GEOLOGY OF THE CENTRAL PORTION OF THE MOUNT PINOS QUADRANGLE
VENTURA AND KERN COUNTIES, SOUTHERN CALIFORNIA

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ABSTRACT

The central portion of the Mount Pinos quadrangle lies principally in northern Ventura County and includes a small district in the adjacent part of Kern County. The rocks within the area mapped are of pre-Cretaceous, Cretaceous(?), Eocene, Miocene, and Quaternary ages.

The oldest rocks consist of metamorphosed sediments, principally calcareous; quartz/diorite porphyry; and granitic gneiss and schist. The Cretaceous(?) and Eocene have not been differentiated and only the latter has been definitely recognized; the combined thickness exposed approaches 15,000 feet. The Miocene rocks are predominantly marine west of the Cuyama River, but to the east a very thick section of terrestrial deposits has accumulated, extending into Lockwood Basin, and perhaps farther. These strata are strikingly colored and give rise to an extensive area of badlands.

The structure of the western part of the area is characterized by numerous folds and occasional faults; both have roughly a N.W.W. trend. In the eastern portion or Lockwood Basin the deformation is more acute and faulting has played a larger part. The majority of the structural features in this eastern region strike northeasterly and are of a compressional nature, although normal faulting also occurs. Transverse to the prevalent strike in Lockwood Valley, and at least in part of later origin, is a group of faults which have had dominantly horizontal movement. The San Andreas Rift, extending across the northeastern corner of the area, is the major feature in the latter group.

From an economic standpoint this area is of historic interest, as one of the early discoveries of gold in California was made in or near San Guillermo Creek, and the colemanite deposits in Lockwood Valley played an important part in the early borax mining of the State.

INTRODUCTION

The present study is concerned primarily with the structure, stratigraphy, and history of one of the most interesting districts in the southern coast ranges of California. The area mapped in the course of the investigation covers about 350 square miles and lies in the northern portion of Ventura County, extending into southwestern Kern County. It is just south of the southern extremity of San Joaquin Valley, and includes a large portion of the region Dr. B. L. Clark has designated as the "knot." The Mount Pinos Quadrangle, published by the U. S. Geological Survey, was enlarged for use as a base map in the field work.

The writer's interest in this problem followed as the result of an earlier investigation of the occurrence of Miocene vertebrate remains in the upper Cuyama drainage basin. The faunal study was encouraged by Dr. Chester Stock. The subsequent investigation of the geologic relations has been carried on under the supervision of Dr. J. P. Buwalda.

PREVIOUS STUDIES OF THE REGION

During the period 1854-55, following the explorations of Fremont, the Cuyama Valley was visited by one of the Pacific Railroad Survey parties and the geological features of the region were described by Thomas Antisell (1857, pp. 53-57). Fossils collected by this survey in Grapevine Canyon to the northeast of

Mount Pinos were described by Conrad in 1856. Fairbanks (1894, pp. 493-526) made a reconnaissance survey of the northern part of Ventura and of several counties to the west and northwest, and later (1895, pp. 273-300) described an analcite diabase on the northern side of Cuyama Valley. The report by A. C. Lawson (1908, pp. 22, 42) on the California earthquake of 1906 includes a discussion of the principal physiographic features of the area. In the same publication Fairbanks described the San Andreas Rift, which traverses the northern part of the region. In studies relating to the occurrence of borax deposits H. S. Gale (1914, pp. 434-456) discussed the geology of the basin of Lockwood Valley. W. A. English (1916, pp. 191-215) published a detailed description of the geology of Cuyama Valley, including a map of the formations involved in the structure of the basin to the northwest of the area considered in this paper. The region north of the San Andreas Rift adjoining the southern end of the San Joaquin Valley has been described by R. W. Pack (1920, pp. 13-61), and later a portion of it near San Emigdio Mountain was considered by C. M. Wagner and K. H. Schilling (1923, pp. 235-276). W. S. W. Kew (1919, pp. 1-21) and R. N. Nelson (1925, pp. 327-276) investigated the geology of portions of the upper Santa Ynez drainage basin lying to the southwest of Cuyama Valley. A recent paper by H. W. Hoots (1930) on the oil resources along the southern border of the San Joaquin Valley is devoted primarily to a study of the stratigraphy and structure of the formations present north of the crystalline mass and between Santiago Creek and the Tejon Hills. This publication contains the most recent data available on the adjacent region to the north of the San Andreas Rift. The writer (1930) in a paper on the occurrence of fossil vertebrates in Cuyama Valley considered briefly the geologic sequence.

GEOGRAPHY

The Mount Pinos territory is a rugged upland area with considerable relief. Elevations vary from about 3600 feet in Cuyama Valley to a little less than 9000 feet at the top of Mount Pinos. This peak (see Fig. 1) is the highest in the region and holds a unique position in the mountain system. It lies within the coast ranges and at the same time may be considered to form a part of the southwestward extension of the Sierra Nevada range. It furthermore forms the apex of a four-way drainage pattern. The southeast and southwest slopes drain toward the ocean by separate hydrographic systems. The north and northeast flanks are tributary to inland lakes; namely, Buena Vista Lake in the San Joaquin Valley and Castac Lake at the head of Grapevine Canyon.

For descriptive purposes the area is divided into two parts; the western or Cuyama basin, only the southeastern part of which is represented in the area; and the Lockwood depression to the east. These basins are roughly bounded by the higher lying

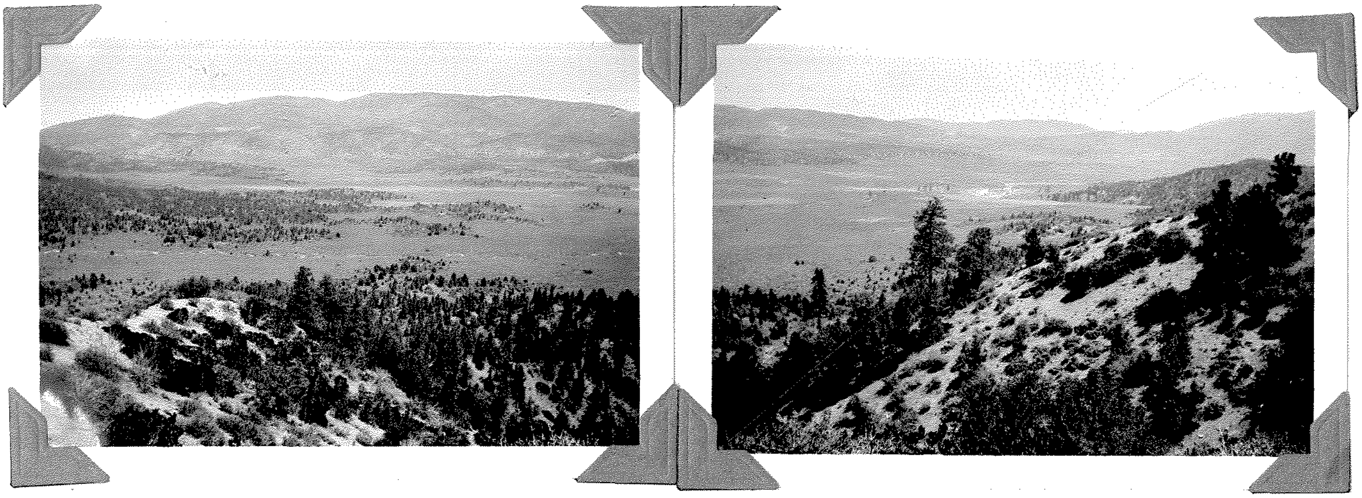

Fig. 1. Panorama of Lockwood Valley and Mount Pinos from the southwest end of the valley. Frazier Mountain can be seen in the background on the extreme right.

Fig. 2. View westward along the southern margin of the Cuyama basin from San Guillermo Peak. A portion of an old mesa remnant is visible in the foreground. Pine Mountain is the highest ridge in the left background.

masses of older rocks but are not isolated from one another. Mount Pinos in the north is situated as a wedge in separating the basins, and the Pine Mountain mass (Fig. 2) in its entirety forms a southern boundary for the depressions. Lockwood Valley is limited on the east and southeast by Frazier Mountain and a northwest extension of the Alamo Mountain rocks.

The climate of the region, as in most parts of the coast ranges of southern California, is semi-arid. The area ~~is subject to~~ frequent rains in winter as well as light snow storms, and most of the higher peaks, as for example Mount Pinos, carry a small snow cap on their north sides during this season. In summer occasional cloudbursts occur which have a very pronounced effect on the finer details of the topography. Many of the stream beds draining toward Cuyama Valley are dry except after rains. During periods of precipitation broad shallow streams of muddy water are formed, making travel in the valley difficult. Springs are few in number in the Cuyama basin except along the margin of the salient masses. In the eastern and southern part of the area, where the relief is greater, water is somewhat more plentiful.

STRATIGRAPHY

General Features

The stratigraphic sequence in the area includes the extensively exposed crystalline rocks of Jurassic or earlier age, and the still older metamorphosed sediments. The oldest group of unaltered strata are the Eocene and possibly Cretaceous rocks exposed in the southern part of the area. The Miocene rocks consist of a thick accumulation of terrestrial deposits and a series of marine strata. The beds of marine origin occur in upper parts of the group. This middle Tertiary sequence has been divided into ten lithologic units in order to more clearly illustrate the structure. The Quaternary deposits consist of mesa and terrace materials and valley alluvium.

Crystalline Rocks

The oldest rocks in the area are probably the metamorphosed limestone and shale in the crystalline aggregate along the northeast side of the San Andreas Rift, in Cuddy Valley and at the head of San Emigdio Canyon. The limestone is coarsely crystalline and occurs in masses surrounded and intruded by granite. Patches of cherty hornfels also occur in the aggregate.

Quartz diorite porphyry makes up a large part of Frazier Mountain and outcrops over a relatively large area south of it. It is well exposed along Lockwood Creek. It varies from an unchanged quartz diorite porphyry at the north end of the gorge through gneiss to schist with augen structure near the south end where the stream joins Piru Creek. Roof pendants of this rock in granite were observed near Piru and Alamo Creeks. The rock is dark but its ground mass contains considerable quartz in addition to plagioclase and femic minerals such as hornblende and biotite. The feldspar phenocrysts are rather large, commonly an inch or more in length, and light gray colored on weathered surfaces. The age of the quartz diorite porphyry relative to that of the altered limestone is indefinite. The rock is clearly older than the granite of the district.

Granite, which intrudes these earlier rocks, occurs along the north side of the rift and south of the quartz diorite porphyry mass between San Guillermo Creek and Alamo Peak. Mount Pinos is essentially granitic, and a few fault inliers of granite are found to the west in the Cuyama basin. In the southern part of Mount Pinos the rock is coarsely crystalline and to a certain extent porphyritic, with orthoclase phenocrysts. A large part of the mass is gneissic and along the rift to the north and near the thrust fault on the west side the rock is schistose.

Cretaceous(?) and Eocene Rocks

The pre-Miocene sandstones, shales and conglomerates are exposed in the southern part of the area and to the northwest in the

San Rafael range. A band also extends along the south flank of Mount Pinos. The beds are essentially yellow to brown sandstones and dark gray clay shales. The lower beds present to the west of San Guillermo Peak (Figs. 3 and 4) are predominantly shale, but the younger strata between Reyes Peak and Cuyama River are frequently sandstone. The upturned edges of alternate thick sandstone members and softer shales are in a large part responsible for the rugged topography in the region of Pine Mountain (Fig. 2). The light colored sandstones occasionally carry rather coarse conglomerate. In the upper part of the series exposed between Lockwood Valley and Mount Pinos two very well indurated beds of granitic arkose occur (Fig. 5). The material in these two beds is similar to that in the crystalline part of Mount Pinos. At this locality the strata are standing nearly vertical and erosion has left the arkosic members projecting as prominent parallel ridges.

An abundance of Eocene fossils, probably of Tejon age, were found near the top of the formation in Reyes and Beartrap Creeks. The older strata are apparently unfossiliferous. Fossils were also found in the Eocene beds along North Fork Creek near Mount Pinos. The invertebrate collections obtained from these beds have not been analyzed. The fauna is rather large and might well receive separate treatment by someone making a more comprehensive study of the Eocene. Drs. W. P. Woodring and H. B. Stewart

Fig. 3. Eocene and Cretaceous(?) strata in the basin of Wagon Road Creek. San Guillermo Peak is in the center background to the east.

Fig. 4. Eocene or Cretaceous shale with thin limestone beds. Lower part of series as exposed near Cuyama fault east of Dry Canyon. Canyon on the left follows the fault line. Miocene strata in left background.

Fig. 5. Granitic arkose and conglomerate one mile above mouth of North Fork. This bed forms a prominent ridge for several miles along the south flank of Mount Pinos.

upon examining some of the specimens considered their age to be Tejon. Of especially common occurrence in the fauna is the form Turritella uvasana.

The total thickness of the rocks is not known, but a cross-section (Section F-G) taken just west of San Guillermo Peak, from the upper part of Wagon Road Canyon southeast to the first synclinal axis, shows a thickness of about 15,000 feet. The total thickness is probably much greater and undoubtedly includes strata of Cretaceous age. Neither the upper nor lower limits of the sequence are exposed in the southern part of the area, but near Mount Pinos Miocene beds rest with apparent conformity on pre-Miocene strata. The two groups, however, are separated by lava flows.

No sediments of Oligocene age have been recognized in the area. The locality in North Fork Creek where Eocene fossils were found is approximately five hundred feet south of the contact between shale and granite. There still remains a considerable thickness, perhaps several thousand feet, of shale, sandstone, and arkose below the Miocene lava flows. The strata in this interval are badly crumpled and no separation seemed practicable. However, there is no reason why some of these beds may not be of Oligocene age. Directly north in San Emigdio Canyon 3800 feet of strata have been identified as San Lorenzo, but eight miles to the east of there the formation is entirely absent, with Vaqueros rocks resting on Tejon. This condition has been attributed to progressive overlap by the lower Miocene Vaqueros (Hoots, H.W., 1930, p. 256). In the absence of positive evidence for the Oligocene age of any of the beds south of Mount Pinos it seems more satisfactory to group tentatively the uppermost strata below the lava with the Eocene.

Miocene Rocks

General statement.- Perhaps the most interesting feature of the area, aside from its structure, is the Miocene accumulation. It was a study of these rocks in connection with the collecting of fossil land mammals that led to the investigation of the region. The major portion of this series is of terrestrial origin, but west of Cuyama Valley, in the region studied by W. A. English, the formations are predominantly marine.

In the investigation of the geology of Cuyama Valley English recognized three primary divisions of the Miocene rocks; the Vaqueros formation, Maricopa shales, and Santa Margarita. Faunal lists were given in support of the use of these names. In parts of the valley the formations were further subdivided into members on the basis of lithology. In his classification of the rocks he used the term Monterey as a group name, including under this description the Vaqueros and Maricopa formations. In the eastern part of Cuyama Valley adjacent to the area described in the present report the series was divided into two parts. The lower strata English considered to be roughly equivalent to the Monterey group as recognized farther to the west. The upper portion was correlated with the Santa Margarita. No faunal evidence was cited in support of these correlations. The structure of the basin and the distribution and continuity of the formations illustrated by his map favors the age assignments made.

In the present investigation the earlier separation of the Miocene rocks into the two groups Monterey and Santa Margarita (in the broad sense) was used as a starting point. The whole series was further divided into eight consecutive members on the basis of lithology and coloration. The exact point of separation for the two groups was indefinite but is here arbitrarily placed at the bottom of the Lockwood clay. The reason for this selection is discussed in the description of the Lockwood clay.

Stauffer basalt.- At the base of the Monterey group on the north side of Lockwood Valley a series of thin basalt flows rest on Eocene(?) beds, but are considered to be a part of the Miocene sequence. The lava does not exhibit columnar structure but is vesicular and scoriaceous, the vesicular portions being frequently amygdaloidal. Interbedded with the lava flows are lenticular layers of limestones which carry colemanite. The borax deposits were described by

H. S. Gale in 1914. Colemanite has been shown by W. F. Foshag to be an alteration from ulexite, which in turn is a product of desiccation from saline lakes in volcanic regions. This evidence for a terrestrial origin of the limestone and basalt favors the placing of the Stauffer basalt with the overlying section rather than with the marine Eocene. The thickness of the member is probably not greater than 600 feet near Stauffer, and is only about 200 feet thick farther west.

The exposures of this member are restricted to the south flank of Mount Pinos from the divide between North Fork and Dry Canyon to Cuddy Valley. To the west the flows are steeply dipping and give rise to a prominent ridge parallel to the ridges of arkose in the Eocene(?) below. Between Seymour and Bitter Creeks the lava though folded is less steeply inclined and conforms more nearly to the surface.

Basalt and andesitic agglomerates, flows, and tuffs are interbedded with lower Vaqueros rocks along the south border of the San Joaquin Valley from San Emigdio Canyon to Tunis Creek. In the vicinity of Tecuya Creek the volcanic series consists of 50 to 100 feet of light bluish-gray andesite agglomerate in the lower part and 50 to 150 feet of dark red and brown basalt flows and agglomerate above. Intercalated in the sequence are layers of light sandstones, red clay, and green bentonitic clay. Farther east andesite is inconspicuous or absent and the basalt exposures show thicknesses of 50 to 1200 feet. Between Pastoria and Tunis

Creeks basalt is underlain by 50 feet of cream colored rhyolite agglomerate.

In the volcanic accumulation along the north side of Lockwood Valley none of the more acidic lavas have been recognized. The rock is a very dark, brownish to greenish black basalt, intercalated with limestone and colemanite. The evidence for a marine origin of the lava north of the rift (Hoots, H.W., 1930, pp. 262-263) does not apply to the Stauffer basalt and evidence for a terrestrial origin has been cited above. However, the following evidence taken collectively indicates contemporaneous activity in the two areas: 1) The stratigraphic position assigned to the Stauffer basalt is the same as that occupied by the lavas and agglomerates along the south border of the San Joaquin Valley, and was arrived at from independent consideration previous to an understanding of the stratigraphic relations north of the rift. 2) The volcanic rocks immediately to the north are distributed along the valley border for about twenty miles in an east-west direction and the Stauffer basalt is exposed nine miles or less to the south of the outcrops near Salt Creek. 3) Basic flows occur at only one other horizon in the region, near the top of the Monterey group in the area mapped by W. A. English. The flows in these later strata do not continue southeast beyond a point on the north side of Quatal Canyon.

<u>North Fork member</u>.- Conformably overlying the Stauffer basalt is a series of sandstones, shales and conglomerates. The

bottom portion is composed of relatively fine gray and white sandstone and sandy shale grading upward into coarser red and gray sandstone near the top (Figs. 6 and 7). Conglomerate phases are more common in upper levels. The reddish horizons resemble red beds in the Quatal sandstone higher in the group, but are somewhat more sandy and show better stratification. The total thickness of this member is difficult to determine but is estimated at 3000 feet.

The North Fork member is unfossiliferous but is probably equivalent to the Vaqueros west of Cuyama Valley. Its position relative to the basalt is similar to that of the massive sandstone and shale of the Vaqueros immediately to the north in San Joaquin Valley.

The origin of the materials composing this member is not as clear as for some of the later strata. The lower levels vary considerably from east to west, but are rather shaly and better sorted than in the higher horizons. Parts of the formation may be of marine origin, but the shale phases do not resemble the marine strata below the lava. The increase in coarseness in the upper parts of the member suggests greater relief at this locality. The younger beds are also much coarser, show brighter coloration, and weather into badlands. A terrestrial origin is more evident. Furthermore, there is no indication that the underlying basalt contributed material to these beds. The source of the lower sediments may well have

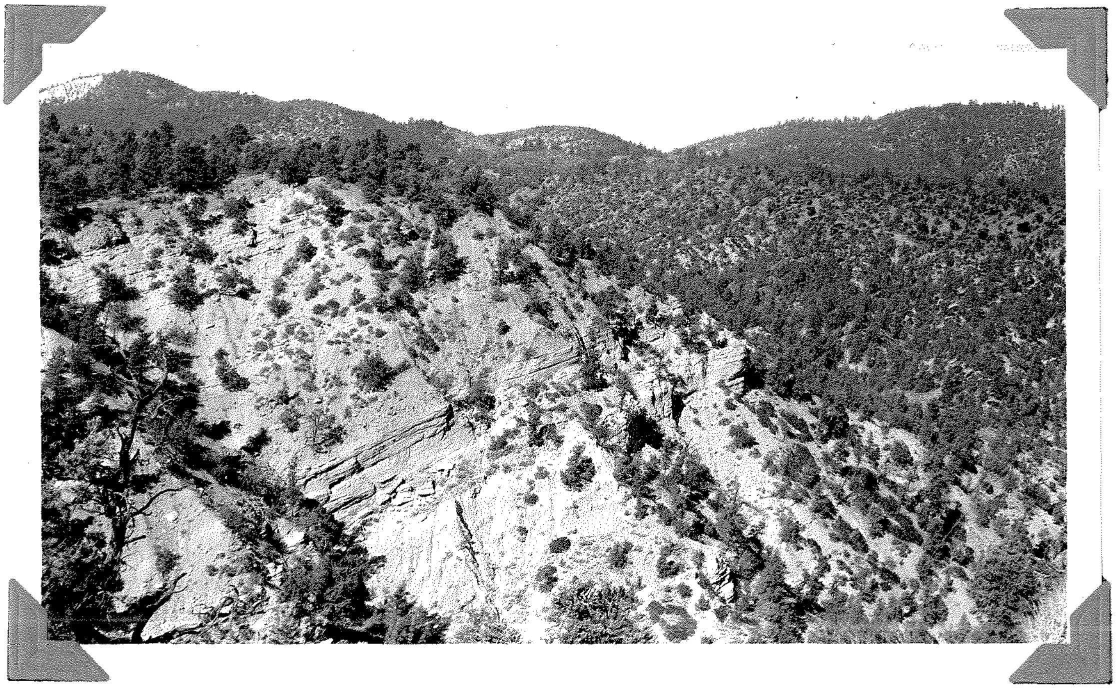

Fig. 6. Exposure of North Fork member west of the mouth of the North Fork Canyon. The strata are sandstone, shaly sandstone, and conglomerate. The peak in the left background is the high point on the Lockwood-Cuyama divide (elev. 6675 ft.).

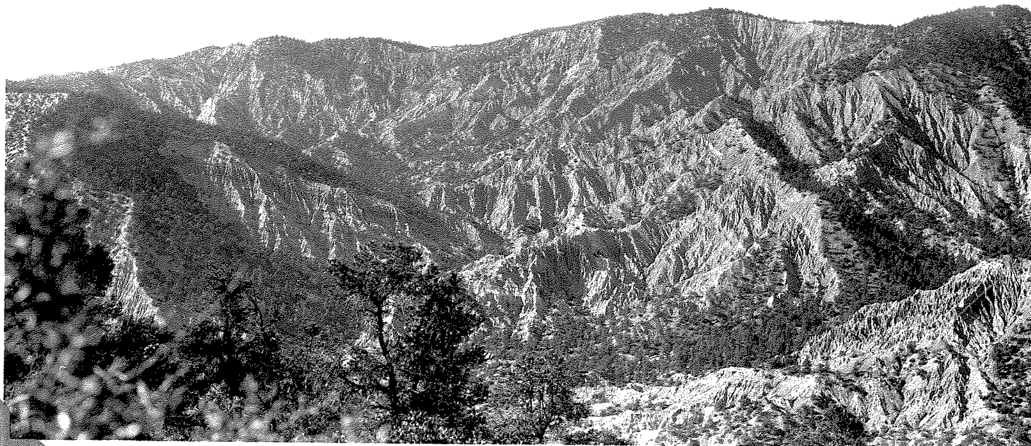

Fig. 7. View west across badlands of North Fork and Dry Canyon members from the divide between Lockwood Valley and Wagon Road Canyon. Beds of the Dry Canyon member to the left dip north toward the canyon where they are sharply overturned exposing North Fork strata on the spurs to the right (north). This acute syncline is an open fold on the ridge in the background. At the observer's position on the divide it appears to be a thrust.

been from the Eocene and Cretaceous rocks or still earlier granite. The upper strata contain both granitic and quartz diorite porphyry boulders as in the overlying Dry Canyon member but the latter material is not as plentiful.

Pato red member.- In the lowest part of the Miocene sequence in Quatal Canyon is a series of brick-red sandy clays and conglomerates. These beds are recognized as belonging to the Pato red member of the Vaqueros. The lithology is nearly identical to the equivalent strata in Pato and Santa Barbara Canyons on the west side of Cuyama Valley. The most unique feature is the peculiar red color which is entirely different from the brownish red beds in other parts of the area. Two kinds of conglomerate are included in the formation. One is a local accumulation of small weathered pebbles of granitic material in an arkosic ground mass. The other is more generally distributed, being recognized also in Santa Barbara Canyon, and consists of flat worn boulders of a very basic, greenish schist. In some places the basic conglomerate is essentially a breccia. The sandstone and clay were undoubtedly derived from the same material as that composing the boulders. The thickness of the Pato red member in this region is unknown, as only the upper few hundred feet are exposed at the head of Quatal Canyon.

The Pato red member occupies a stratigraphic position close to that of the North Fork member near Lockwood Valley and may be in part contemporaneous; however, the lithology of the strata in the two cases is entirely different. The clay and conglomerate composing the Pato red beds were derived essentially from a highly ferromagnesian schist, the source of which may have been the Franciscan formation. Franciscan is present in the ranges farther to the west. Furthermore, the brilliant coloration, lack of sorting, and the badland physiography developed in this member are indicative of a terrestrial origin.

The Pato red beds resemble to a marked degree similar beds in the Sespe formation. The coloration, composition, origin, and erosional features typical of this member make it seem highly probable that strata which have elsewhere been called Sespe may in a number of cases be of Vaqueros age. However, this is not meant to imply that Sespe is confined to a terrestrial phase of the Vaqueros, as beds in the Santa Ynez range referred to the Sespe have been shown to be of San Lorenzo age. Moreover, an Oligocene age is recognized for a part of the Sespe beds south of the Santa Clara Valley on evidence furnished by vertebrate remains.

The thickness of the Pato red member in this region is unknown, as only the upper few hundred feet are exposed at the head of Quatal Canyon.

Dry Canyon member.- This formation lies stratigraphically above the North Fork member. The separation of the two is rather arbitrary and depends upon coloration and coarseness. The higher member is typically exposed between Dry Canyon and Lockwood Valley

(Figs. 7 and 8) and shows the greatest lateral variation in lithology among any of the formations in the region. In Quatal Canyon it has not been recognized separate from the overlying Quatal sandstone. In the northern part of Dry Canyon the beds are a dull gray or blue-green color and composed of thick bedded to massive sandy clay or mudstone. In the upper part they grade into alternate red and white layers (Fig. 8). Farther south on the east side of the canyon the beds change to a coarse white sandstone with an occasional pinkish cast. The sandy phases contain a small amount of well weathered lava detritus, particularly bluish andesite, as well as more coarsely crystalline pebbles. Toward Lockwood Valley the material becomes extremely coarse and rather dark blue-gray in color. By far the largest component of the conglomerate phase is quartz diorite porphyry. Granitic boulders make up a smaller percentage of the material. The dark porphyry is unmistakably the same as that occurring in place near Lockwood Creek and on Frazier Mountain at least ten miles to the east. The boulders are commonly a foot or two in diameter and often much larger. The origin of this material was probably closer than the site of Frazier Mountain as shown by the coarseness of the conglomerate. The lateral gradation in coarseness of the material is such as to indicate its derivation from the east, possibly from the site of Mount Pinos to the northeast. At the present time Mount Pinos is furnishing only granitic debris. The old

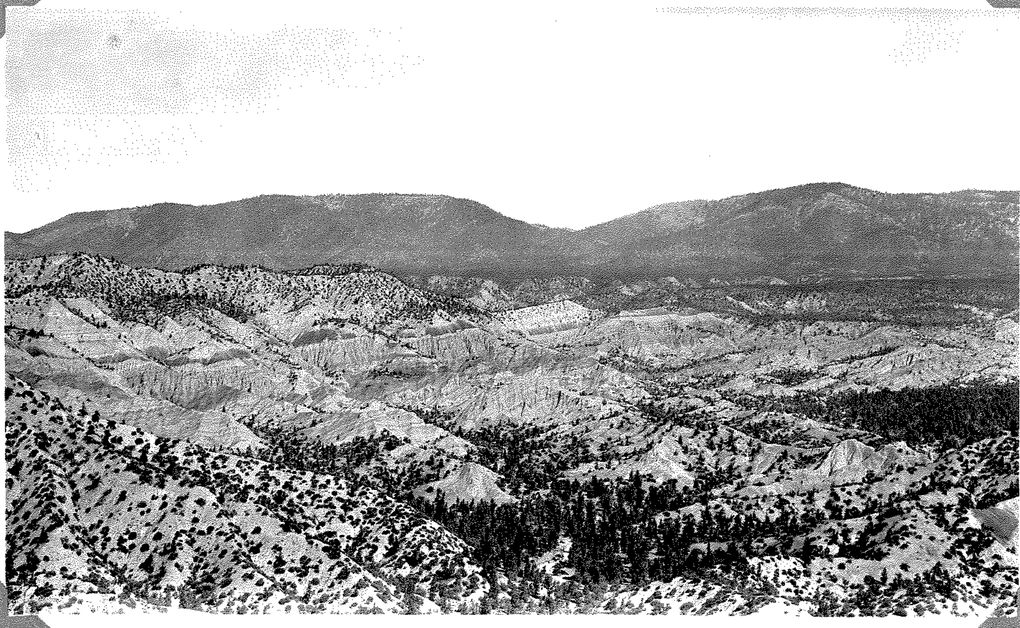

Fig. 8. Miocene strata exposed on west side of Dry Canyon. Section from bottom (right) to top includes part of Dry Canyon member, Quatal sandstone, Lockwood clay (conspicuous dark band), Corral and Castle sandstones. Mesa level is conspicuous to the north near Mount Pinos ridge.

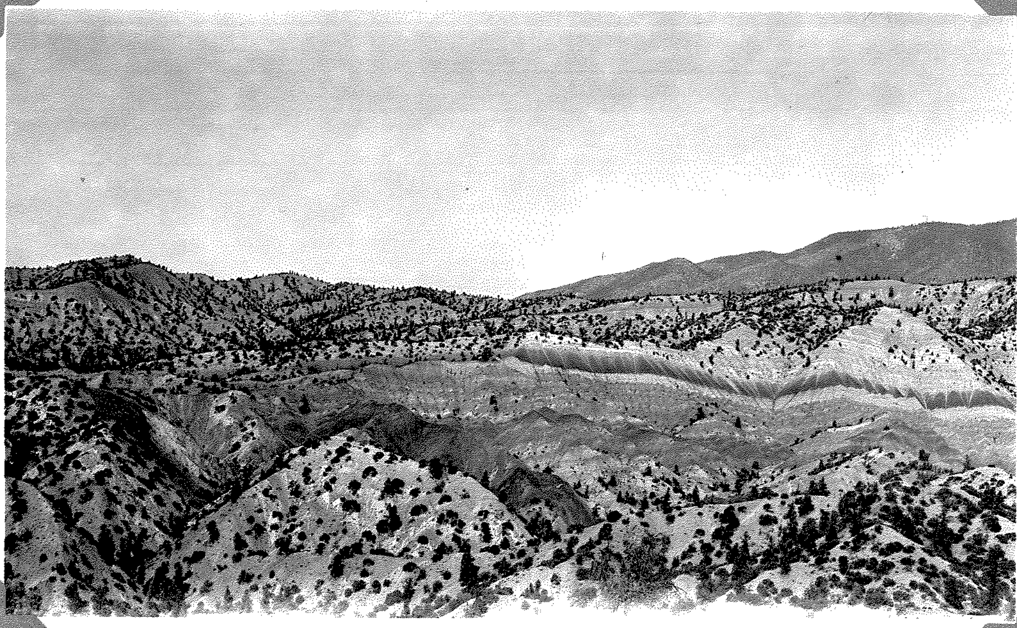

Fig. 9. View northwest across westward plunging anticline in Dry Canyon. Note unconformity or overlap below Lockwood clay (conspicuous dark band).

terrace gravels around its base are also free from quartz diorite porphyry except in places farther away where it was evidently derived from the underlying Miocene.

The Dry Canyon member has a thickness of about 4,000 feet in a section taken across the upper end of Dry Canyon. This thickness includes the upper few hundred feet of the group which have been referred to the Quatal sandstone. The bulk of the member belongs in the upper part of the Monterey group as recognized in this region. However, a Vaqueros age for the lower levels is not excluded inasmuch as the separation of this member from the underlying North Fork beds was rather arbitrary.

A terrestrial origin for this member is evident from the extremely poor sorting and massive bedding of the material, in addition to the characteristic badland features developed by erosion.

Quatal sandstone.- The Quatal member is a thick accumulation of alternate red clayey mudstone and coarse white sandstone. Wherever this terrestrial member outcrops, as in Quatal and Dry Canyons, it gives rise to a very picturesque landscape of brightly colored badlands (Figs. 8, 10, and 11). In Dry Canyon (Fig. 8) this formation and the members above and below present a remarkable display of colors over a very extensive area.

The coarse white sandstones of this member are composed of grains, pebbles, and boulders, unsorted and exhibiting every

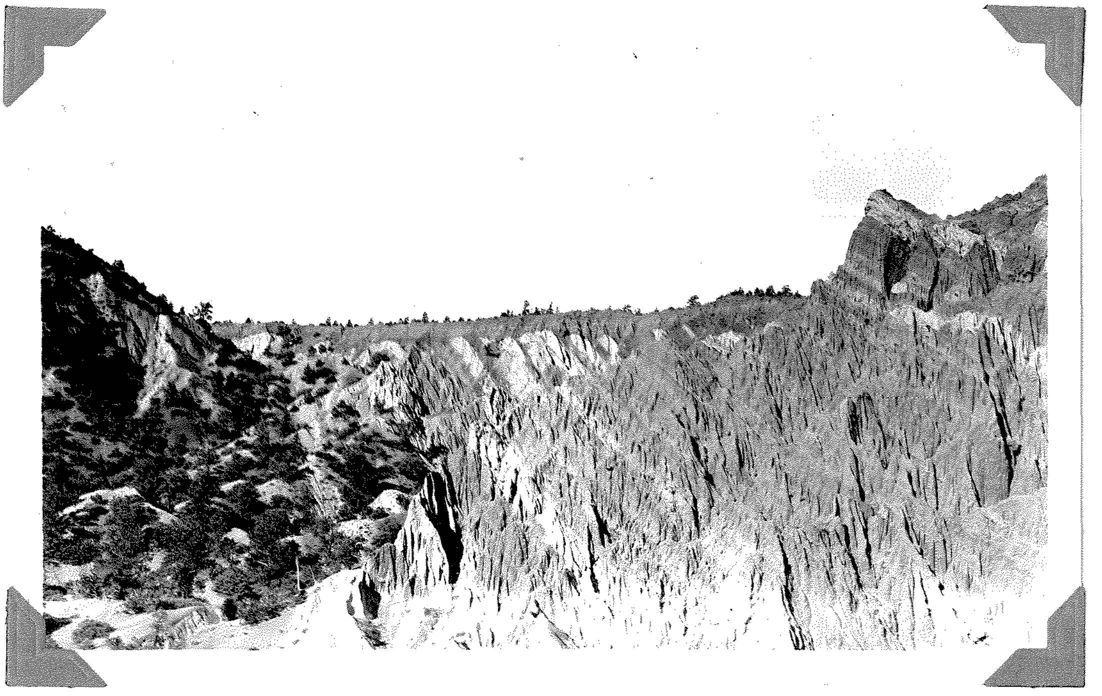

Fig. 10. Quatal sandstone exhibiting characteristic badlands in northeastern part of Apache Canyon. Quaternary mesa deposits resting unconformably on Quatal sandstone can be seen on the canyon rim.

Fig. 11. Quatal sandstone at the vertebrate fossil locality in Quatal Canyon. The peak in the distance is Mount Pinos.

variation in size. The grains are angular and include a number of different minerals, quartz being by far the most abundant. The boulders are more rounded and consist of a large assortment of rock types. Granite and granitic gneisses and schists predominate with less frequent quartzite, andesite, diorite, diabase, and basalt. The most noteworthy feature is absence of the dark quartz diorite porphyry, so characteristic of lower horizons between Dry Canyon and Lockwood Valley. The reddish brown or ocher colored beds are massive, thick bedded, uniform sandy clays. The cementing substance is relatively soluble as indicated by the physiographic expression of this member. The thickness of the white beds varies from a few feet to twenty or thirty, ten feet being an average. The brownish beds are generally thicker and range from five or six to thirty or more feet. The total thickness of the formation in Quatal Canyon is about 4,000 feet, but in Dry Canyon only the upper 200-300 feet are recognized as representing this member.

The upper part of the formation has much the same appearance throughout the area but lower strata are not as constant in character. As stated above the dissimilarity in lithology of these lower beds has resulted in their being mapped as a separate unit in Dry Canyon and to the east. It is a noticeable fact that the lateral variation in lithology for members in this group is progressively greater in the earlier strata. The conclusion drawn from this is that different parts of the area were receiving deposits from markedly different sources in the earlier stages and that later some sources were eliminated and the basins of deposition more completely coalesced. The Quatal sandstone is of a decidedly consistent character through the greater part of its thickness in Quatal Canyon, and the source for these strata contributed the material in the later coalescing of the basins.

A terrestrial origin for the Quatal sandstone is evident from a consideration of the following points: 1) The beds are massive and do not show clean cut lines of stratification at any place in the series. The attitude of the strata can often be determined only by observation of the differently colored layers from a little distance. 2) The material composing the beds is of a heterogeneous nature, varying from an earthy argillaceous mudstone to a coarse or conglomeratic sandstone. 3) The beds are brightly colored. A typical section shows alternate bands of white and light reddish brown strata (Figs. 9 and 10). 4) Badlands are developed where this member is exposed. The occurrence of this type of topography is dependent not entirely upon the climate of the region in which the strata are being eroded, but rather upon the conditions under which the beds were deposited. This evidence will be more fully treated in the geomorphology of the area. 5) Bone fragments of land vertebrates are rather plentifully distributed in upper levels from Apache Canyon to the north side of Quatal Canyon. No marine fossils were found.

The age of the Quatal sandstone has been previously determined (Gazin, 1930) by the vertebrate fauna. The evidence from this source indicates a stage in the Miocene comparable to the Barstow horizon in the Mohave Desert region. According to the time scale set up by vertebrate paleontologists for Tertiary formations of the west, the Barstow-Santa Fe stage is upper Miocene and equivalent to Sansan in the European sequence. The stratigraphic position of Quatal sandstone is equivalent to the upper part of the Monterey group or Maricopa shales according to the map and sections given by English. This position is further substantiated by the occurrence of a basic lava flow in the upper part of the formation, near the same horizon in which the bone fragments occur. Basic (diabase described from here by Fairbanks, 1895) intrusions and flows are common in the Maricopa shales of the Caliente Range a short distance to the northwest. Evidence for an upper age limit to the member is seen in the scanty invertebrate fauna from marine strata in the overlying group in Quatal Canyon. The forms recognized, Ostrea titan and Pecten crassicardo, are also found together in the Santa Margarita formation southwest of the Cuyama Valley. Correlation with the marine Maricopa shales demonstrates a middle Miocene age for the Quatal sandstone. The discrepancy between this age and the upper Miocene stage shown by the vertebrate fauna suggests an incomplete adjustment between invertebrate and terrestrial vertebrate chronologic scales.

Lockwood clay.- The Santa Margarita series (designated as the San Pablo group(?) in legend of the map and sections) has been divided into four consecutive members. The basal member or Lockwood clay is a thin, dark olive-brown, gypsiferous clay, which on the east side of Lockwood Valley is being mined for rotary mud. The bed is readily discriminated from the overlying and underlying material and is very persistent; hence it has been useful as a key horizon in field work (see Fig. 8). The member has a uniform thickness of about 75 feet in Dry Canyon.

The inclusion of the Lockwood clay in the overlying Santa Margarita formation is open to question, but certain evidence cited below favors a separation from the strata referred to the Monterey group: 1) The clay member marks an important change in lithology from the series of mudstones, sandstones, and conglomerates of the underlying group. 2) The remarkable persistence of the clay bed between the extremes of the area (see map) excludes the possibility of an erosional interval between this horizon and overlying beds. 3) A low angular unconformity or overlap exists between Lockwood clay and Quatal sandstone in the Dry Canyon basin (Fig. 9).

The origin of the clay is not known for a certainty but several features of its occurrence are highly suggestive of a volcanic source. The clay is remarkably pure, quite free of grit and sand, yet lies within a series of several thousand feet of sandy to conglomeratic strata. This requires a sudden change of source for a series of rapidly accumulating strata without an admixture of detritus in the clay. The material is presumably not marine as indicated by the high percentage of gypsum it contains. It is astonishingly uniform in thickness in all parts of the area for a terrestrial deposit unless of volcanic or bentonitic origin. In appearance it strongly resembles the finer part of soil derived from weathered basalt, both in coloration and composition. In fact at one place a badly decomposed outcrop of basalt observed at a short distance was mistaken for Lockwood clay. Volcanic extrusions of a basic nature at this horizon would account for the abrupt change in lithology. This would also account for the uniform composition of the clay over a large area. Deposition in a playa lake would explain the gypsum content and possibly the fineness of the material.

The stratigraphic position of the Lockwood clay above the basic lava flows in the top part of the Quatal sandstone is not conclusive. The assignment of the clay bed to the Santa Margarita formation on the basis of evidence cited above suggests this relation. At the locality in Quatal Canyon where the lava is exposed the relation between clay and lava is obscured in a crushed and faulted zone. However, the possibility of their being contemporaneous is not disproven. Furthermore, if a volcanic origin of the clay be accepted strong evidence is afforded the correlation of the lava and clay unless another period of volcanism be considered. In view of the latter possibility and of evidence previously cited favoring the separation of the clay from older strata a Santa Margarita age is retained.

Corral sandstone.- The Corral member is as widely distributed as Lockwood clay but is not as consistent lithologically. Its recognition in different parts of the area is based rather on its stratigraphic position between Lockwood clay and the overlying Castle Canyon member than on any unique characters possessed by the member. It is easily separated from Lockwood clay, but somewhat less readily from the overlying material. In the Cuyama basin the section consists rather uniformly of a fine, white or light yellow sand low in clay, showing fairly good stratification in places (Figs. 9 and 12). Farther east, in the southwestern part of Lockwood Valley and at the head of Wagon Road Canyon, the member shows a rather high percentage of clay and is pale green to buff in color. In the eastern part of Lockwood Valley the sandstone is principally white and somewhat stratified, but coarser than in the Cuyama basin. The thickness of the Corral member averages about 150 feet, probably more than this in the vicinity of Frazier Mountain.

The evidence for a terrestrial origin of this member is not conclusive. The stratification in most places is good, and the sandstone is frequently clear. The beds exhibit better sorting than is common in the Monterey group. In Quatal Canyon, however, the bedding is somewhat more massive and badlands are developed through the erosion of these strata. It is possible that the sandstone is of marine origin in the southern parts of the basins and terrestrial in the north. Numerous small fragments of petrified wood were found in the Corral sandstone in the northwestern part of Lockwood Valley which is suggestive of a continental origin for that area. Other than petrified wood no organic remains were discovered in the member.

Castle sandstone.- The Castle member is well represented in both Cuyama (Fig. 12) and Lockwood basins. It is distributed along the east, south and west sides of Lockwood Valley and is exposed in the north and south limbs of the Cuyama syncline. The material ranges from a sandy clay to a rather coarse clayey sandstone. The bedding is massive and the stratification indistinct. It is similar in this respect to the Quatal sandstone. The lithology of the member also is similar to that of the Quatal sandstone. However, a noticeable difference exists between the two formations. The Castle sandstone does not show the frequent alternations from coarse white sand to red sandy clay

Fig. 12. Castle sandstone as exposed on the west side of Dry Canyon. The upper and lower contacts with lighter sandstone of Apache and Corral members are clearly shown. Compare mode of weathering with that of Quatal sandstone, figures 10 and 11.

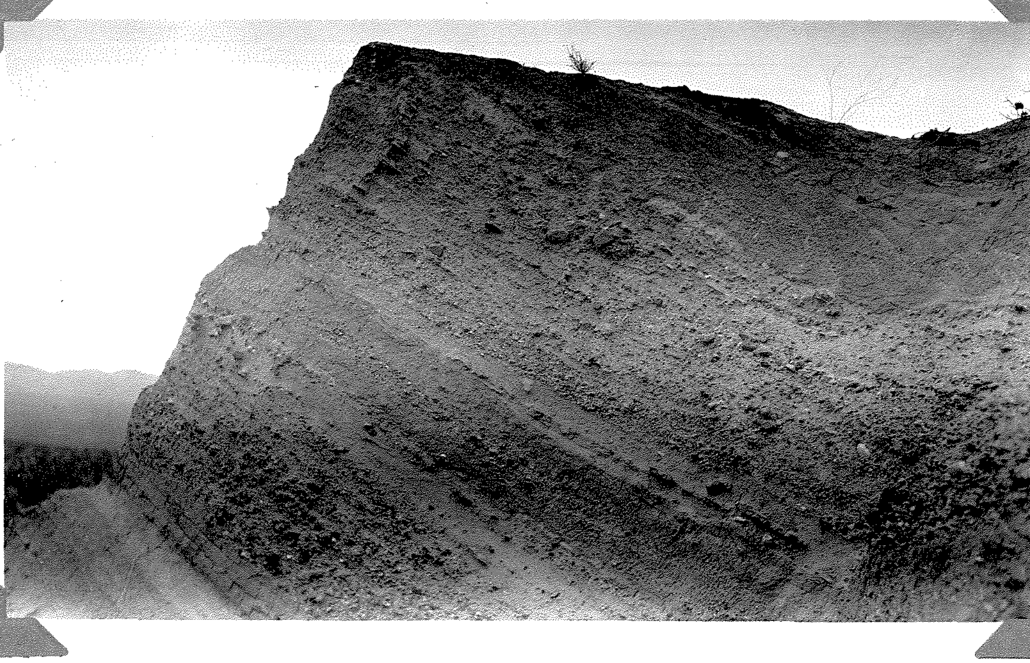

Fig. 13. Coarse sandstone or gravel in the upper part of the Santa Margarita near Apache Canyon.

characteristic of the Quatal member, but in most places consists of a rather uniformly tan or buff colored sandstone having a composition which might easily be obtained through a reworking of the Quatal beds. In addition the strata contain a larger proportion of basaltic detritus than do the Quatal beds. Furthermore, erosion does not affect the two deposits in the same way. Weathering usually develops smooth slopes and obscures the stratification in the younger beds. This type of topography is in marked contrast to the badlands formed in Monterey strata.

In the region between the upper part of Apache Canyon and Quatal Canyon the Castle member resembles the Lockwood clay in composition and appearance but is somewhat lighter brown in color and much thicker. In the early stages of the mapping the two members were confused but subsequent and more detailed mapping demonstrated the presence of two distinct beds of clay separated by the white Corral sandstone. Farther south in the Cuyama basin the Castle member is coarser and sandier, and shows an indistinct banding of light and dark shades of brown. Coarse phases are scattered through the beds and occasionally occur as channel fillings within the member. To the east in the vicinity of Frazier Mountain the coarser texture of the sandstone and the badland topography developed make the recognition of the member difficult. The reference of a part of the sandstone on the west side of Frazier Mountain to the Castle member is based on the conclusion that they are stratigraphically above the Lockwood clay.

The source for the materials in the Castle sandstone as suggested above may be in part the older Quatal sandstone in some adjacent region. The presence of basalt fragments in the accumulation further supports such a conclusion. The material in the northwest part of the area may have had an origin similar to Lockwood clay or was perhaps derived from the latter.

A terrestrial origin seems evident for this member in parts of Lockwood Valley as indicated by the coarse and poorly sorted character of the beds. In the lower part of Apache Canyon the beds are much better stratified and more closely resemble marine strata. The beds are probably of marine origin over a major part of the area although no fossils were found.

The Castle sandstone thickens a little toward the southern part of the Cuyama basin but an average measure in Dry Canyon is about 500 feet.

Apache member.- The Apache member is the major portion of the Santa Margarita formation and is well exposed in the Cuyama basin. Its distribution is from a point just east of Dry Canyon northwestward across the central part of the Cuyama basin. It occurs as the core of the Cuyama syncline. In the vicinity of Apache Canyon the member consists of a series of coarse, rather well sorted and thin-bedded sandstones, shales, and gravels, reaching a thickness of perhaps 4,000 feet. The series thickens noticeably to the north as indicated by the north and south limbs of the syncline (see section O-P).

The color on weathered surfaces varies from gray to white and cream.

This member is probably equivalent to a part of the Santa Margarita as recognized to the west of Cuyama Valley. Fossils are very scarce but Pecten crassicardo and Ostrea titan have been identified from these beds as mentioned in the discussion of Quatal sandstone. The coarseness of the materials composing this member (Fig. 13) indicates a near shore facies of Santa Margarita. The beds are less distinctly stratified in the southeast part of the basin and may have graded eastward into a terrestrial deposit in Lockwood Valley, which if present has not been discriminated from the Castle sandstone in that region.

The erosion of this member is similar to that of the underlying Castle sandstone but does not yield as readily. It frequently composes high, clean-cut bluffs overlooking more subdued features in the Castle sandstone. Northwest of Apache Canyon the exposures are remarkably fresh and bold.

Potrero Seco member.- At the west end of Pine Mountain, south of the divide, is a series of gray and white sandstones and shales which is designated as the Potrero Seco member. These beds are probably equivalent to a part of the Apache member in Cuyama basin north of the divide. A fossiliferous horizon yielding pectens, oysters, and echinoderms was found in the beds. The specimens were examined by Dr. W. P. Woodring and considered to be of Santa Margarita age.

Quaternary Deposits

The Pleistocene and Recent accumulations include the terrace and potrero sands and gravels, and the valley alluvium. The mesa deposits are distributed over remnants of old erosion surfaces, between canyons and around the margins of some of the larger mountainous masses.

North of Quatal Canyon (see map) an old mesa surface known as Apache Potrero extends from the west end of Mount Pinos along the divide between Cuyama Valley and San Joaquin Valley to a point beyond Pattiway Postoffice, several miles to the northwest of the area mapped. The deposit on this surface is made up almost entirely of material redeposited from the underlying Miocene strata, except near Mount Pinos and San Emigdio Mountain where the accumulation is composed of detritus from crystalline rocks.

The mesa at the head of Apache Canyon is covered with material derived largely from Mount Pinos. This extensive surface is largely undissected and is still receiving sediments close to the crystalline mass. A discrimination between older and later Quaternary deposits here has not been made on the map. The peninsular shaped surface extending from the northern extremity of this mesa along the divide between Apache and Quatal Canyons carries on the other hand only redeposited Miocene material (Fig. 10). The terraces in Berges Canyon (Fig. 14) and those in the vicinity of Ozena are similarly covered with

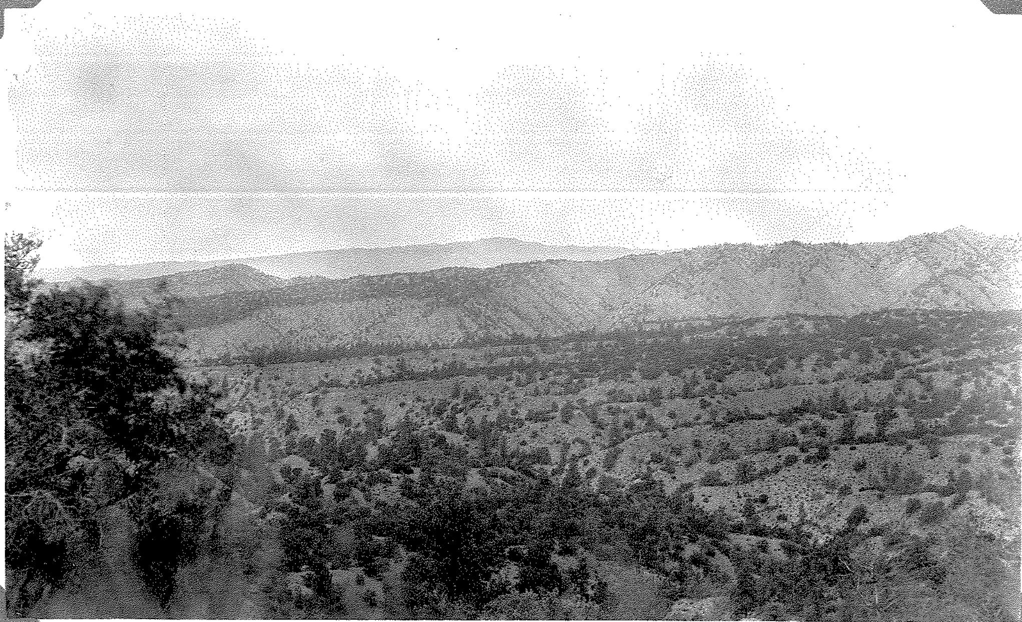

Fig. 14. Terraces at the head of Berges Canyon between Apache and Quatal Canyons.

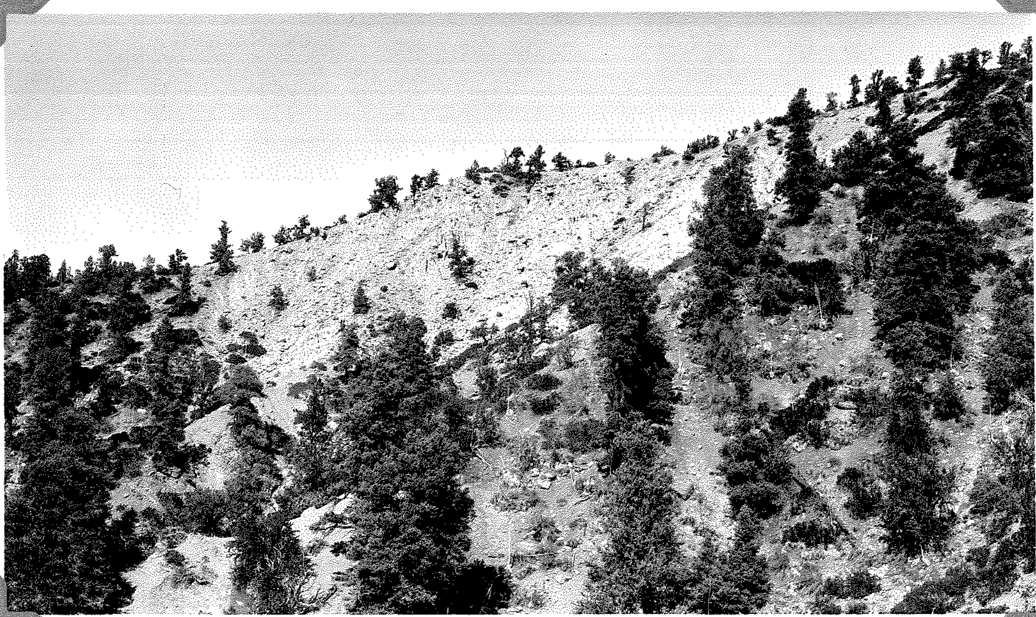

Fig. 15. Coarse granite debris on the peak west of North Fork. This accumulation is about 600 feet thick.

deposits from underlying strata. South of Cuyama River the sediment was derived from Pine Mountain.

The highest peak (elev. 6675 feet) between Lockwood Valley and Dry Canyon has a cap 600 feet thick of coarse granitic gravel (Fig. 15) from Mount Pinos. The gravels scattered from this point southwest down into Dry Canyon are essentially granitic with some redeposited Miocene material. Deposits of a similar nature occur farther east along the south flank of Mount Pinos north of the basalt exposures. The low terraces south of the basalt extending out into Lockwood Valley are probably of later age. The material on the surfaces of these terraces consists of a mixture of detritus from granite, basalt, and earlier sedimentary material.

The surface on the granite, Eocene and Miocene rocks south of Lockwood Valley carries principally granitic material apparently derived from the crystalline ridges projecting above the surface and, to a less extent, material from Eocene and Cretaceous rocks. Occasional fragments of quartz diorite porphyry may have come from the Dry Canyon formation several miles to the northwest or from the crystalline basement near Lockwood Creek.

The source of the greater part of the deposits along the northwest end of Frazier Mountain is not clearly understood. A portion of the accumulation, apparently the more recent sediments, unquestionably came from Frazier Mountain. The latter deposits are coarse and consist principally of quartz diorite porphyry and granite boulders and gravel. A large amount of the older material is coarse brown clayey sand to dark reddish-brown sandy clay. The beds lie unconformably on the somewhat coarser and brighter colored Miocene rocks and on the crystalline basement. To the southeast of the pass between Lockwood and Cuddy Valleys the deposit may be as thick as 500 feet. Movement has taken place on the fault bounding the west end of Frazier Mountain since these deposits were laid down, as shown by drag folding in the beds at the most westerly point of the Frazier block. Furthermore a dip of as much as 23 degrees was observed at one locality (see map). A Pliocene age for this deposit is not improbable but cannot be proven by the above evidence.

Summary of Stratigraphy

The basement complex of the area is composed of old metamorphosed sediments along the north side of the San Andreas Rift, quartz diorite porphyry in Frazier Mountain and to the south, and granite which intrudes the foregoing rocks. Granite occurs in many parts of the area but is most extensively exposed on Mount Pinos. Unaltered sediments of Eocene and Cretaceous(?) age are present in the southern part of the area from the vicinity of San Guillermo Peak westward beyond Pine Mountain. The thickness probably exceeds 15,000 feet. These early sediments are marine and principally light brown to yellow sandstones and dark gray shales. A band of early Tertiary strata along the southeast border of Mount Pinos granite includes Eocene and possibly Oligocene beds although the latter have not been recognized.

The Miocene series includes over 10,000 feet of strata which have been divided into two parts. The lower division is probably entirely terrestrial in origin and is equivalent to the Monterey group as recognized to the west. The upper part is mainly marine and of Santa Margarita age. The Monterey group has been further divided into four consecutive members. At the base of the series north of Lockwood Valley is a series of basalt flows probably of Vaqueros age. This is overlain by nearly 5,000 feet of thin-bedded to coarse massive sandstones which are designated as the North Fork member. Equivalent to these strata a red clay and conglomerate in Quatal Canyon has been recognized as the Pato red member of the Vaqueros. The source of the material in the Pato red member is thought to be Franciscan.

Stratigraphically above the North Fork member between Dry Canyon and Lockwood Valley a series of coarse gray conglomerates, white sandstones and blue-gray mudstones are locally named the Dry Canyon member. Their thickness is nearly 4,000 feet. This member grades upward into alternate red and white sandstone beds which are recognized as belonging to the upper part of the Quatal sandstone. The latter sandstone is best exposed in Quatal Canyon where its thickness is about 4,000 feet. In that part of the area the Dry Canyon member is not discriminated from Quatal sandstone.

Overlying the Quatal sandstone is a thin very persistent bed of gypsiferous clay which is believed to be of volcanic origin. This bed, the Lockwood clay, has been referred to the Santa Margarita. Above the clay horizon is approximately 150 feet of rather well stratified white to yellow sandstone, the Corral member, followed by about 500 feet of tan to brown clayey sandstone. The latter strata are designated as the Castle sandstone and are well exposed in Lockwood Valley and several places in Cuyama Valley.

The upper 4,000 feet of the Miocene rocks, the Apache member, are of marine origin and exposed only in Cuyama Valley. The strata consist of gray or white to cream sandstone, shale, and conglomerate. The material averages rather coarse but is thin bedded. This member is considered to represent a near shore facies of Santa Margarita. A series of sandstones and shales south of the Pine Mountain divide have been designated the Potrero Seco member and are probably equivalent to a part of the Apache member.

The old Quaternary deposits in the area occur on the mesas between the canyons, the surface remnants around the base of Mount Pinos and Frazier Mountain, and on the terraces in Lockwood and Cuyama Valleys. The accumulations consist of redeposited material from the underlying strata and detritus from the adjacent peaks in varying proportions. Part of the material mapped as Quaternary on the northwest flank of Frazier Mountain may be of Pliocene age.

STRUCTURE

General Features

Structurally as well as physiographically the basin area may be divided into two portions, the western or Cuyama region and Lockwood Valley to the east. The Cuyama basin west of Dry Canyon is characterized by numerous folds, the most important being the Cuyama syncline which is responsible for the preservation of the Santa Margarita formation. The axes of the folds in this district plunge to the northwest in most cases, exposing lower beds toward Dry Canyon. The exception to this rule occurs in the southern part of the basin where several en echelon folds plunge southeastward, away from a granite fault block at the mouth of Apache Canyon.

In the eastern division or Lockwood basin the deformation is more acute and faulting has played a larger part. The majority of structural features in this basin strike northeasterly and are of a compressional nature, although normal faulting has also occurred. North of Lockwood Valley a band of highly inclined Tertiary rocks is separated by faults from the valley and from the Mount Pinos crystalline mass.

The pre-Monterey rocks which are faulted up to the south of the Miocene strata are strongly folded. Pine Mountain is an anticlinal feature, the south limb of which appears to have been dropped down by a fault.

Western Basin

The San Andreas rift traverses the area immediately to the northeast of the divide between the Cuyama basin and San Joaquin Valley. The Miocene strata adjacent to the rift are severely crumpled. Farther to the southwest in Quatal Canyon the shattered zone is followed by a series of open folds striking parallel to the rift (see Section O-P).

On the north side of Quatal Canyon a fault extending about five miles in a northwest-southeasterly direction may be responsible for the presence at the surface of a small block of granite (Fig. 16). The fault plane dips about 70° N. and the granite is on the south side which would suggest a normal fault. However, the actual fault displacement seems to have been negligible compared to the amount of crushing which has taken place. The fault apparently becomes a syncline a short distance to the east. Furthermore, an acute anticline parallels the fault on each side at a distance of two or three hundred feet. This indicates that the syncline was closely folded before the break occurred.

Farther south open folding prevails (Fig. 17) for eight or ten miles, the most conspicuous feature being the broad Cuyama syncline. The axis of this fold is the center-line for the structure of the basin. Along a major part of the line the Tertiary strata are more depressed than at any other place in the area (Section O-P). When projected northwestward the axis of the Cuyama syncline nearly coincides with the center-line of the wide portion of Cuyama Valley.

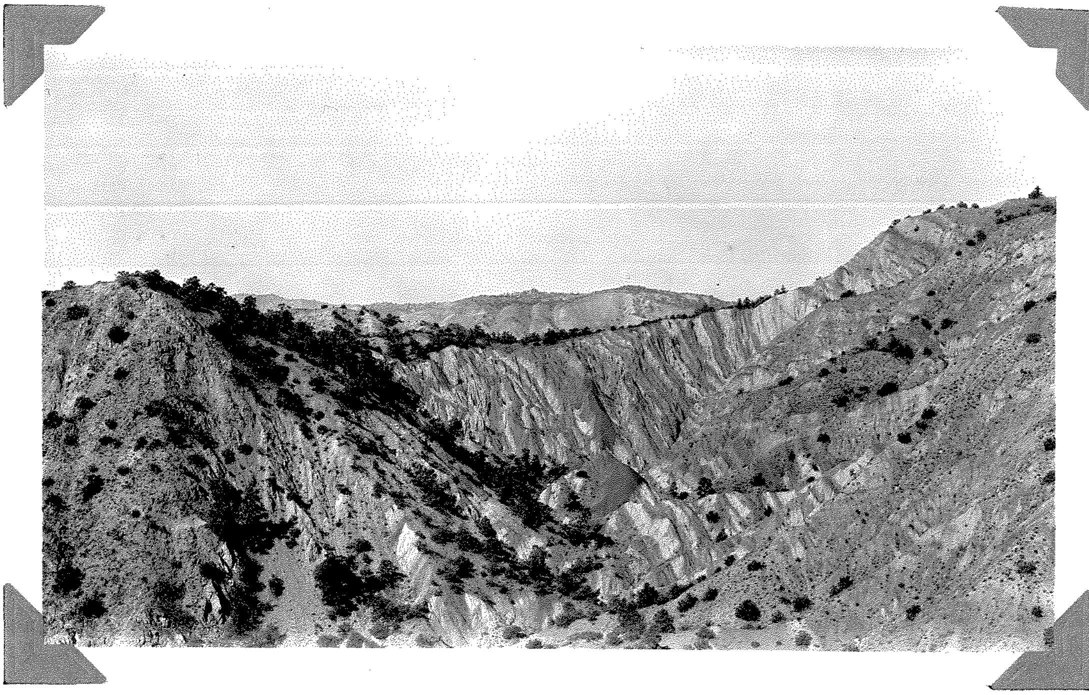

Fig. 16. Fault zone along north side of Quatal Canyon. Granite block on left has apparently been uplifted on this fault. The acute anticline on the north side of the fault zone can be seen to the right.

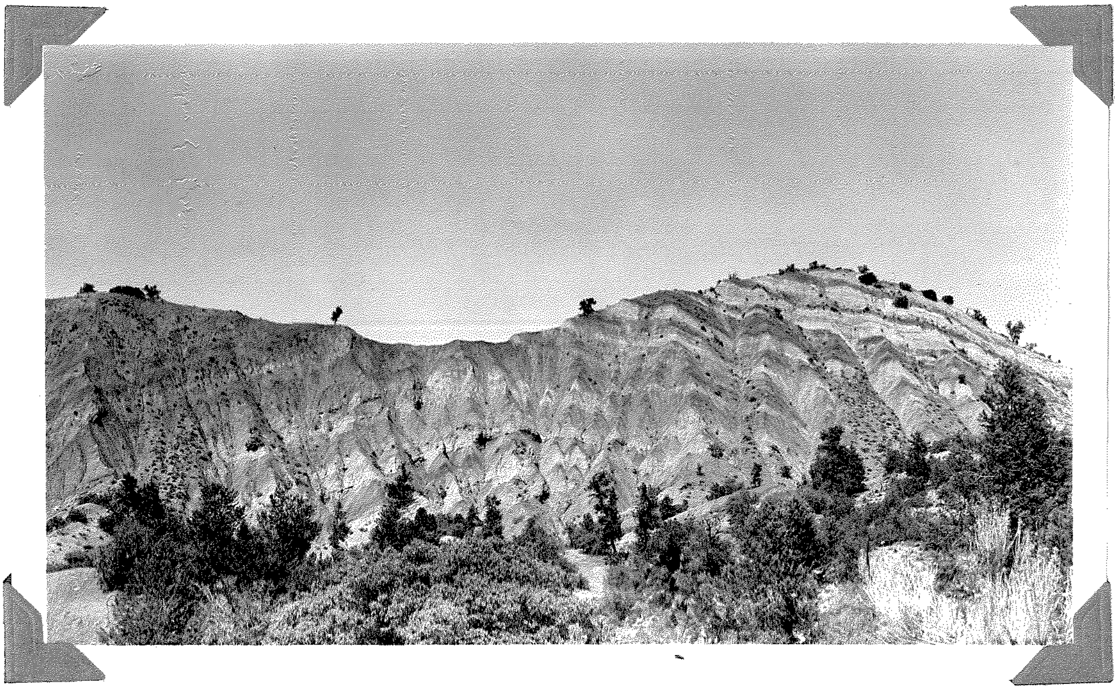

Fig. 17. Broad anticline in Quatal sandstone striking northwesterly across upper end of Apache Canyon.

This fact led English to the conclusion that the greater part of Cuyama Valley is of synclinal origin.

To the south of the Cuyama syncline and about four miles above the mouth of Apache Canyon a small normal fault has had approximately 200 feet displacement, the south block having dropped relative to the north. The fault occurs at the crest of an anticline which two miles farther east is unfractured. Between this dislocation and the granite fault block at the mouth of Apache Canyon the beds are gently folded. The fault bounding the north and east sides of the granite is steep and apparently reverse; the eastward continuation between sedimentary rocks has a dip of 65° S. and is reverse (see Section N-O-P). Less than a mile and a half to the east of the granite this fault changes to an anticline. The southern margin of the crystalline block seems to be in fault contact with the adjoining strata but the relation is not clearly shown.

The Cuyama fault in the southern part of the area is one of the important structural features in the region. This fault forms the southern boundary for Miocene rocks for several miles to the northwest. The trace of the fault within the area is far from a straight line. From a southeasterly strike up Cuyama Valley it changes to east-west near Ozena and then to northeast in Dry Canyon. Between Dry Canyon and Lockwood Valley the fault trace outlines two salients in the older sedimentary rocks and then extends southeast toward the crystalline mass in that part of the area.

Between the old Ozena postoffice and Dry Canyon the Cuyama fault is obscured beneath a covering of alluvium. Its attitude in that vicinity is indicated by the steep southwest dip of the Eocene strata a few feet from the contact, suggesting a reverse fault. East of Dry Canyon the fault has a dip of 80° S. and is clearly reverse as indicated by drag folds (Section L-M).

The Eocene and Cretaceous(?) rocks in the southern part of the area are acutely folded although only three or four structural axes are present. A considerable thickness of rock is involved in the folding. The northerly syncline which crosses the upper part of Alamo Creek dies out westward with the anticline to the south. Reyes syncline at the foot of Pine Mountain is more persistent and can be traced several miles in either direction from the area mapped. The strata in the south limb of this syncline form the north slopes of Pine Mountain. At the top of Reyes Peak the strata become more nearly level and south dips can be seen on the south side of the ridge. The south limb of this anticline is believed to have been faulted down.

In the vicinity of Dry Canyon a transition from the open folding characteristic of the Cuyama basin to the more acute folds and faults of the eastern basin occurs. The folds along the west side of Dry Canyon (Section L-M and Fig. 9) plunge westward, including the Cuyama syncline, exposing lower beds toward the divide between the two basins. The abrupt rise of the axes eastward indicates pronounced uplift or bulging in the region of the divide.

The east-west striking folds lose their identity in the westerly dip on the west side of the dome-like area. The structure however is not as simple as a dome, but involves acute folding and thrust faulting (Sections I-J, J'-K, and G-H, also Fig. 7).

Eastern Basin

The most highly compressed zone in the area is the three miles of Tertiary strata between the most southerly part of Mount Pinos and the salient of pre-Miocene rocks northwest of San Guillermo Peak. The deformation illustrated in Section F-G-H was taken near the divide between Lockwood and Cuyama Valleys.

Bounding Mount Pinos granite on the south, the Chula Vista fault (Fig. 18) can be traced from the divide west of Lockwood Valley in a N.E.E. direction almost to the San Andreas rift which it probably joins. The fault is normal with a south dip of 70° to 80° and has had total displacement of several thousand feet as indicated by the height of Mount Pinos. The strata between the granite and a fault which crosses North Fork about one-half mile above its mouth are highly inclined with variable dips.

The first recognized fault to the south of the Chula Vista fault can be traced from an acutely folded syncline in the basin of Wagon Road Canyon (Fig. 7) through what appears to be a thrust on the divide to a nearly vertical fault in Middle Fork

Fig. 18. Chula Vista fault at head of lower North Fork Canyon. Eocene shale is in contact with granite (left). Above the granite is an old Quaternary deposit of debris from Mount Pinos.

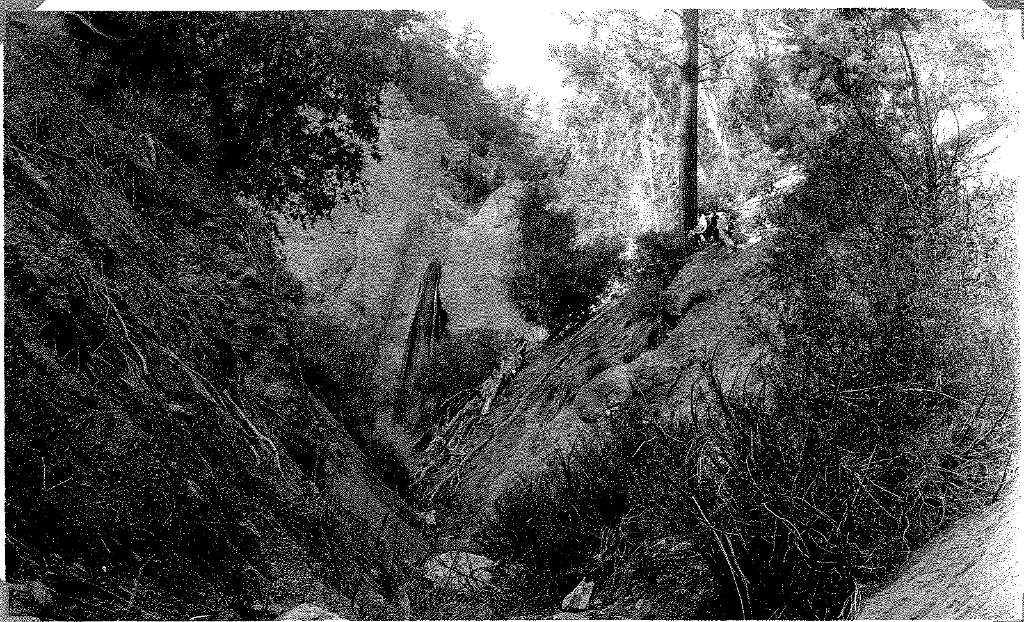

Fig. 19. Falls at granite contact (Chula Vista fault) in Bitter Creek Canyon.

Canyon. The above syncline to the west of the divide is broad and open near Dry Canyon, but is acutely folded in the vicinity of the divide. Between the point of fracture and North Fork the beds on the north side of the fault are overturned (Fig. 7). East of Middle Fork the structure apparently continues on as a syncline as far as Cuddy Valley.

Lockwood fault which bounds Lockwood Valley on the northwest extends from the Cuyama fault at the divide between Dry and Wagon Road Canyons to Cuddy Valley. The rocks along the north side of Lockwood fault belong either to the Dry Canyon member or earlier formations and those along the south side are Quatal sandstone or later strata. The displacement may have been as much as 7,000 feet in some places as shown by the adjacent position of Quatal sandstone and Eocene(?) strata in Bitter Creek. The attitude of Lockwood fault is not known. Observations made at the mouths of several canyons indicate that it may be nearly vertical. On the divide west of Lockwood Valley the attitude of the beds on the north and south side of the fault suggests that it is reverse (north dip).

Two smaller faults to the south of Lockwood fault on the divide are also reverse. Between these and the Cuyama fault at the head of Wagon Road Canyon the Miocene strata have been rather strongly folded, as shown in the vicinity of G in Section F-G-H. Farther east in the central part of Lockwood Valley folding is pronounced but not as acute (see Section D-E).

Bounding the south side of Lockwood Valley, San Guillermo fault extends from Cuyama fault northeast and eastward into the adjoining area of the Tejon quadrangle. The surface of contact is exposed in several places east of Griffin (Snedden's Ranch) and clearly indicates a normal fault. Measurements of the dip vary from 45° to 80° N., 65° to 70° being most frequent (Sections A-B and D-E). The displacement is unknown; upper Miocene strata are placed adjacent to the crystalline basement.

Matau fault, extending southeast from the old erosion surface south of Lockwood Valley, may be a continuation of Cuyama fault. It can be traced as far south as Hot Spring Canyon near Sespe Creek, probably farther. The attitude of the fault plane has not been observed but it is apparently quite steep. Matau fault has had a resultant displacement opposite to that of Cuyama fault. The former has placed early Tertiary or Cretaceous rocks on the southwest against granite, whereas along the north side of Cuyama fault the strata are of Miocene age.

Thrust faulting in which crystalline rocks ride over Tertiary sediments is recognized in two different parts of the area, on the south side of Frazier Mountain and at the west end of Mount Pinos. At Frazier Mountain the quartz diorite porphyry and granite complex has been thrust south or southeast over beds of upper Miocene age. Immediately above the plane of thrusting the crystalline rock is badly shattered for ten or twenty feet but the underlying strata are relatively unaffected. Along the most southerly part of the mountain the thrust plane dips northward at an angle of 10° to 20° (Section A-B-C). The south end of the upper block is separated by only a few hundred feet from the same kind of rocks which have been uplifted along the San Guillermo fault. At the west end of Frazier Mountain the contact between basement and Miocene is a reverse fault having a dip of 50° to 60° under the crystalline mass. A small section of the contact between the western extremity of the thrust and south end of the reverse fault is obscured by talus and terrace deposits.

Thrust faulting recognized at the west end of Mount Pinos has been exposed through headward erosion in Cuatal Canyon (Fig. 20). The half mile trace shown on the map is the only locality where the thrust has been seen. To the north and south it is hidden by the old mesa covering and by more recent talus. The extent of the fault is not known. It has not been recognized in the structures north of Lockwood Valley (Section I-E). The granite there is limited southward by a normal fault. The thrust is believed to exist beneath granite along the southwest part of the mountain north of Dry Canyon. This is suggested by the proximity of the thrust exposure and the nature of the folding in strata to the south. The south limbs of the anticlines exposed on the west side of Dry Canyon are much steeper than the north (Section L-M), presumably due to a tangential shearing force from the north as in cases of step folding.

At least two faults with horizontal displacement radiate from Mount Pinos and offset the northeast-southwest structures

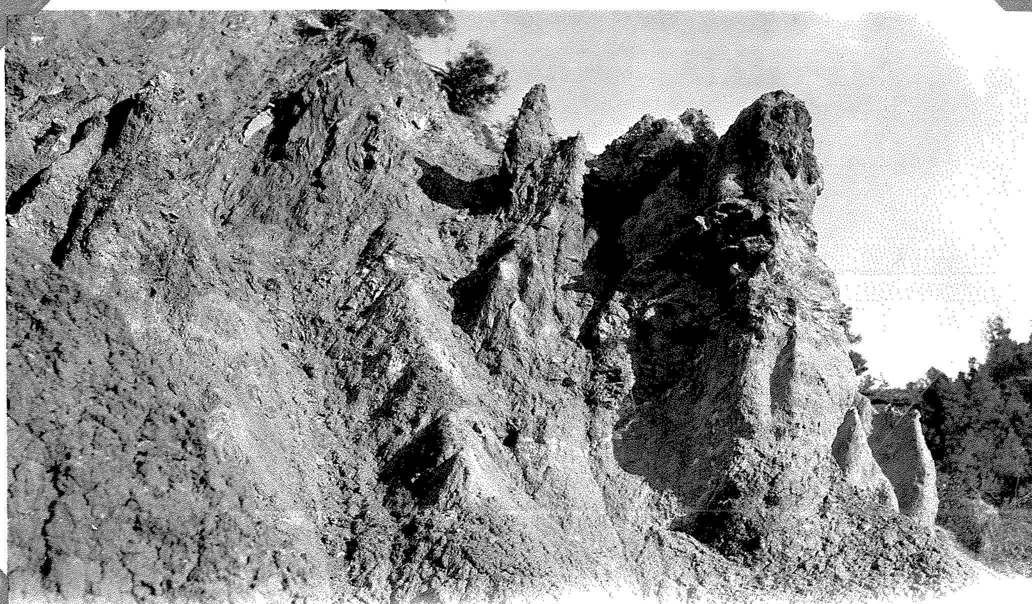

Fig. 20. Thrust at head of Quatal Canyon on west end of Mount Pinos. Highly crumpled schist resting on Quatal sandstone.

along the south flank of the mountain. Their displacement is greatest at the Chula Vista fault but decreases toward the valley and in each case the westerly block moved south. In Seymour Creek the fault is marked by a line of springs and is nearly parallel to the San Andreas rift. At the granite contact the displacement may be as great as 1000 feet but near the mouth of the creek Lockwood fault is only offset 200-300 feet, indicating greater compression in the western block. H. S. Gale (1914, pl. IX) believed two faults to be present in this canyon. Gale (p. 451) also suggested that Bitter Canyon possibly represents a line of transverse faulting. For lack of substantiating evidence the two latter faults are not shown on the map.

The second recognized transverse fault occurs in North Fork Canyon. It offsets the Chula Vista fault 100-200 feet and a slight dislocation of the arkose beds farther down the canyon was observed.

Summary and Conclusions

The structural axes in the Cuyama basin are for the most part parallel to the San Andreas rift, but in the vicinity of Mount Pinos they are arranged either concentric or radial to this crystalline mass (see map). The folding and faulting in the basin sediments, as illustrated in the cross-sections, clearly show considerable tangential shortening of the crust in this region.

Compression in the Cuyama basin is perpendicular to the rift, but in the central part of the area and in the eastern basin the shortening has taken place in a direction radial to Mount Pinos. The major structures in Cuyama Valley as the Cuyama syncline, Cuyama fault and the Pine Mountain-San Rafael uplift are probably related to coast range deformation. The more local folds and faults appear to be accessory features, in many cases resulting from forces associated with rift activity.

The structural pattern and the directions of crustal shortening in the basin region adjacent to Mount Pinos strongly indicate that the compression and distortion was due to the relative movement of the more competent masses. The Mount Pinos block has acted as an obtuse wedge in transmitting pressures to the basin sediments. The Pine Mountain block and the crystalline mass in the southeastern part of the area have acted as bulwarks against which the basin rocks have been shoved. The more acute deformation close to Mount Pinos compared with the broader folds farther away (Sections D-E, F-G-H, and L-M) further indicate that the forces came from the north through Mount Pinos.

Pressure from the north has affected the rocks differently over the area. At the west end of Mount Pinos ridge shortening is expressed in thrust faulting (Section L-M), but the eastern and central part of the mountain mass have crumpled the basin sediments in the movement (Section F-G-H). Still farther east at Frazier Mountain the compression is again taken up in thrust faulting (Section A-B-C).

The conclusion that the forces which deformed the strata south of Mount Pinos came from the north is important in view of observations by H. W. Hoots (1930) on the structure north of San Andreas rift. Hoots considers that forces which affected the strata to the north came from the south. These conclusions indicate that the structures resulting from pressures transmitted by Mount Pinos are related to the rift.

The origin or cause for such forces, as suggested by Dr. J. P. Buwalda for the case of Frazier Mountain, may lie in the irregularity of the rift in this vicinity. The decided change in the strike of the rift from southeast in the McKittrick quadrangle to nearly east-west between Mount Pinos and San Emigdio Mountain would involve marked difficulties in the event of horizontal displacement.

GEOMORPHOLOGY

Terraces and Mesas

The numerous mesa remnants and the general conformity of ridge heights over a large part of the Cuyama basin show beyond question the former existence of an extensive surface having considerably less relief than is present in the basin now. The continuity of the surfaces around Mount Pinos from Apache Potrero north of Quatal Canyon to the surface between Seymour and Bitter Creeks north of Lockwood Valley is quite evident (see map). The continuation of the surface across the head of Dry Canyon is illustrated in figure 8.

The well preserved table south of Lockwood Valley (Fig. 22) has about the same elevation as those around Mount Pinos. The former coextension of this mesa with those to the north is highly probable. Their continuity is suggested on the divide west of Lockwood Valley along which small remnants are distributed at an elevation near 6000 feet. Both surfaces extend across soft terrestrial Miocene strata, hence it is not likely that one would have been preserved during the subsequent development of the other if their ages were different.

The conformation of these mesa remnants is decidedly suggestive of the physiography of this early land surface. The slope of the land was in a general direction similar to that of to-day. The surface was roughly 500 feet above the present valley floors in most parts of the region. Observations from these mesa

Fig. 21. View northwest over basin of Wagon Road Creek from San Guillermo Peak. Eocene or Cretaceous in foreground and Miocene to the north of canyon. Scarred dome in middle background is high point on divide between North Fork and Dry Canyons.

Fig. 22. Mesa surface south of Lockwood Valley from south side of San Guillermo Peak. Frazier Mountain is in the left background and Alamo Peak in the right.

remnants in various parts of the area show that the present valleys and many of the canyons had their positions defined on this old land level. Evidence supporting this conclusion is found in superimposed streams which will be discussed in the section devoted to stream features.

In the Wagon Road Canyon region between Lockwood Valley and Dry Canyon the elevation of the mesa remnants above the canyon floor in most cases greatly exceeds 500 feet. The mesa south of Lockwood Valley at an average elevation of 500 feet above the valley rises at its western extremity to the top of San Guillermo Peak which reaches an elevation of about 700 feet above the mesa. On the western side the peak (Fig. 3) is 1500 feet above the bed of the canyon at its foot. The topography of this surface indicates that San Guillermo Peak was in Pleistocene as now on the divide between the east and west drainage.

Similarly, the peak (elev. 6675 feet) (Figs. 15 and 21) between North Fork Creek and Dry Canyon is 1500 feet above a part of Wagon Road Canyon and is a high point for the surrounding mesa remnants. Presumably this peak and San Guillermo Peak were united by a ridge or series of peaks across the intervening now highly dissected basin (Figs. 7 and 21). The ridge is considered to have been somewhat west of the existing divide inasmuch as erosion is much more active on the west side, due to steeper stream gradients and lower base level.

The terraces formed in Cuyama and Lockwood Valleys subsequent to the mesa surface are at more than one elevation above the valley floor. The most conspicuous set of terraces occurs at a height of approximately 100 feet above the present stream beds. The similar development and preservation of terraces at this level in both the eastern and western basins suggests an equivalent age. A later level is well represented around the mouth of several of the canyons opening into Cuyama Valley farther to the northwest. These terraces vary from ten to twenty feet above the stream beds. The latest terrace features are quite recent and make up the larger part of the valley floors. Nearly all of the stream beds in valleys and canyons are incised from two to four feet below the main part of the alluvial surface.

Stream Features

The stream pattern and history is closely related to the original configuration of the old land surface discussed above. The position of the major portion of most of the large canyons was defined on this surface. Many of the canyons have subsequently enlarged their basins by headward erosion and perhaps in a few cases through piracy. Quatal Creek has enlarged its basin in the upper portion by headward erosion and at the same time robbed Apache Canyon of a part of its original upland basin. Evidence for this lies in the south slope of the mesa remnant between Apache and Quatal Canyons. The surface of this mesa has no drainage into Quatal Canyon. Several of the tributaries to Apache Canyon end northward in a wind gap on the divide between the basins. The greater erosion in Quatal Canyon is due to the shorter stream route, hence a steeper average gradient, and to the presence of more easily eroded sediments.

The headward erosion in Dry Canyon has been going on rapidly due to the character of the strata in the upper part of its basin. Dry Canyon is about to capture a portion of the headwaters of Apache Canyon near the northern end of the former. Wagon Road Canyon between Dry Canyon and Lockwood Valley has succeeded in cutting down the originally high country between the two major basins and through headward erosion has moved the divide farther east. Evidence for this is present in the wind gaps along the divide at the heads of short but rather prominent canyons on the Lockwood side. Two such canyons whose mouths meet at the lower end of North Fork Creek when followed upward rise gradually to the gap where they terminate abruptly in a steep slope down into Wagon Road basin. A similar, but less pronounced case occurs at the head of Wagon Road Canyon where the old abandoned road between Lockwood and Cuyama Valleys crosses the divide.

Many of the canyons in the earlier sedimentary rocks south of Cuyama and Lockwood basins are of subsequent origin in that they follow the strike of the softer shale horizons. This is particularly noticeable in the upper parts of Reyes and Beartrap Creeks. These creeks are largely guided by the soft shale core of a close folded syncline. Most of the southerly tributaries of Wagon Road Creek flow between strike ridges.

Lockwood Valley is bounded in part by structural features but owes its present shape entirely to differential erosion. It formerly extended at a higher level to the north and south over harder rocks, but its present pattern is due to rejuvenated stream action and the relative hardness and softness of rocks.

The conclusion that the physiography of the former land surface defined the present stream pattern is substantiated by evidence for the superimposed character of many of the canyons. Nearly all of the creeks in the southeastern part of the area flow toward a rugged crystalline mass; a more direct route would have been west and south to Sespe Creek. Piru, Mutau, and Lockwood Creeks enter gorges from soft sedimentary formations, unite and flow eastward across the mass and out into sedimentary rocks in the area of the Tejon quadrangle. A small tributary to Lockwood Creek just south of Lockwood Valley flows parallel to the granite sedimentary contact just within the crystalline area for a distance of about four miles. Piracy from the north is imminent in several places along its course.

The superimposed character of canyons in the Cuyama basin is illustrated in several places. The upper part of Wagon Road Canyon is expanded in an area of soft Miocene rocks where headward erosion is probably largely responsible for its position as previously discussed. Farther west the lower part of the canyon enters harder Eocene and Cretaceous(?) rocks instead of following the softer beds or possibly the shattered contact between them.

Subsequent streams following the fault zone may have decapitated some tributaries which originally flowed across the contact at a higher elevation. The alignment of small canyons suggests such a history.

The upper part of Cuyama Valley in general follows the Eocene-Miocene contact for about twelve miles, but in two instances it cuts through harder rock rather than the fault zone or Miocene rocks. Near Ozena (Wagy Ranch) the fault contact is found high up on the northeast cliff of the canyon. The second and more striking case occurs at the mouth of Apache Canyon. The latter tributary and Cuyama Valley join in the western part of a small area of granite. Apache Creek enters the block from the eastern side, flows across its widest part through a relatively narrow gorge, and joins Cuyama River as it passes through a part of the block. This is clearly due to superposition from the old land surface. A more conformable position for Cuyama River would have been a few hundred feet farther west in the fault zone between the granite and Eocene shale.

Badlands

The development of typical badlands in the area is restricted to exposures of terrestrial deposits occurring in the middle and lower part of the Miocene series (Figs. 7, 9, 10 and 11). A rugged relief simulating badland physiography is present in the

Eocene and Cretaceous(?) rocks in the southern part of the region (Figs. 2 and 3). Although steep and highly dissected the exposures do not show the fluted and pinnacle structure characteristic of Quatal sandstone (compare Figs. 4 and 10). The badland physiography developed in the terrestrial portions of the Miocene rocks is in marked contrast to the relatively smooth surfaces typical of the marine strata higher in the sequence (compare Figs. 7, 10 and 11 with 12 and 13, also lower and upper parts of Fig. 8).

The association of the two types of physiographic expression represented by the different parts of the Miocene series shows that one is not developed in a more arid or more humid condition than the other (the semi-arid climate of this area is indicated by the vegetation in Figs. 8 and 11). It is evident that the difference is due to lithology. The heterogeneous unsorted character of terrestrial deposits in which some constituents may be more soluble than others lends itself readily to the formation of badlands through the selective action of rain wash. Places where soluble or softer parts are exposed become dissolved or washed out. Immediately adjacent places, perhaps protected by a few coarser fragments, are preserved and may eventually become pinnacles. In better sorted marine deposits the more soluble constituents are either absent or perhaps uniformly distributed. The sorting tends to destroy to a certain extent the selective action of rain wash. Consequently the presence of badlands of the type described above is good evidence for a terrestrial origin of beds.

Fault Line Scarps and Fault Scarps

Scarps along faults occur in several places in the region and in many instances it can be shown that they are erosional features. The granite block at the mouth of Apache Canyon has a scarp along its south face which is not due to recent movement inasmuch as the top of the block conforms to the early Quaternary land surface and two canyons have been superimposed on it.

The most striking examples of fault line scarps are found in the southeastern part of the area. The scarp along San Guillermo fault southeast of Lockwood Valley rises about 500 feet above the valley between Lockwood and San Guillermo Creeks. With the exception of a few old peaks the upper surface of the crystalline block conforms with the elevation of the old land surface, in fact mesa remnants can be traced from one block to the other. Furthermore, Lockwood Creek flows from the lower block to a gorge in the higher. If the scarp were due to recent faulting and not differential erosion it would be expected that the drainage would be in the reverse direction, unless Lockwood Creek is an antecedent stream. There is no evidence to show that Lockwood Creek is antecedent and much to show that it is superimposed. The latter has been previously discussed.

The scarp along the southwest margin of the crystalline block south of Lockwood Valley is similarly crossed by streams flowing toward the crystalline block. If the scarp were raised across their paths Mutau Creek would never have followed its present course. Mutau Creek is a relatively weak tributary to Piru and enters the crystalline mass a short distance south of the Piru gorge and joins it about two miles down stream. Furthermore, the mesa surface extending over the crystalline and Lockwood blocks also continues over this southwesterly block without dislocation at the fault.

The evidence used to show that the above scarps are fault line scarps may be summarized as follows: 1) The top of the higher block is a part of an old surface which extends across the fault in one or more places without dislocation. 2) The streams invariably flow from the lower to the higher block by entering gorges. 3) The streams are superimposed. 4) The higher block is the more resistant.

The scarps along the faults bounding Mount Pinos and Frazier Mountain cannot be classed as fault line scarps or erosional features on the basis of the preceding evidence. They project above the mesa level and all drainage is toward the lower blocks. Their streams are probably all consequent and subsequent, not superimposed. There is evidence along the Chula Vista fault south of Mount Pinos that the scarp may be in part a fault scarp. Each of the three streams, Bitter Creek, Middle Fork, and North Fork, on the south flank of Mount Pinos have high, sharply defined falls at the fault contact (Fig. 19). However, it would be difficult to say that these are due to faulting and not to differential erosion.

Summary of Physiographic History

Although the Cuyama River shows in a few cases that its pattern was inherited from the early mesa surface its position near the contact between Miocene and older rocks for many miles to the northwest indicates that its location was defined by regional structure earlier than the development of the mesa. Other indications of the nature of the physiography previous to the mesa surface are scarce. It is probable, however, that the high and low areas were defined at a very early period. The Cuyama formation of Pliocene(?) age is considered by English to have been deposited over a little broader area than the present Cuyama Valley, but the basin was roughly defined at that time.

Erosion which followed the deposition of the Cuyama formation developed the mesa surface discussed in earlier paragraphs. The topography at that time was not a level plain and most of the present canyons inherited their pattern from the irregularity of this surface. Rejuvenation of the streams, probably through regional uplift, caused them to become deeply incised, and several streams flowing in softer material than others have enlarged their basins at the expense of adjacent canyons. That uplift has not been steady is indicated by the terraces preserved on the sides of the valleys.

Lockwood Valley, bounded by faults and high masses along most of its periphery, strikingly simulates a structural depression but its physiographic development has been almost entirely erosional since the rejuvenation of stream activity on the mesa surface.

Further changes in the physiography are imminent provided the cycle is not interrupted through diastrophism. Those streams such as Sespe and Cuyama which have their upper courses exclusively in sedimentary materials are making rapid strides toward the capture of headwaters of Piru Creek. Piru, Mutau, and Lockwood Creeks are handicapped in their rate of downcutting by crossing an area of hard crystalline rock.

GEOLOGIC HISTORY

Sedimentation

The early history of the region is very obscure and the few events recorded are poorly dated. The time relation between the quartz diorite porphyry intrusion and the deposition of the early Mesozoic or Paleozoic limestones and shales is indefinite. Both, however, have been intruded by granite which W. A. English considered to be of Jurassic age.

The post-Jurassic history of the region may be summarized as follows: The Eocene and Cretaceous(?) seas were very extensive and probably covered the whole of this area, although there are brackish water phases in the sequence. Not until near the top of the series north of Lockwood Valley is there any evidence of an emergent land mass in the vicinity of Mount Pinos. At that horizon there are two well indurated reefs of granitic arkose, very similar to the present material on Mount Pinos. It is not certain whether this upper series of strata between recognized Eocene beds and Miocene lava is of Eocene or Oligocene age.

The Miocene sequence as recognized in this area was initiated by basaltic lava extrusions with intervening periods of arid desiccation which have resulted in the colemanite deposits. During the heavy terrestrial sedimentation that followed there is good evidence for a mountainous mass of bold relief near the site of Mount Pinos, or possibly Lockwood Valley. This mass contributed to the accumulation quartz diorite porphyry as well as granite boulders, such as are now being deposited near Frazier Mountain. Later in Monterey time the deposition of quartz diorite porphyry boulders ceased, the accumulation became finer and was spread over larger areas, perhaps covering much of the territory now occupied by crystalline rocks. Degradation and filling continued into the upper Miocene, at which time the sea invaded at least the western part of the region. This apparently represents the first and last marine deposition since the Eocene.

After the Miocene the entire region was lifted above sea level, extensively folded and faulted. The basin areas were beveled and covered with a mantle of debris derived in part from crystalline areas and in part from the underlying beds. Further uplifts rejuvenated erosive action and the present cycle was evolved. The later physiographic history has been outlined on preceding pages.

Diastrophism

The post-Miocene diastrophic history has been very complicated, but apparently three periods of faulting can be discerned, which may greatly overlap. One period was that in which Mount Pinos and the crystalline mass southeast of Lockwood Valley were elevated by high angle normal faulting, perhaps by radial forces. A period of compression took place during which the basin sediments were folded and faulted. In the vicinity of Mount Pinos the strata were highly deformed by forces recognised as coming from the north. The third was that during which the previously developed structures were offset by faults with horizontal displacement, and was probably associated with activity on the San Andreas rift.

The order of the first two periods is not certain, but the crumpling in sediments north and west of Lockwood Valley suggests the presence of a competent mass at the site of Mount Pinos. However, this mountain may have been further uplifted since compressional forces became active. The thrust faulting which unmistakably occurs in Frazier Mountain and in the western part of Mount Pinos may be associated with the third period of horizontal fracturing, or may well have originated during the intense crumpling of the basin sediments. It is apparent from the relative shortening of the blocks adjacent to the faults with horizontal displacement that compression continued into the third period.

ECONOMIC RESOURCES

Various kinds of mining have been undertaken in the area investigated, but little is being done at the present time. Past and present operations include the mining of gold, antimony, borax, and clay, and drilling for oil.

The gold mining in Ventura County has been confined to the region of the upper Piru drainage basin in the vicinity of Frazier and Alamo Mountains and the crystalline area to the south of Lockwood Valley. Gold has been obtained both from fissure veins and placers. Vein mining began about in 1867 at the Frazier Mine and since that time a number of different properties have been operated. A production of about $1,000,000 is reported for the Frazier Mine but it has not operated since 1895. Mining in the district has been intermittent but development work has continued into recent years. The veins are principally associated with the more shattered portions of the quartz diorite porphyry of Frazier Mountain.

Placer mining has been carried on in the gravels of the stream beds on the west end of Frazier Mountain and particularly in the terraces from San Guillermo Creek to Lockwood Creek on the southeast side of Lockwood Valley. The deposits between Lockwood and San Guillermo Creeks are considered to be the first worked placers in the state (Fairbanks, 1894, p. 494; see also gold resources of Ventura County in various annual reports of the State Mineralogist). The deposits were discovered in 1841 by Andres

Castillero, and in 1842 gold was shipped from here to the mint in Philadelphia. Sluicing and rocking has gone on intermittently for many years but nothing is being done at the present time.

The antimony deposits of this region occur in the crystalline complex north of the rift in the vicinity of San Emigdio Mountain and Antimony Peak. The deposits were supposedly worked by the Padres during the missionary period (see 3rd, 10th, and 14th Annual Reports of State Mining Bureau). The localities were reopened in 1876 and the ore obtained was crushed, concentrated and smelted in San Emigdio Canyon below the mines. The ore is reported to contain 30-45% stibnite and from $4.00 to $16.00 of silver per ton. At Antimony Peak the ledge is about eleven feet wide and has a north-south trend. Also a fair sized body of magnetite has been reported in the vicinity of the San Emigdio mines. The antimony deposits have not been worked for a number of years due to low prices. California antimony was revived during the World War but the production again subsided at its close, due principally to the Chinese output.

The colemanite deposits on the north side of Lockwood Valley were first discovered in 1898 and are classed among the few important borax deposits of the United States. Three mines were developed, the Frazier (Fig. 23), Russell (Fig. 24) and Columbus properties, and production which began in 1899 continued until 1907 and was resumed from 1911 to 1915.

Fig. 23. Frazier borax mine (abandoned) on north side of Lockwood Valley. Colemanite was mined from lenses of limestone and colemanite interbedded with basalt flows.

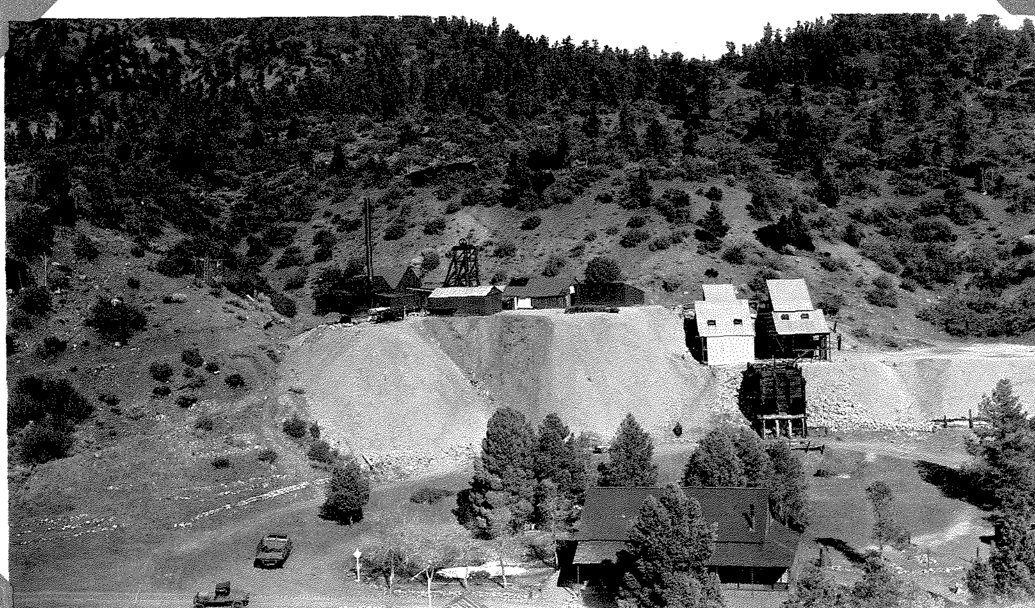

Fig. 24. Russell borax mine (abandoned) on Seymour Creek. Building in foreground is Stauffer P.O.

Transportation has been the chief problem and is responsible for the discontinuance of operations. The recent development in the vicinity of Kramer on the Mojave Desert has resulted in the discovery of the mineral kernite which is of higher quality than colemanite.

The principal occurrence of colemanite in Lockwood Valley is in association with limestone lenses interbedded with basaltic lava flows. Borax minerals are also found in the gypsum-bearing shales below and above the lava. The beds and flows strike N.N.E. and are highly folded and faulted.

The presence of the borax minerals in association with lava at first led H. S. Gale (1914, pp. 438-443) to believe that the colemanite was derived from the lava and occurred as a replacement of the limestone. W. F. Foshag showed later that the replacement was more likely in the reverse direction, and in connection with his investigation at Kramer discovered that colemanite forms as an alteration from ulexite. Ulexite is a product of playa lake desiccation, where the borax content of the playa may be derived from volcanic springs.

Clay is being mined at the present time from a large exposure near the east end of Lockwood Valley. The material is part of the basal member of the Santa Margarita. Excavation work has only recently started and consists simply in operating a cable shovel (see Figs. 26 and 27). The clay is hauled by truck to points in San Joaquin Valley to be used as a rotary mud in drilling for oil.

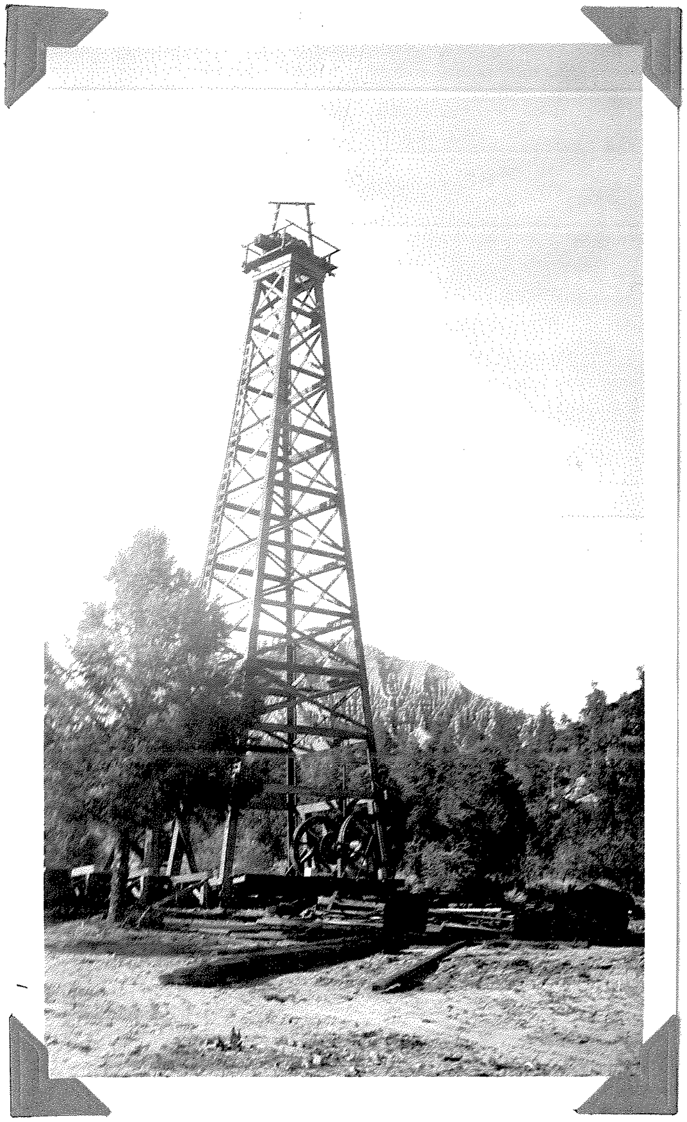

Fig. 25. Oil derrick recently erected in Lockwood Valley just south of the mouth of Middle Fork Canyon.

Figs. 26 and 27. Clay mine at east end of Lockwood Valley. Lockwood clay at base of Santa Margarita formation.

A fire-test has shown the clay to be a poor refractory material.

The oil prospects of the Cuyama Valley have already been reported on by W. A. English (1916, p. 214) and considered unfavorable. Two wells drilled in the Cuyama basin to the west and northwest have been unsuccessful. A well started near Ozena has been abandoned, and another in the basin of the Piru was abandoned after the tools were lost.

A well is being drilled at the present time in Lockwood Valley, in the southeast part of section 28, T. 8 N., R. 21 W., S.B.M. (Fig. 25). The drilling has started near the top of a conspicuous anticline.

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