GEOLOGY AND OIL PROSPECTS OF CUYAMA VALLEY, CALIFORNIA.

By Walter A. English.

INTRODUCTION.

The Cuyama Valley (shown in fig. 12), lying between the Santa Maria oil fields on the coast and the Sunset-Midway field in the San Joaquin Valley, has attracted the attention of oil men for many years; and were it not that the region lies far from the railroad and that the price of oil during the last few years has been so low as to render wildcat drilling somewhat unattractive, the valley would probably have been tested by a considerable number of wells before this time. The region not only lies between two of the richest oil fields of the State, but much of it is underlain by rock formations similar to those in which oil occurs in the productive fields, and in places oil seeps out at the surface. In order to determine whether or not oil might be expected to occur in commercial quantity in this region, and if so to point out the areas that offer the greatest promise, the writer undertook an examination during the fall of 1914.

On the basis of the geologic evidence in hand the chance for the development of a commercially successful oil field in the Cuyama Valley may be regarded as poor; and it is highly probable that no field comparable to the larger of the present productive fields of California will be found here. It is possible that in a few small areas pools comparable in size to the smaller pools in Santa Clara River valley, in northern Ventura County, may be found, but this possibility does not seem to offer great encouragement for exploratory drilling.

Throughout the field season the writer was assisted by Wallace Gordon, and many of the data here recorded are the results of Mr. Gordon's work. He also wishes to acknowledge the uniform courtesy and hospitality of the inhabitants of the region.

PREVIOUS REPORTS.

Although much of southern California has been studied by geologists, there appears to be very little information published concerning the geology of the Cuyama Valley. The valley was visited in 1854–55 by one of the Pacific railroad survey parties, and the geology is described in a report by Thomas Antisell.[1] He commented on the narrowness of the canyon of lower Cuyama River, above which is the wide valley which he likened to the basin of a great arm of the

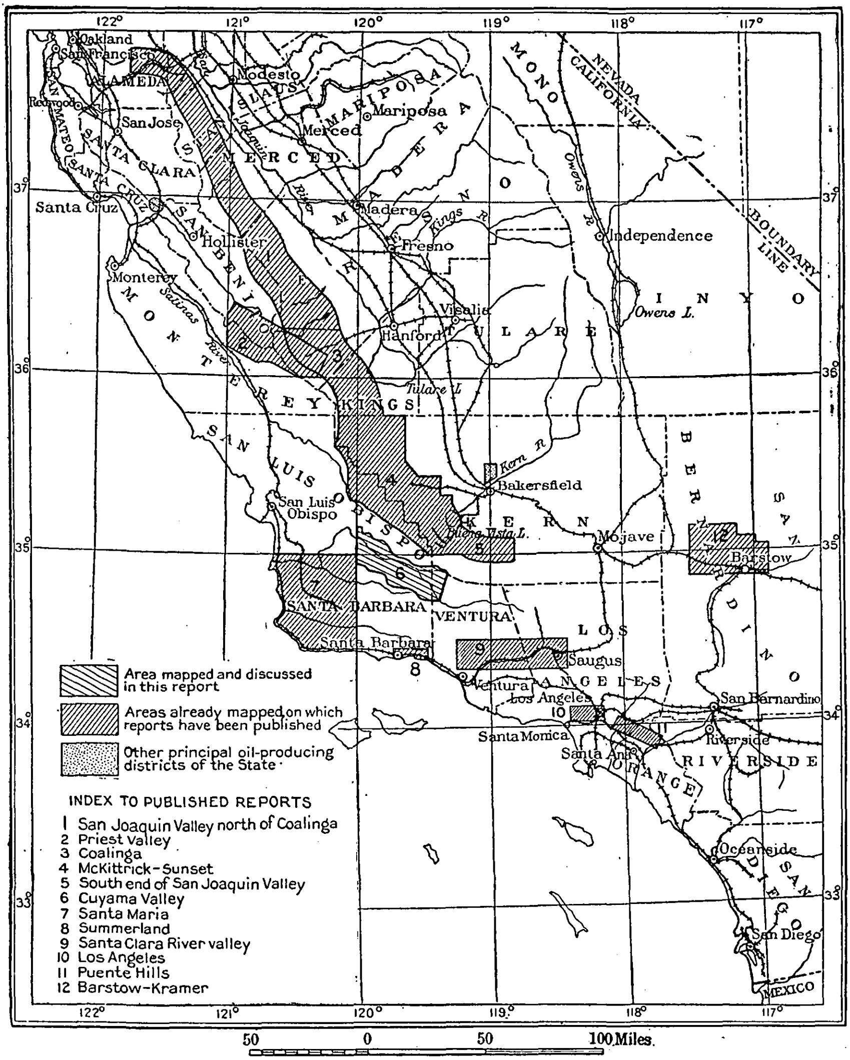


FIGURE 12.—Index map of a part of California.

sea. Antisell gave only a very general statement as to the geologic structure and stratigraphy.

A paper by Fairbanks[2] describes an analcite diabase which he had observed on the north side of Cuyama Valley.

[1] U. S. Pacific R. R. Expl., vol. 7, pt. 2, pp. 53–57, 1857.

[2] Fairbanks, H. W., Analcite diabase in San Luis Obispo County, Cal.: California Univ. Dept. Geology Pub., vol. 1, No. 9, pp. 273–300, 1895.

Lawson,[1] in a report on the California earthquake of 1906, gives a brief description of the main physiographic features of this region, and in the same volume Fairbanks describes the rift features along the San Andreas fault.

GEOGRAPHY.

The area of which a detailed study was made and which is shown on the geologic map (Pl. XIX) lies at the south end of the Coast Ranges, approximately 250 miles southeast of San Francisco and 100 miles northwest of Los Angeles. It includes about 300 square miles in Ventura, Santa Barbara, and San Luis Obispo counties. The topography and drainage of this area are shown on the maps of the Santa Ynez, McKittrick, and Mount Pinos quadrangles published by the United States Geological Survey.

The State of California extends along the shore of the Pacific for some 750 miles in a northwest-southeast direction, and its eastern boundary lies 200 to 250 miles back from the coast. Through the central part of the State runs the great interior valley, drained by Sacramento and San Joaquin rivers, bounded on the west by the Coast Ranges and on the east by the lofty Sierra Nevada. At the southeast end of the interior valley the Sierra Nevada narrows and swings southwestward in a broad sweep to meet the Coast Ranges, forming the rugged mountains at the south end of the Great Valley. The area described in this paper lies at the south end of the Coast Ranges, west of their junction with the Sierra Nevada.

The Coast Ranges south of San Francisco are made up of a number of long ridges which trend somewhat more to the west of north than the range as a whole. These ridges reach heights of 4,000 to 5,000 feet and are separated by comparatively wide, alluvium-floored structural valleys that range in altitude from a few hundred feet to 3,000 feet. The larger streams follow the structural valleys for the greater part of their length, but at places they have cut narrow canyons directly across the bordering ranges.

The region represented by Plate XIX includes the large structural Cuyama Valley and parts of the San Rafael and Caliente ranges, which border it. The San Rafael Range, which lies on the southwest side of Cuyama Valley, forms an area of high relief 15 to 20 miles wide, extending in a northwesterly direction across eastern Santa Barbara County. This range is one of the largest and most rugged of the units forming the Coast Ranges in this part of the State. Northeast of and roughly parallel to the San Rafael Range is a succession of valleys and ranges of structural origin. Named from

[1] Lawson, A. C., and others, The California earthquake of April 18, 1906: State Earthquake Invest. Com. Rept., vol. 1, pt. 1, pp. 22, 42, Carnegie Inst. Washington, 1908.

southwest to northeast these are Cuyama Valley, Caliente Range, Carrizo Plain, Temblor Range, and San Joaquin Valley.

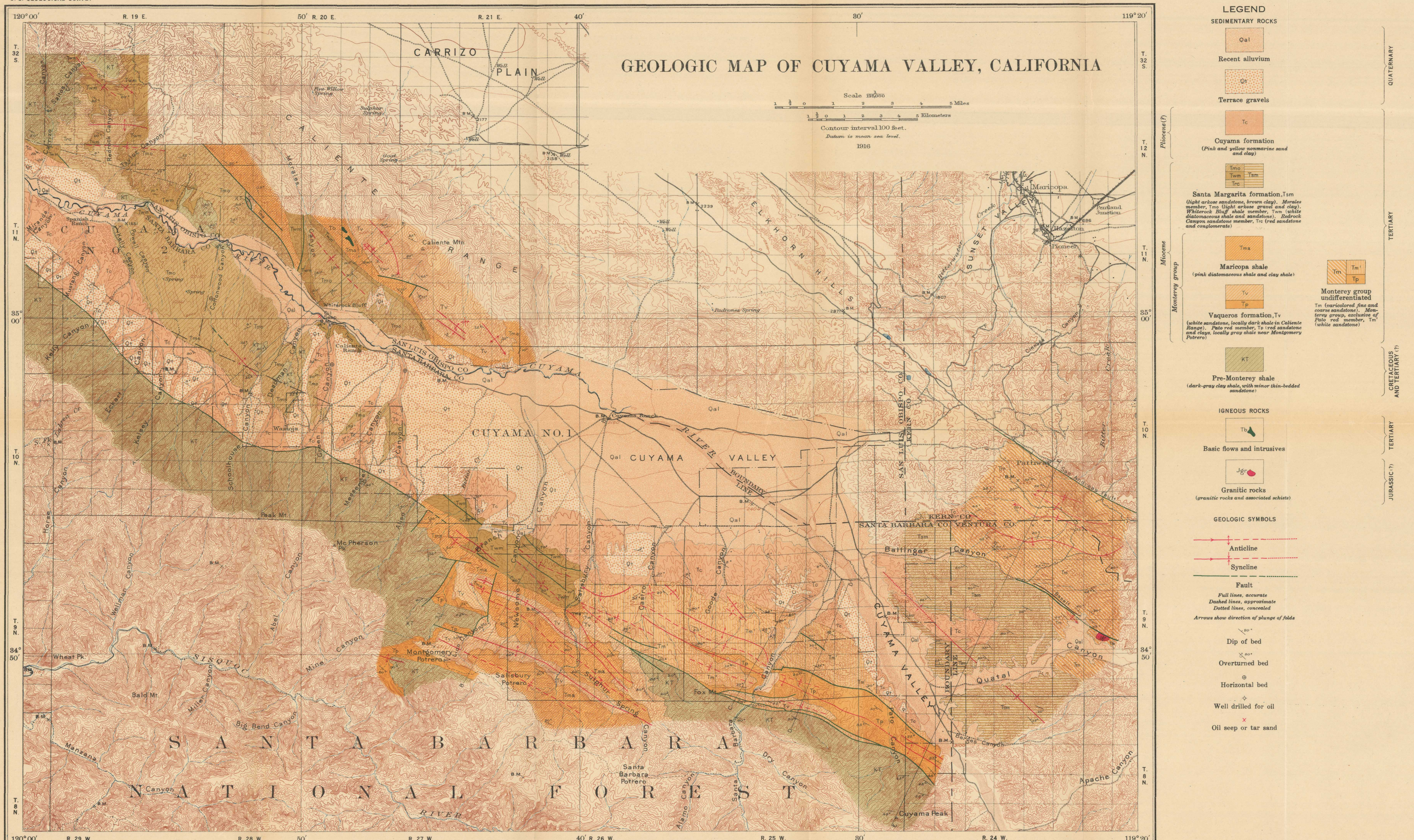
The middle course of Cuyama River follows a northwestward-trending broad structural valley some 40 miles in length. In its eastern half this valley is nearly flat for a width of 4 to 6 miles, but toward the west the continuation of its floor has been cut into by the streams, and it is now represented by gravel-covered mesas that slope toward the narrower valley followed by Cuyama River.

There are two good roads from Maricopa, the nearest point on the railroad in the San Joaquin Valley, to the divide at the head of a north branch of the Cuyama; the new grade is about 12 miles long and the old grade up Cienaga Canyon a few miles longer. From the divide down the valley westward as far as the edge of the area mapped, the road is level but sandy. West of the area mapped the road to Santa Maria, on the coast, is said to be poor in the narrow canyon through which Cuyama River crosses the San Rafael Range, and for this reason the main route of travel from Cuyama Valley is to the San Joaquin Valley and not to the coast.

The climate of the Cuyama Valley is much the same as in other parts of the southern Coast Ranges. The annual rainfall is said to average from 10 to 20 inches, subject to considerable variation. In winter the higher ridges are snow covered and light snowfalls are not unusual in the valley bottom. The summer weather is hot and dry. Cuyama River, like many other Coast Range streams, though nearly dry during the larger part of the year, is often impassable for several days after heavy rains.

Except for a few scattered oaks this region is treeless, the hills being covered with more or less brush, the amount depending on the slope, kind of soil, and amount of sunlight. The brush ranges from a scattered growth to an impenetrable tangle of chamisal, scrub oak, and mountain laurel. In general the mountains to the south of the Cuyama Valley are much more brushy than those of the Caliente Range.

The level land in the broad part of the valley produces in wet years good crops of hay, but the frequency of dry years greatly detracts from the value of the land, and only a few hundred acres are farmed. Recently a number of settlers have taken homesteads on the mesas in the western part of the valley and are clearing them of their dense covering of brush. Springs of good water are rare in the older rocks, but between Salisbury Canyon and the Spanish ranch a number of springs issue from the base of the gravel along the lower edges of the broad mesas. At the present time preparations are being made on the Caliente ranch to use the water from a few of these springs to irrigate some 2,000 acres of land on a low river bench, on which



Base map from U. S. Geological Survey topographic atlas sheets

Geology by W. A. English
Assisted by W. Gordon

alfalfa will be planted. Although only very locally suited for agriculture, nearly all of this portion of the Coast Ranges is a fair stock range, and cattle raising is the main occupation of the inhabitants.

GEOLOGY.

CONDITIONS OF SEDIMENTATION.

In the Coast Range province conditions of sedimentation were subject to great local variation during the Tertiary period. The variations were necessary results of the constantly changing relations of land and sea caused by the many warping movements to which the province was subjected. Tectonic forces were active, with varying degrees of intensity at different times and in different parts of the Coast Ranges, practically throughout the Tertiary period. There were both widespread movements that elevated or depressed the major part of the province and caused marine waters to retreat from or transgress over most of it, and more local movements that caused the relative elevation or depression of small blocks of the earth's crust within the province. Differential uplifts similar to those that formed the present ranges accompanied the earlier general movements of subsidence and uplift and formed long island ridges in the sea which, during parts of the Tertiary period, covered the Coast Range area and in which the sediments now constituting the Tertiary formations were deposited. The mingling of sediment derived from these islands with that derived from the main land areas, and the effect of the islands of low relief in sheltering certain areas from deposition of such material, produced the puzzling variations in lithology shown by the Tertiary formations.

As a result of the repeated warping movements which the Coast Range region suffered during Tertiary time, land masses of pronounced relief existed for a considerable part of that period. Erosion was active, a large amount of sediment was carried to the areas of deposition, and formations many thousands of feet in thickness were laid down during the same period in which only a few hundred feet of deposits accumulated in more stable areas such as the eastern part of North America.

Exclusive of local movements it is commonly believed that seven or eight rather widespread transgressions and subsequent recessions of the sea can be recognized as having taken place in the Coast Ranges during Tertiary time. However, the recognition of the results of these movements is extremely difficult because of the many local unconformities and variations in lithology. The area here described illustrates the great local variation in formations resulting from such conditions, for although the area studied in the Cuyama

Valley is comparatively small it is impossible to give a general description of the formations occurring there, as features characteristic of a formation at one place are absent elsewhere. The lines separating the formations mapped were selected as far as possible to make the formations correspond in time of deposition to the epochs of general subsidence which have been worked out for the Coast Ranges as a whole. Thus it must be borne in mind that each formational unit is made to include as nearly as possible all beds in the region which were deposited during a certain period of time and that it comprises local members of different lithologic types. Likewise beds included in a single formation may be separated by marked local unconformities and on the other hand the division lines between formations may come at horizons marked by little or no evidence of unconformity.

STRATIGRAPHY.

GENERAL FEATURES.

The general character and local variations of the formations present in the area mapped are shown in Plate XX. Though rocks of Franciscan age (Jurassic?) are widely distributed in the Coast Ranges, they do not crop out and are not known to be present in this area, so that except for a small fault block of granite (pre-Franciscan?) the oldest formation present is a mass, not less than 9,000 feet thick, of rather uniform dark-green shale, the age of which is not definitely known and may be either Cretaceous or early Tertiary (Eocene). Resting on this shale, everywhere with marked unconformity, is the Monterey group (Miocene). The beds present here are of the same age as the Vaqueros formation and Maricopa shale and perhaps part of the Sespe, as that formation is mapped in the Santa Clara River valley.[1] The Monterey group here consists of a maximum of 8,000 feet of gray and pinkish shales, together with red and white sandstones. Locally unconformable but, in general, apparently conformable above the Monterey group is the Santa Margarita formation (Miocene), composed of white clay and diatomaceous shale, together with white sand and conglomerate formed largely of granitic material. A marked local unconformity separates the lower part of the Santa Margarita from the upper part. Resting on the eroded edge of the Santa Margarita, and with much lower dips, is the Cuyama formation (Pliocene?), which consists of 500 to 600 feet of nonfossiliferous yellow and pink clays, sand, and gravel, in large part of nonmarine origin. Quaternary terrace gravel, important with relation to water supply, covers the dissected surface of a former wide valley in the western part of the area

[1] U. S. Geol. Survey Bull. 309, 1907.

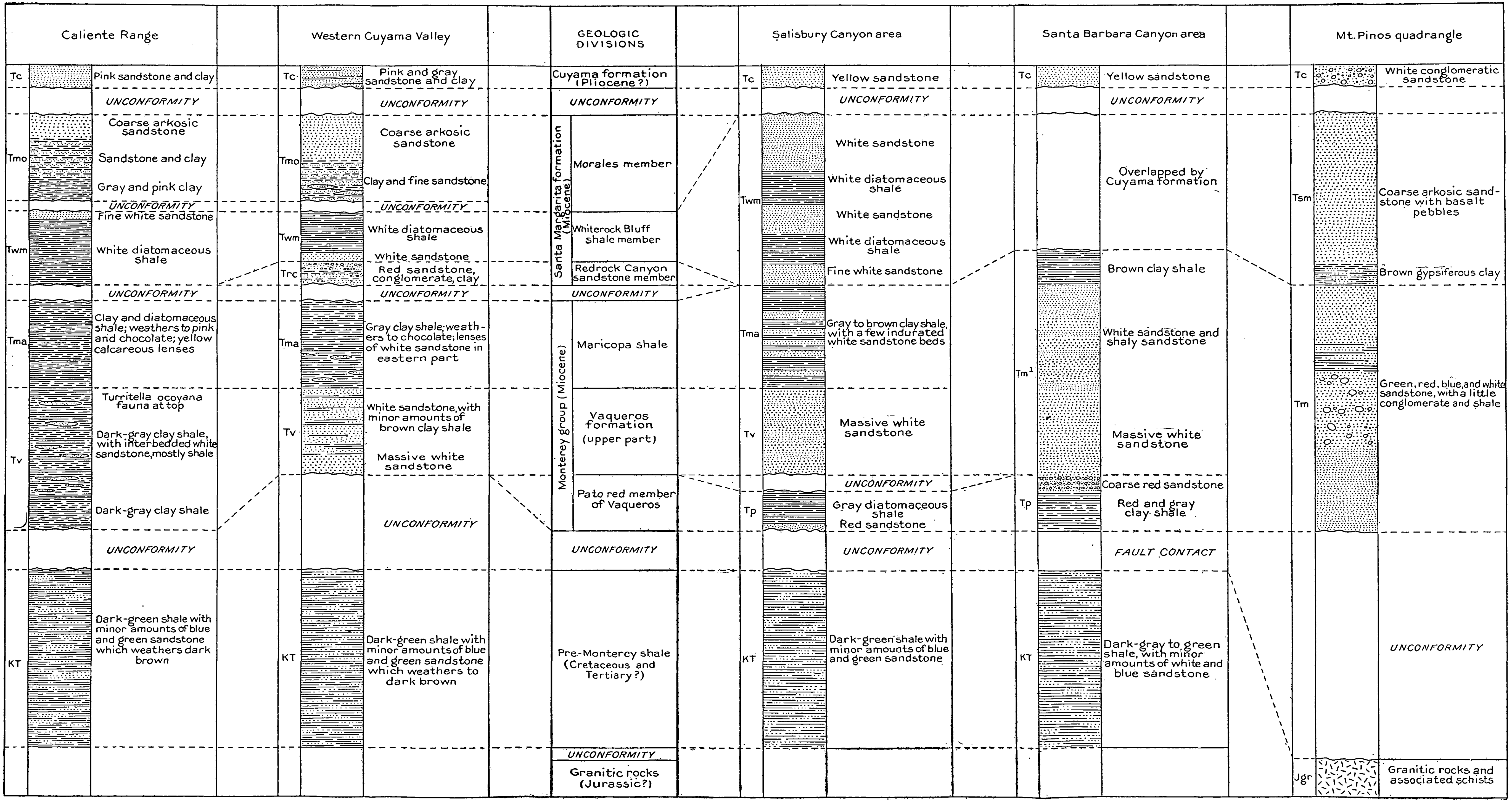


TABLE SHOWING LOCAL LITHOLOGIC VARIATIONS OF FORMATIONS IN CUYAMA VALLEY, CAL.

Vertical scale indicates time equivalence; broken lines show grouping into formations mapped and is also present near Ballinger and Quatal canyons, where it occurs as scattered remnants of once extensive land-laid deposits formed on an old surface of low relief.

GRANITIC ROCKS.

Near the head of Quatal Canyon is a small fault block of a crushed gneissoid granitic rock, which consists largely of feldspar, hornblende, and mica. This is the only outcrop of granitic rock known to occur between the westernmost exposure of the granite of the Sierra Nevada, about 5 miles to the northeast, and the extensive area of granitic rocks in the Huasna quadrangle, about 50 miles to the northwest. The granite of the Sierra Nevada is intrusive into the Mariposa slate (Upper Jurassic) and is considered to be of Jurassic or post-Jurassic age. It is supposed by many that the granite of the Coast Ranges, though not actually continuous in outcrop with that of the Sierra Nevada, is of the same age, but others regard it as possibly pre-Jurassic.

PRE-MONTEREY SHALE.

A formation not less than 9,000 feet thick, of rather uniform dark marine clay shale, containing a small amount of thin-bedded sandstone, crops out over a considerable part of the area mapped. A poorly preserved Pecten and the cast of a Cerithium, the only fossils found in this formation in the Cuyama area, give no definite evidence as to its age. In adjacent regions there are lithologically similar formations of both Cretaceous and Eocene age, and the formation here present may be of either age, or possibly grade from one to the other. The term pre-Monterey is used in the absence of more definite evidence as to the age of the formation. This formation is continuous with beds in the northeast corner of the Lompoc quadrangle, mapped by H. R. Johnson[1] as pre-Monterey and said to include rock of Knoxville age (Lower Cretaceous), together with Chico (Upper Cretaceous) or Eocene, or perhaps both. Specimens of Aucellæ, characteristic of the Knoxville, were the only fossils found in that area. About 25 miles south and southeast of the Cuyama Valley are the Summerland[2] and Santa Clara River valley[3] oil fields. In these areas the name Topatopa formation is applied to dark-colored shale and sandstone, the upper part of which contains well-preserved Eocene fossils, though the lower part is nonfossiliferous. The Topatopa formation may be of the same age as the beds

[1] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Cal.: U. S. Geol. Survey Bull. 322, pl. 1, 1907.

[2] Arnold, Ralph, Geology and oil resources of the Summerland district, Santa Barbara County, Cal.: U. S. Geol. Survey Bull. 321, 1907.

[3] Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, 1907.

in the Cuyama Valley, but no definite correlation can be made at present. East of the Cuyama Valley, around the south end of the San Joaquin Valley, is the Tejon formation (Eocene), which consists of about 4,000 feet of greenish and gray sandstone and shale that are lithologically somewhat similar to a part of the pre-Monterey rocks of the Cuyama Valley and may be of the same age.

In the area mapped the nearly uniform character of the dark clay shale is in contrast to the great local variation in lithology of the younger formations. Shale forms about 90 per cent of the formation near Cuyama Peak, the remaining 10 per cent being made up of hard white sandstone which weathers to brown and which is interstratified with the shale in beds varying from 3 to 10 feet in thickness. Farther west, near Aliso Canyon, most of the sandstone when fresh is of a light-blue color and weathers to mottled brown and white, and a few thin beds of conglomerate containing pebbles of metamorphic rocks are present. Near Saltos Canyon the shale is interbedded with sandstone or graywacke, blue when fresh but weathering brown, the color being due to the large amount of ferromagnesian minerals present. About 8,000 feet of this formation is exposed between Cuyama Peak and the fault to the northeast, and a thickness of 9,000 feet was measured in Saltos Canyon, near the west edge of the area mapped. Neither of these sections includes the lowest or the highest beds of the formation, so that the total thickness is unknown and probably is considerably greater than the 9,000 feet measured.

MONTEREY GROUP.

The term Monterey group is here applied to some 7,000 to 8,000 feet of beds of locally variable lithology, which rest with marked unconformity on the pre-Monterey shale. The lower part of the group is correlated with the Vaqueros formation, and the upper part with the Maricopa shale[1] of the southwest edge of the San Joaquin Valley. Though these correlations are believed to be roughly correct, the beds in the Cuyama Valley are not the precise equivalents in time of deposition of these formations, nor are they of identical lithologic character at their type localities. The shale, which is here called Maricopa, probably includes lower rocks than the formation near Maricopa and farther east. In the Caliente Range lava flows and intrusions of basalt or diabase are associated with the upper part of the Maricopa shale, whereas in the San Emigdio Mountains, east of Maricopa, a considerable thickness of beds mapped as Vaqueros overlie similar igneous flows and separate them from the shale there mapped as Maricopa.

[1] The name Maricopa shale is used in the report on the Sunset-Midway region, now in preparation by R. W. Pack, for a great thickness of diatomaceous shale which in the preliminary report was mapped as Monterey shale.

North of Cuyama River the Monterey group consists largely of dark-gray shale of the Vaqueros in the lower part, and chocolate-colored to pink Maricopa shale in the upper part; south of Cuyama River the Vaqueros is mostly white and red sandstone, and the upper part of the Monterey (Maricopa shale) is brown clay shale, locally grading into white sandstone; east of the upper part of Cuyama River the Monterey group consists entirely of gray, green, red, and white sandstone and arkosic sandstone. Because of these local variations in lithology the three areas of outcrop of the formations of the Monterey group will be described separately.

In the Caliente Range, north of Cuyama River, the Vaqueros formation consists of dark-gray marine clay shale with a small amount of interbedded white sandstone and is overlain by the yellow and pink to chocolate-colored, somewhat diatomaceous Maricopa shale. A section through Caliente Mountain gives a thickness of 6,000 feet of the dark shale of the Vaqueros, though the base is not exposed, the lowest beds cropping out being those next to the fault in the southwestern part of sec. 21, T. 11 N., R. 27 W. The lower 1,500 feet in this section consists of nearly black clay shale without sandstone, above which lenticular beds of white sandstone from 2 to 25 feet thick make up 10 to 15 per cent of the total thickness. The formation is well exposed on the steep slope of the south flank of Caliente Mountain. Similar interbedded shale and sandstone crop out for a distance of 1½ miles down the northeast slope of the mountain.[1] The Maricopa shale conformably overlies the dark-gray clay shale and sandstone of the Vaqueros on both flanks of the Caliente Mountain uplift. On the south flank there is about 2,000 feet of shale weathering pink to chocolate-colored, prevailingly clayey but in part a "chalky" diatomaceous shale. Lenses of hard yellow-weathering impure limestone are numerous. On the northeast side of the Caliente Range about 2,000 feet of similar beds are associated with both interbedded and intrusive basic igneous rocks.

South of Cuyama River the Monterey group consists in ascending order of the Pato red member of the Vaqueros, made up of gray and red clay shale and sandstone; white sandstone of the Vaqueros; and brown Maricopa shale. The massive pure-white sandstone of the Vaqueros is the only part of the group which is sufficiently uniform to be recognizable throughout this area. This sandstone, which contains a good marine fauna of lower Miocene age, is formed of material derived largely from the erosion of granitic rocks. It has a maximum thickness of about 1,300 feet and is especially prominent in the region of Montgomery Potrero and the head of Castro Canyon, where

[1] The writer's work extended only as far north as the crest of Caliente Mountain, and the data concerning the north flank of the mountain are furnished by R. W. Pack, who, in company with Robert Anderson, made a reconnaissance of the south side of the Carrizo Plain in 1909.

it weathers to extremely rugged white cliffs that may be seen for a distance of 15 or 20 miles. On the southwest slope of Fox Mountain and west of Branch Canyon it was deposited on the pre-Monterey shale, but elsewhere it is underlain by red sandstone and conglomerate which form the lowest member of the Vaqueros formation.

East of Santa Barbara Canyon the Vaqueros formation can be divided into two parts, white sandstone above and red sandstone, conglomerate, and clay below. The red rocks are so conspicuous that they have been mapped separately and called the Pato red member of the Vaqueros formation, from Pato Canyon, where they are well exposed. The Pato red member has a thickness of 1,300 feet. The upper 500 feet of beds are of a brilliant crimson color and are composed of material eroded from the adjacent land at the time the red beds were being deposited, the red color being due to the oxidation of the abundant ferromagnesian minerals composing the pre-Monterey rocks. Conformably below the bright-red beds is about 800 feet of gray and red clay. These beds are in fault contact with the pre-Monterey shale, and their base is not exposed.

The absence of red beds west of Fox Mountain is believed to be due to a conformable overlapping of the red beds by the white sandstone of the Vaqueros, the Fox Mountain area having been land at the time the Pato red member was deposited and having furnished the material of which it was formed.

In the vicinity of Montgomery Potrero the massive white sandstone of the Vaqueros is underlain by a pearl-gray shale, partly "chalky" and made up of diatom skeletons, at the base of which is locally about 150 feet of red beds formed of material derived from the underlying pre-Monterey rocks. The maximum thickness of this shale that was noted is 1,800 feet. As this shale is not of a lithologic type which would normally have been deposited in an area of progressive overlap upon an uneven land surface, its irregular distribution suggests that it is uncomfortable below the white sandstone, though for the present purpose it is included with the Pato red member of the Vaqueros formation.

The Maricopa shale, which overlies the white sandstone of the Vaqueros formation south of the Cuyama Valley and which forms the upper part of the Monterey group, has been mapped separately only as far eastward as Salisbury Canyon. It consists of about 1,700 feet of brown shale in which reef-like outcrops of white sandstone are locally prominent. The shale is made up mostly of clastic fragments, locally clayey, and is not noticeably diatomaceous. East of Salisbury Canyon the upper part of the Monterey group consists largely of white sandstone and is not separable from similar beds which underlie it.

In the northeastern part of the area mapped there is about 7,500 feet of nonfossiliferous bright-colored sandstone, which is believed to be roughly equivalent to the Monterey group in the areas to the west. These beds, though prevailingly marine, are coarser grained than those to the west, and were undoubtedly laid down closer to the shore line. The following description gives the character of the beds exposed along the line of section B–B′, Plate XXI: The lowest beds, which crop out close to the San Andreas fault, consist of a greenish sandstone, composed of ill-sorted quartz grains, interstratified in beds 4 or 5 feet thick, with finer and softer gray sandstone. Though the irregular structure makes estimates of thickness uncertain, there is probably about 2,000 feet of these lower beds exposed. Above them is 800 feet of prevailingly massive sandstone, gray to grayish green, varying to a bright red. This sandstone is a prominent feature on both flanks of the steep anticline north of Ballinger Canyon, where it forms wall-like outcrops and prominent cavernous rocky points. Above it is 900 feet of more varicolored blue, red, and gray sandstones and sandy clays, consisting of rather ill-sorted material and containing bowlders of schist and granite, some of which are 6 feet in diameter. These beds and those overlying them are softer than the lower sandstone and weather to badlands, with steep slopes and narrow, nearly impassable gulches. At the top of the bright-colored sands there is a locally prominent bed of yellow sandstone, 50 feet thick, overlying which is about 600 feet of bluish sandy shale, that weathers to a light brown. Above the shale is 200 feet of soft, nearly white sandstone, in which a few thin calcareous beds stand out prominently. The white sand grades upward into similar white and ocher-colored sand and conglomerate which contain lenses of yellow clay, in all probably about 2,000 feet thick. In these beds the material is poorly sorted and the grains are only slightly rounded. They are evidently the products of rather rapid erosion from near-by areas of considerable relief, and are probably, in part at least, of nonmarine deposition. In the eastern part of the area mapped, very close to the upper limit of these beds, is a 20 to 40 foot basalt flow, interbedded with the yellow and white arkosic sands.

The following fossils were found close to the base of the white sandstone of the Vaqueros near Santa Barbara Canyon:

Pecten magnolia.
Pecten bowersi.
Pecten volæformis.
Turritella inezana.

The following were found near the top of the Vaqueros formation southeast of Caliente Mountain:

Chione panzana?
Chione n. sp., near diabloana.
Mytilus mathewsoni var. expansus.
Panopea estrellanus.
Pecten crassicardo.
Calyptræa sp.?
Murex vaquerosensis new var.
Trophosycon sp.?
Turritella ocoyana.

In the upper part of the Monterey group south of the Cuyama Valley the following occur:

Scutella norrisi.
Chione securis.
Ostrea veatchii?
Pecten andersoni
Phacoides acutilineatus.
Venus pertenuis.
Turritella ocoyana.

SANTA MARGARITA FORMATION.

The Santa Margarita formation, consisting of 2,000 to 4,000 feet of light-colored sand and shale, rests with apparent conformity on the underlying Monterey group, though the overlap of the Santa Margarita on the pre-Monterey rocks in the western part of the Cuyama Valley shows that it is at least locally separated from the Monterey group by an unconformity. In the western part of the area mapped the Santa Margarita formation consists of a basal red sandstone, overlain by interbedded diatomaceous shale and white sandstone containing a characteristic marine fauna, and this in turn is overlain by clay, sand, and gravel. The beds mapped as Santa Margarita east of Cuyama River are nonfossiliferous coarse white sand, gravel, and brown clay, lying conformably on the underlying Monterey group.

The basal red sandstone, having a thickness of 500 feet, is limited to a small area in Redrock Canyon. Because of its marked difference in color from the remainder of the formation and because it represents a phase of sedimentation that is important in a study of the geologic history of the region, this red sandstone has been mapped and is here named the Redrock Canyon sandstone member of the Santa Margarita formation.

The Redrock Canyon sandstone consists of bright-red sandstone, clay, and conglomerate, the materials of which were derived from an adjacent land mass of pre-Monterey rocks, and the deposition of materials of this kind ended when the land was overlapped. The color of this member, like that of the Pato red member of the Vaqueros formation in Santa Barbara Canyon, is due to the oxidation of ferromagnesian minerals in the fragments of sandstone of the pre-Monterey rocks, of which the member is composed. The Redrock Canyon member rests directly on the pre-Monterey rocks, the absence of the Monterey group probably being due to its removal by erosion before the deposition of the Santa Margarita.

The shale which conformably overlies the Redrock Canyon sandstone represents a more widespread phase of deposition, though it varies considerably in lithologic character in the western part of the Cuyama Valley. Because of its distinctive lithologic character this shale has been mapped separately and is named the Whiterock Bluff shale member of the Santa Margarita formation, from

Whiterock Bluff, on the north side of the Cuyama Valley. Near this point it consists of not less than 1,500 feet of a white "chalky" diatomaceous shale, which is believed to be separated by an unconformity from the Monterey group, upon which it rests. Above this shale is about 100 to 150 feet of fine white sandstone that probably belongs to the overlying member of the formation. Two miles north of Whiterock Bluff the "chalky" shale, which there stands nearly vertical, is about 1,000 feet thick. Farther west, near Taylor Canyon, it is only a few hundred feet thick, and the shale part is underlain by 25 to 200 feet of white sandstone, conformably below which is the Redrock Canyon member. On the south side of the Cuyama Valley the Whiterock Bluff shale, consisting of interbedded white clay shale, diatomaceous shale, and sandstone, apparently grades into the underlying sandstone and shale beds mapped as the Maricopa shale, the line of separation being drawn at the lowest horizon at which Santa Margarita echinoderms occur. Three zones of white sandstone and two zones of shale are present, the total thickness being 2,000 to 2,500 feet, of which the shale makes up about one-third.

The remainder of the formation is called the Morales member of the Santa Margarita because of its development in the vicinity of Morales Canyon, where it consists of some 2,000 feet of clay, white sand, and gravel. It is unconformable on the Whiterock Bluff shale, as is shown by the fact that it overlaps the shale and rests upon the pre-Monterey rocks. The lower part of the Morales member consists of 300 to 400 feet of a light-gray, poorly bedded soft clay shale, containing a few thin beds of white limestone which on weathering break up into small irregular fragments that become scattered over the surface. On the south side of Cuyama River nearly all of the Morales member is of the lower fine-grained phase, but north of the river the lower clay is overlain by 500 to 600 feet of white sandstone and clayey sandstone, above which is 1,000 feet of largely incoherent gravel, which contains abundant shale pebbles, probably derived from erosion of the Whiterock Bluff shale, along with a few large oyster shells that are secondary, being probably also derived from the same member.

In the eastern part of the area mapped the Santa Margarita is represented by about 4,000 feet of nonfossiliferous light-colored gravel and 500 feet of brown clay in which layers of gypsum are interbedded and large secondary crystals of gypsum are common. This zone of brown gypsiferous clay, which rests conformably on the orange-colored and white beds of the Monterey group, is easily traceable and therefore has been somewhat arbitrarily assumed to be the base of the Santa Margarita formation. The gypsiferous clay is only a short distance above the interbedded basalt, which is similar to basic intrusive rocks that are closely associated with the Monterey group in this general region. The gravel above the gypsiferous clay contains basalt bowlders, which are absent at lower horizons, indicating that the upper beds are unconformable upon the beds associated with the basalt flows and belong to a later formation.

The following fossils were found in the Whiterock Bluff shale member of the Santa Margarita formation:

Astrodapsis antiselli.
Astrodapsis tumidus.
Ostrea titan.
Pecten crassicardo.
Trophon gabbianum?
Venus pertenuis.
Agasoma sinuatum.
Turritella carisaensis.
Turritella ocoyana new var.?
Tamiosoma gregaria.

CUYAMA FORMATION.

Beds of nonmarine yellow and pink sands which rest with very marked unconformity on the Santa Margarita and older beds are here named the Cuyama formation, because they crop out only in the Cuyama Valley. This formation was laid down in a broad valley, possibly somewhat wider than the present distribution of the deposits would indicate, which had been eroded in the previously folded and faulted older formations. At the time the Cuyama formation was deposited the main ranges and valleys were much as they are at present, though with less relief, and since its deposition the region has been affected by only minor movements compared to those which disturbed the Santa Margarita and older formations. Because of the low dips, a good section of the Cuyama formation is nowhere exposed. In the eastern part of the Santa Ynez quadrangle the formation is probably not over 250 or 300 feet thick and consists of incoherent yellow sand with here and there a shale-pebble conglomerate, probably in large part a river deposit. Farther west, where these beds are probably twice as thick, the sand is pink, poorly sorted, and in part clayey. This is presumably a playa or estuarine deposit.

No fossils were found in the Cuyama formation. Its deposition was probably coincident with the formation of the extensive Santa Lucia peneplain, which was described by Fairbanks in the San Luis folio[1] and which he believed to be of Pliocene age.

TERRACE GRAVEL.

The Cuyama formation was gently folded and faulted, after which a second wide valley was cut in the Cuyama structural trough. In this valley from 10 to 50 feet of orange and ocher colored gravels were laid down as an alluvial apron sloping from the foot of the adjacent ranges toward the middle of the valley. Since that time

[1] Fairbanks, H. W., U. S. Geol. Survey Geol. Atlas, San Luis folio (No. 101), 1904.

Cuyama River has cut its channel below the gravel-covered surface of the western half of this old valley, and fragments of the former valley bottom now form mesas separated by narrow steep-sided gulches. During this process of downward cutting by Cuyama River a number of intermediate river benches or terraces were formed and gravel was deposited on them. Thus the terraces are of various ages, some of them having been formed long ago and some very recently, During the most recent period of downward cutting, which probably commenced not over a few hundred years ago, Cuyama River has carved a narrow channel, with vertical sides 15 to 30 feet high, in the western part of the area mapped.

TERTIARY IGNEOUS ROCKS.

In the southern part of the Coast Ranges small flows and intrusions of basic igneous rocks are commonly associated with beds of the Monterey group. West of the Caliente Range a basic rock described by Fairbanks[1] as analcite diabase is intrusive into the Maricopa shale of the Monterey group. The areas of intrusive rocks are so small and irregular in outline that it is very difficult to map them, and only two such areas are shown on the map accompanying this report. On the north side of the Caliente Range a similar rock forms a number of flows of considerable size in the Maricopa shale and is associated with similar intrusives. Just west of the small block of granite in Quatal Canyon a basalt flow 20 to 40 feet thick and about 2 miles long is interbedded near the top of the Monterey group.

STRUCTURE.

GENERAL STRUCTURE OF THE REGION.

The Coast Ranges of California are made up of a series of long northwestward-trending ridges, the individual ranges of the system, separated by wide valleys. These ridges and valleys are of structural origin, having been formed by the folding and faulting that accompanied the general uplift which, near the close of Pliocene and during early Pleistocene time, raised the Coast Ranges to their present altitude. Though subsequent erosion has cut gulches and canyons in the ranges, the main topographic features are still clearly structural, and the larger streams, for most of their courses, follow the structural valleys. Where streams cut across structural ridges, the narrow canyons that they follow are in striking contrast with the wide valleys that trend parallel to the structure, showing what a small part of the width of the valleys can be due to erosion.

[1] Fairbanks, H. W., Analcite diabase in San Luis Obispo County, Cal.: Univ. California Dept. Geology Pub., vol. 1, No. 9, pp. 273–300, 1895.

When examined in more detail the main ranges and valleys are seen to have a more complex structure than would result from a single epoch of folding and uplift. The structure above outlined as resulting from the comparatively recent folding is superimposed upon structures formed by earlier movements, the present complexity being the result of several movements during Tertiary time. An interesting result of this combination of movements is that, although the general trend of the major lines of structure produced by the earlier movements was northwest and thus parallel to the major lines of the present structure, the blocks subjected to differential uplift during the earlier part of the Tertiary were in many places not the same as those which have been most recently uplifted. Moreover, the relative movement of any particular area has not always been in the same direction, for at one time it may have formed part of a block that was depressed and at another time part of a block that was elevated with respect to adjacent blocks. Thus the area recently faulted down to form the western part of the Cuyama Valley was at an earlier time uplifted, and the Monterey group was removed from it by erosion, while the area of the present Caliente Range was either under water or subjected to much less erosion.

The main structural features of the area mapped (see Pl. XXI) are the structural depressions of the Cuyama Valley and the upfolds or uplifted blocks of the earth's crust on both sides, forming the Caliente and San Rafael ranges. The Caliente Range was formed largely by the folding of the rocks, but this folding was accompanied in places by breaking, producing faults. Two strike faults along which the rocks moved at least 1,000 feet bound the Cuyama trough on the southwest through most of its length. Between Branch and Castro canyons, however, there are no faults, and the Monterey group extends in unbroken outcrop southward to the crest of the ridge. A number of cross faults north of Montgomery Potrero bound the east end of the great block of uplifted pre-Monterey rocks, against which the beds of the Monterey group are faulted down. From Castro Canyon eastward the other large strike fault has brought the pre-Monterey rocks up on the south. Here the main fault dies out toward the west, and there are no cross faults, the Maricopa shale resting with normal contact upon the southwest side of the tilted block of pre-Monterey rocks.

The structure of the east end of the Cuyama Valley is obscured by the heavy cover of alluvium, but the topographic form of the valley, together with the presence of a broad, open syncline that crosses Quatal Canyon, a mile above its mouth and directly in line with the axis of the valley, strongly suggest that this part of the valley is also synclinal.

DETAILS OF STRUCTURE.

The complex anticlinal structure of the Caliente Range includes a number of folds, of which the largest two in the area mapped cross the range at a considerable angle, trending more nearly north than the range as a whole. The dips on the north flank of the great fold and on the upper slopes of the mountain are not over 30°, but on the south flank, or the side of the mountain facing the Cuyama Valley, the dips vary from 75° S. to vertical, or the beds are in places even overturned and dip steeply toward the north. The great fold composing the mountain is thus asymmetric, the dips on one side being very much steeper than those on the other side. Northwest of Whiterock Bluff the Caliente anticline is separated from the Cuyama trough by a fault which has brought the Maricopa shale into contact with the Morales member of the Santa Margarita formation.

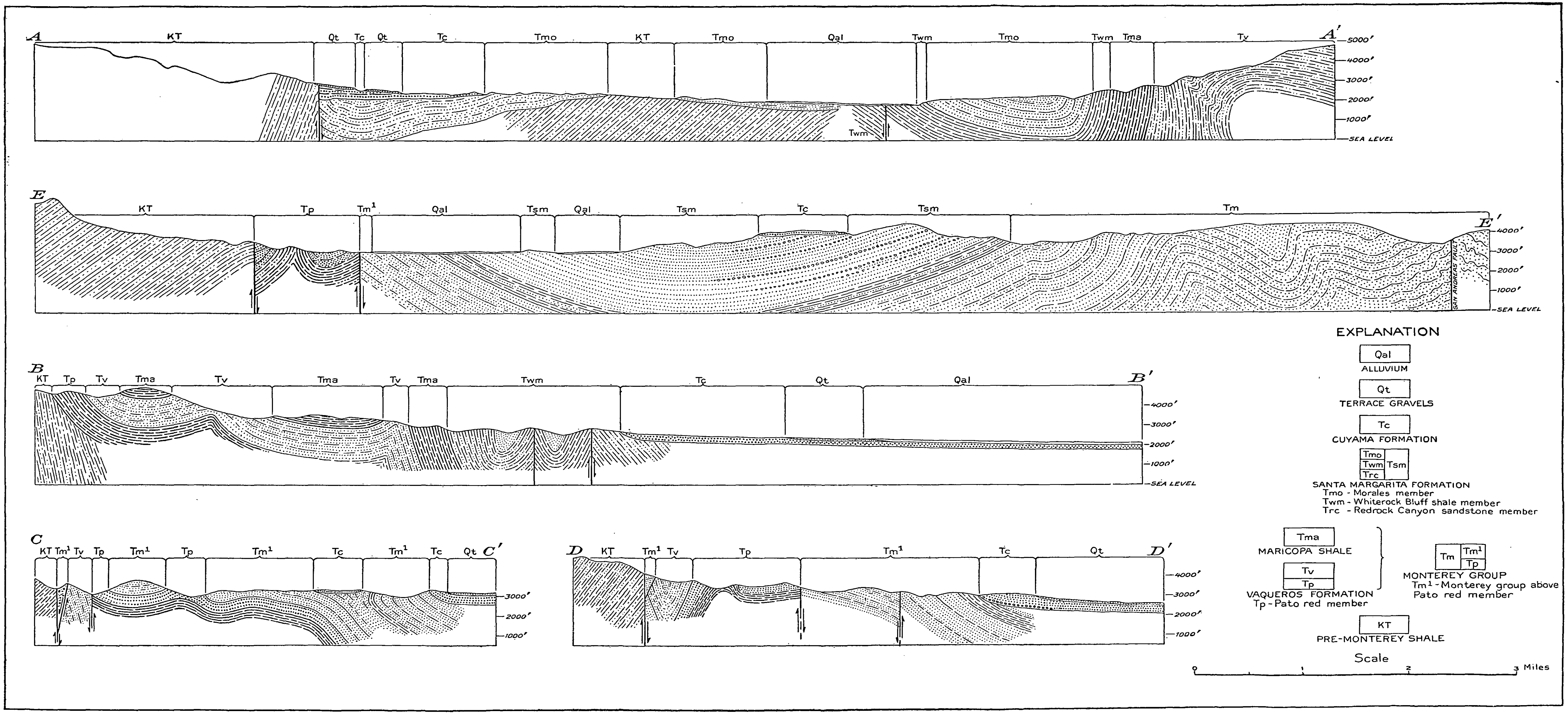
A block which was depressed as a structural unit in the last great epoch of deformation lies in the western part of the Cuyama trough, between the fault south of the Caliente Range just mentioned and the great fault southwest of the Cuyama trough, and extends from Aliso Canyon northwestward beyond the edge of the mapped territory. In this area the Santa Margarita formation, where its base is exposed, rests directly on the pre-Monterey shale, and the Monterey group does not appear to be present. The dips in the shale of the older formations range from 35° to 70° SW., whereas those in the overlying Santa Margarita are generally less than 20°. The broad folds into which the Santa Margarita is here flexed are striking when contrasted with the close folds and steep dips shown by the same formation in other parts of the trough. The absence of the Monterey group in this great fault block indicates that after the deposition of that group the block was raised above the adjacent area, now occupied by the Caliente Range, and the Monterey group was removed by erosion. The pre-Monterey rocks thus exposed were also reduced by erosion to a region of low hills on which the Santa Margarita formation was deposited when the land again became submerged. A later movement in the opposite direction brought the block down to its present position in the trough, faulting the gravel of the Morales member against the pink Maricopa shale. It is possible that the uplift on the northwest side of this block was accompanied by a downward movement along the plane of the fault that now bounds the block on the southwest, and if so there may be a strip of the Monterey group along the southwest edge of the tilted block, which escaped erosion and is now concealed by later deposits.

There have been two later movements along this fault on the southwest side of the Cuyama trough. The earlier one preceded the deposition of the Cuyama formation and formed an uplifted block from which material was derived to form the bowlder beds in that formation near the fault. The later movement faulted the Cuyama formation and left the steep scarp which now exists along this fault line.

On the south side of Cuyama River, east of Aliso Canyon, the Monterey group and Santa Margarita formation are flexed into fairly steep folds, the general character of which is illustrated by section B–B′, Plate XXI. The beds that compose the Santa Margarita formation are, because of their softness, more irregularly folded and faulted than those of the Monterey group. Only a few of the individual folds and faults will be described. The white sandstone which is involved in a sharply folded syncline of the Vaqueros that crosses Santa Barbara Canyon along the south line of T. 9 N. is, in part, faulted down against the Pato red member, and forms a striking feature by reason of the contrast in color between the pure white massive sandstone and the bright-red conglomerate and clay. A very narrow fault block of dark-green or gray to rusty unindurated angular conglomerate, which dips about 20° S., lies between the syncline of white sandstone and the pre-Monterey rocks. These conglomeratic beds evidently originated as a talus deposit along a steep slope produced by an early movement on the main fault, and later the narrow block was faulted down to its present position. The fault that extends eastward from Santa Barbara Canyon, about a mile north of the large fault, has brought the white sandstone down on the north side against the bright-red beds. Throughout this area the older Tertiary rocks are overlain with marked unconformity by the comparatively flat-lying Cuyama formation, in which the dips are mostly under 10°. The plane of contact at the base of the Cuyama is apparently steeper than the dip of the formation, suggesting that the surface on which these beds were deposited was marked by a steep slope near the limit of their present distribution.

No attempt was made to work out in detail the geologic structure in the areas of pre-Monterey rocks which form the rugged mountains on the south side of the Cuyama Valley. The dips in the areas examined suggest that the folds are much larger than those in the later formations, and the structural lines are possibly less markedly northwest in trend.

The largest structural feature in the northeastern part of the area mapped is the broad syncline which crosses Quatal Canyon near its mouth and which is probably a continuation of the Cuyama trough. North of this syncline the sandstone of the Monterey group is flexed into steep and irregular folds and the beds are greatly broken close to the San Andreas fault, which here as elsewhere has formed a zone of very intricate structure a mile or more wide.



GEOLOGIC SECTIONS ACROSS CUYAMA VALLEY, CAL., ALONG LINES INDICATED ON GEOLOGIC MAP (PLATE XIX).

PETROLEUM.

GENERAL CONDITIONS OF OCCURRENCE.

An examination of the geology of the Cuyama Valley was undertaken with the object of determining, so far as it is possible to determine from the study of surface evidence alone, whether or not commercially important quantities of oil might reasonably be expected to occur here. The preceding sketch of the general geologic features is given in order that the reader may understand the reasons for reaching the conclusions stated below.

It must be borne in mind, however, that one can not, from a study of the surface alone, determine positively whether or not oil occurs beneath the surface. It is possible by such a study to designate areas in which it is extremely unlikely that oil may occur, and other areas in which the structure is favorable for the accumulation of oil, but the presence or absence of oil can be definitely determined only by drilling. As the cost of putting down a well is great, drilling should not be undertaken in a new region until a careful geologic examination of the surface has been made and the most favorable area determined, for not only is the chance better for getting oil in that particular area, but if the drill finds the sand dry it is a fair inference that the sands beneath the surrounding areas are also dry. Many wildcat wells, by reason of their poor location, add little or nothing to our knowledge of the oil possibilities of the region other than to show that the particular spot drilled on is not underlain by oil.

CONDITIONS IN PRODUCTIVE FIELDS OF CALIFORNIA.

One of the most significant facts that suggests the occurrence of petroleum in this region is its situation between the very productive Sunset field on the northeast and the Santa Maria field on the southwest, with the smaller scattered fields of the Santa Clara River valley some distance to the south. Therefore a brief statement of the condition under which oil occurs in these productive fields is given for comparison with conditions in the Cuyama Valley.

Oil is known to occur in various sands throughout the Tertiary system in the productive fields of California. Although some oil has been found in older rocks, the Tertiary beds are the most productive, but the precise geologic age of any particular bed within the Tertiary seems to have little or no bearing on the question of its possible petroleum content. Thus beds at the same horizon as the oil sands in an adjacent productive field are not necessarily the beds most likely to yield oil in an undeveloped area. The geologic structure of possible oil-bearing rocks and their association with shale formations which are believed to have been the original source of the oil are of greater importance than the precise geologic position of the rocks.

In the Santa Maria field and the Sunset and other San Joaquin Valley fields the oil-bearing sands are close to large bodies of light-pink diatomaceous shale or "chalk" rock. When this "chalky" shale is examined under a microscope it is seen to contain a great many small, variously shaped objects, which are the skeletons or shells of Radiolaria and Foraminifera, two kinds of small animals that lived in the sea at the time this shale was being deposited. Much more numerous than the animal remains are skeletons which are recognized by their peculiar forms as having been secreted by diatoms, small and very simple marine plants, which were extremely abundant in the ocean at the time the shale was deposited. The great number of animals and plants whose skeletons are preserved, together with others which may have been even more abundant, but which lacked skeletons, sank to the ocean bottom and formed great deposits of slimy mud or ooze. The organic material from this mud, which subsequently became shale, was later changed into the oil that is now found in near-by sandy rocks. That the oil has really come from this shale is shown by the fact that in nearly all the thousands of successful wells drilled in California the oil comes from sands or other porous beds which are either interbedded with or close to diatomaceous shale.

Although oil is still present in much of the diatomaceous shale, it can be obtained in considerable amounts only from porous rocks into which it has migrated from the close-grained shale. All of the sandy beds in contact with the diatomaceous shale are not oil bearing, for factors other than the texture of the rocks control the distribution of the oil and cause its local concentration at certain points in the porous beds, thus forming the pools of the productive fields. The cause of this migration and local concentration of the oil is still an unsettled problem, but from an examination of successful fields it is seen that beds showing certain types of geologic structure are most likely to contain large amounts of oil. One of the most common structural features of the large California oil fields is the unconformable contact at the base of the oil sands, showing that the sands were laid down upon the eroded edges of diatomaceous shale. Apparently this unconformable contact allows the oil, which migrated freely upward along the bedding planes in the shale, to reach the overlying sands. Within these sands the oil has in most places migrated up the rise of the beds in the different folds and collected in anticlines or on the upper slopes of monoclines and at the upper ends of plunging synclines. However, these points of local concentration have no fixed and invariable relation to structure, and in many places no concentration has taken place in sands which are seemingly as favorably situated as other sands that are highly productive.

The oil fields of the San Joaquin Valley are all situated on rather low folds in the foothill belt around the edges of the valley. The oil sands crop out only on the side of the productive areas farther from the valley, and oil may have migrated up from a considerable distance down the dip in the wide San Joaquin Valley syncline. Thus another important condition of productive fields is the presence over a considerable area adjacent to the oil pools of impervious beds overlying the masses of diatomaceous shale.

In the Santa Maria field the oil migrated from bodies of diatomaceous shale and collected in overlying sandstone beds and in bodies of shale which had been previously folded and crushed into angular fragments between which the oil found a resting place. The folds in this field are smaller and the dips steeper than in the San Joaquin Valley fields, and the areas from which oil could have migrated to form the local concentrations are less extensive. Despite this fact there are a number of exceedingly productive local areas in this field.

In the fields of the Santa Clara River valley much of the oil apparently originated in clay shale, possibly in part diatomaceous, and is found concentrated mostly in overlying sandstones, along anticlines, and close to faults. In this field many of the folds in which oil occurs are closely compressed and narrow and are similar in type to the folds which occur in the Cuyama Valley.

Oil seeps are present in the vicinity of all the developed fields, and independent of later developments they prove the presence of at least some oil in the region. Many of the seeps occur along the outcrops of productive oil sands, and thus they also indicate the position of the sand in which the oil occurs. In an undeveloped field the prospector should therefore expect to find oil seeps, and their location should indicate the part of the formation most favorable to prospect. Though many oil pools have been discovered by drilling near seeps and neglecting other features, this has generally proved a costly and roundabout way of eventually discovering the productive areas.

CONDITIONS IN CUYAMA VALLEY.

As the association of sandy beds with the shale which was the original source of the oil is one of the most important conditions in productive fields, the discussion of the Cuyama Valley area will be based on the areal distribution and character of such shale. The shales present in the Cuyama Valley are the thick mass of pre-Monterey shale, the shale in the Vaqueros formation, the Maricopa shale, and the locally well-developed Whiterock Bluff shale member of the Santa Margarita formation.

There appears to be little possibility of obtaining oil from beds associated with the dark clay shale of the pre-Monterey rocks, which crops out over considerable areas in the rugged mountains on the south side and in the western part of the Cuyama Valley. Lithologically similar shale of Cretaceous age on the west side of the Sacramento Valley contains oil seeps, and in the Santa Clara River valley some of the oil probably originated in the Topatopa (Eocene) shale, which is of much the same type and possibly of the same age as the shale of the pre-Monterey in this area. However, in the area examined no seeps or other evidence of the presence of oil were found or were reported in this shale, or in overlying beds, so that it seems unlikely that any appreciable amount of oil derived from it is present either in the interbedded sandstones or in porous overlying formations. Much the same reasoning may be applied to the dark clay shale and interbedded sandstone of the Vaqueros formation, which constitutes the main mass of the Caliente Range.

Of the other formations the pearl-gray shale in the vicinity of Montgomery Potrero, the pinkish Maricopa shale on the flanks of the Caliente Range, and the "chalky" Whiterock Bluff shale member of the Santa Margarita are the only beds that are of a lithologic type in which it seems likely that oil may have originated, and only those general areas in which one of these shales crops out or is believed to be present below the surface are thought to be likely to produce oil.

The gray diatomaceous shale which is mapped as a part of the Pato red member of the Vaqueros and which underlies the prominent white sandstone of the Vaqueros at Montgomery Potrero has a very irregular distribution, being absent along the Monterey and pre-Monterey contact west of Branch Canyon and on the south side of the tilted block of pre-Monterey rocks at the head of Castro Canyon. It probably underlies the western part of the prominent anticline north of Salisbury Potrero, but its slight thickness and meager content of diatomaceous material make it insignificant in comparison with the great mass of diatomaceous shale in productive fields. No seeps are known to occur in this shale or in associated porous rocks. The chance of obtaining commercial quantities of oil from beds overlying this shale in the area mapped is therefore probably slight.

The Maricopa shale, in the upper part of the Monterey group of the Caliente Range, has a maximum thickness of about 2,000 feet, and although less diatomaceous than the typical "Monterey shale" it may have been the source of considerable quantities of petroleum. Two or three oil seeps have been reported in this shale.

The white diatomaceous shale in the Whiterock Bluff shale member is locally over 1,000 feet thick and may have been the source of considerable quantities of oil. It is significant that the seep south of Whiterock Bluff occurs at a point where this shale is thickest as well as most diatomaceous. Areas of favorable structure underlain by either this or the Maricopa shale would deserve very careful consideration as being possibly productive. Unfortunately no such areas of favorable structure were found.

The structure in the Caliente Range is unfavorable for the collection of oil from either of these formations, as they are overlain by porous beds only on the flanks of the anticline, where the beds stand nearly on edge. The Whiterock Bluff shale member of the Santa Margarita west of the fault that trends northwest from the mouth of Morales Canyon is thin but very diatomaceous. However, the broad syncline in which it lies is not a favorable structure for the accumulation of oil.

Between Whiterock Bluff and the outcrop of the Santa Margarita formation, west of Salisbury Canyon, and northward to Cuyama River is an area in which a determination of either the structure or the distribution of the formations that may have been a source of oil is uncertain because of the presence over most of the surface of the Cuyama formation and terrace gravels. As the underlying structure is unknown this area can not be classed as definitely barren of oil, although there is no positive evidence to recommend it as an area favorable for oil accumulation. The small area of pre-Monterey rocks overlain by the Morales member of the Santa Margarita south of Whiterock Bluff is important as showing that the diatomaceous shale does not extend directly south from Whiterock Bluff to the edge of the valley. In the absence of more definite evidence it may be assumed that the diatomaceous shale is absent south of a line drawn from the small area mentioned to the point where Aliso Canyon enters the main body of pre-Monterey rocks. Northeast of that line the Cuyama formation is presumably underlain by one or both of the diatomaceous shale formations. Though probably present both shales become notably less diatomaceous toward the southeast. The Maricopa shale is a nondiatomaceous brown sandy clay shale south of Cuyama River, and the Whiterock Bluff shale between Salisbury and Aliso canyons is less diatomaceous than at Whiterock Bluff. If one may judge of the amount of oil formed in the shale by its thickness and the amount of diatom skeletons present in it, then only a comparatively small quantity of oil should be expected to occur in this area. Any oil which may have originated in these shales might have collected either in interbedded sandstones or at the base of the Cuyama formation, having seeped up from the eroded edge of the underlying shale. A well of comparatively shallow depth located on any one of a number of low local anticlines in the Cuyama formation would test the sands at the base of that formation, as the Cuyama formation in this area is probably not over 200 or 300 feet thick. This thickness of beds would probably not give sufficient covering to retain any large quantity of oil, and the very marked unconformity between the Santa Margarita and Cuyama formations suggests that a large part of the oil might have escaped from the lower beds before the overlying beds were deposited, so that on the whole the prospect of obtaining more than small quantities of oil, if any, in this area is not promising.

OIL SEEPS.

The largest seep reported, and the only one seen by the writer, occurs in the bed of Cuyama River south of Whiterock Bluff. The river has cut down about 20 feet through Quaternary stream deposits and is flowing on bedrock, here diatomaceous shale of the Whiterock Bluff member of the Santa Margarita. During an earlier epoch the river cut down to the same level and formed a much wider valley in which the stream gravel and sand that form the vertical banks of the present stream were deposited. It was during this earlier epoch in which the river flowed upon bedrock that most of the oil now seen at this locality seeped up from the underlying shale of the Santa Margarita. While the river was flowing on bedrock and while it was depositing 3 or 4 feet of sand a number of pools of oil were formed here, some not less than 100 yards across. The oil in these pools saturated the surface sand, which was later covered by sediment and preserved and which is now traceable along the vertical river banks as thin strata of oil sand interbedded with white sand and clay. At one place, which may have been the original seep, an asphalt-like oil has escaped from the underlying shale very recently. The shale near this seep has irregular dips and the oil may have come up along or close to a fault.

At least three seeps of oil are reported in areas of Maricopa shale of the Monterey group in the Caliente Range, but at the time of the writer's visit they could not be located and had probably ceased to flow. A reported seep in a small canyon in the NW. ¼ sec. 15, T. 11 N., R. 28 W., could not be found. There is said to be a small brea deposit on a ridge in the SE. ¼ sec. 14, T. 11 N., R. 28 W. A seep reported in the creek bed near the forks of Taylor Canyon, in the SE. ¼ sec. 24, T. 32 S., R. 19 E., has also apparently ceased to exist.

WELLS DRILLED FOR OIL.

The Webfoot well, in a narrow gulch on the north side of Ballinger Canyon, in the SW. ¼ sec. 2, T. 9 N., R. 24 W., was started about 1905, and drilling continued intermittently for a number of years. It is said to have reached a depth of 1,800 feet without encountering any oil. This well starts in nearly vertical beds of brown sandy shale of the Monterey group.

The Grand Prize Oil Co., composed of Bakersfield and local people, drilled a well in sec. 6, T. 11 N., R. 28 W., at about the same time as the Webfoot well was drilled. This well is said to have reached a depth of 600 or 700 feet without obtaining any oil. It starts in the "chalky" white shale of the Whiterock Bluff shale member of the Santa Margarita and probably reaches the underlying pre-Monterey rock. It is located on the south flank of a broad syncline.