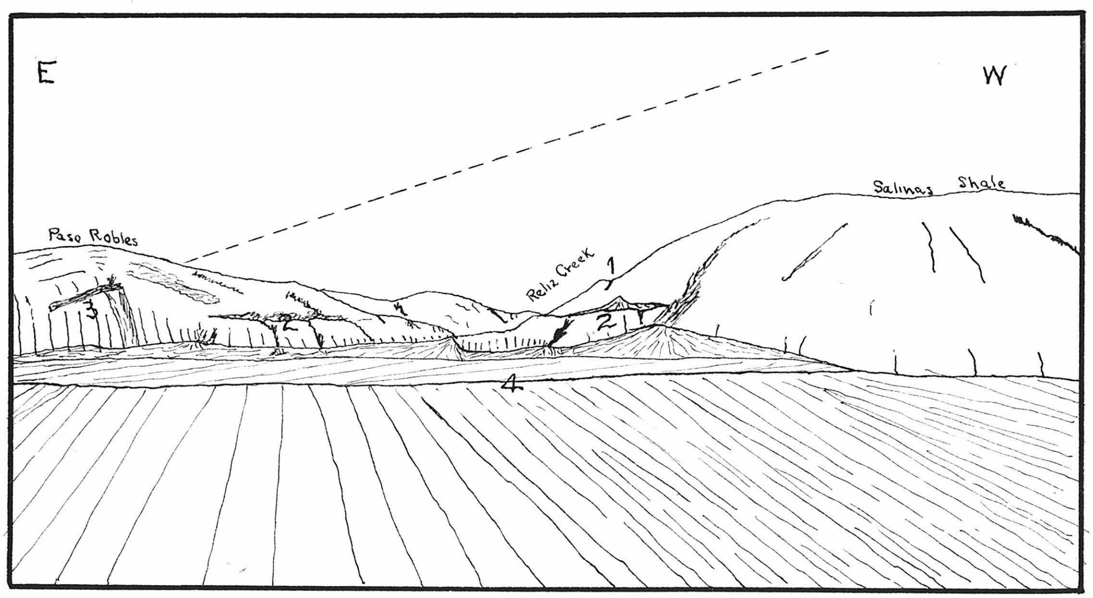
The Paso Robles formation is generally a coarsely bedded, slightly consolidated, series of conglomerates. The rounded cobbles are chiefly Salinas shale in a sandy matrix. Interbedded sandstone and shale are also present. As far as is known, diagnostic fossils have not been found.

The fresh water Salinas basin during the upper Pliocene and lower Pleistocene resulted from the withdrawal of the sea which had occupied it in parts of the Miocene and Pliocene. The present extent of the Paso Robles formation is an approximate measure of its original distribution. The maximum section in the Soledad Quadrangle is 1100 feet.

Folding, which followed San Pablo deposition, had ceased for the greater part by upper Pliocene time. The strata in the Paso Robles formation lie approximately in their original position except where disturbed by faulting.

Local

The Paso Robles beds compose a block of sediments between the Salinas valley and Reliz creek, south of the Arroyo Seco. The block has been tilted by faulting so that the strata now dip eastward towards the valley. The surface on that side is a dip slope. The western edge of the block has been exposed by Reliz creek, a subsequent stream. The strike and dip of the beds vary with position relative to the axis of Herbert's syncline showing that the post-Santa Margarita period of folding persisted with diminished effect into Paso Robles time. As illustrated below, this block of Paso Robles sediment has been rotated between two faults, the King City and Reliz Creek faults. The beds in the upper portion of the block would project considerably over the area of Salinas shale, the source of the cobbles.



Illus. -1. Reliz Creek fault; 2, Terraces, No.3 above the Arroyo Seco; 3, massive bed of Paso Robles conglomerate dipping eastward; 4, present incised channel of Arroyo Seco.

Basal sandstone beds, near the junction of Reliz creek and the Arroyo Seco, show cross-bedding by strong currents from the west and north. The overlying massive beds of conglomerate are as thick as 30 feet.

Lithology

Salinas shale cobbles are characteristic of this formation. Some confusion exists in differentiating between the Paso Robles formation and younger, consolidated, surface wash. The degree of rounding can be used since the recent cobbles are commonly angular. The Paso Robles beds have a buff or white color.

The sandy matrix contains quartz, 50% or more, felspars, and minor amounts of biotite, magnetite and minute particles of shale, totalling a maximum of 2%. Traces of sphalerite, volcanic glass, and ilmenite with leucoxene also are present.

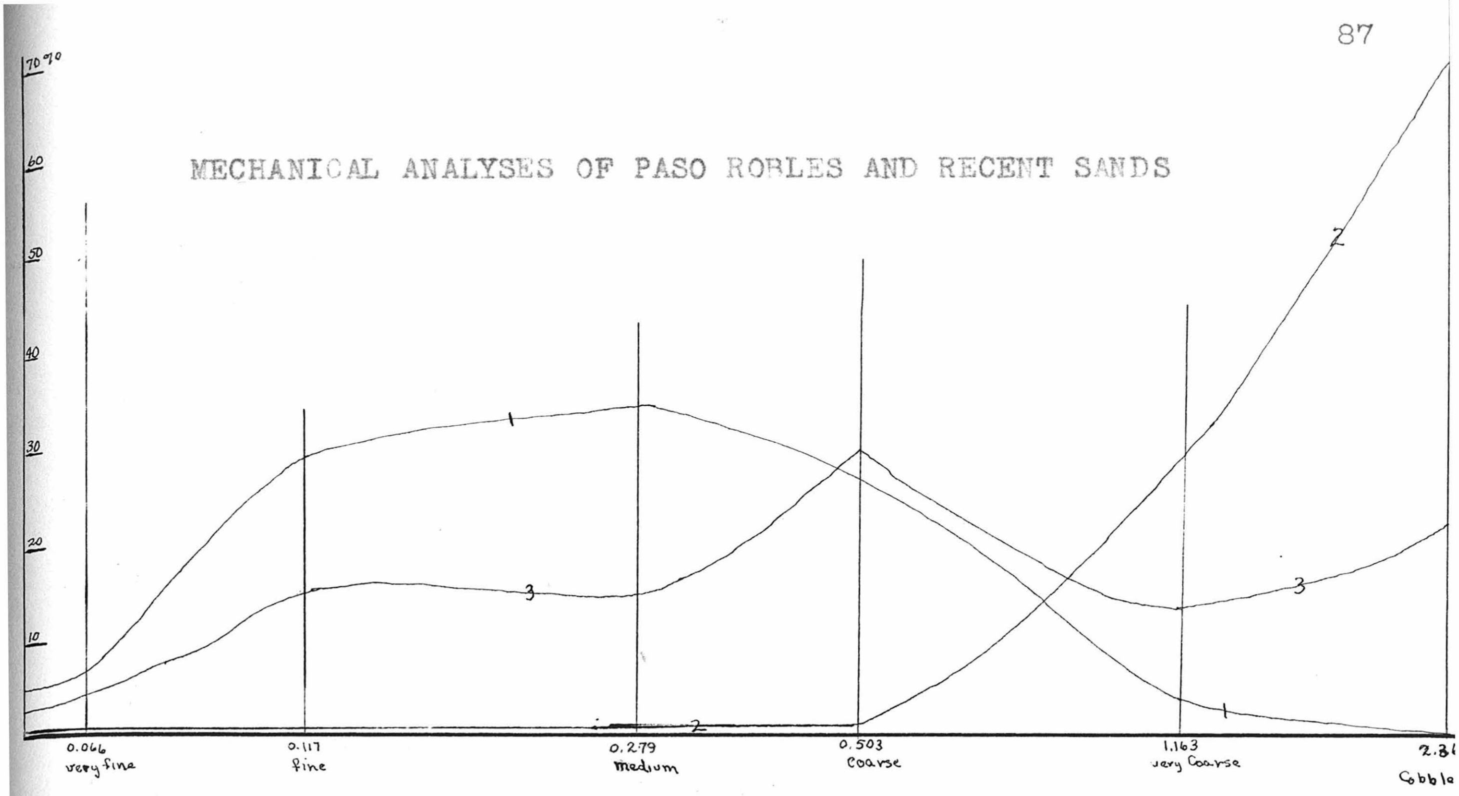
Mechanical analyses show an interesting contrast between the continental Paso Robles beds and earlier marine sandstone. The plotted curves of size with respect to proportion of sample for marine sands have generally one and possibly two maxima, depending on the ability of waves to sort. The curve for the Paso Robles sands shows three such maxima. These curves have a general application in the investigation of the sandstones within a limited area. They show at a glance the relative position of each sample during deposition and give some concept of the origin.

Possible extent of the Paso Robles beds

Although the present outcrops are confined to the western side of the Salinas depression, the Paso Robles series at one time probably extended into the Salinas valley and some miles north of the Arroyo Seco.

Paso Robles beds on the coast possibly were continuous with the section at the mouth of the Arroyo Seco. Faulting, which tilted the Paso Robles beds, depressed the Salinas valley. Recent alluvium conceals any possible area of Paso Robles strata on the down-faulted block.

MECHANICAL ANALYSES OF PASO ROBLES AND RECENT SANDS



Logarithm of size in mm plotted against percentage composition

Location of samples

1). Recent material from stream bed of Piney creek.

2). From the stream bed of the Arroyo Seco near Abbott.
(Boulders excluded).

3). Sandstone matrix of Paso Robles formation near mouth of

Recent sand from Piney creek is medium sized and, although not well sorted, is uniformly rounded. The sample from the Arroyo Seco is typical of a young, powerful stream capable of transporting large quantities of coarse material. The curve of the Paso Robles sands is interesting in that it shows the rough sorting of the material.

Quaternary formations (post-Paso Robles formation)

General

The Quaternary section contains several units of varying stratigraphic importance. Most of the total of 1500 feet was deposited on the depressed Salinas valley block. The divisions within the valley are recent alluvium, fan detritus, and terrace material.

Recent Alluvium

This term includes recent detritus deposited by the Salinas river and minor streams and the large section of older alluvium which has been buried by later fans and terraces.

The alluvium deposited by the Salinas river is largely composed of fine particles of shale and sand. The stream, except in flood, is sluggish with a gradient in this region of only six inches to the miles. Besides this factor the river is unable to carry coarse material because the flow, most of the year, is intermittent and largely underground. The thickness of the alluvium is unknown. The possible maximum on the western side of the depression is 1300 feet. None of the wells on that side drilled for irrigation purposes, reached basement, or for certain, older sediment. The deepest well, near the little junction of Molus in the center of the valley, attained a depth of 350 feet without penetrating the alluvium. In the vicinity of Salinas, 20 miles to the north, the alluvium was penetrated[1] at a depth of 472 feet.

On Plate 2 accompanying this report are plotted the logs of known wells within the Salinas valley of the Soledad Quadrangle. Transverse section, G-G', near the mouth of the Arroyo Seco, shows a rough approximation of depth to comparable members in each well. On the northern transverse section, F-F', the depth to corresponding members increases towards the center of the valley. In longitudinal section, E-E', an abrupt increase in depth to similar members occurs.

An inspection of the logs of wells within the Salinas valley shows that the alluvium increases in amount towards the mouth from the vicinity of Soledad. Similarly, the depth to particular members increases[2]. The Salinas river evidently encountered an area of smaller gradient near its mouth and aggraded.

The greater portion of the alluvium is conglomerate. If the drillers were able to distinguish between conglomerate and shale, well-logs including considerable shale are not characteristic of the Paso Robles section at Soledad. It is believed that Paso Robles beds were not encountered in any of the wells.

The alluvium in the valleys of minor streams west of Palo

1) Hamlin, H.-Water Resources of the Salinas Valley: Water Supply Paper 89:32:1904

2) Mr. H. Peters--consulting engineer in Salinas City.

Escrito ridge is largely coarse sand and boulders. These streams flow intermittently during the rainy months transporting a considerable amount of unsorted detritus.

Fan detritus

The alluvial fans which extend into the Salinas valley from either side occupy a considerable portion of the depressed area. The Salinas river, which flows on the eastern side of the depression, opposite the mouth of the Arroyo Seco, gradually swings to the west. The fans descending from the Gabilan Range are longer than those at the base of Palo Escrito ridge.

Each fan has been truncated more or less by the Salinas river. All fans are cut by the streams crossing them.

The composition depends on the position of the fans. Those at the base of Palo Escrito ridge contain boulders and sand chiefly derived from the Sur Series (?) of metamorphics. The fans on the eastern side of the valley are composed of granitic detritus from the Gabilan Range.

Terraces

Well-defined terraces are developed near the mouth of the Arroyo Seco. Although chiefly cut surfaces, small deposits of coarse conglomerate were deposited by the Arroyo Seco near the mouth.

The first two terraces above the Arroyo Seco are coexten-

Ill. 16

Folding in recent alluvium in the Salinas valley. Looking towards the south on the Paraiso Springs road two miles from Soledad. This small fold indicates that compressive forces are active within the region.

sive with surfaces in the Salinas depression developed by the Salinas river. Both features are deeply trenched by the Arroyo Seco. The aggregate thickness of terrace material in the Salinas valley is about 200 feet. The conglomerate and sand in this formation were derived from the Tertiary formations and crystalline rocks of the Santa Lucia Range.

Recent detritus from the Arroyo Seco and Piney creek

The characters of the Tertiary sandstone and present stream detritus are compared by analyses of samples collected from the Arroyo Seco and Piney creek at their points of entry. The purpose of the comparison was to determine if the Tertiary sandstone was of local origin.

A marked difference exists in composition and size. Sand from the Arroyo Seco is coarse and contains angular particles of quartz, orthoclase and oligoclase with about 15% of magnetite, biotite, muscovite, ilmenite and traces of hornblende. The particles from Piney creek are more rounded varying between medium and coarse grained. Component minerals are biotite, magnetite and ilmenite, 65%, and minor amounts of oligoclase, quartz, hornblende and orthoclase. Both samples contain the essential minerals of any Tertiary sand in this area.

STRUCTURE

General

The mountainous belt on the coast of California is composed of a number of individual ranges with a general northwest trend. The headlands are the promontories and the interrange depressions are the bays and harbors. The coastal province has a variety of structural problems not completely understood. Folding and faulting, modified by erosion, were largely responsible for the formation of each range.

The structure is not monotonous throughout the province. Differences exist even in adjacent areas. However, the folds and thrusts are overturned or directed chiefly towards the ocean on the west. The importance of folding or faulting is dependent in part on the competence of the rocks exposed.

Many of the major structures have persisted over the greater portion of the Tertiary and some since the Mesozoic. Earlier movements along these lines of weakness elevated mountains ancestral to the present ranges. The reduction of these, through erosion, furnished detritus for later formation.

Salient features are manifest in the study of Coast Range structure. As already mentioned, many of the faults have been active through several geologic epochs. The stability of some elevated areas over similarly long intervals is evidence that the crust was deformed unequally in the coastal region. Many of the basins of deposition were dominantly suppressed areas and received sediment over long periods in which adjacent areas, the positive elements, were but slightly submerged if at all.

It is not improbable[1] that some of the major faults in the Central Coast Ranges join the San Andreas rift either along its trace or in depth. Major faults, with their related branches, divide the central Coast Ranges into three major blocks. The Gabilan block lies between the San Andreas Rift to the east and the King City fault along the west side of the Salinas depression. The King City block is located between the King City fault and a discontinuous line of weakness in the Nacimiento river valley. Between the King City block and the ocean is the Santa Lucia block[2].

Although the San Andreas Rift was not investigated in the progress of this report, a general description of it should be included for its possible relation to Coast Range structure. The Rift is essentially a horizontal line of movement. The western block has moved northward with respect to the eastern[3].

Structures, most easily assigned an origin, are those re-

1) Noble, L.-San Andreas Rift and some other active faults in the desert region of southeastern Calif.:Seis.Soc. America:Bul:v17:25-39:March 1927

2) Reed, R.D.-Post-Monterey Disturbance in the Salinas Valley Calif.-J.G.:v33:590:1925

3) Lawson, et al.-San Francisco Earthquake Report:1906

lated to stresses along the San Andreas Rift. Such features are the result of the drag effect of one block on the other or, of the pressure of one block against the other. A number of these may be mentioned as the Matilija Overturn (Kerr and Schenck, 1928), Frazier and Liebre Mts. overthrusts and the Cuyama thrust (Gazin, 1930). The last three are in the Tehachipi mountains. Thrusts are present also at the southern end of the San Joaquin valley (Hoots 1930). Numerous reverse and thrust faults have been described which branch from the Rift in the San Gabriel mountains, (Noble, L., 1927). The branch faults run at a small angle or parallel to the Rift for some distance. Many have been followed back into the master fault. It is possible that vertical faults, not directly related to the Rift, may have resulted from deep-seated forces set up in its movement.

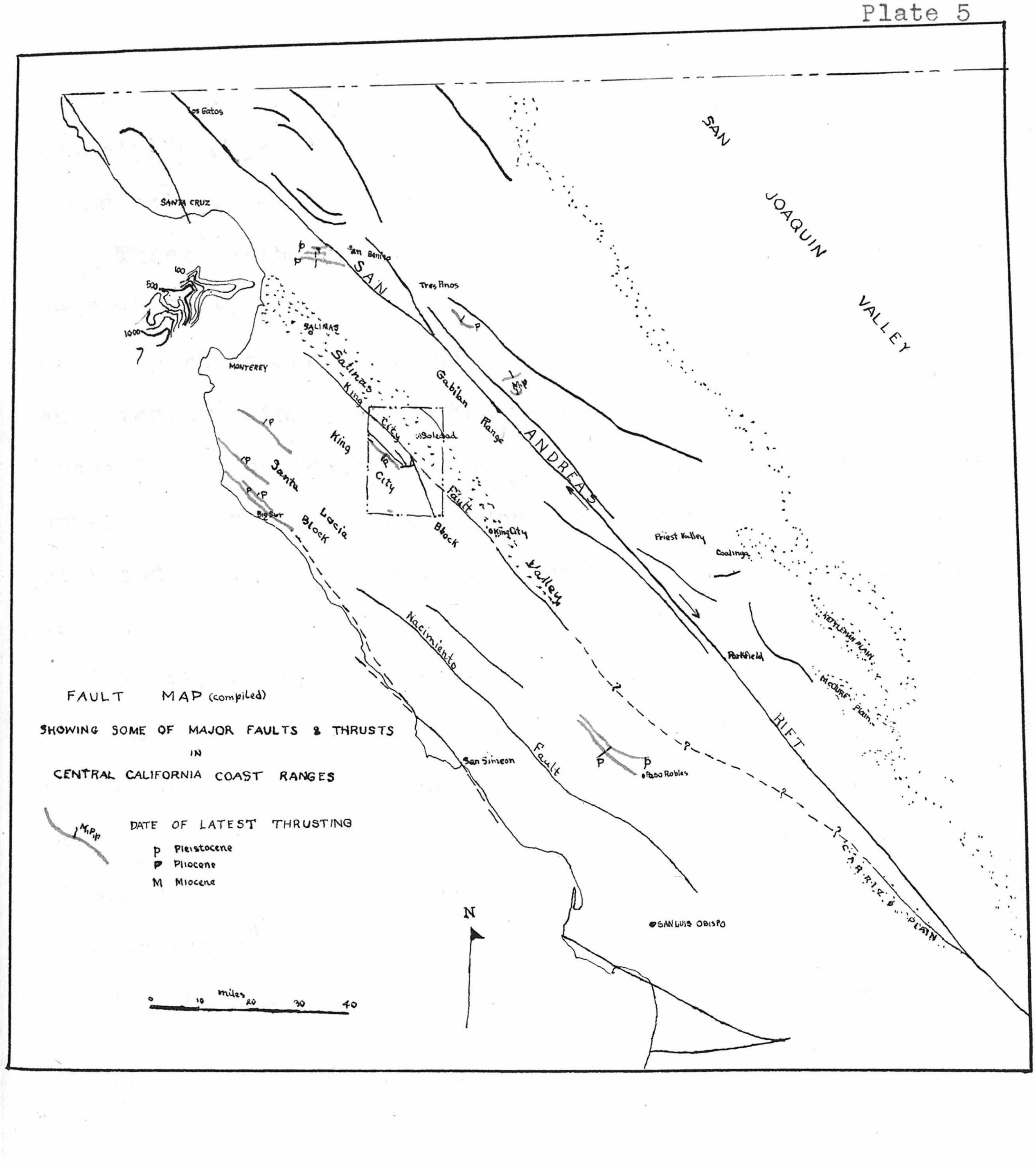
Central Coast Ranges

Many workers believe that many of the faults in this region are related to the San Andreas Rift. B. L. Clark believes that the King City fault joins the Rift in the vicinity of Carrizo Plains[1]. The faults between the King City fault and the ocean have no apparent connection with the Rift.

As previously outlined, the major faults in the central

1) Clark, B.L.-Tectonics of the Valle Grande of Calif.-v13:pp204:Amer. Ass.Pet.Geol:1929-Oral Communication

Plate 5



SAN JOAQUIN VALLEY
Los Gatos
SANTA CRUZ
San Benito
SAN ANDREAS
Tres Pinos
SALINAS
MONTEREY
Salinas King City
Gabilan Range
King City
Soledad
Santa Lucia Block
Big Sur
Fault Block
King City
Valley
Priest Valley
Coalinga
Parkfield
RIFT
Nacimiento Fault
San Simeon
Paso Robles
CARRIZO PLAIN
SAN LUIS OBISPO
N
miles
0 10 20 30 40
FAULT MAP (compiled)
SHOWING SOME OF MAJOR FAULTS & THRUSTS
IN
CENTRAL CALIFORNIA COAST RANGES
DATE OF LATEST THRUSTING
P Pleistocene
P Pliocene
M Miocene

Coast Ranges roughly describe elongate blocks which trend northwest. The Gabilan and the King City blocks are concerned in this report. Within each block are faults which, in part, are branches of the major fault. The sediments on the individual blocks generally are folded. In part, the folds in the sediments are related to fractures, many of them thrusts, in the underlying crystallines. This is also suggested by the mutual trend and age of thrusts and folds.

Three periods of post-Miocene movement occurred in the central Coast Ranges. The first movement during late Pliocene or early Pleistocene was accompanied by folding of the sediments and overthrusting towards the west and some normal faulting, possibly not contemporaneous. The maximum shortening was in a north or northeastern direction. The Santa Lucia Range was elevated during this period. (Nicolls, 1925 and Trask, P. D., 1926).

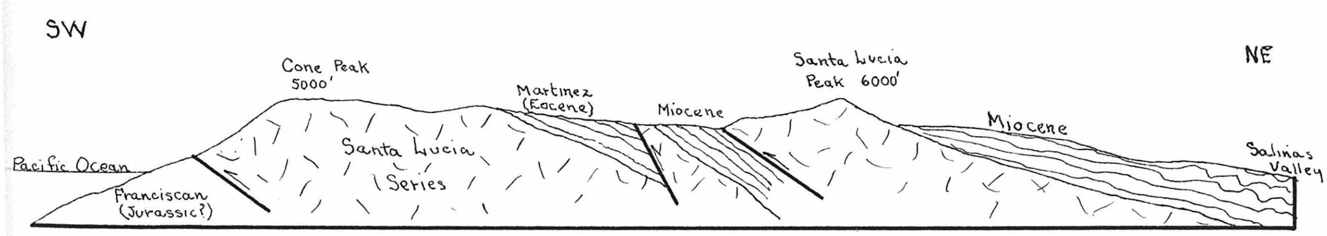
In the early Pleistocene steep-angled and normal faulting took place along both old and new lines of weakness and defined the present topography, now modified by erosion. In the same period probably not simultaneously, thrusting reoccurred along Pliocene thrusts. The Salinas shale near the mouth of the Nacimiento river was thrust eastward in a direction generally opposed to major thrusting during the Pliocene[1]. Thrusting took

1) Stanton, W. L.- Oral Communication

place in both adjacent blocks towards the San Andreas Rift[1].

Most of the faults in the central Coast Ranges have been dead or dormant in historic time. The San Andreas Rift is responsible for recent thrusting from the west in the Gabilan Range since the conditions are not duplicated elsewhere[1].

Pliocene thrusts were directed chiefly towards the west. At the northern end of the Santa Lucia range, Trask (1926) found a number of thrusts which override towards the west on thrust-planes inclined from 30-70°NE. The horizontal component of movement is considerably in excess of 10,000 feet. About forty miles south of this locality thrusts similarly directed involve Salinas shale.[2] A crude sketch, trending southwest across the Santa Lucia Range, (about ten miles south of the Soledad Quadrangle), illustrates this feature:



1) Kerr and Schenck-Active Thrusts in San Benito Co., Calif.: Geol. Soc. Amer: v36:479:1925

2) Sketch by J. P. Buwalda

In the Soledad Quadrangle the Santa Lucia Quartz Diorite has been thrust from the west over Salinas shale on a fault plane dipping 15-45^{0} south and west. The minimum horizontal component is 500 feet. As previously mentioned, a similar thrust is found at the mouth of the Nacimiento river.

The oppositely directed thrust planes, if continued at the same angle, would intersect along a line considerable less than ten miles below the surface, certainly not in the zone of flowage. Mechanical difficulties enter the problem if these thrusts are considered to be of the same age. It is impossible for rock to move in two directions at the same time without flowing. If the thrust planes steepen in depth and do not intersect, the same difficulty occurs. A smaller cross-section, beneath the surface, would occupy a larger area on the surface and this is impossible without rock flowage. If the thrusts are considered as underthrusts of the same age and with fault planes steepening with depth, the problem is possible. Accomodation would occur by portions of the underthrust block entering the zone of flowage.

If the oppositely directed thrusts are considered as overthrusts, which seems more probable, there must have been an elapse of time between their movements. Overthrusting towards the east might take place after the crust was thickened through the enormous movement in a westerly direction.

One of the unanswered questions in the central Coast Ranges, as in other regions, is in regard to the reversal of stresses in succeeding periods. The solution may involve changes in direction of application of the forces.

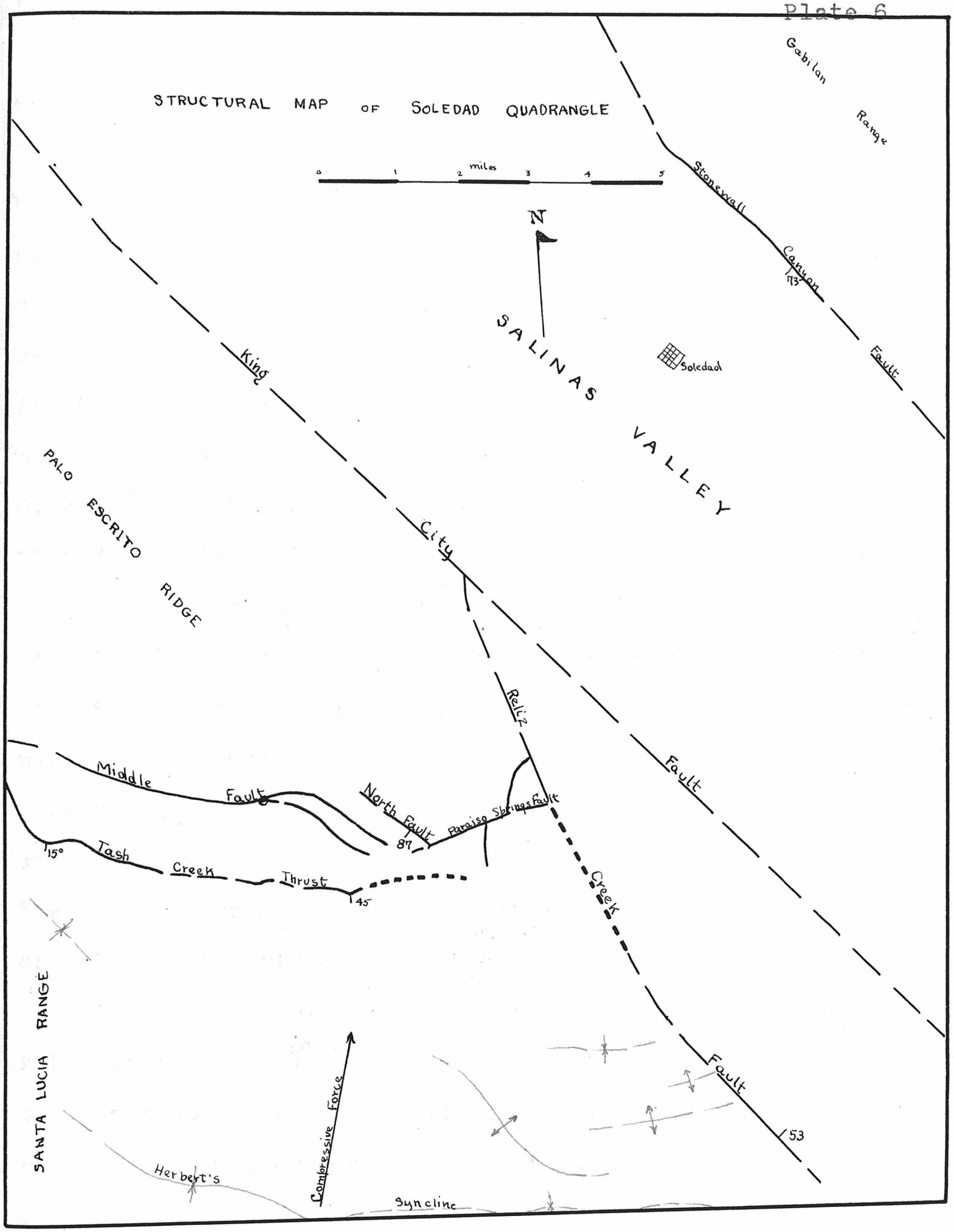
Although folding has been mentioned as incidental in the central Coast Ranges, it is equally or more important than faulting in areas of sedimentary rocks. No clear evidence can be cited as to what effect folding in the overlying sediments has on the rocks of the underlying basement. The folds, in part, have some relation to the faults. Most of the Pleistocene faults cut the Pliocene folds.

Soledad Quadrangle

The importance of either folding or faulting is related to the rocks exposed. In the area occupied by sediments west of the Salinas valley, folding is the most prominent structure. The crystalline rocks elsewhere are cut by several faults of considerable magnitude. On the whole, folding is less important than faulting which has produced the present modified topography and, in part, may be responsible for the folding.

There were two major, and possibly a third minor, periods of movement. These stages were in the early Pliocene and in the Pleistocene possibly with minor movement between them. Pliocene faults are established on their lack of any topographic expression. The period of erosion following faulting was of sufficient duration to remove all surface expression. Pliocene movement is recognized by stratigraphic discordances. Pleistocene faulting, taking place on a much larger scale than the Pliocene, was recent

Plate 6


STRUCTURAL MAP OF SOLEDAD QUADRANGLE
miles
N
Gabilan Range
Stonewall Canyon Fault
73
SALINAS VALLEY
Soledad
King City Fault
PALO ESCRITO RIDGE
Reliz Creek Fault
Middle Fault
North Fault
87
Paraiso Springs Fault
Tash Creek Thrust
15°
45
53
SANTA LUCIA RANGE
Compressive Force
Herbert's Syncline

enough and of sufficient magnitude still to be manifested in the topography.

The Gabilan block was cut in Pleistocene time by the Stonewall Canyon fault along the eastern side of the Salinas valley. The King City block is divided into a number of minor components by faults which trend at an angle to the King City fault. The Reliz Canyon fault elevated the Salinas shale west of Reliz creek so that it now has an angular contact with the Santa Margarita sandstone. This fault probably is coextensive with a marginal fault at the base of Palo Escrito ridge in the vicinity of Paraiso Springs. Thus conceived, the Reliz Creek fault joins the King City fault north of Paraiso Springs. The last movement on it tilted the block of Paso Robles strata east of Reliz creek.

The Paraiso Springs fault, oblique to the trend of the King City fault, has offset structures and elevated a tongue of crystalline rocks in a ridge north of Paraiso Springs. Its trace is marked by a subsequent valley in the crystalline rocks west of Paraiso Springs. Near the crest of Palo Escrito ridge, a wedge of Temblor sandstone has been dropped between crystalline rocks. The Paraiso Springs fault may terminate some of the faults west of Palo Escrito ridge.

A number of faults with minor branches are present west of Palo Escrito ridge. The ridge is outlined as a structural unit between them and the King City fault on the east. Palo Escrito ridge has been elevated on the west by the North and Middle faults.

The North fault is local and can not be traced far. Movement on it may have occurred either in the Pliocene or Pleistocene. It probably was formed in the Pleistocene period since it is aligned.

The Middle fault is an important structure in the King City block. It has elevated Palo Escrito ridge and can be followed a number of miles beyond this area by a continuous break in the topography. Since the Middle fault offsets the Salinas surface, early Pleistocene, it is of that age. The branches of the Middle fault have two trends. The chief trend is east-west. In the vicinity of Sand Creek the trend is northwest.

Pliocene faulting

Tash Creek Thrust

The Tash Creek thrust was formed during the Pliocene by compressive stresses acting from the south and west. The period of faulting was followed by an erosional interval of sufficient duration to remove any topographic expression that may have existed. In the field the evidence for this fault is largely stratigraphic. The crystalline rocks of the Santa Lucia quartz diorite series, capped by southward dipping Temblor sandstone, have been thrust over Salinas shale north of the fault.

The trace of this structure, although in a general east-west direction, is irregular in the localities where the fault can be established. The dip, varying between 15-45°S, is less steep towards the west and the contact is more irregular .

The massive Temblor sandstone lying on the southern slope of the overriding block has been tilted and now **dips** $17^{O}S$ near the fault and $12^{O}S$ one half mile south of it.

The minimum throw on the Tash Creek Thrust is 500 feet. The minimum horizontal component, depending on the dip of the fault, is either 500 or 1865 feet. This is considerably less than the minimum of 10,000 feet which Trask found at the northern end of the Santa Lucia Range to be towards the ocean.

The thrust continues for an unknown distance towards the west. In the vicinity of Basin Creek the fault is lost in Salinas shale. It probably extends farther east than it can be traced on the surface and possibly is cut by Pleistocene movement on Reliz Creek fault. North of the projected line of the thrust, the Temblor beds dip $24^{O}S$ while the overlying Salinas shale, ordinarily accordant, dips $40-50^{O}N$ for one half a mile south of this projected line.

Since the Pliocene disturbance was dominantly compression, other faults in this area, which are steep-angled or normal faults, are assigned to the Pleistocene period. The age of some faults, however, can not be definitely determined.

Pleistocene faulting

King City Fault

Normal faulting occurred on a wide scale during the early Pleistocene. The King City fault, the most prominent structure, follows the base of Palo Escrito ridge on the western side of the Salinas depression. Movement along this fault elevated the ridge to the west and depressed the Gabilan block to the east. Although the King City fault is buried under later fan and terrace deposits, its presence can be established by stratigraphic and physiographic evidence, as discussed previously. The field relations, are indicated in section A-A'. Tertiary sediments may lie under the alluvium of the valley although they are not shown there.

The King City fault can be established where the crystalline rocks of Palo Escrito ridge have preserved the topographic expression of a fault. The evidence south of the Arroyo Seco is not clear and has led to doubt of the presence of a fault in the Salinas depression. South of King City the Salinas shale and Santa Margarita sandstone continue across the valley in a synclinal fold[1]. Clark[2] believes that fault relations can be traced continuously southward and that the King City fault joins the San Andreas Rift in the vicinity of the Carrizo Plains.

In this area the King City fault[3] is a master fault with great displacement and a profound effect on the present topo-

1) English, W.A.-Geology and Oil Prospects of the Salinas Valley-Parkfield Area, U.S.G.S. Bul. 691

2) Clark, B.L.-Oral communication

3) Termed the Santa Lucia Fault-Report of State Earthquake Commission-v1:part 1:pp19:1908

graphy. The nature of the fault plane can not be established. The Reliz Creek fault, a branch structure, is a steep normal fault and the King City fault may be likewise.

Computation of the throw on the King City fault is based on the displacement of the Salinas surface on Palo Escrito ridge above its projection under the valley alluvium. The approximate movement of 4000 feet includes the 3000 feet of the scarp above the fan heads on the western side of the depression.

The age of the King City fault is early Pleistocene. The latest movement displaced the Pleistocene, Salinas, old age surface, and tilted and possibly truncated the Paso Robles beds. The fault is dead or dormant since it has not cut the surfaces of either the fans or terraces which conceal it.

Stonewall Canyon Fault

A minor normal fault follows the eastern side of the Salinas depression in the Gabilan block. Four prominent shear zones with an average dip of $73\frac{1}{2}^{\circ}$SW are exposed in a roadcut in Stonewall Canyon. The trace northwestward is marked by occasional areas of breccia, white granulated rock, and green chloritized granite. The trend of the fault changes abruptly towards the north in that portion of the Gabilan Range.

The displacement increases towards the northwest. Beyond this quadrangle the fault is responsible for the definite topographic break along the eastern side of the Salinas depression.

Ill. 17

Stonewall Canyon fault as seen in Stonewall Canyon one half mile from its mouth. This shows one of the four zones of movement which are present at this locality. This normal fault follows the eastern edge of the Salinas valley and at this place, dips 73° westward. This fault was formed in early Pleistocene time.

Ill. 17

Stonewall Canyon fault as seen in Stonewall Canyon one half mile from its mouth. This shows one of the four zones of movement which are present at this locality. This normal fault follows the eastern edge of the Salinas valley and at this place, dips 73° westward. This fault was formed in early Pleistocene time.

The trace cam not be followed southeast of Stonewall Canyon. The fault may die out in that direction. The displacement is small, probably no more than a few tens of feet. Since the Stonewall Canyon fault cuts the Salinas surface, it is of Pleistocene age.

Faults in the King City block

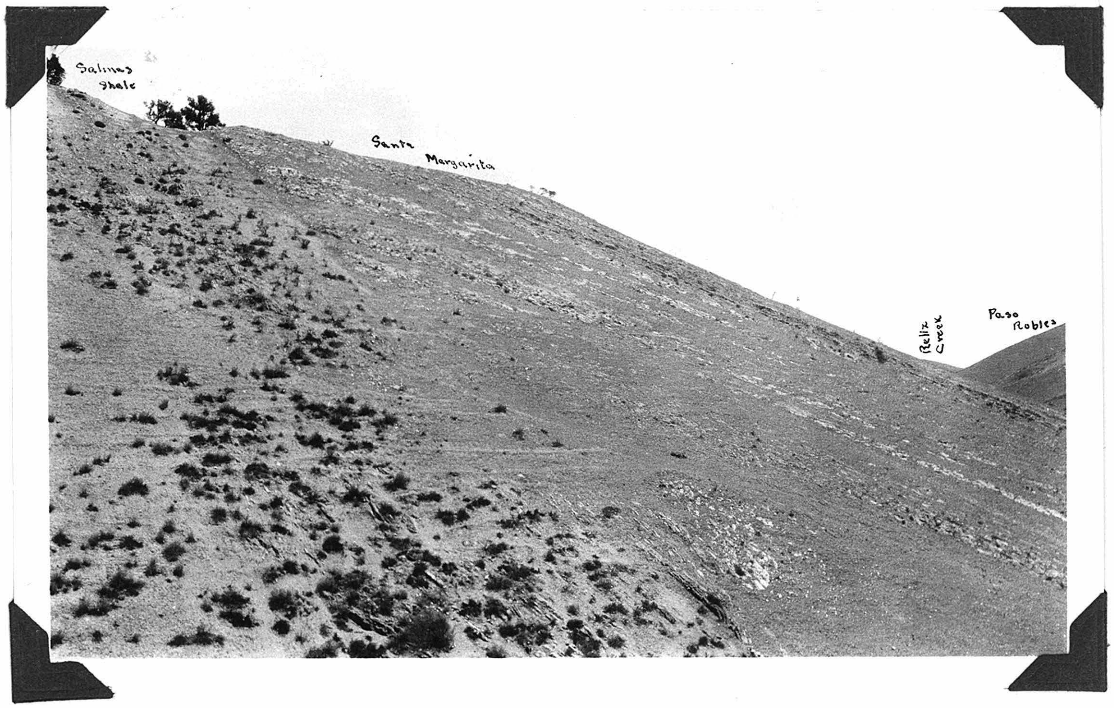
Reliz Creek Fault

The Reliz Creek fault separates a wedge shaped segment from the King City block. This normal fault has raised the Salinas shale on its west so that the contact is discordant with the overlying Santa Margarita sandstone. Beautiful exposures of the fault plane are seen along Reliz Creek and near the northern bridge head on the Arroyo Seco. At these points the fault dips $53^{O}E$. The uplifted Salinas shale west of the fault dips $53\text{-}65^{O}E$. The downthrown Santa Margarita beds dip $35\text{-}43^{O}E$.

Northward from the Arroyo Seco the Reliz Creek fault can be traced by areas of down faulted Santa Margarita sandstone. The fault in the vicinity of Paraiso Springs is not apparent although it probably continues into a similar fault north of that resort at the base of Palo Escrito ridge and there joins the King City fault at a slight angle.

As illustrated under the stratigraphic discussion of the Paso Robles formation, movement along the Reliz Creek fault on

Ill. 18



Reliz Canyon fault between Santa Margarita sandstone on the right and Salinas shale on the left. The dip of the fault plane at this point is 53° east. The picture was taken near Herbert's ranchhouse on the west side of Reliz Creek and the view is towards the north.

the west and probably on the King City fault to the east has rotated the block of Paso Robles sediment so that the upper beds of conglomerate now project considerably above the area of Salinas shale, the source of the cobbles.

The amount of movement on the Reliz Creek fault is indeterminate. The fault dies out to the south. If the presumed correlation with the marginal fault north of Paraiso Springs is correct, the minimum throw, responsible at that point for the scarp along Palo Escrito ridge, is nearly 1500 feet.

The evidence is not decisive as to the relation between the Reliz Creek fault and the Paraiso Springs cross-fault. The Reliz Creek fault can be projected northward, without apparent offset, into what is evidently its continuation north of the Paraiso Springs fault. Whatever movement occurred on the Reliz Creek fault was later than that on the Paraiso Springs fault which, in turn, may terminate against it.

The folds in the sediments are truncated by the Reliz Creek fault so that its age is later than Pliocene folding. The Paso Robles formation lies with an angular unconformity of from 27-30^{0} on the Santa Margarita beds. A portion of this discordance may be related to earlier movements along the Reliz Creek fault and not to erosion. Further support for earlier movement along this fault is found in the vicinity of Paraiso Springs. At this locality a branch fault of the Reliz Creek fault between the basement rocks of the Sur Series (?) and basal Temblor Red Beds

Ill. 19

North Fault at the head of Basin Creek, west of Palo Escrito Ridge.

was offset by movement along the transverse Paraiso Springs fault. Mineralizing solutions ascended this branch fault and deposited traces of chalcopyrite, pyrite and quartz.

Faults west of Palo Escrito ridge

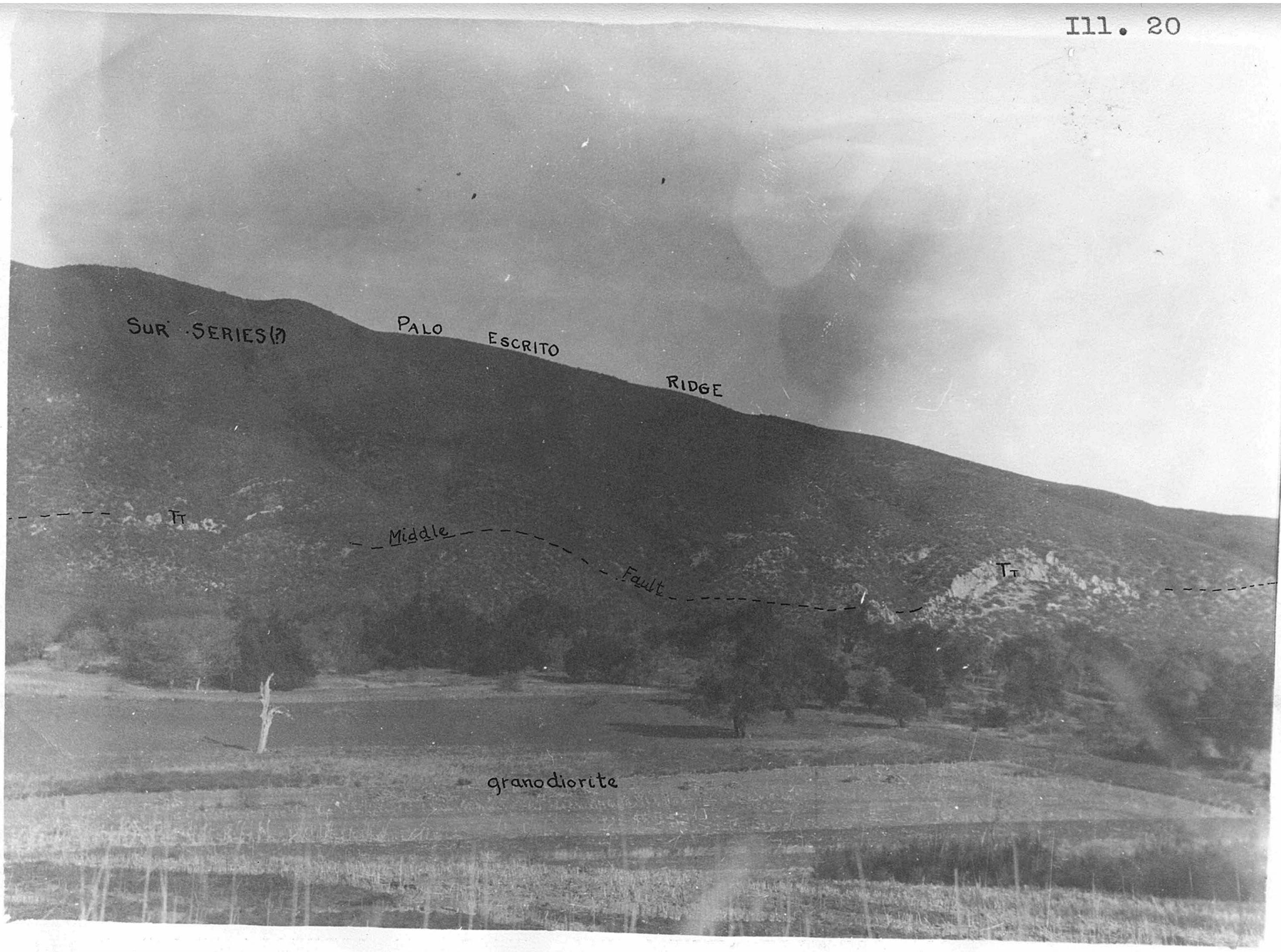
North fault

Movement on two normal faults in this vicinity has depressed Tertiary sediments and elevated Palo Escrito ridge. The northeastern of these two faults is called the North fault. It is marked in the topography by a series of erosion saddles on the ridges crossing it and is shown structurally by Temblor sandstone dipping into the crystalline rocks of the ridge.

The North fault can not be traced past the area occupied by sediments. Southeastward the fault is not found in Miocene beds which pass around the nose of Palo Escrito ridge. The North fault may, in fact, be cut by the Paraiso Springs fault although no evidence was found in support of this. The computed dip is 80°SW. The displacement is not known.

Middle Fault

This fault is one of the important structures within the King City block. It continues with increasing displacement towards the west. Near Sand Creek the fault divides. Between the branches a small block of Temblor sandstone is downfaulted into crystalline rocks so that the beds dip into the contacts. At the junction of these branches near Sand Creek, the rock is ex-



In the vicinity of Little Sand creek, isolated wedges of steeply dipping Temblor sandstone have been dropped between crystalline rocks by movement along the Middle fault.

tremely granulated and altered. Both branches are followed by small subsequent stream valleys.

The Middle fault is generally marked by a topographic break and by falls in the streams which cross it. The scarp is never more than 200 feet. West of Little Sand creek a small block of Temblor sandstone, dipping 85°S, has been dropped between crystalline rocks.

The attitude of the fault plane is very steep, vertical in some places. The trace of the Middle fault has two bearings. The trend for most of its length is east-west. The branches follow a northwestern direction. The two directions are probably the result of earlier lines of weakness. Since the Pliocene Tash Creek Thrust is in an east-west direction, the inference is that this is an earlier trend for structures.

The minimum movement on the Middle fault is 200 feet. The minimum displacement westward beyond the area mapped, as evidenced by the topography, is 1100 feet. Since the Middle fault cuts the Salinas surface upon Palo Escrito ridge, the fault is of Pleistocene age.

Paraiso Springs fault

The Paraiso Springs fault cuts obliquely across the dominant northwest trend of the faults in the vicinity of Paraiso Springs resort. The attitude of the fault plane can not be determined. Its position is indicated by a number of phenomena along its trace. In the vicinity of Paraiso Springs, movement

Ill. 21

The Middle Fault, the depressed block of sediments, and Palo Escrito Ridge.

on this fault has elevated Palo Escrito ridge north and west of the resort and exposed a ridge of crystalline rocks at the base of the Red Beds. The uplift offset the eastward dipping basement fault between the Red Beds and the metamorphic rocks of the Sur Series (?). West of the resort the fault plane is followed by a subsequent valley. Near the crest of Palo Escrito ridge, the fault has dropped Temblor sandstone between crystalline rocks and possibly has truncated some of the faults on the western side of the ridge.

As previously mentioned, the Reliz Creek fault does not seem to be offset by the Paraiso Springs fault. The age of the Paraiso Springs fault is, consequently, between the Pleistocene and Pliocene periods of diastrophism. The magnitude of displacement is not known. The basement fault is offset about 1530 feet. If the dip of the basement fault is the same as the Reliz Creek fault, i.e. $53^{O}E$, the throw on the Paraiso Springs fault is nearly 2100 feet in the vicinity of the resort.

The hot mineral waters at the Paraiso Springs resort can be encountered at almost any depth below the surface to basement rock at 120 feet. The average temperature of the water is $112^{O}F$ at 15 feet and $116^{O}F$ at 120 feet below the surface. The maximum possible flow is 200 gallons a minute. Three quarters of a mile east of Paraiso Springs the nearest well was drilled to a depth of 400 feet before water was reached. The water was unmineralized. This indicates a barrier between the two localities which not only raises the water level at Paraiso Springs but also prevents underground flow of the mineralized waters to the east. This barrier is presumedly the Reliz Creek fault.

According to the present management of the resort, interesting disturbances took place after the Santa Barbara earthquake in 1925. A few days after the shock the temperature of the water at Paraiso Springs increased 25^{O}F together with increased flow. The return to normal was gradual over a period of weeks. The same phenomena followed the San Francisco earthquake in 1906.

Folding

The compressive stresses, during the Pliocene, folded the Miocene sediments on the western side of the Salinas depression into a composite syncline, Herbert's syncline. Herbert's syncline is a symmetrical fold and the minor flectures on its northern limb are asymmetrical with the southern limb being steeper. The maximum shortening was in a north to northeast direction.

Most of the folds show the influence of the underlying basement. They follow approximately the shape of the basin in which the sediments were deposited. In the vicinity of the Salinas valley the folds are in a east-west direction. In the vicinity of the crystalline rocks of the Santa Lucia Range the trend is northwest. Herbert's syncline is shaped like a spoon.

It pitches towards the east and rises and disappears in the vicinity of the Santa Lucia Range. Many of the minor folds show the same tendency, rising and disappearing where the sedimentary cover is thin and pitching and increasing in size out in the basin.

Some of the folds , particularly south of Paraiso Springs, are nearly parallel to the Tash Creek Thrust. Although the folds trend in the same direction, it is not known whether or not they are related to the thrusting. It is believed that the forces which produced the folding came from the south and west as did those which gave rise to the thrust.

Jointing

The jointing planes in the crystalline rocks of this area can be divided roughly into two groups. Most of the joint planes trend approximately north-south, while another less certain grouping occurs in a northwest direction. The minor jointing planes vary more in trend than the more prominent. The forces which produced jointing acted in a southwest or west direction.

GEOLOGICAL HISTORY

Regional

The central Coast Ranges have undergone submergence and elevation several times since the Triassic. The deformation occurred unequally along the coast.

The pre-Jurassic history is obscured by the absence of sediments of determinable age. Early deposits, perhaps of Paleozoic age, are metamorphosed sediments in the Coast Ranges and as detritus are included in the basal beds of the Jurassic (?) beds. Metamorphism and the wide-spread intrusion of one or more related series of coarse-grained crystalline rocks are incidents in this early history. Legible events in the pre-Jurassic (?) history are the deposition of sediments, as the Sur Series, and their later metamorphism by batholithic intrusions of the Santa Lucia granite and the Santa Lucia quartz diorite.

The Franciscan (Jurassic?) sandstone, chert, and shale were deposited during regional submergence and are in depositional unconformity with the rocks of the underlying basement. Later uplift and the intrusion of basic rocks into the Franciscan series were followed by faulting during the lower and middle Cretaceous since representatives of this period are not found over most of the region. Subsequently, the Chico (upper Cretaceous) formation was deposited incorporating material derived from the Franciscan and earlier formations.

Submergence reoccurred locally in Paleocene (Martinez) time as beds of this age are found in the Salinas valley and isolated areas within the Santa Lucia Range. The region was elevated during the interval between lower Eocene and Miocene. Faulting or warping of the crust during this interval produced a topography of considerable relief so that the basal Miocene beds are coarse conglomerates in many localities.

In the lower Miocene, probably with minor oscillations, the region began to sink and the depression was at a maximum during upper middle Miocene when the Salinas shale was deposited over most or all of the central coastal region. The lower Miocene (Vaqueros) and lower middle Miocene (Temblor) sandstones derived most of their material from the adjacent crystalline rocks which were still exposed. Lava was extruded locally in upper Vaqueros and lower Temblor time. The source of the Salinas shale is not known definitely although the inference in some localities is that the source was towards the west.

The sea partly or entirely withdrew during the upper Miocene. However, with but slight erosion, this was followed by the deposition of the Santa Margarita sandstone accordantly upon the underlying Salinas shale. The sea gradually retreated and was entirely gone by the upper Pliocene.

Subsequent to uplift in the Pliocene, compressive stresses, acting along a south or southwest line, folded the existing sediments and formed thrusts, chiefly towards the west. The aggregate movement was over 10,000 feet. The forces possibly persisted into the upper Pliocene. After the folding, thrusting, and elevation of the Pliocene, the coastal region was comparatively stable. A long period of erosion developed the reduced Summit surface and furnished detrital material for the non-marine Paso Robles formation (upper Pliocene, lower Pleistocene) which was deposited in the fresh water basins. With possible complications, the region was again uplifted a few hundred feet, the Summit cycle of erosion was interrupted, and a new cycle was initiated in which the Salinas old age surface was formed.

Extensive early Pleistocene normal faulting, with a total movement of thousands of feet, interrupted the Salinas cycle, divided the region into northwestward trending blocks and greatly accentuated the existing topography, which, modified by erosion, is seen today. With intermittent uplift and perhaps oscillations of the coast line, the region has continued to rise to the present time.

Local

The pre-Cretaceous rocks in this area include the Sur Series (?), in part of sedimentary origin, the Santa Lucia granite of the Santa Lucia and Gabilan Ranges, and the Santa Lucia quartz diorite series in the Santa Lucia Range and intrusive into the granite of the Gabilan Range. The earlier history represented by these formations indicates the deposition of sediments, including limestone, of unknown origin. The granite, locally, may be earlier or later than the Sur Series (?). The Santa Lucia quartz diorite series was intruded as a batholith into the Santa Lucia granite and metamorphosed, at the same time, the sediments of the Sur Series(?).

The Soledad Quadrangle stood high during the period following the intrusion of the quartz diorite series until middle Miocene time. In this interval the sea deposited the Martinez (lower Eocene) a few miles south of the Arroyo Seco and may have extended farther, once or many times. Any materials deposited were later removed by erosion. During this period erosion and possibly local warping or faulting formed an inland basin ancestral to the Salinas depression.

Submergence began again in the lower Miocene, proceeding from the south. The Vaqueros sandstone was deposited at the type section south of the Arroyo Seco. The lower Miocene is represented north of this stream by the erosional interval which produced the cut surface upon which later sediments were deposited. Detritus was undoubtedly furnished for the Vaqueros sea. The water gradually encroached upon the Soledad Quadrangle in the middle Miocene and deposited the Temblor sandstone upon the submerged irregular surface. Material was derived from the adjacent land masses in the Santa Lucia Range, Palo Escrito ridge, and possibly the Gabilan Range. The relief was considerable during the initial stage of Temblor deposition since the basal Temblor Red Beds in the Salinas depression are largely conglomerates.

Extensive, and possibly complete, submergence occurred in the middle Miocene when the Salinas shale, nearly 8000 feet thick, was deposited. The uniformity and the fine texture of these shales together with interbedded limestone show that deposition was in water of moderate depth. No influence of adjacent land masses is seen in this series. The Salinas depression gradually sank with accumulating load since a sea over 8000 feet deep is unlikely.

Partial or complete uplift, with but slight erosion, was followed by renewed submergence and the deposition of the Santa Margarita sandstone accordantly upon the underlying Salinas shale. This period of depression may have lasted into the Pliocene (Jacalitos). Later elevation in the Pliocene forced the complete withdrawal of the sea and left an inland depression in its place.

Compressive forces during the Pliocene folded the existing sediments into a composite syncline and, in the same general period, thrust the Santa Lucia quartz diorite series northward over the Salinas shale. The folding may have lasted into Paso Robles (upper Pliocene, lower Pleistocene) time.

The non-marine Paso Robles formation was deposited in the Salinas depression during the period of erosion which followed the folding. Later uplift and a long period of erosion developed the Salinas old age surface upon the Gabilan and eastern flanks of the Santa Lucia Ranges.

The Salinas cycle was interrupted in the early Pleistocene by normal faulting which divided the area into two northwest trending blocks. In this movement, possibly along older faults, the King City block was tilted westward and the newly formed Gabilan Range was arched and tilted southwestward.

During the Quaternary and Recent the region has intermittently risen. Vigorous erosive processes have cut terraces in the Salinas valley and along minor streams. Enormous fans have been formed in the depression as a result of the reduction of the relief produced by Pleistocene faulting.

ECONOMIC RESOURCES

The resources of this area are largely of agrarian interest. The future possibilities are unfavorable for the development of either metallic or non-metallic economic deposits.

Gilleylen's Cinnabar claim

During the war advanced prices encouraged exploration work on a quicksilver claim near the junction of Little Sand and Paloma creeks. A small showing of cinnabar was found in massive Temblor sandstone capping quartz monzonite. The work was carried on at two levels. Only a few flasks were produced.

The cinnabar occurs along minor fractures in calcite veins. The deposit is of most interest for its relation to the Tash Creek Thrust, a few feet north of the deposit. Mineralizing solutions undoubtedly ascended the fault plane and deposited in the sandstone. Since the thrusting is of Pliocene age, the mineralization took place at a slighly later date. The ore is of the poor grade and the small areal extent of the Temblor capping prohibits any future development.

Paraiso Springs

Of considerable historical, geological and economic interest are the hot mineral springs at Paraiso Springs on the western side of the Salinas valley. In the five springs the water varies between a temperature of $65-112^{0}$. Analyses of the water have been published.[1-2]

The mineral content varies in different springs. Although advertisements declare the presence of arsenic, iron, carbonate and sulphur springs, only traces of iron and arsenic are found. The water is charged mostly with carbon dioxide and hydrogen sulfide. The springs have been known since the time of the Mission Fathers in the latter part of the eighteenth century. The present resort is a pleasant, though somewhat rustic, establishment.

The water is probably meteoric. It is of geologic interest not only because of its high temperature but also because of its probable relation to faults in the vicinity. The Paraiso Springs fault trends in an east-west direction and passes through the site of the resort. The springs reflect in their rate of flow and increase of temperature the occurrence of major earthquakes in central California.

Oil prospects

Several oil companies have made plane table surveys of the Miocene sediments west of the Salinas depression. The sediments lie in a large syncline which trends in an east-west direction and has several minor folds on its northern limb.

1) Water Supply Paper, No. 338-Paraiso Springs:pp60-61:1915
2) Mines and Mineral Resources of Monterey, San Benito, etc. Counties, Calif. State Mineral Bureau: Dec. 1916

The Harriman Jones Oil Co. drilled one structure on the Arroyo Seco about eight years ago. The well is located in Section 20, T 19S R6E and reached a depth of 4608 feet before a fire destroyed the rig. Operations have not been resumed. A complete log was available to a depth of 2560 feet. Gas and tar were encountered at 260-80 feet; gas at 1265-90 feet and oil sands at 2415 and 2565 feet. A small flow of 50 barrels was reported from the lower levels.

Besides the indications in this well, several oil seeps and sulphur springs are found along the Arroyo Seco showing the presence of a certain amount of organic matter in the Salinas shale series. However, all folds are cut by the Reliz Creek fault. It is improbable that oil, which may have accumulated, would be present still. The area holds little promise of future development. Not only are the structures small and cut by faults, but oil sands, which are capable of producing only small quantities of oil, are at a great depth.

Development of Water resources

The water resources of the portion of Salinas valley in the Soledad Quadrangle are capable of being developed much more fully. It is possible to build a dam across the Arroyo Seco at two or three sites[1], and assure a constant supply of water for land in

1) Hamlin, H.-op.cit.

the valley.

The underground water gradually is being used by the farmers for irrigating purposes. The small owner does not have the financial standing to drill the necessary wells which must attain a depth of two, three, or four hundred feet.

The land in the vicinity of the town of Salinas, 20 miles to the north, is intensely productive for truck farming. The Soledad district undoubtedly could attain equal prominence with the development of an adequate water supply.

BIBLIOGRAPHY

Arnold, R.

.. and others: The Geology of the Santa Cruz Quadrangle, California:U.S.G.S. Folio 163:1909
.. Tertiary and Quaternary Pectens of Calif.:U.S.G.S. Professional Paper 47
.. Description of New Cretaceous and Tertiary Fossils from the Santa Cruz Mts., Calif.: Proceedings U.S. Nat. Museum:v34:345-90:1908
.. New and Characteristic Species of Fossil Mollusks from Oil-bearing Tertiary of Santa Barbara County, Calif., Smithsonian Miscellaneous Collections, Quarterly Issue:v50 Part 4:1907
.. Paleontology of the Coalinga District, Calif.:U.S.G.S. Bul:396

Bagg, R.M.

.. Miocene Foraminifera:U.S.G.S. Bul:268:pp12

Blackwelder, E.

.. Geologic Age of Existing Topographic Features (abstract): Geol. Soc. Amer. Cordilleran Section: April 1929
.. Recognition of Fault Scarps:Journ. Geol.v36:1928

Calif. State Mineral Bureau

.. Mines and Mineral Resources of Monterey, San Benito, etc., Counties, Calif.:1916

Clark, B.L.

.. Marine Tertiary of the West Coast:Journ. Geol. v29: 583:1921
.. Studies in Tectonics of the Coast Ranges (abstract): Geol. Soc. Amer. v38:163:1927
.. Tectonics of the Valley Grande of Calif. Amer. Ass. Pet. Geol.: v13:no.3: March 1, 1929
.. Thrust faulting in the Mt. Diablo region of middle Calif. (abstract):Geol. Soc. Amer. Bul.v36:no.1:152:1925
.. Fauna of the San Pablo Group of middle Calif.:Univ. Calif. Pub. Geol. Ser. v8:385-572:1915
.. Tectonics of the Coast Ranges of Middle California: Geol.Soc.Amer. Bul.:v41:no.4: 747-828: 1930

Clark and Twitchell

.. Mesozoic and Cenozoic Echinodermata of the U.S.:U.S. G.S. Monograph 54

Cotton, C.A.

.. Geomorphology of New Zealand, Part 1, Systematic:1926

Cushman, J.S.

.. Contributions from the Cushman Laboratory for Foraminiferal Research:
v 1: no 1: April, 1925
v 1: Part 2: July 1925
v 1: Part 4: Jan. 1926
v 2: Part 3: Oct. 1926
v 5: June 1929

Diller, J.S.

.. Geology of Northern Calif. U.S.G.S. Bul v33:21:1886

English, W.

.. Geology and Oil Prospects of the Salinas Valley-Parfield Area:U.S.G.S.Bul.69IH:pp219

Fairbanks, H.W.

.. Review of our Knowledge of the Calif. Coast Ranges: Geol. Soc. Amer.Bul.v6:71-102:1894
.. Geology of the San Luis Quadrangle, Calif. U.S.G.S. Folio 101:1904
.. Geology of N. Ventura, San Luis Obispo, Santa Barbara, Monterey and San Benito counties-12th report:pp493: Calif. State Mining Bureau
.. Age of the Calif. Coast Ranges:Amer. Geol. v18:271-82: 1896

Gazin, C.L.

.. Geology of a Portion of the Mt. Pinos Quadrangle, Calif. unpublished thesis:Calif.Institute of Technology:1930

Hamlin, H.

.. Water Resources of the Salinas Valley, Calif.:Water Supply Paper 89:1904

Hawley, H.J.

.. Stratigraphy and Paleontology of the Salinas and Monterey Quadrangles, Calif. (abstract) Geol.Soc.Amer. Bul. 28:225:1917

Hoots, H.W.

.. Geology and Oil Resources along the Southern Border of the San Joaquin Valley, Calif. U.S.G.S. Bul.812-D

Kerr, P.F. and Schenk, H.G.

.. Active Thrust-faults in San Benito County, Calif., Geol. Soc.Amer. Bul.v36:465-94:1925
.. Significance of the Matilija Overturn:Geol.Soc.Amer.Bul. v39:1087-1102:1928

Kew, W.S.A.

.. Cretaceous and Cenozoic Echinoidea:Univ.Calif.Pub.Geol. Series:v12:1919

Knopf, A.

.. The Mother Lode System of Calif.:U.S.G.S.Prof.Paper 157

Lawson, A.C.

.. Geology of Carmelo Bay:Univ.Calif.Pub. Geol.Series:vl: 1-59:1893
.. and others: Report of the Calif.Earthquake Commission:1908
.. The Continental Shelf of the Coast of California. Nat. Research Council Bul.:v8:pt2:No44:April, 1924

Le Conte, J.

.. Tertiary and post-Tertiary Changes in the Atlantic and Pacific Coasts:Geol.Soc.Amer. Bul.2:1891

Lindgren, W.

.. Economic Deposits:1926

Louderback, G.D.

.. The Monterey Series:Univ.Calif.Pub. Geol. Series: v7:177-241:1913

Martin, B.

.. Fauna from the Type Locality of the Monterey Series, Calif.:Univ. Calif.Pub.Geol.Series:v7:143-50:1912

Nicolls, W.M.

.. Geologic Section across the middle Salinas Valley from San Antonio to San Lorenzo Creeks, Calif. (abstract): Geol.Soc.Amer.Bul. v36:201:1925

Noble, L.

.. The San Andreas Rift and Some Other Active Faults in the Desert Region of Southeastern Calif.:Seis.Soc.Amer.Bul. v17:no1:25-39:1927

Nomland, J.O.

.. Fauna of the Santa Margarita Beds in N. Coalinga, Calif.: Univ. Calif. Pub. Geol. Series:v10:304:1917

Nutter, E.H.

.. Geology of the Salinas Valley:Journ,Geol.v9:330-36:1901

Osmont, U.C.

.. Arcas of the Calif. Neocene:Univ.Calif.Pub.Geol.Series: v4:no4:1905

Pike, R.W.

.. Geologic Studies in the Nacimiento-San Antonio Valleys, Calif. (abstract):Geol.Soc.Amer.Bul.v37:213:1926

Reed, R.D.

.. Post-Miocene Disturbance in the Salinas Valley, Calif.: Journ.Geol.v36:588-607:1925
.. Miocene Paleogeography in the Central Coast Ranges: Amer. Ass.Pet.Geol.Bul.v10:130-37:1926
.. Effect of the Wind in the San Joaquin and Salinas Valleys: Geol.Soc.Amer.v37:214-15:1930

Stalder, W.

.. A Section of the Monterey (Salinas) Shales in Pine Canyon Monterey Co., Calif.Amer.Ass.Pet.Geol.Bul.v8:55-60:1924

Trask, P.D.

.. Geomorphology of the Northern Part of the Santa Lucia Range, Calif.:Amer.Journ.Science:v12:293-300:1926
.. Origin of the Santa Lucia Coast Ranges, Calif.:Geol.Soc. Amer.Bul. v36:151:1925
.. Geology of the Point Sur Quadrangle, Calif.:Univ. Calif. Pub. Geol. Series:v16:119-86:1926

U.S. Explorations and Survey for a Railroad to the Pacific Coast during the years 1853-56:
.. The Salinas Valley:v7:Chapt.4

Vickery, F.P.

.. The Structural Dynamics of the Livermore Region:Journ. Geol.v33:608-28:1925

U.S.G.S. Water Supply Papers

.. No81:202-4:1903
.. No100:311:1903
.. No134:50:1904
.. No177:123-26:1905
.. No338:Paraiso Springs:60-61:1915

Wiedley, L.W.

.. Notes on the Vaqueros and Temblor Formations of the Calif. Miocene with Descriptions of New Species: Transactions San Diego Soc.Nat.History:Mar.1928

Willis, R.

.. Physiography of the Calif. Coast Ranges:Geol.Soc.Amer. Bul.v36:641-78:1925