GEOLOGY OF THE
QUIEN SABE
QUADRANGLE
CALIFORNIA

BULLETIN 147
1949

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO
GEOLOGY OF THE
QUIEN SABE
QUADRANGLE
CALIFORNIA

By
CARLTON JAMES LEITH

QUICKSILVER AND ANTIMONY DEPOSITS OF THE
STAYTON DISTRICT, CALIFORNIA

BY EDGAR H. BAILEY AND W. BRADLEY MYERS
U. S. DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY
LETTER OF TRANSMITTAL

To His Excellency

The Honorable Earl Warren
Governor of the State of California

I have the honor to submit herewith Bulletin 147, Geology of the Quien Sabe quadrangle, prepared under the direction of Olaf P. Jenkins, Chief, Division of Mines, Department of Natural Resources. It is one of a series of such bulletins on specific areas in California which the Division of Mines is engaged in publishing. Accompanying this report are detailed geologic and economic mineral maps of the Quien Sabe quadrangle, which covers portions of the counties of San Benito, Merced, and Santa Clara.

The author of Geology of the Quien Sabe quadrangle, Dr. Carlton James Leith, prepared this report in partial fulfillment of the requirement for the degree of Doctor of Philosophy at the University of California. His work was done under the supervision of the Department of Geological Sciences and also in cooperation with the Division of Mines. The results of the work are basic and fundamental to the understanding of the state’s mineral deposits and related geological features.

Included in this same bulletin is a detailed economic report prepared by the Geological Survey, Department of the Interior, Quicksilver and antimony deposits of the Stayton district, California, by Edgar H. Bailey and W. Bradley Myers. The Stayton district is located within the Quien Sabe quadrangle and is the principal commercial mineral-bearing area in it.

Respectfully submitted,

Warren T. Hannum, Director
Department of Natural Resources

May 24, 1949
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GEOLOGY OF THE QUIEN SABE QUADRANGLE, CALIFORNIA*

BY CARLTON JAMES LEITH**

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* This report represents a portion of a dissertation accepted for the requirements of the degree of Doctor of Philosophy in Geology, in the Graduate Division of the University of California, Berkeley, California. Manuscript submitted to the Division of Mines for publication August 4, 1947.
** Assistant professor, Indiana University.
Fig. 1. Index map showing location of Quien Sabe quadrangle. Underlined quadrangle names indicate other recently published geologic quadrangle maps in the region.
ABSTRACT

The Quien Sabe quadrangle, located 90 miles southeast of San Francisco, includes a portion of the crest of the Diablo Range of the central Coast Ranges of California, and lower rolling country toward the San Joaquin Valley to the east. The following stratigraphic units were mapped: Franciscan group, Upper Jurassic, arkosic sandstone with subordinate siltstone, shale, conglomerate, volcanic rock, radiolarian chert, basic and ultrabasic intrusive rock, and glauconite schist; Upper Cretaceous arkosic sandstone, conglomerate, and shale; Vaqueros formation, lower Miocene, limestone; Quien Sabe volcanics, probably middle Miocene, including biotite andesite, oxyhornblende andesite, hypersthene-augite andesite, olivine basalt, dacite, tuffaceous sediment and agglomerate, plagioclase intrusive masses of andite-hornblende-biotite andesite, and hydrothermally altered rhyolite plugs; Peckham formation, upper Pleistocene, lake beds consisting of gravel, sand, silt, and limestone; and Quaternary alluvium, terrace deposits, and landslides. Most of the Franciscan sandstones of the Quien Sabe quadrangle have suffered only slight metamorphism.

The Ortigalita fault marks the boundary between the volcanic-capped Franciscan core of the Diablo Range and the Cretaceous rocks in the foothills to the east. Two periods of faulting are represented in the southwestern portion of the quadrangle; post-middle Miocene northeastward-trending faults are offset by faults which show evidence of Quaternary movement and which strike northwest. Except for the Franciscan, which has suffered a long and complex deformational history, folding is less pronounced than faulting. Cretaceous sediments locally are overturned against the Ortigalita fault; their general dip in the northeast quarter of the quadrangle is moderate to the northeast. Exposures of Cretaceous rocks in the southwest portion of the area are not abundant, but the attitudes that can be seen suggest an anticlinal structure. Miocene volcanics are warped and faulted, and upper Pleistocene lake beds are undisturbed.

Manganiferous Franciscan cherts have yielded a small amount of manganese ore from oxide deposits located in the south-central portion of the quadrangle. The Stayton mining district, near the northwest corner of the area, has produced minor amounts of antimony and quicksilver since 1870; stibnite and cinnabar occur in silicified fault zones in the Quien Sabe volcanics. Most of the properties are idle.

INTRODUCTION

Location and Geographic Features

The Quien Sabe quadrangle (scale 1:62,500) of the U. S. Geological Survey, is located 90 miles southeast of San Francisco and 13 miles east of Hollister, California. It includes the southeast corner of Santa Clara County, the northeastern portion of San Benito County, and a portion of western Merced County. The corner common to the three counties is in the northwest quarter of the quadrangle. There are no towns or settlements within the limits of the area. The land is used chiefly for cattle grazing, but in favorable local areas, such as the wide, flat bottom lands of Los Banos Valley and Quien Sabe Valley, grain and alfalfa are grown for hay and seed.

Numerous roads make the area accessible from Hollister on the west, or from Los Banos on the east. Most of these are passable in dry weather, and become impassable during the winter rainy season. Access to the southwestern portion of the quadrangle is via Santa Ana Valley from Hollister, the road branching at the Indart Ranch. The east fork leads to Rancho Quien Sabe and Quien Sabe Valley, and the south fork to Los Muertos and Las Aguillas Valleys. State Highway 152, from Gilroy to Los Banos, crosses the Diablo Range through Pacheco Pass four miles north of the Quien Sabe quadrangle; private roads and fire trails intersecting this highway provide access to the northern and eastern portions of the quadrangle. The Comstock Road and the Lone Tree Road, both reached from Hollister, terminate in the Stayton mining district at the crest of the range near the northwest corner of the area.
The crest of the Diablo Range extends southeastward from the northwest corner of the quadrangle and attains its maximum elevation of 3560 feet in the area centering at Laveaga Peak (elevation 3801 feet). The lowest elevation, 400 feet, is in the northeast corner of the quadrangle where Los Banos Creek turns to the northeast and leaves the area.

**Climate and Vegetation**

The climate of the Quien Sabe region is semi-arid, the average annual rainfall at Hollister being only 13 inches. The higher slopes of the Diablo Range, however, receive somewhat greater precipitation. The eastern side of the range is much more arid, and the climate is similar to that of the San Joaquin Valley to the east.

Grassland devoid of trees has developed principally on Cretaceous clay-shales and sandstones in the eastern portion of the quadrangle. It is also developed locally on areas of Franciscan sandstones and shales. Savanna type vegetation, including various species of live oaks scattered among annual grasses and herbs, is more characteristic of Franciscan areas. Chaparral occurs in dense, almost impenetrable, patches on volcanic rocks with little soil cover. Woodland, characterized by the bay tree, is common in parts of the volcanic areas where the soil cover is well developed.

**Acknowledgments**

The writer wishes to express his thanks to Dr. N. L. Taliaferro, who suggested the problem, accompanied the writer in the field, and made valuable suggestions and criticisms. He is also grateful to Dr. F. J. Turner who helped in the petrographic studies of the igneous and metamorphic rocks; Dr. C. M. Gilbert made valuable suggestions concerning the separation of mineral grains. Without the financial assistance of the Board of Research of the University of California it would not have been possible to carry out this work, and to this board the writer wishes to express his appreciation.

**Previous Literature**

Becker,¹ the first to have written about any part of the Quien Sabe quadrangle, mentioned the Stayton mine (section 5, T. 12 S., R. 7 E., M. D.) in an 1888 survey of quicksilver deposits in the Pacific coast. Angel,² in 1890, described the same area under the name “M’Leod district.” He states that the veins of this district were discovered in 1861, and were worked from time to time with no great success. The mineralized region was known as the Stayton mining district in 1903, when Forstner³ made a reconnaissance map of the area.

Other writers⁴ in succeeding years mentioned the Stayton district, and in 1906 the first mention of a portion of the Quien Sabe area outside the Stayton district was made in the description of a manganese property.⁵ The coming of the first World War brought an increased interest

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in the mineral areas of the region. Logan \(^6\) wrote of manganese prospects and mines, and Bradley \(^7\) again briefly mentioned the Stayton district in writing of quicksilver. In 1925, Laizure \(^8\) presented short descriptions of mineral properties in Merced County, and in 1926 \(^9\) of mineral properties in San Benito County. In 1939 the Stayton district was again described, this time by Ransome and Kellogg. \(^10\) In 1942 Bailey and Myers \(^11\) mapped and described the Stayton district in detail as a part of the strategic minerals investigation program of the U. S. Government. In connection with this same program, Trask, Wilson, and Simons \(^12\) summarized the manganese properties of California, including locations within this quadrangle.

A portion of the quadrangle is included in the area mapped by Anderson and Pack \(^13\) and described by them in 1915.

The San Benito quadrangle, adjoining the Quien Sabe quadrangle on the south, was mapped by Wilson \(^14\) and the Hollister quadrangle, to the west of the Quien Sabe quadrangle, has been mapped by Taliaferro. \(^15\)

**GEOMORPHOLOGY**

In the latitude of San Benito County the Coast Ranges have the following major divisions, from west to east: the Santa Lucia Range; the Salinas Valley; the Gabilan Range; the Hollister basin or San Benito Valley; and the Diablo Range. To the east, the main belt of the Diablo Range is separated from the San Joaquin Valley by lower rolling country underlain by Cretaceous and Tertiary sediments. The Quien Sabe quadrangle includes a portion of the Diablo Range and the hills of Cretaceous rocks to the east. Los Banos Valley forms a distinct dividing line between the two in the northeast quarter of the quadrangle.

There are two important drainage systems within the Quien Sabe quadrangle. Los Banos Creek, with its north and south fork and tributaries, drains the eastern and central portions of the quadrangle. Quien Sabe Creek joins with Canada Verde in the southwestern portion of the quadrangle and passes southward into the San Benito quadrangle where a junction is made with Los Muertos Creek.

In general, the drainage pattern is dendritic, modified somewhat by the nature of the underlying rock. Quien Sabe Creek, the south fork of Los Banos Creek, and Los Banos Creek in Los Banos Valley are all subsequent and roughly parallel the structural trends of the area. The north fork of Los Banos Creek is consequent on the land surface generated by Tertiary volcanism.

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\(^{8}\) Laizure, C. McK., Merced Co.: California Min. Bur. Rept. 21, pp. 175, 181-182, 1925.


\(^{15}\) Taliaferro, N. L., Geology of the Hollister quadrangle, California: Unpublished report.
### Table: Stratigraphic Column

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Column</th>
<th>Thickness FT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Alluv. &amp; Terraces</td>
<td></td>
<td>0-100</td>
<td>Gravel, sand, clay</td>
</tr>
<tr>
<td>Upper Pleistocene</td>
<td>Peckham Formation</td>
<td></td>
<td>0-300</td>
<td>Non-marine gravel, sand, silt and limestone.</td>
</tr>
<tr>
<td>Middle (?) Miocene</td>
<td>Quien Sabe Volcanics</td>
<td></td>
<td>0-4000</td>
<td>Andesite and basalt flows, agglomerates; intruded by andesite and rhyolite.</td>
</tr>
<tr>
<td>Lower Miocene</td>
<td>Vaqueros</td>
<td></td>
<td>0-20</td>
<td>Thin limestone lens.</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td></td>
<td></td>
<td>0-6000</td>
<td>Dark colored clay shale, and buff concretionary sandstone with lenses of conglomerate.</td>
</tr>
<tr>
<td>Upper Jurassic (?)</td>
<td>Franciscan Group</td>
<td></td>
<td>Base not exposed</td>
<td>Well indurated arkosic sandstone (partially re-crystallized) shale, conglomerate, radiolarian chert, basalt, serpentine intrusions locally producing metasomatic amphibole-mica schists.</td>
</tr>
</tbody>
</table>

**Fig. 2.** Stratigraphic column, Quien Sabe quadrangle.
Two late cycles of erosion are represented within the Quien Sabe quadrangle. The first cycle reached a stage of late maturity, characterized by broad alluviated valleys and well rounded ridges. These valleys have been entrenched over large areas by actively down-cutting streams, representing the second or present cycle, which is still in a stage of youth or, in part, of early maturity. Remnants of the first cycle are represented by broad, alluviated valleys, including Los Banos Valley, Quien Sabe Valley, Las Aguilas Valley, Dairy Flat, and Los Muertos Valley. In addition, terrace levels were developed during this cycle at various localities within the quadrangle. These valleys and terraces are now being entrenched by the youthful streams of the second cycle.

STRATIGRAPHY

In the Quien Sabe quadrangle Franciscan rocks of late Upper Jurassic age form the basement and are overlain by Cretaceous sediments. The Tertiary is represented by Miocene sediments that are mostly of volcanic origin and are associated with lava flows and related intrusive bodies. The volcanics overlap both Jurassic and Cretaceous rocks. Local sedimentary remnants of a Pleistocene lake basin overlie both volcanic and Franciscan rocks. Terraces were formed in late Pleistocene or Recent time, and are now somewhat dissected. Recent alluvium is found in many of the creek bottoms, and landslides of Recent age (some may be older) scar many of the hill slopes.

Franciscan Group (Upper Jurassic)

Distribution. The Franciscan group is composed of arkosic sandstones, radiolarian cherts, basalts, basic and ultra-basic intrusives, and metasomatic metamorphic rocks (glauconite and related schists). These rocks underlie the entire southeastern portion of the quadrangle and continue northward between Los Banos Valley on the east and the Tertiary volcanic area on the west. The belt also extends around the northern limit of the volcanic area to the northwest corner of the quadrangle. In the southern part of the quadrangle the main belt of Franciscan extends westward around the southern end of the volcanic area.

Sandstone. The predominant rock type in the Franciscan of the Quien Sabe quadrangle is arkosic sandstone, bluish gray or buff when fresh, weathering to yellowish brown. The structure is commonly massive, but north of the junction of the north and south forks of Los Banos Creek the sandstone is dominantly thin bedded and has a pronounced shaly parting. This rock is buff colored, characteristically fine grained, and is cut by quartz and calcite veins. In general the Franciscan sandstones are poorly sorted rocks composed mainly of angular grains of quartz and feldspar (in approximately equal amounts) and less abundant fragments of dark shale. In numerous localities within the quadrangle a blue, relatively fine-grained sandstone occurs. Shaly portions of this rock impart a bluish color to the soil that may be useful in interpreting structure for limited distances.

Close examination shows that throughout the whole area the Franciscan sandstones have been sufficiently deformed to cause at least incipient recrystallization of clastic materials. In thin section, the original clastic structure is still present, but the surviving grains of quartz, feldspar, and fragments of shaly material are set in a fine-grained matrix in
which recrystallized quartz and feldspar are associated with minute crystals of muscovite, chlorite, pumpellyite, clinozoisite, and other metamorphic minerals.

The feldspar of the Franciscan sandstones occurs in clastic grains, altered to greater or less degree. Plagioclase, the dominant feldspar, commonly comprises about half the volume of the sandstone. It ranges from oligoclase to labradorite, with calcic oligoclase and oligoclase-andesine the usual varieties; microcline is rare. Quartz is about equal in amount to plagioclase and sometimes exceeds it. Granulation effects are evident in some of the quartz grains, but are not uniform in intensity throughout a given thin section. Other clastic grains include dark shale fragments, igneous material that is largely glassy, and recrystallized chert (common in some sections). Minor constituents include spherne, apatite, magnetite, and epidote. Secondary calcite is found occasionally, and abundant rather coarse grains of lawsonite are present in some cases.

*Fine-Grained Sediments.* The fine-grained sediments, including the shaly sandstones, the siltstones, and the shales, are similar to the coarser-grained arkosic sandstones in their content of determinable minerals. Some are only slightly recrystallized; others show a more advanced stage of recrystallization, with slight development of schistosity. The coarsest fine-grained sediments contain clastic grains of oligoclase-andesine. Clastic quartz is present in quantity equal to or greater than feldspar; apatite and epidote are present in very minor amounts, and all contain earthy iron oxide. The detrital grains are enclosed in a matrix of fine-grained muscovite, chlorite, and indeterminate material in which possibly pumpellyite and stilpnomelane are present.

*Conglomerate.* Conglomerate occurs as local lenses within the sandstone-shale sequence. Pebbles are composed of sandstone, blue quartz, white quartz, pebble conglomerate fragments, porphyritic igneous rock, black chert, white chert, pale green chert, granodiorite, and aplite. Pebbles and boulders range from 1/2 inch to 2 1/2 feet in diameter. The most common sizes lie between 1/2 and 2 inches. The pebbles are rounded, and generally occur in a hard sandy matrix. One conglomerate reef, within the Stayton mining district, has been unsuccessfully prospected; in the NE 4 sec. 34, T. 11 S., R. 7 E., M. D., conglomerate, occurring with coarse-grained arkosic sandstone, is exposed in the bottom of the canyon of the north fork of Los Banos Creek; in the southern part of the quadrangle, the crest of the hills trending southeastward and culminating at Bench Mark 3014, in sec. 21, T. 13 S., R. 8 E., M.D., is made up of a large conglomerate lens; and the fourth outcrop is in the northern part of the quadrangle, in sec. 29, T. 11 S., R. 7 E., M.D.

*Volcanic Rocks.* Volcanic rocks of the Franciscan are present within the Quien Sabe area, but are not extensive or widespread. They are green to black on fresh surfaces, but oxidize readily to various shades of brown and red. The volcanics are easily recognized in the field by their rugged outcrops and by the red color they impart to the soil. The rocks are basaltic and are vesicular with variable texture. With the exception of a sill-like body at the Franciscan-Cretaceous contact between Wildcat Creek and Chileno Creek, they are closely associated with cherts. Veinlets and amygdules of quartz and calcite are common.
The sill-like body on the Franciscan-Cretaceous contact between Wildcat Creek and Chileno Creek is diabasic in texture, with anhedral augite grains surrounded by lath-shaped feldspars and smaller augite crystals. Much of the groundmass is composed of cloudy, brownish yellow, devitrified glass. The larger feldspars are andesine, while the feldspar microlites have the same composition as the most sodic of the phenocrysts. This outcrop represents a portion of El Puerto volcanics which Taliaferro mentions as common in the exposed top of the Franciscan along the east side of the Diablo Range.

**Chert.** Some of the Franciscan shales contain chert nodules, around which the bedding of the shale is distorted. Rhythmically banded radiolarian chert has a more striking appearance. This material consists of light-colored, partly recrystallized chert bands between alternate bands of shale. In some places the shale is dominant and in others it is represented only as a shaly parting between chert bands. In mapping, the banded chert was not separated from the rest of the Franciscan group. The major area of chert is in the eastern half of the northeast quarter of the quadrangle. This area extends southeastward from the northeast corner of sec. 26, T. 11 S., R. 8 E., M. D., to the eastern portion of sec. 20, T. 12 S., R. 9 E., M. D. The belt reaches a maximum width of 2 ½ miles in Herrero Canyon and is cut near its northern end by the Ortigalita fault. Within the chert belt igneous rocks and other types of sedimentary rocks are present. Rhythmically banded chert also occurs in scattered areas elsewhere in the quadrangle and is often brecciated and slickensided. The breccia is composed of chert fragments cemented by chert of a slightly different color. Frequently the surface of the chert is coated with manganese and iron oxides, giving the outcrop a dark blue or brown color. Such an occurrence in sec. 9, T. 13 S., R. 8 E., M. D. (the Fries Ranch prospect) has been prospected for manganese, the ore occurring as oxide in the thicker chert layers. The bedding of the chert is irregular with pronounced pinching and swelling; near the mouth of the workings the chert is brecciated and contains extensive gouge. Some of the chert fragments are well polished and rounded and resemble pebbles. At the Hendricks manganese mine in sec. 24, T. 13 S., R. 8 E., M. D., the chert again is similarly sheared and brecciated. Some of the chert layers are as much as 5 feet thick, and where these layers are broken, less competent shale and thin chert are folded around the large blocks. Attitudes of the chert, wherever they are found, are exceedingly variable.

The chert is recrystallized and is often cut with veins of coarse quartz aggregates. Grains of magnetite are present, and locally chlorite and iron oxide stains occur between the grains in the veins.

The lens-like nature of the cherts, as well as their close association and even interfingering with coarse clastic sediments, indicates shallow water conditions of deposition. The abundance of silica in the water provided favorable conditions for the growth of radiolaria.

The original material containing much of the manganese associated with the cherts is neotocite, a light to dark brown manganiferous opal. Oxidation of the primary material produces the coatings of black manganese oxides (psilomelane, pyrolusite, and wad) previously mentioned.

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The manganiferous lenses are syngentic, and owe their origin to the same volcanism which was responsible for the concentration of silica producing the chert. Breciation of the chert provides avenues for the downward oxidation of contained iron and manganese.

**Basic and Ultrabasic Intrusives.** In the Quien Sabe quadrangle intrusions of basic and ultrabasic rocks have the forms of dikes, sills, and plugs. Although these masses are all represented on the map as serpentinite, they include rock types ranging from diorite to serpentinitized peridotite or dunite. One common variety, exposed along Wildcat Creek and Chileno Creek, is massive, has numerous slickensided and polished surfaces, and contains blocks of volcanic material probably derived from the El Puerto (Franciscan) volcanics with which it is in contact. Blocks of serpentinite with shells of magnesite are also included in the distorted mass. The west side of hill 1012, north of Chileno Creek, is badly sheared serpentinite bounded on the east by El Puerto volcanics which outcrop on the crest of the hill and continue down the east slope to the Ortigalita fault.

A second variety of serpentinite is coarsely crystalline and contains bastite pseudomorphs of orthorhombic pyroxene. This variety is found in sec. 2, T. 12 S., R. 8 E., M. D., where it is completely brecciated; and also northwest of the Buena Vista Ranch. In the latter locality the bastite serpentinite is associated with other types of basic intrusive rocks. The area of the outcrop is clearly outlined by dark colored scrub brush. The igneous rocks apparently were intruded in sheets, which now dip steeply northeast. Extensive breciation and distortion of the mass is apparent in the outcrop. The intrusive body also contains hornblende-biotite diorite with fresh hornblende cores surrounded by chlorite, pale biotite (chloritized in part), andesine, and minor magnetite. Gabbro, consisting of biotite and augite; and olivine gabbro with labradorite, somewhat altered olivine, and augite, are other rock types present in this intrusive mass.

A fourth occurrence of serpentinite, a distorted mass too small to be shown on the map, contains inclusions of green Franciscan chert, Franciscan sandstone, vein quartz, and basic igneous rock. The sandstone inclusions are abundant, and are somewhat rounded, ranging to a maximum diameter of 8 feet. This outcrop is in an area of blue Franciscan sandstone and black shale in sec. 27, T. 12 S., R. 8 E., M. D.

The serpentines are not found in rocks younger than Franciscan but they are intrusive into the Franciscan sediments. It is possible that the period of intrusion was contemporaneous with the deposition of the sediments. The existence of serpentine and metasomatic rocks older than some of the Franciscan sediments is proved by the presence of glaucophane as a detrital mineral in the Franciscan sandstone and the presence of both serpentine and glaucophane schist pebbles in Franciscan conglomerates of other areas.

**Glaucophane Schist and Related Rocks.** As a result of soda-iron metasomatism that has accompanied ultrabasic intrusions, various Franciscan sediments have been converted into glaucophane schist and related rock types. The most widespread occurrence of glaucophane-muscovite schist is in the southwestern portion of the quadrangle where an aureole, terminated by faults on the northeast, northwest, and southwest sides, has developed around the intrusive body. The southeastern margin of the aureole must be inferred, as it is hidden by the soil cover. Exposures
RHYTHMICALLY BANDED FRANCISCAN
CHERT AND SHALE
SW. corner sec. 9, T. 13 S., R. 8 E.
A. SPHEROIDAL WEATHERING OF "CANNONBALL" CONCRETION
EAST OF LOS BANOS VALLEY

B. MASSIVE, HEAVY UPPER CRETAEOUS CONGLOMERATE
EAST END OF LOS BANOS VALLEY
A. PEBBLY TUFFACEOUS SANDSTONE AT BASE OF QUIEN SABE VOLCANICS
Sec. 9, T. 13 S., R. 8 E.

B. TWIN PEAKS FROM EAST SLOPE OF ANTIMONY PEAK
J. RHYOLITE INTRUSIVE (CENTER) ON NORTH SIDE OF CATHEDRAL PEAK

B. JOINTED OUTCROP OF MASSIVE AGGLOMERATE SOUTH END OF QUEEN SABE VALLEY
along the Santa Ana Creek road show unaltered sediments, while a short
distance to the north there are poor outcrops of glauconphane-muscovite
schist. Similar schist is found associated with actinolite schist in an
isolated outcrop south of the Santa Ana Creek road, southeast of Hill
1398, 1,000 feet north of the center of the north line of sec. 4, T. 14 S., R.
7 E., M. D. Glauconphane-muscovite schist with minor chlorite and epidote,
and occasionally with calcite and sphene, or with garnet, sphene, and
rutile, is the type found most frequently within the quadrangle.

Source, Relationships and Age. The land mass which furnished the
debris for the Franciscan must have been extensive to provide for the
wide distribution of uniform rock types found with the Franciscan.
It must have been of considerable relief to account for the abundance,
freshness, and angularity of the feldspar in the accumulated material.
Lack of Sierran debris in the coarser elastic sediments, and a westward
coarsening of grain size of Franciscan sediments in other parts of Cali-
ifornia 17 suggest that the land mass lay somewhere to the west of the
gosyncline in which the Franciscan was deposited.
The Franciscan is not in contact with older rocks within the Quien
Sabe quadrangle. It is in fault contact with Cretaceous sediments and is
overlain unconformably by Tertiary and Quaternary sediments and vol-
canic rocks.

Physical evidence for the Upper Jurassic age of the Franciscan
group is obtained by correlation with rocks of the Sierra Nevada region
through northern California and southwestern Oregon. 18 Camp 19 has
established the same age from faunal evidence in describing two Upper
Jurassic (Tithonian) ichthyosaur rostra contained in worn Franciscan
chert cobbles. The Franciscan of the Quien Sabe quadrangle probably
represents a portion of the second stage, Upper Franciscan, as recognized
by Taliaferro. 20

Upper Cretaceous

General Distribution and Stratigraphic Relationships. The Upper
Cretaceous in the Quien Sabe quadrangle is represented by a minimum of
6,000 feet of brownish concretionary arkosic sandstones, interbedded
dark clay shales, and heavy conglomerates. These beds represent a portion
of the Panoche formation of Anderson and Pack. 21 Since later work has
shown that the Panoche as mapped by these workers includes Knoxvile
(Upper Jurassic), Paskenta (Lower Cretaceous), and Horsetown (Lower
Cretaceous), and extends across several disconformities, the writer prefers
the classification proposed by Taliaferro 22 in which the Upper
Cretaceous is divided into a lower Pacheco group and an upper Asuncion
group, separated by an orogenic interval. According to Taliaferro, 23 the

17 Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geolo-
18 Taliaferro, N. L., Geologic history and correlation of the Jurassic of southwestern
19 Camp, C. L., Ichthyosaurus from the Franciscan formation of central California
20 Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of
California: California Div. Mines Bull. 118, pp. 126-127, 1941. . . . Franciscan-Knoxville-
22 Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of
23 Oral communication, May 1947.
heavy conglomerates in the eastern part of the quadrangle are an extension of Asuncion conglomerates to the southeast, but since no stratigraphic break or faunal record was found in the Quien Sabe Cretaceous, the entire assemblage is mapped as undifferentiated Upper Cretaceous, the inference being that it is part of the Asuncion group. The Upper Cretaceous crops out over a triangular area of 17 square miles in the northeast corner of the quadrangle, and is also exposed in the southwest corner and in limited patches along the western boundary.

Later sediments, volcanics, terrace deposits, landslides, and alluvium commonly overlap the Upper Cretaceous sediments but the Cretaceous is in fault contact with volcanics near the south end of Quien Sabe Valley and in sec. 7, T. 12 S., R. 7 E., M. D. The Franciscan-Cretaceous contact is a fault wherever it is exposed, with the possible exception of the small area in sec. 30, T. 11 S., R. 7 E., M. D. In this locality the contact is obscured by a small andesite plug, landslides, and thick soil cover, but has been mapped to correspond to the highest position of Franciscan debris on the soil covered hill slope.

Description and Distribution of Lithologic Units. The northeastern quarter of the quadrangle provides the best picture of the relationships of the various lithologic types of the Upper Cretaceous sediments. A strip of brown clay shale in Los Banos Valley parallels the creek for a distance of more than four miles. It appears at the edge of the second terrace level, and although it forms no outcrops, it can be traced by the brown color imparted to the soil and by the presence of shale chips in the soil. At the north end of the valley, beyond the margins of the terrace deposits, it forms the gentle slopes of the hills, and crops out in gullies immediately to the north of the quadrangle, in sec. 4, T. 11 S., R. 8 E., M. D. Lenses of feldspathic sandstone, bluish-gray in color and weathering to buff, occur locally within the shale, as at the contact with the Franciscan at the north end of Los Banos Valley. The sand is composed of medium sized, fairly well sorted, angular to subangular grains of quartz, intermediate plagioclase, bleached biotite (some altering to chlorite), muscovite, recrystallized chert fragments, and organic material. Minute calcite veins are present, and the cementing material appears to be calcareous clay.

At the south end of Los Banos Valley, east of the Ortigalita fault, bluish arkosic sandstone, shaly sandstone, and black shale strike north-west with a vertical or steep northeasterly dip. Conglomerate occurs at the Franciscan-Cretaceous contact. Northeast of Los Banos Creek is a nearly uniform sequence of gray to bluff concretionary sandstone, with some interbedded shale. The sandstone contains numerous "cannonball" concretions which have dark iron-stained surfaces and weather out of the sandstone outcrops.

In places the stratification is uniform and regular, with beds 2 to 4 inches thick. Elsewhere beds are much thicker. Locally they are as much as 5 feet thick and are separated by several inches of silty material. Resistance to weathering and erosion varies within a single bed, resulting in hollows and lumps on the surface of the outcrop. Frequently the sandstone shows cut-and-fill lensing, with even-grained fine sandstone making up the lenses. Occasional shale fragments are found in the sandstone layers, and are particularly abundant within the more shaly facies of
the sandstone or where thinly stratified sandstone and shale are interbedded.

The Cretaceous sandstones northeast of Los Banos Creek are typically medium- to coarse-grained, with a fair degree of sorting. Grains are angular to subangular, and include clouded feldspar (oligoclase to andesine), quartz, biotite, recrystallized chert fragments, shale fragments, organic material, and lesser amounts of muscovite, epidote, chlorite, and hornblende. Matrices are generally calcareous and yellow limonite stain is common. Heavy mineral concentrations contain magnetite, zircon, augite, tourmaline, garnet, zoisite, and apatite.

In the E2 1/2 sec. 20, T. 11 S., R. 9 E., M. D., Los Banos Creek, as it leaves the quadrangle, has cut a gorge through thick conglomerate lenses striking northwest and dipping to the northeast. Within the limits of the Quien Sabe quadrangle the conglomerate crops out in two lenses separated by silty shale and having an aggregate thickness of at least 350 feet. More lenses appear to the east in the Ortigalita Peak quadrangle. The conglomerate is massive and heavy, and contains numerous well-stratified sandstone lenses. Some lenses reach 80 feet in length and 6 feet in thickness. Some are pebbly; others are not. The matrix of the conglomerate is sand, and is well cemented, hard, and coherent. The pebbles and boulders are well rounded but poorly sorted; they are commonly coated with a brown polish, range in size from 1 to 12 inches, and average 2 to 4 inches in diameter. The debris includes granodiorite, various types of porphyritic igneous rocks, aplite, pegmatite, dark chert, red chert, green chert, and white chert. Some of the red chert pebbles contain radiolaria, and Franciscan volcanic rocks are also represented. In addition, Cretaceous debris is present and includes poorly consolidated sandstone and pebbles of dense limestone similar to limestones in the Horsetown (Lower Cretaceous), Paskenta (Lower Cretaceous), and even in the lower Upper Cretaceous formations. A specimen of sandstone from a lens within the conglomerate contained quartz and clouded sericitized feldspar in about equal amounts, biotite, muscovite, and chlorite. The heavy portion of the sample was composed of magnetite, zircon, clouded epidote, brown tourmaline, zoisite, augite, green hornblende, garnet, and minor sphene and apatite.

The materials present in this conglomerate are all of types that occur within the Coast Ranges, and there is a complete absence of anything resembling Sierran debris. The nature of the conglomerate with its included sand lenses suggests rapid deposition with frequent shifting of channels. There is no stratigraphic break at the base; the deposit apparently represents an uplift somewhere to the west, with no break in sedimentation.

The Cretaceous sediments are in contact with the Franciscan to the west along the Ortigalita fault. In almost every exposure of the fault Franciscan is brought into contact with a heavy Cretaceous conglomerate. Like the conglomerate described above, it is composed of pebbles with a brown polish and embedded in a sandy matrix. The pebbles include dark blue and black chert, various porphyritic igneous rocks, granodiorite, pegmatite, and aplite, as well as some weathered diabase or

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21 N. L. Taliaferro, oral communication, May 1947.
gabbro doubtfully referred to a Franciscan source. The pebbles range from 1 inch to \(1\frac{1}{2}\) feet in diameter and average 2 to 6 inches. There are also lenses of fine pebble conglomerate and sand within the conglomerate. The conglomerate is locally veined with quartz and is noticeably sheared in good exposures. The porphyries, black cherts, and black quartzites also are found in the conglomerates of the Franciscan, but there are no known exposures of the source of these rocks in the present Coast Ranges; probably many of these pebbles have been reworked.

The conglomerate has been traced for a distance of more than four miles along the Ortigalita fault. It reaches a thickness of between 300 and 350 feet in sec. 25, T. 11 S., R. 8 E., M. D. To the south, the strike of the conglomerate intersects the trend of the fault and the conglomerate appears to be cut out. On the north side of Chileno Creek, sandstone just to the east of the conglomerate is overturned and dips to the northwest. Farther to the east, the dips become vertical, and, at a distance of 1000 feet from the fault, dips are to the northeast.

The Upper Cretaceous in the southwestern corner of the quadrangle is a continuation of the Paynes shale and sandstone member of the Panoche group of the San Benito quadrangle to the south, and consists of sandstone, shale, and thick, heavy conglomerate. The sandstone is a tan, medium- to fine-grained, poorly sorted rock, occurring in beds 2 inches to 18 inches thick and separated by shale beds of the same range of thickness. Carbonaceous material is common. The grains are angular to subrounded, and include quartz and feldspar in nearly equal amounts. The feldspar is untwinned intermediate plagioclase, somewhat sericitized. Abundant flakes of bleached biotite are also present. Accessories include abundantapatite and magnetite; zircon, clouded epidote, and garnet are common; tourmaline and sphene are minor constituents.

The clay shales are typically greenish to black in color. At Salt Creek, where they are interbedded with sandstone, Wilson has reported foraminifera that indicate Panoche (Upper Cretaceous) age.

Thick, heavy conglomerate, with well rounded pebbles and boulders of black quartzite, quartz-feldspar porphyry, biotite-feldspar porphyry, granodiorite, aplite, and Franciscan-type debris occurs on the Santa Ana Creek road, opposite Hill 1398. This is a lens near the fault contact with the Franciscan and is bounded on both sides by sandstone and shale. Conglomerate also occurs at the fault contact a mile to the northeast, and again south of the Santa Ana Creek road, 1000 feet northeast of Hill 1398. The pebbles of these conglomerates average 2 to 6 inches in diameter, range up to 18 inches, and are set in a sandstone matrix.

A road cut in the NW\(\frac{1}{4}\) sec. 7, T. 12 S., R. 7 E., M. D., exposes a conglomerate consisting of well rounded, polished pebbles (about 2 inches in diameter) of the usual black chert, black quartzite, various types of porphyries, and granodiorite. The rock at this outcrop is sheared and somewhat mashed by movement on the fault that marks its northern boundary. A similar conglomerate along the same fault is exposed in a ravine cut through the overlying volcanics in the southeast quarter of section 7 and the central part of sec. 18, T. 12 S., R. 7 E., M. D. Upper Cretaceous arkosic sandstone is present on the west side of the ravine.


Faulting and erosion have exposed interbedded soft brown crumbly sandstone and brown and gray shale in the banks of a ravine in the northwest corner of sec 15, T. 12 S., R. 7 E., M. D. The sandstone is poorly sorted and consists of subangular grains of black organic material, quartz, clouded feldspar (oligoclase), abundant biotite, and chlorite. Heavy minerals include magnetite, clouded epidote, apatite, augite, garnet, zircon, sphene, tourmaline, and minor hornblende. Stratification is in beds about 1 to 3 inches thick, which are broken and contorted.

Dark clay-shale, which breaks readily into small fragments, is present at the quadrangle boundary on the Comstock Road, in sec. 30, T. 11 S., R. 7 E., M. D. It is succeeded to the east by light colored siltstone which forms the knob just north of the road and south of Jacks Hill. It does not crop out through the soil cover, but its presence is determined by debris around the holes of ground squirrels.

Age. It is possible that the uplift reflected by the Los Banos Creek conglomerates was the mid-Upper Cretaceous Santa Lucian orogeny, in which case the conglomerate would mark the base of the Asuncion group, and the sandstones, shales, and conglomerates to the west and southwest would be a portion of the Pacheco group. As there is no physical evidence of unconformity at the base of the conglomerate, or of overlap of the conglomerate onto the sediments to the west such a correlation is inadvisable. Faunal evidence unfortunately also is lacking.

**Vaqueros Formation (Lower Miocene)**

In the Hollister quadrangle, which borders the Quien Sabe quadrangle on the west, Taliaferro reports a maximum of 225 feet of sandstone, gravel, and limestone containing upper Vaqueros fossils; these rest on Cretaceous and are overlain by the Quien Sabe volcanics. These sediments thin eastward and, at the boundary of the Hollister and Quien Sabe quadrangles, the Vaqueros is represented by 15 feet of limestone. The presence of marine Vaqueros in this area sheds new light on the extent of the lower Miocene sea, and provides definite evidence for delineating the lower limit of the age of the overlying volcanics.

A second outcrop of questionable Vaqueros is found in the northeast quarter of sec. 9, T. 11 S., R. 7 E., M. D., where gravels are exposed at the base of the volcanics and overlying the Franciscan in an area too small to be shown on the map. Pebbles are Franciscan-type sandstone with quartz veinlets, and shale. They are subangular to subround, range from 1 to 12 inches in diameter, average 2 to 4 inches, and are set in a clay matrix. Absence of volcanic debris suggests a pre-volcanic age. The degree of consolidation is much less than any pre-Tertiary sediments in the Quien Sabe area. Lack of fossils makes a definite age determination impossible, but the writer feels that this may be a near-shore facies of the Vaqueros (lower Miocene) exposed more extensively in the quadrangle to the west. Adding to the uncertainty of the correlation of this outcrop with others is that fact that the gravels are in a badly slumped area at the base of the volcanics.

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Quien Sabe Volcanics (Middle ? Miocene)

Distribution, Age, and Stratigraphic Relationships. Volcanic rocks about 4000 feet thick occur in the west central part of the Quien Sabe quadrangle and extend westward into the Hollister quadrangle where they rest conformably on sediments of upper Vaqueros (lower Miocene) age. Taliaferro 30 has given them the name "Quien Sabe volcanics." They consist of flows, agglomerates, and minor conglomerates, with associated dikes and plugs; the center of the volcanic activity is located in the northwest quarter of the Quien Sabe quadrangle.

The flows and agglomerates, probably submarine in part, were deposited on the Vaqueros sediments, but no exact upper age limit can be established; they are overlain unconformably by Pleistocene lake sediments in the center of the quadrangle. Abundant volcanic material similar to the Quien Sabe volcanics was found by Wilson 31 in the San Benito gravels north of Tres Pinos Creek in the San Benito quadrangle. He considers the gravels Plio-Pleistocene in age, which would make the volcanics at least older than upper Pliocene. According to Taliaferro, 32 volcanism reached its maximum intensity in the central Coast Ranges during middle and upper Miocene time; the Quien Sabe volcanics probably represent a portion of this activity.

The Cretaceous-volcanic contact is in part depositional, and in part marked by a fault. On the northwest side of Hill 2303, half a mile east of the sharp bend in the road to Little Quien Sabe Valley, the contact is bordered by a baked zone in the underlying Cretaceous sandstone, and by a sandstone breccia. One half mile to the southeast of this exposure the contact is a fault. Here a sheared zone marks the base of the volcanics, which were thrust to the southwest over Cretaceous sandstone; farther to the south they are thrust over Franciscan schist. Near the center of sec. 8, T. 13 S., R. 8 E., M. D., the basal member of the volcanics is a fine, well-bedded agglomerate, which resembles a coarse sandstone or a fine pebble conglomerate, but is composed of volcanic pebbles set in a tuffaceous matrix. These agglomerates overlie a basement of Franciscan sandstone and are in fault contact with a platy flow. In a volcanic outlier in sec. 9, T. 13 S., R. 8 E., M. D., the same type of agglomerate occurs at the base of the volcanic series and is overlain by flows. Even, regular stratification indicates that the agglomerate was water-laid.

Good exposures of the contact between the volcanics and older rocks are rare, as the volcanics slump and slide easily; but the contact is often expressed topographically by a pronounced break in slope, because the lavas form steeper slopes than the underlying material. Springs frequently occur at or near the contact. In many places the flows and agglomerates form rugged outcrops, with vertical faces 50 feet or more in height. The tops of the ridges and the gentler slopes of the volcanic area are strewn with blocks of volcanic debris, some reaching 20 feet in diameter. Dense, adobe-type soil, resulting from the weathering of the volcanics, is readily distinguishable from the sandy loam found on Franciscan and Cretaceous rocks. Volcanic slopes, gentle enough to retain a soil cover, support a woodland vegetation with considerable brush; park-like areas are found on many of the volcanic landslides.

31 Wilson, I. F., op. cit. p. 248.
Lithology and Petrography. The various rock types represented in the volcanic series fall within the following groups: (a) andesitic flows, including biotite andesite, oxyhornblende andesite, and hypersthene-augite andesite; (b) basaltic flows, classified as such because of the presence of olivine, since chemical analyses are not available; (c) dacite flows, with quartz and indeterminate feldspar phenocrysts and oligoclase microlites; (d) sediments, including agglomerates, conglomerates, and tuffaceous sandstones; (e) andesitic intrusives, in the form of plugs and irregular masses; (f) rhyolitic intrusives, hydrothermally altered plugs.

The effusive rocks cannot be divided into stratigraphic units characterized by a dominance of a particular rock type, as representatives of each group are found throughout the sequence and there are no major stratigraphic breaks. The writer found no evidence for the presence of an unconformity between a lower basaltic unit and an upper andesitic unit as reported by Bailey and Myers.53

The biotite andesites consist of phenocrysts of zoned plagioclase, andesine to labradorite, and yellowish-brown biotite set in a groundmass of feldspar microlites and brownish glass. The plagioclase microlites of the groundmass range from oligoclase to andesine.

The oxyhornblende andesite flows contain phenocrysts of zoned plagioclase, ranging from oligoclase to andesine. The groundmass consists of feldspar microlites and altered brownish glass.

The hypersthene-augite andesites contain normally zoned feldspar phenocrysts ranging from andesine at the cores to oligoclase in the marginal zones. Plagioclase microlites in the hyalopilitic groundmass are oligoclase. Prismatic hypersthene phenocrysts are weakly pleochroic, from pale yellow to pale green; inclusions are common but lack the regular arrangement typical of schiller structure. Oxyhornblende, epidote, augite, and biotite are present in minor amounts.

Olivine basalt is a common rock type of the Quien Sabe volcanics. Some have phenocrysts only of olivine (often partially altered to iddingsite), while in others phenocrysts of plagioclase, augite, oxyhornblende, and biotite also occur. Plagioclase phenocrysts are zoned and range from andesine to labradorite. Plagioclase microlites in the microcrystalline to glassy groundmass are oligoclase to andesine.

Near the base of the Quien Sabe volcanics, close to the northwest corner of sec. 35, T. 11 S., R. 7 E., M. D., is an outcrop of light-colored, gray to pink rock in which a few quartz phenocrysts and occasional feldspar crystals are visible with a hand lens. In thin section the quartz phenocrysts are clearly visible, but the feldspar phenocrysts are too altered to be determined. The groundmass contains much calcite and finely divided quartz, some chlorite, and laths of altered feldspar. The rock is a dacite, hydrothermally altered.

The flows of the Quien Sabe volcanics are interbedded with agglomerates and water-deposited sediments. The agglomerates generally are massive and erode to a miniature pinnacles type topography in many parts of the quadrangle. This massive character makes it difficult to obtain reliable strike and dip measurements from a single outcrop; it is often more satisfactory to observe attitudes from a distance, where bedding and jointing can be seen in their true perspective. Crude stratification,

slight rounding of pebbles, and inclusion of extraneous material suggest that water had a part in the process of deposition of some of these rocks. The agglomerates are composed of mineral and rock fragments in a tuffaceous matrix. The larger fragments are more resistant to erosion than the glassy, honeycombed matrix. Rock fragments include tuff, andesite, basalt, and some pre-volcanic rock types, the diameter of the coarser debris averaging 1 to 3 inches but sometimes reaching as much as 3 feet.

The mineral content of the agglomerates, when determinable, is similar to the lavas with which they are associated. Olivine, hypersthene, augite, oligoclase-andesine, and quartz are present in a specimen collected in sec. 25, T. 11 S., R. 7 E., M. D. Rock fragments in the same specimen include fine-grained feldspathic sandstone, recrystallized chert, and olivine basalt; the presence of quartz and olivine in the same rock, therefore, is not surprising. Antimony Peak is composed predominantly of crudely bedded agglomerate containing pebbles and blocks of volcanic debris set in a tuffaceous matrix. Mineral fragments in this rock are of small size, are angular and broken, and include plagioclase (oligoclase to labradorite) and augite. The augite is sometimes included in pumiceous masses. At the south end of the row of hills separating Quien Sabe Valley and Little Quien Sabe Valley, olivine basalt is overlain by agglomerate containing olivine basalt and pumice fragments 1 to 2 inches in diameter, and crystals of olivine and sericitized andesine.

Conglomerate, interbedded with coarse tuffaceous sand, crops out in a gully in sec. 24, T. 11 S., R. 7 E., M. D. The conglomerate is composed of poorly rounded pebbles and boulders of volcanic debris that are enclosed in a buff-colored matrix; pebbles range from 1/2 inch to 2 feet in diameter. Similar conglomerate, apparently slumped, is found in sec. 25, T. 11 S., R. 7 E., M. D. About 50 feet of conglomerate, composed of sub-rounded andesitic fragments half an inch to 2 feet in diameter in a clay matrix, is overlain by platy lavas on the north side of Mariposa Peak. Interbedded pebble conglomerate and tuffaceous sand occurs in secs. 8 and 9, T. 13 S., R. 8 E., M. D.

Three types of andesitic intrusive bodies are found within the quadrangle. One type has sharp contacts, nearly circular outline, and arches the surrounding rocks. Bodies of this type, a good example of which occurs at the head of Quien Sabe Valley, may best be described as plugs. A second type is represented by the intrusive mass at the head of the north fork of Los Banos Creek. The rocks surrounding this type are somewhat altered as a result of the intrusion, and numerous small dikes border the mass. The third type, represented by a body in the area north of Mariposa Peak and Cathedral Peak, has sharply angular contacts, with no alteration effects. The intrusive bodies are younger than some of the volcanics, and in other cases the relationships cannot be determined. They apparently served as vents and feeders, supplying the material which was poured out on the surface. The andesitic intrusive activity is believed to have occurred contemporaneously with the accumulation of the extrusive rocks.

The small knob of intrusive andesite near the center of sec. 29, T. 11 S., R. 7 E., M. D., is composed of plagioclase phenocrystals and prismatic limonite pseudomorphs in a cryptoocrystalline groundmass. The plagioclase ranges from andesine to labradorite and contains irregular patches of caleite.
The large intrusive body north of Mariposa Peak is an augite-hornblende-biotite andesite. The augite shows marked dispersion, is twinned, and is sprinkled with magnetite inclusions. Feldspar phenocrysts are andesine; some are zoned, and some are noticeably saussuritized. Feldspar microlites in the microcrystalline groundmass are andesine.

Augite-hornblende-biotite andesite also occurs in an intrusive mass in sec. 20, T. 12 S., R. 8 E., M. D. It is porphyritic with a microcrystalline to glassy groundmass, containing phenocrysts of zoned plagioclase, augite, and chloritized hornblende and biotite. The plagioclase of the phenocrysts is normally zoned oligoclase, with the outer rims about 3 per cent richer in soda than the cores. Feldspar microlites in the groundmass are of the same range of composition as the plagioclase of the phenocrysts. Apatite is present in minor amount.

An andesite plug occurs on the Comstock road at the west line of the quadrangle, in sec. 30, T. 11 S., R. 7 E., M. D. In this rock phenocrysts are oligoclase to andesine, and prismatic limonite-chlorite pseudomorphs. A few small grains of biotite and subhedral apatite are present. Feldspar microlites in the microcrystalline groundmass are andesine. On the eastern slope of the Diablo Range intrusive andesite has been exposed by headward erosion of the north fork of Los Banos Creek. This andesite contains phenocrysts of andesine in zoned crystals; saussuritization is shown by patches of calcite, sericite, and finely divided epidote. Deeply pleochroic oxyhornblende phenocrysts are partially chloritized and contain abundant inclusions of opaque iron ore. The groundmass contains microlites of andesine, chlorite flakes, finely divided epidote, magnetite dust, and limonite stain. Secondary quartz locally fills open spaces within the rock.

St. Marys Peak is an andesite plug which has baked the intruded sediments and volcanics near its contacts. Phenocrysts are predominantly andesine but occasionally consist of augite. They are enclosed in a microcrystalline to cryptocrystalline groundmass that contains microlites of andesine and microcrystalline augite. Limonite patches and magnetite grains are scattered throughout the groundmass.

Two small plugs of rhyolite were found in the Quien Sabe quadrangle, one forming the steep-sided point of Mariposa Peak, and the other cropping out on the north side of Cathedral Peak. The rhyolite is intrusive into all other types of igneous rock within the area, and is therefore the youngest of the Quien Sabe volcanics. The straight boundaries of the Cathedral Peak plug are striking and suggest that its shape was influenced by pre-existing fractures.

Jointing and banding, approximately vertical and parallel to the intrusive contact, are characteristic features of the rhyolite. As seen near the base of the exposed rhyolite on the south side of Mariposa Peak the joints curve outward from the major part of the body. Here the joints at the bottom of the outcrop strike N. 37° W. and dip 85° SW.; 50 feet higher the same joints strike N. 43° W. and dip 79° NE. At the top of Mariposa Peak, the nearly vertical set of joints is accompanied by a second set dipping approximately 20° north. The rhyolite of Cathedral Peak is cut by two sets of joints, one striking N. 35° E. and dipping 64° SE., the other striking N. 32° W. and dipping 76° SW.
The rhyolite is chalky white to gray in color, with brown iron oxide stains. Occasional phenocrysts of quartz, feldspar, and biotite may be seen in the hand specimen, and thin sections reveal a porphyritic texture with small phenocrysts of sanidine and oligoclase. Quartz is sparsely distributed in somewhat rounded and fractured grains. Biotite is present, but commonly has been converted to bauerite. A few chlorite flakes and hexagonal grains of apatite are present. The groundmass of the rhyolite is a mixture of opal and glass with a few laths of orthoclase. The baueritization of the biotite and the opalization of the glass are visible effects of hydrothermal alteration of the rhyolite.

Andesite inclusions are common in the Mariposa Peak rhyolite. These are somewhat brecciated when near the intrusive contact, but are in the form of lens-shaped schlieren striking N. 30° E. with vertical dip when found nearer the center of the intrusive mass. A specimen from one of the schlieren proved to be andesite with phenocrysts of andesine and chloritized hornblende and biotite, and with microlites of oligoclase-andesine in a glassy groundmass containing magnetite dust. The contaminated host rock immediately adjacent to this inclusion is intermediate in color between the dark gray included material and the light gray to white rhyolite. It is porphyritic, with some phenocrysts of oligoclase and some of andesine, and patches of chlorite which appear to be pseudomorph after biotite and amphibole. Orthoclase microlites, granular epidote, magnetite dust, and limonite patches occur in the microcrystalline to cryptocrystalline groundmass.

Peckham Formation (Upper Pleistocene)

Name, Distribution, and Relationships. The name Peckham formation is proposed for the non-marine silts, sands, gravels, and limestone occurring near the center of the quadrangle. The name is derived from Peckham Ridge, an eastward trending spur of the Diablo Range which marks the northern limit of the exposures of the sediments. The formation is flat-lying and rests with as much as 90° angular discordance upon the Franciscan, and as much as 25° upon the Miocene volcanics. It is undisrupted, the top of a portion of the formation forming a level surface.

Exposures of the Peckham formation occupy two geographic areas, each of which covers approximately 2 square miles. The northern area lies east of St. Marys Peak and north of Lookout Mountain; the southern area is principally on the eastern side of the south fork of Los Banos Creek, south of Lookout Mountain. The maximum thickness of the formation is 300 feet. The poorly consolidated sediments are less resistant to erosion than the older rocks and are cut by sharp gullies developing on the slopes of rounded hills. Soil cover is thin or absent on the slopes and grassland is found on the flatter areas.

Lithology. The gravels of this formation are poorly cemented, with well-rounded pebbles and boulders that have a maximum diameter of 1 foot; the average size of the pebbles is \( \frac{1}{2} \) inch to \( \frac{3}{4} \) inches. In sec. 17, T. 12 S., R. 8 E., M. D., the gravels rest directly on the Quien Sabe volcanics, and the pebbles are composed almost entirely of volcanic debris, while in sec. 27, T. 12 S., R. 8 E., M. D., the formation rests on the Franciscan, and pebbles in the gravels include an appreciable amount of Franciscan sandstone and some chert, in addition to Tertiary volcanic material. The
coarser material is enclosed in a matrix of pebbly sand. Channeling, cut-and-fill structures, and cross-bedding are characteristic features of many of the exposures. The gravels are interbedded with pebbly sands, clays, and silts, which also contain small pebbles of volcanic debris. Volcanic material is everywhere the most abundant constituent of the coarse grains and pebbles, but smaller amounts of Franciscan material are present where the formation rests upon the Franciscan terrain. A specimen from the northern area contained grains of cloudy feldspar, quartz (in less amount than feldspar), and a heavy fraction including augite, hypersthene, green hornblende, magnetite, epidote, and biotite, with minor amounts of garnet, zircon, glaucophane, and a grain or two of rutile.

A similar assemblage occurs in the finer-grained sediments of the southern area, except that here no garnet was noted and brown hornblende, in addition to green hornblende, was present. The similarity of the mineralogy of these sediments with that of the contiguous Quien Sabe volcanics is an indication that the latter provided the principal source of the material which collected within the local basin. A contribution from the Franciscan, on a smaller scale, is indicated by the presence in the sediments of a small amount of elastic glaucophane.

A dense, fine-grained, gray limestone, with scattered small subangular grains of elastic quartz crops out near the center of sec. 16, T. 12 S., R. 8 E., M. D. This appears to be a typical lacustrine limestone.

Environment of Deposition. Salients of lava project upward through the Peckham formation in sec. 17, T. 12 S., R. 8 E., M. D. In the southern area of the Peckham formation, rugged masses of Franciscan rocks also project upward into the younger sediments. These are exposed by the downward cutting of the southfork of Los Banos Creek. Exposures in which the sediments overlap the older rocks show that the younger formation accumulated on a very irregular surface, in part Franciscan, and in part volcanic. The stratification, cross-bedding, lensing, and channeling, of the sediments are strongly indicative of deposition by water. This deposition probably took place in a lake occupying this portion of the quadrangle in late Pleistocene time. Although no definite proof of the existence of a landslide dam was found, water may have accumulated behind such a dam near the northern end of the south fork of Los Banos Creek, flooding lower country to the south and west. Around the margins of the lake, deposits were built above the lake level, the transporting streams cutting migratory channels and forming cut-and-fill structures such as are found on present day floodplains and deltas.

Age. No fossils were found in the Peckham formation and its exact age can not be determined. In the Hollister quadrangle to the west and in the San Benito quadrangle to the south Plio-Pleistocene San Benito gravels are gently folded and faulted. The Peckham sediments are not deformed and are probably younger than the deformation affecting the San Benito gravels. The Lower Pleistocene is separated from the Upper Pleistocene by a diastrophism which was more pronounced in the southern part of California than in the central portion of the state,34 but which nevertheless noticeably disturbed the Plio-Pleistocene gravels of the Hollister-San Benito region. No statement can be made regarding the upper limit of age for the Peckham formation.

Landslides (Quaternary)

Quaternary landslides are common, particularly in the western half of the quadrangle where Franciscan and volcanic slopes are steep. Numerous small slides scar hill slopes composed of Franciscan sandy shales and shaly sandstones, as in the northwest corner of the quadrangle. The sliding and slumping of the volcanics has already been discussed. Only the more prominent of the landslides were mapped.

The largest slide occurs on the north side of Peakham Ridge west of Twin Peaks, reaches a length of 2 1/2 miles, and has an average width of a half mile. The mass does not represent material that was all once near the top of the ridge, but is more correctly pictured as a continuous zone in which the surface material has moved some distance down the slope from its original location. Three other large slides are present in the high country of the northeastern portion of the quadrangle; all are composed of volcanic debris.

Terrace Deposits

Quaternary terrace deposits, consisting of unconsolidated gravel, sand, silt, and clay, occupy much of Los Banos Valley where three levels were mapped. The first occurs at a height of 20 feet, the second at 100 feet, and the third at 120 feet above the level of the stream. Terrace deposits also occur around the common corner of secs. 28, 29, 32, and 33, T. 12 S., R. 8 E., M. D., in secs. 19 and 20, T. 13 S., R. 9 E., M. D., and in Los Muertos Valley, but different levels were not differentiated in these localities.

Alluvium

Recent alluvium, composed of unconsolidated gravel, sand, silt, and clay, is present in the beds of many of the streams of the area, and forms the flat bottom lands of the larger valleys. Quien Sabe Valley is floored with the largest expanse of alluvium in the quadrangle.

STRUCTURE

The Quien Sabe quadrangle is a portion of one structural unit of the Coast Ranges, the Diablo Range. This range has a basement of folded Franciscan strata, overlain by several thousand feet of later sediments and volcanic rocks. It has been deformed by folding and thrust faulting, with pronounced overturning in places.

The Ortigalita fault, in the northeastern quarter of the quadrangle, is one of the most important structural features in the area. It continues along the eastern front of the Diablo Range, to the north and south of the Quien Sabe region, and marks the Franciscan-Cretaceous contact. Thrust movement on this fault has moved Franciscan rocks to the northeast over the later Cretaceous sediments, overturning the Cretaceous rocks in the process. Additional displacement has occurred on a fault paralleling the Ortigalita fault, usually at the base of the El Puerto volcanics within the Franciscan. These faults will be considered together, as they are closely related.

The Ortigalita fault is exposed within the Quien Sabe quadrangle, from the vicinity of Carrisolito Spring to the southwest corner of sec. 24, T. 11 S., R. 8 E., M. D. It has an average strike of N. 15° W. and dips steeply to the southwest. The secondary fault within the Franciscan is exposed over the same area, paralleling the strike of the Ortigalita fault, but dipping 50° to 55° SW. The amount of displacement on both is inde-
terminate, but movement on the Ortigalita fault has sheared the conglomerate at the base of the Cretaceous, and slickensided, sheared serpentine marks the position of the parallel fault at the base of the El Puerto volcanics; chert immediately to the west of the serpentine is also sheared and brecciated. In general, slickensides are very poorly preserved, but indicate an upward movement of the hanging wall. The stratigraphic position of the Franciscan above the Cretaceous, separated by the fault, also indicates thrust movement.

A short distance to the east of the Ortigalita fault the Cretaceous beds dip 50 to 65 degrees to the east. The beds are vertical closer to the fault, and at the fault on the north side of Chileno Creek the beds are overturned 65° NW. The strike is affected somewhat by a minor cross-fault which offsets the Ortigalita fault slightly to the east on the south side of Chileno Creek. The overturning is apparently a drag effect produced by the movement on the Ortigalita fault. There are no indications of recent movement on either of these faults. As Upper Cretaceous sediments are involved in the movement, the age of the disturbance is post-Upper Cretaceous. No Tertiary rocks occur near the fault within this quadrangle, but in other portions of the Coast Ranges Paleocene and Upper Cretaceous sediments have the same geographic distribution, and are lithologically similar. There is no evidence of any great disturbance.35 The compressive forces which began to affect the Coast Ranges in the early Tertiary reached their peak in the late Pliocene, at which time the ranges were uplifted by folding and thrusting of their margins. Direct evidence of this peak is present in the San Benito quadrangle.36 Although there may have been earlier movements along the Ortigalita fault, the features observed today probably were produced during the late Pliocene disturbance.

In the southwestern corner of the quadrangle, Franciscan rocks are thrust to the northwest over Cretaceous sediments along a fault trending northeast. This fault is offset by later, northwestward-trending faults, along which a portion of the Miocene Quien Sabe volcanics is thrust over Cretaceous and Franciscan rocks to the south. Northwest of Little Quien Sabe Valley, a northeastward-trending fault has offset the contact between the Cretaceous sandstone and the Quien Sabe volcanics. This dates the northeastward-trending set of faults as later than the middle (?) Miocene volcanic series, and as these are offset by northwestward-trending faults, the northwestward-trending faults postdate the first set. Sag ponds and short trough-like valleys mark the position of the later faults and suggest active movement as recent as Quaternary. Dikes occur in some of the fault zones and the mineralization of the Stayton mining district is localized along certain of these faults.

The structure of the Franciscan is generalized on the cross sections accompanying this report. This group of rocks is intricately folded and faulted and in the time available it was not possible to work out in detail all of the relationships existing within this group. Attitudes are exceedingly variable over a short distance. A small east-west-trending, plunging anticline, eroded along its axis, occurs in sec. 9, T. 11 S., R. 8 E., M. D., and forms an amphitheater-shaped valley opening into the north

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end of Los Banos Valley. West of Wildcat Creek are an anticline and syncline in the Franciscan, the axes trending roughly east-west; dips on the north limb of the anticline range from 50° N. to vertical, and on its south limb average 60° to 65° S. In this area interpretation of the structure was aided by the presence of a blue sand horizon which could be used as a marker over a limited area.

The Cretaceous sediments in the northeastern corner of the quadrangle dip fairly uniformly to the northeast. No pronounced structural features stand out in this area except the overturning of the beds against the Ortigalita fault. Exposures of the Cretaceous in the southwest quarter of the quadrangle are very poor, except in road cuts. Hills are rounded with very few outcrops, and the flatter land has been under cultivation for so long that exposures of the rock through the soil are almost non-existent. Along the Santa Ana Creek road dips are moderate to the northeast, while on the road to Little Quien Sabe Valley there is moderate southeastward dip. Comparison of the map accompanying this report with the geologic map of the Hollister quadrangle suggests an anticline in the Cretaceous of this area, as dip symbols on the two maps, though sparsely scattered, are opposed in a regular manner.

The Quien Sabe volcanics are broadly warped and in places, extensively faulted. A broad curving downwarp at the east end of Peckham Ridge is reflected by the attitudes of the volcanics in this area, and slight upwarps and downwarps are present in other localities; not all of them are indicated on the map. The north half of an eroded east-west anticline, plunging to the west, can be followed along the outcrops of light colored tuffaceous agglomerates on the north side of the north fork of Los Banos Creek, in secs. 23 and 27, T. 11 S., R. 7 E., M. D. The fold is not traceable on the south side of the creek, as it is obscured by a large landside.

**GEOLOGIC HISTORY**

During Upper Jurassic time a thick sequence of terrigenous sediments, predominantly arkosic sandstone (Franciscan group), was deposited. The freshness of the feldspar, angularity of grain, and thickness of accumulation indicate a source region of strong relief with a rigorous climate. The character of the material, the coarsening of the sediments to the west, and the absence of Sierran type debris in the Franciscan conglomerates are evidences that the source region lay to the west of the basin of accumulation. The climatic conditions in the source region probably ranged from low temperatures and heavy precipitation in the highlands to more moderate temperatures favoring wooded areas on the lower slopes. The sandstones and shales of the Franciscan commonly contain carbonized wood and plant fragments. Mechanical disintegration predominated over chemical decomposition in the rugged area from which the Franciscan was derived. The basin of deposition of the Franciscan group was a geosyncline occupying a position between the ancestral Sierra Nevada and the present coast line. This geosyncline came into existence as a result of the Nevadan orogeny. West of the present coast line, a new high and rugged land mass came into existence, or an

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old land mass in this position was strongly uplifted. The thickness of the Franciscan in the Quien Sabe quadrangle is unknown, as nowhere within the area is it in contact with older rocks. On the basis of incomplete sections which are exposed and which measure 10,000 feet, an estimate of 25,000 feet for the total thickness of the Franciscan is not excessive.

Volcanic activity reached a maximum near the middle of this period of accumulation of clastic material, then lessened. Basic flows poured out, probably on the sea floor, and were accompanied by sills and other hypabyssal and shallow types of intrusions, all of which combined were responsible for the large contribution of silica that resulted in thick lenses of radiolarian chert. The entire sequence was intruded by ultrabasic magma that was commonly serpentinized either at the time of intrusion or shortly thereafter. Many of these intrusions metasomatically metamorphosed the wall rock and produced glaucophane schists and related rock types.

The deformation of the Franciscan is in marked contrast to that of the younger formations. At least two orogenic disturbances which took place between the Upper Jurassic and the Upper Cretaceous are recorded in other portions of the Coast Ranges. Although these disturbances did not greatly affect the position and extent of the geosyncline, they may have been the cause of the deformation and slight regional metamorphism of the materials deeply buried in the geosyncline. The weight of the overlying sediments has probably caused the slaty appearance of many of the Franciscan shales. Furthermore, the presence of rigid intrusive masses within the Franciscan may account for the greater deformation of these sediments, as the rigid masses would act as buttresses against which the sediments would be crushed during succeeding periods of deformation.

Knoxville (Upper Jurassic) and Lower Cretaceous rocks are absent within the quadrangle and may never have been deposited in this area; or they may have been completely removed by erosion prior to the deposition of the Upper Cretaceous sediments.

A second sequence of arkosic clastic sediments with thick conglomerate lenses was deposited during Upper Cretaceous time. The conglomerate, which contains Franciscan and Lower Cretaceous debris, probably reflects uplifts in the land area bordering the basin of deposition. The abundance of shale and fine- to medium-grained sandstones of Upper Cretaceous age indicates derivation from a comparatively low land mass, but the arkosic and frequently coarse nature of these sediments suggests rapid erosion of the source area by large streams.

Early Tertiary sediments are absent in this region but the presence of the lower Miocene sea is indicated by the thin bed of Vaqueros limestone in a small area in the western portion of the quadrangle. Either the remainder of the area was above sea level during Vaqueros (lower Miocene) time, or erosion has completely removed what material was deposited.

Volcanic activity was pronounced following the lower Miocene (Vaqueros), and extensive andesitic and basaltic debris accumulated along what is now the crest of the Diablo Range. Some of the pyroclastic material was deposited or reworked by streams flowing on the new land

9 Wilson, I. F., op. cit, p. 195.
surface. Plugs and irregular masses of intrusive andesite, centering in the northwestern portion of the quadrangle, were the feeders for this volcanic activity. A later phase of the volcanism consisted of intrusion of rhyolite into both intrusive and extrusive andesite. No flows, or pyroclastics, of rhyolitic material remain on the surface today; they may never have been extruded, or perhaps active erosion in the region has removed whatever originally was present. Antimony and quicksilver mineralization, localized along faults which resulted from the disturbance accompanying the igneous activity, represents the final volcanic phase. Mineral veins are fractured and often brecciated.

The present features of Ortigalita fault probably were developed during the upper Pliocene elevation of the Coast Ranges, when the Franciscan core of the Diablo Range was thrust outward over the bordering Cretaceous sediments. The maximum deformation occurred along the margins of the mountain blocks. The cap of Quien Sabe volcanics at the center of the Diablo block was much less affected, but in places it was also thrust outward over Cretaceous sediments. Faulting of the volcanic area continued into Quaternary time, but the upper Pliocene faulting and uplift in large part determined the present topography and was responsible for the establishment of a drainage pattern which, except for minor modifications, has continued to the present time.

Gravels, sands, silts, and limestone accumulated in an upper Pleistocene lake in the central portion of the quadrangle. Terraces were formed along the edges of the valleys of the main streams of the area and two cycles of erosion ensued. The first reached a stage of late maturity, the second a stage of late youth or early maturity.

ECONOMIC GEOLOGY

Manganese

Hendricks (Cleveland) mine is located in sec. 24, T. 13 S., R. 8 E., M. D. The property covers 80 acres, with manganese occurring in rhythmically banded Franciscan chert in which some bands are as much as 5 feet thick. The workings consist of a caved inclined shaft on the hillside, and a trench 75 feet long, 20 feet wide and 20 feet deep, cut along the top of the outcrop. The shaft, 50 feet below the trench, reportedly was driven 153 feet and encountered the deposit about 80 feet from the collar, according to Bradley. 41 Four or five truck loads of ore were removed from the trench in 1944. The ore is typical Franciscan oxidized, manganiferous chert, containing carbonate and bementite (hydrous manganese silicate), oxidized to psilomelane near the surface.

Fries Ranch Prospect. At the Fries Ranch prospect in the southwest quarter of sec. 9, T. 13 S., R. 8 E., M. D., a trench has been cut in manganiferous Franciscan chert. The ore is a punky oxide derived from neotocite and occurs primarily in the thicker beds of the rhythmically bedded chert. An inclined shaft about 8 feet deep terminates in a stope at one end of the open cut. The dump is grown over with grass and weeds and the prospect apparently has not been worked in recent years.

Manganese stain is pronounced on the Franciscan cherts cropping out in Herrero Canyon and Hoffman Canyon, near the eastern edge of the quadrangle, and in secs. 5 and 8, T. 13 S., R. 8 E., M. D.

Antimony

Ambrose Mine. The Ambrose mine, also known as the Rip Van Winkle mine, is in sec. 30, T. 11 S., R. 7 E., M. D. The last production from the mine was during the first World War, but an attempt to recover stibnite from the dump was made during the recent war. The ore mineral is stibnite which, with a little milky quartz, occurs in a vein that strikes N. 20° W. and dips 65° SW. The country rock is intrusive andesite. Workings consist of adits on three levels, the lowest one flooded, and the upper one caved. In the second level, run about 250 feet into the hillside, the stibnite vein pinches out 200 feet from the portal.

Shriver mine, located in sec. 31, T. 11 S., R. 7 E., M. D., is caved and inaccessible. Workings apparently consist of two tunnels with drifts on the vein. The property was first exploited for quicksilver, and the ore also carried values in gold and silver.42

Blue Wing mine is in sec. 5, T. 12 S., R. 7 E., M. D., a short distance southwest of the Stayton mine. Workings are flooded, but according to Bailey and Myers the ore is in northward-trending quartz-stibnite veins which have been opened by a 75-foot vertical shaft with short drifts to the north and south. The ore is low grade. In November, 1948, the mine was again being worked, with the ore being hand sorted with the intent of shipping all better than 50 percent antimony.

Other antimony properties within the Quien Sabe quadrangle include the Florence mine group in sec. 8, T. 12 S., R. 7 E., M. D., the French antimony group in sec. 5, T. 12 S., R. 7 E., M. D., and the Gleason mine in sec. 6, T. 12 S., R. 7 E., M. D.44 The ore in all cases is stibnite-bearing quartz of low grade. These properties are idle at the present time, with the exception noted.

Quicksilver

Stayton mine, in sec. 5, T. 12 S., R. 7 E., M. D., is being worked by the owner, Mr. R. B. Knox, and an assistant. Production is very small, approximately 1400 flasks having been recovered since 1880. A 12-ton furnace and retort is located on the property. The ore is cinnabar in quartz veinlets that fill fractures in basalt along a normal fault. Pyrite and stibnite occur with the quartz and cinnabar. The mine was located originally as an antimony property in 1870. The general strike of the veins is north-south with a steep dip to the west. Underground workings reportedly consist of an inclined shaft 250 feet deep, with levels at 70 feet, 150 feet, and 235 feet, and drifts of 150 feet, 775 feet, and 10 feet in length respectively.45 At present the deeper levels are either flooded or filled with waste. An adit 70 feet north of the main portal intersects what is probably the northerly extension of the main Stayton vein.

The portal of the Yellow Jacket mine is about 500 feet northwest of the portal of the Stayton mine, in sec. 5, T. 12 S., R. 7 E., M. D. This mine has produced very little ore. Workings consist of an adit and a crosscut which are entirely in nearly barren basalt.

Gypsy mine is about 2400 feet north of the Stayton mine and on the same fracture zone. The ore is cinnabar, associated with quartz and opal. Production has been small and workings consist of a stope open to the surface, several short drifts, and two adits.

Comstock mine is in sec. 19, T. 11 S., R. 7 E., M. D., in the south-eastern corner of Santa Clara County. The workings are flooded and partially caved. The ore is cinnabar in silica-carbonate rock produced by the alteration of Franciscan serpentine. A northeast-trending fault, dipping moderately to the south, has localized the ore in the silicified serpentine of the hanging wall. Crosscuts extend east and west from an inclined shaft immediately above the fault zone, and old stopes follow fractures in the silicified mineralized zone.

Mariposa Mine. There is no record of production from the Mariposa mine, in sec. 28, T. 11 S., R. 7 E., M. D. The lower level of workings consists of three shafts connecting with an adit; a raise joins this level with an upper level consisting of three adits, all caved. The principal shear zone consists of several closely spaced faults striking northwest and dipping moderately northeast. Very little cinnabar is present and no stibnite was seen. The same altered zone continues to the southeast where, about 1400 feet from the Mariposa mine, there are three shafts. One shaft is timbered and flooded. A caved adit and a prospect pit comprise the other workings at this locality.

Other prospect pits are located in the northwestern portion of the Quien Sabe quadrangle. The Franciscan conglomerate in the northwest quarter of sec. 29, T. 11 S., R. 7 E., M. D., has been prospected with no apparent success. On the west side of Cathedral Peak, sec. 21, T. 11 S., R. 7 E., M. D., a caved shaft penetrates andesite at the contact with the rhyolite intrusive. A small amount of quicksilver "paint" was observed on some of the waste material. A small shear zone has been prospected in sec. 32, T. 11 S., R. 7 E., M. D., but the workings are now completely caved.

Some of the veins of the Stayton mining district contain only antimony (Ambrose mine), some contain both antimony and quicksilver (Gypsy and Stayton mines), and some contain only quicksilver (Mariposa mine). The antimony and quicksilver deposition took place during several successive stages following the intrusion of andesite masses and along faults in andesite plugs. Thus the mineralization is later than all other igneous activity, with the possible exception of the rhyolite intrusions. A period of fracturing separates the time of quicksilver deposition from that of the earlier antimony.

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QUICKSILVER AND ANTIMONY DEPOSITS OF THE
STAYTON DISTRICT, CALIFORNIA*

BY EDGAR H. BAILEY** AND W. BRADLEY MYERS**

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The Stayton district, which lies 13 miles northeast of Hollister, California, includes parts of San Benito, Santa Clara, and Merced Counties. The district has yielded about 1,700 flasks of quicksilver, mostly between 1870 and 1880, and a few tons of antimony ore.

The rocks of the district include Jurassic (?) (Franciscan formation) and Cretaceous (?) sedimentary rocks, serpentinized ultrabasic rocks intruded into the Franciscan rocks, Miocene (?) basaltic and andesitic extrusive rocks, and several intrusive bodies of Miocene (?) andesite and rhyolite. The basaltic extrusive rocks were arched into a northward-trending asymmetrical anticline, then planed by erosion and capped by the andesitic rock. All the rocks are cut by northward-trending faults along which there have been several periods of movement.

Veins containing stibnite occur mainly in the basaltic rocks along faults in the central part of the district. They are estimated to contain several tens of thousands of tons of potential ore averaging about 1½ percent of antimony.

Cinnabar, the only commercially important quicksilver mineral, has three different modes of occurrence: (1) Veins and coatings in fractures in broken antimony veins, (2) coatings on otherwise unmineralized fractures in basalt, and (3) veins and replacement deposits in silica-carbonate rock derived from serpentine.

The possible reserves of the five largest mines amount to slightly more than 1,000 flasks of quicksilver. The largest mine, the Stayton, is probably capable of producing nearly 100 flasks per year for a few years. Additional prospecting along broken antimony veins immediately below the contact between the two volcanic units might uncover additional deposits of medium-grade quicksilver ore.

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1 A flask contains 76 pounds.
INTRODUCTION

The Stayton quicksilver and antimony district is on the crest of the Diablo Range 90 miles southeast of San Francisco and 13 miles northeast of Hollister, California (fig. 1). It is in Tps.11 and 12 S., R. 7 E., in the northwestern corner of the Quien Sabe quadrangle. The district lies mostly in northeastern San Benito County, but it also includes parts of southeastern Santa Clara County and western Merced County. The only good road into the district extends from Hollister, on the Southern Pacific Railroad, to the Stayton mine, which is the largest in the district; other roads are passable only during the dry summer months.

Little geologic work has been done hitherto in the region. Becker\(^2\) briefly mentioned the mines, and Forstner\(^3\) made a reconnaissance map of the area in 1903.


The field work furnishing the basis for this report was done during approximately two months in the spring of 1941. The areal geology was plotted on airplane photographs and later fitted to photographic enlargements of the Quien Sabe topographic sheet.

The operators and miners in the district, especially Mr. R. B. Knox, owner and operator of the Stayton mine, were uniformly courteous and helpful. The writers are indebted to E. B. Eckel of the Geological Survey for advice during the field work and the preparation of this report.

**HISTORY AND PRODUCTION**

The veins of the Stayton district were mined for antimony when first worked, between 1870 and 1875, but the more valuable cinnabar was soon discovered. By 1876 the Stayton Mining Company had gained control of the Gypsy, Stayton, and several smaller mines, and the company is reported to have produced about 1,000 flasks of quicksilver before 1880. The Comstock mine in the northern part of the district was also discovered in the seventies and produced about 300 flasks prior to 1880. The production of the district from 1880 to 1920 is not known but is believed to have been very small. An accurate record is available only for the Stayton mine, which has produced 390½ flasks since the revival of mining in 1920.

<table>
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</tr>
<tr>
<td>1933</td>
<td>12</td>
</tr>
<tr>
<td>1934</td>
<td>1</td>
</tr>
<tr>
<td>1935</td>
<td>18</td>
</tr>
<tr>
<td>1936</td>
<td>9</td>
</tr>
<tr>
<td>1937</td>
<td>11</td>
</tr>
<tr>
<td>1938</td>
<td>18</td>
</tr>
<tr>
<td>1939</td>
<td>10</td>
</tr>
<tr>
<td>1940</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>390½</strong></td>
</tr>
</tbody>
</table>

1 From records of the California State Mining Bureau. Published with the permission of Mr. R. B. Knox.

The total quicksilver production of the district prior to 1940 is summarized in Table 2.

<table>
<thead>
<tr>
<th>Mine</th>
<th>Years</th>
<th>Quicksilver (flasks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comstock mine</td>
<td>1870-1880</td>
<td>300</td>
</tr>
<tr>
<td>Stayton and Gypsy mines</td>
<td>1870-1919</td>
<td>(?)1,000</td>
</tr>
<tr>
<td>Stayton mine</td>
<td>1920-1940</td>
<td>390</td>
</tr>
<tr>
<td><strong>Approximate total</strong></td>
<td></td>
<td>(?)1,690</td>
</tr>
</tbody>
</table>

The amount of antimony produced is unrecorded, but the total probably is only a few hundred tons.

*Forstner, William, op. cit., p. 147.*
GEOL OGY

The Stayton district is underlain chiefly by Tertiary igneous rocks, for it lies in the north-central part of a dissected Tertiary (Miocene?) volcanic field, which extends over an area of about a hundred square miles (fig. 1). Exposures of pre-Tertiary rocks are relatively small, and lie mainly in the lowest canyon bottoms and around some volcanic plugs that have upturned the invaded rocks, as is shown on the geologic map of the district (pl. 8). Parts of the district are covered by Quaternary landslides and alluvial deposits; these require no further mention.

The pre-Tertiary rocks were divided for mapping into two units. One unit includes some typical rocks of the Franciscan (Jurassic?) formation and some younger sedimentary rocks that are probably of Cretaceous age. These rocks are much folded, faulted, and crushed, but no dominant structural trend was recognized in them. The second unit includes serpentine and masses of silica-carbonate rock derived from serpentine. The serpentine is intrusive into the Franciscan rocks but nowhere cuts the Cretaceous (?) rocks. There are pebbles of serpentine in the Cretaceous (?) conglomerate.

The Tertiary igneous rocks were divided for mapping into four units. The oldest includes basaltic extrusive rocks, flows, and interbedded layers of agglomerate and tuff, which are separated from the older pre-Tertiary rocks by a major unconformity. These basaltic rocks are arched in a north-trending asymmetrical anticline which was formed and partly eroded before the extrusion of the andesite extrusive rocks that make up the second unit. The third unit comprises andesitic rocks of intrusive bodies, some older than the andesitic extrusive rocks, some younger, and some of undetermined relative age. The youngest Tertiary igneous rocks are intrusive bodies of rhyolitic rock. Although some of the intrusive bodies turned up the adjacent layers of older rocks, others cut sharply across the bedding.

The structural features of principal interest are north-trending faults, along some of which the ore bodies occur. All the known ore bodies are along faults in the basaltic rocks, except one that is in an andesitic intrusive body and one that is in a body of silica-carbonate rock.

Pre-Tertiary Rocks

Franciscan (Jurassic?) and Cretaceous (?) Rocks

The Franciscan rocks are dark brown to black silty shale, gray or greenish arkosic sandstone, conglomerate, light-green to cream-colored chert, and basic intrusive and extrusive rocks that are now altered to greenstone. The total thickness is unknown.

The Cretaceous (?) rocks include black shale, gray sandstone which weathers either buff or brown, and chert conglomerate. The exposed thickness within the district is more than 500 feet. These rocks are lithologically similar to those in Cretaceous formations in the Coast Range, but no attempt was made to establish the correlation fully. The absence of massive chert, greenstone, and serpentine in the Cretaceous (?) rocks, as well as their uncrushed condition, serves to distinguish them from the Franciscan rocks.
Serpentine

Serpentine crops out only in three small areas in the northwestern part of the district. The rock is various shades of green, but in some places it is nearly white. Small crystals of picotite, a black, nearly opaque mineral with brilliant luster, generally stud the serpentine, and in fresh rock magnetite is also abundant. The texture resembles that of a coarse sandstone in which the grains are elongated as a result of slight shearing; the texture is probably a relict of the intrusive peridotite from which the serpentine is believed to have been formed.

Some of the serpentine has been further altered to the peculiar rock termed "silica-carbonate rock" or "quicksilver rock." In the Stayton district the silica in this rock is largely chalcedonic quartz. Most of this rock has a sheared or irregularly schistose structure which it probably inherited from the serpentine. Nearly all of the silica-carbonate rock found on the surface is weathered, and is characteristically stained pale tan by iron oxides. As the carbonates are readily dissolved, outcrops are also distinguished by a deeply pitted surface on which an irregular and intricate network of narrow walls separates lens-shaped cavities. In the vicinity of the Comstock mine the rock is largely chalcedonic quartz and pyrite with very little carbonate and is like the twice-silicified rock described by Ross. This rock stands out as an elongate reef because of its resistance to erosion.

Tertiary Igneous Rocks

Basaltic Extrusive Rocks

The basaltic rocks cover more than half of the area mapped. Their aggregate thickness differs greatly from place to place and locally amounts to more than a thousand feet.

The dominant rock, represented by nearly three-quarters of the surface exposures, is massive but intricately fractured basalt. The basalt is poorly exposed, but soil derived from it contains small angular fragments that are easily recognized. Although the basalt is nearly black when fresh, almost all specimens found on the surface are brown or tan because of weathering. Commonly only a few very small crystals can be seen in the dense rock, but some varieties contain phenocrysts of plagioclase an eighth of an inch long. Vesicles, which are rare, are filled with limonite at some exposures and with calcite or chabazite at others. In the vicinity of the large irregular intrusive body of andesite in the eastern part of the district, the basalt is hydrothermally altered almost beyond recognition.

Soft, white- to buff-colored tuff interbedded with the basalt is particularly abundant in the western and southern parts of the district. The tuff resembles sandstone for it is generally composed of small, light-colored grains with little finer-grained matrix, and it is generally well-bedded and in a few places cross-bedded. The characteristic fragments, which are generally about the size of a pea or smaller, consist of tuff of a somewhat lighter color than the matrix. Scattered at fairly wide intervals through the tuff in some exposures are angular blocks of black basalt a foot long. In the southwestern corner of the district these angular

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blocks are so numerous and prominent that here the rock is aptly termed a basaltic agglomerate. In outerops of this rock the matrix is hardly noticeable because of the abundance and resistant nature of the blocks.

A mottled-green or brownish-green tuffaceous agglomerate is the most common rock in the area south and east of Antimony Peak. The agglomerate can be distinguished from the overlying andesitic agglomerate only with difficulty. However, it is so well indurated that the boulders are the least resistant part of the rock and weather out leaving a pitted or cavernous surface, whereas in the overlying andesitic unit the boulders protrude as knobs on weathered outerops.

**Andesitic Extrusive Rocks**

The andesitic extrusive rocks are more than 1,500 feet thick. The dominant variety is an agglomerate with an igneous matrix, but tuffaceous agglomerate and tuff are locally abundant in the lower part.

The agglomeratic character of the rock is most noticeable in weathered outcrop where the slightly more resistant boulders stand out. The boulders range from 6 inches to 3 feet in size. Most of the agglomerate is light gray or pink, but some denser varieties are red or nearly black. Phenocrysts of pale-yellow plagioclase, a quarter of an inch long and amounting to a tenth of the rock, are embedded in a fine-grained, nearly glassy matrix. Crystals commonly form complexly twinned or intergrown clots, and some are rounded and altered on the surface to soft white kaolin. Hornblende, occurring in only minor quantity, is generally altered to a soft, brownish-gray aggregate; biotite is commonly fresh. A platy fracture is locally developed, and incipient short parallel cracks and open spaces are usually present.

A few flows are probably present in the upper part of the unit. On Henrietta Peak and in the two areas east of Mariposa Peak and east of the Stayton mine bodies of intrusive andesite are included in the areas mapped as extrusive andesite.

**Andesitic Intrusive Rocks**

At least three kinds of andesitic intrusive bodies can be distinguished within the area. One kind, characterized by sharp contacts, nearly circular outline, arching of the surrounding formations, and lack of any contact-metamorphic effects, is best represented by the plug at the head of Quien Sabe Valley. Such bodies were intruded after the arching of the basaltic rocks, but before the deposition of the andesitic extrusive rocks.

The second kind is exemplified by the large irregular intrusive body that is exposed in the area surrounding the fork of North Los Banos Creek. Numerous tongues and dikes that border the mass could not be mapped in detail in the time available. Hydrothermal metamorphism has altered the surrounding basalt but appears to have had little effect on the invaded shale. Several large slivers of basalt caught in the intrusive mass are shown on the map, but others are not delineated. The relative ages of this irregular intrusive body and the andesitic extrusive rocks were not determined.

The third kind, characterized by sharply angular contacts and absence of metamorphic effects, is exemplified by the large intrusive mass
at the northern boundary of the area. Masses of this kind, as well as certain other masses which have not been mapped, are intrusive into the andesitic agglomerates.

**Rhyolitic Intrusive Rocks**

Two small plugs of rhyolite crop out in the northeastern corner of the district. The rock is light-colored, in places white, and contains small phenocrysts of quartz as well as orthoclase. The shape of the eastern mass evidently was controlled by pre-existing fractures. The only obsidian found in the district occurs along its sheared southern edge.

The rhyolite is probably the youngest igneous rock in the area, as it is intrusive into the effusive as well as one of the younger intrusive andesites.

**Faults**

More than a score of northward- and northwestward-trending faults have been mapped within the district. Movement along them occurred or recurred during at least three, and possibly four different stages: (1) Between the deposition of the basaltic and andesitic units, (2) after the deposition of the andesitic unit and prior to the antimony mineralization, (3) following the antimony mineralization but before the quicksilver mineralization, and possibly (4) after mineralization. The faults formed after mineralization are confined to the southwest quarter of the area mapped. All the others are mineralized, and it is probable that many of them were active during all but the last period of movement.

The mineralized faults, which contain the ore bodies, strike west of north through the middle of the area. None of them is known to be more than 2 miles long, and many are much shorter. Those on the west are reverse faults which dip steeply to the west. The dip of the mineralized fault on the east slope of Antimony Peak ridge changes sharply along the strike. In the south, near the Stayton mine road, the fault dips steeply to the west and is reverse. At the first canyon crossing, some 600 feet north, the dip decreases to 35° W. A little farther north, where it crosses the southern elbow of Antimony Peak ridge, it is vertical, and in the good exposures along the slope of the ridge it dips 65°-75° E. and is normal with a displacement of more than 500 feet. Still farther north, west of Antimony Peak, exposures are poor, but the fault is believed to be again nearly vertical. Other faults of the district show less extreme changes in dip.

The fault of the Gypsy vein is normal and dips west at a moderate angle. It allows a keystone block in the anticline to be depressed west of the Gypsy vein, and in this respect it is similar to all of the mineralized faults along which the crest of the anticline has been lowered (pl. 8, section A-A').

The faults of the district are readily traceable only where mineralized and, therefore, may be more continuous or more widely distributed than is suggested on plate 8.

A group of more than a dozen faults in the southwestern quarter of the district are not silicified or otherwise mineralized. The positions of some of these faults are shown by topographic features such as ponds and short troughlike valleys. These faults seem to be geologically very young, and were probably formed after the ore deposition.
ORE DEPOSITS

Antimony Veins

Most of the antimony deposits of the Stayton district consist of stibnite-bearing quartz veins along northward-trending faults within the basalt. These veins crop out on both sides of Antimony Peak ridge and extend southward a short distance beyond the Stayton mine where they pass under the younger andesitic rocks. Although the exposures are good, neither the veins nor the faults were found on the southern side of the narrow ridge covered with andesitic agglomerate.

The antimony veins and the adjacent parts of the wall rock are commonly resistant to erosion and consequently stand up above the surface of the ground as low irregular walls. The weathered outcrops of the more silicified and mineralized parts of the veins generally are relatively smooth and stained yellowish green. Most of these veins are a few feet wide but a few exceptional ones exceed 30 feet. They are bordered by kaolinized and somewhat silicified breccia made up of angular fragments about 1 inch in size. The breccia is irregularly cut, replaced, and cemented by veins of black chaledonic quartz containing pyrite and some needles of stibnite. Small pods and irregular veins of stibnite with little or no quartz replace and fill fractures in the black quartz vein filling.

The breccia can be found throughout most of the length of the veins, but it is invariably of low grade, averaging less than 1 percent of antimony. Veins of nearly pure stibnite, which form small lenses and pockets less than a foot wide and containing only a few cubic feet of ore, locally increase the tenor of the ore considerably above 1 percent. The abundance of these lenses, which can only be established by careful prospecting, ordinarily determines whether the mining of a block of ground is profitable.

Three small mines, the Ambrose, Shriver, and Blue Wing, have produced some antimony from widely separated parts of three different veins. Numerous small pits, drifts, and small prospects on other veins may have yielded a few sacks of hand-picked ore although there is no record of the amounts produced.

Quicksilver Deposits

The quicksilver deposits, which are more valuable than the antimony deposits, are cinnabar-filled fractures in and near portions of the southeastern antimony veins. Isolated quicksilver deposits not related to antimony veins occur west of Mariposa Peak and also in the northwestern corner of the district. Three distinct types of quicksilver deposits have been mined in the district: (1) Fractured antimony veins with later cinnabar encrustations and impregnations, (2) cinnabar fillings in otherwise unmineralized fractures in basalt, and (3) cinnabar veins and replacements in silica-carbonate rock derived from serpentine.

Faults localize the ore bodies of all the principal mines. Within the fault zones the cinnabar commonly coats rather closely spaced, nearly vertical, late fractures.

The ore shoots exist where these cinnabar-filled fractures are abundant or, exceptionally, where single veinlets of cinnabar about an inch thick are closely paralleled by a few thinner veinlets which increase the tenor of the ore. No large ore bodies have been found.
Most of the ore mined in 1941 at the Stayton mine contained less than one-half of 1 percent of quicksilver (10 pounds to the ton), but the tenor was raised by hand-sorting to about 2 percent.

Mineralogy

Cinnabar (HgS) is the only commercially important quicksilver mineral of the district. No native mercury is known in any of the mines, and metacinnabar occurs only in the Comstock mine. Bright-red cinnabar replaces quartz, chalcedony, and opal in the silica-carbonate rock of the Comstock mine, but elsewhere it is found as coatings or crusts in open spaces. Some of the crusts are purple-red and crystalline; the majority are microcrystalline or, in the lower-grade ores, the earthy bright-red variety known as "paint." Although some evidence for re-solution of cinnabar was found there is no direct evidence that the "paint" has formed through the action of surface waters.

A few veinlets of massive metacinnabar (HgS), partly replaced by cinnabar, were found in the Comstock mine.

Stibnite (Sb₂S₃) is the only antimony ore mineral recognized in the district. It is steel gray to lead gray in color, and in large crystals it shows brilliant metallic luster on fresh surfaces. It occurs as small needles in clear, gray to black, sugary quartz veins and as more coarsely crystalline masses in veins up to 10 inches in width. A few crystals are found in open cavities. Fractured stibnite crystals are coated with cinnabar in mines of the central and eastern part of the district. Jet-black velvety coatings of minute needles of stibnite deposited on cinnabar encrustations in the Stayton mine may be of supergene origin.

All of the more common oxides of antimony are probably present as surface coatings and replacements of stibnite in the shallow, oxidized parts of the stibnite veins. Brownish valentinite (Sb₂O₃), white waxy senarmontite (Sb₂O₅), white or light-yellow cervantite (Sb₂O₃·Sb₂O₅) are the common oxides, and the bright-yellow hydrous oxide stibconite (Sb₂O₅·H₂O) is less common.

Minute crystals of sulfur occur with antimony oxides on stibnite in a few places.

Pyrite is present in all of the mines of the district but is particularly abundant in the Stayton mine. Much of it occurs as small cubes or pyritohedrons in vein quartz that is older than the antimony mineralization, but some is definitely younger. The oxidation of the pyrite in the Yellow Jacket and Stayton mines has introduced considerable amounts of sulfuric acid into the mine waters. Some of the sulfates occurring as secondary encrustations on the mine walls are epsomite (MgSO₄·7H₂O) in long tapering hairlike needles, melanterite (FeSO₄·7H₂O) in bright-green stalactites, and rarer white fibrous gypsum (CaSO₄·2H₂O).

Barite (BaSO₄) occurs as thin tabular crystals with quartz in the Yellow Jacket mine and in the gossan of one of the prospects on Mariposa Peak, but it is nowhere abundant.

Jarosite, a hydrous sulfate of potassium and iron, forms rare yellow-brown colloform crusts in a few antimony veins in the district.

Although gold was not seen in any of the antimony veins Mr. R. B. Knox * reported that they contain between $0.50 and $6 worth of gold to the ton.

* Oral communication.
Carbonates are locally developed in the silica-carbonate rock in the vicinity of the Comstock mine. Their buff coloration on weathering suggests they are dominantly ankerite. A few hollow, scalenohedral, quartz-coated molds found in the Stayton mine dump indicate the former presence of calcite crystals in the quartz-stibnite veins.

**Paragenesis**

All gradations exist between veins with only antimony, in the Ambrose mine, through deposits with both antimony and quicksilver, as in the Gypsy and Stayton mines, to quicksilver deposits with no antimony, in the Mariposa deposit. The antimony and quicksilver deposition took place during several successive stages some of which were separated by periods of fracturing whereas others were gradational. The mineral composition of each vein is probably dependent on whether the vein was open during early, middle, or late stages of ore deposition. The stages that have been recognized in each of the mines are shown in table 3.

**Origin and Location**

The antimony veins were probably deposited at relatively low temperatures and pressure by aqueous solutions ascending from deep-seated igneous sources. Although the mineralized area is surrounded by numerous igneous intrusive bodies, no direct genetic relation between them and the veins can be demonstrated. That the antimony veins are later than at least some of the intrusive andesite bodies is indicated by the presence of a vein along a fault in one of the larger plugs. In the vicinity of Antimony Peak two faults in andesitic extrusive rocks contain antimony veins, which suggests that part of this mineralization followed the faulting. These facts indicate that the earliest mineralization in the area is later than all igneous activity except possibly the emplacement of the intrusive rhyolite. The quicksilver deposition took place at a later date for it is separated from the antimony mineralization by a period of fracturing.

Many of the antimony veins end upward a few feet below the unconformity between the basaltic and andesitic rocks, and neither antimony nor quicksilver deposits are known to occur in the andesitic rocks except along faults bordered on one side by basalt. Some, and possibly all, of the mineralized faults were developed before the deposition of the andesitic rocks. Where there has been no later movement such fractures offered

**Table 3. Mineralization of veins in the mines of the Stayton district**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Ambrose</th>
<th>Blue Wing</th>
<th>Gypsy</th>
<th>Stayton</th>
<th>Mariposa</th>
<th>Comstock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalcedony or quartz</td>
<td>?</td>
<td>A</td>
<td>A</td>
<td>M</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>and pyrite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black flinty quartz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and stibnite</td>
<td>?</td>
<td>A</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stibnite</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracturing</td>
<td></td>
<td>M</td>
<td>M</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinnabar and quartz,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chalcedony, or opal</td>
<td></td>
<td>A</td>
<td></td>
<td>M</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>&quot;Paint&quot; cinnabar</td>
<td></td>
<td>R</td>
<td>A</td>
<td>A</td>
<td>M</td>
<td>R</td>
</tr>
<tr>
<td>Stibnite (supergene?)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

1. A, abundant; M, moderate; R, rare.
conduits along which mineralizing solutions could flow easily. The solutions probably penetrated the agglomerate in a few spots, but the relatively open spaces of the underlying fracture zone offered the most favorable locations for deposition of stibnite and accompanying quartz. Even after renewed movement on the faults much the same conditions prevailed. The andesitic agglomerate, which readily yielded to crushing and kaolinization, was perhaps even more impervious than before; on the other hand, the massive basalt and well-indurated tuffaceous agglomerate of the basaltic unit, together with quartz-stibnite veins, were shattered but not ground or crushed. Conditions were again favorable for ore deposition in the lower rocks, but the tightly sealed fractures above offered little chance for mineralization.

RESERVES

Antimony

The antimony reserves of the district cannot be closely estimated because high-grade pockets are distributed sporadically. The breccia veins, exclusive of rich pockets, average less than 1 percent of antimony, and although the total amount of antimony in them is a few tens of thousands of tons, the average grade is much too low for mining to be profitable, even with the high average price of 22 cents per pound that prevailed during the war years of 1915-18. Small high-grade pockets might be mined selectively but cannot be expected to yield large tonnages. These pockets do not appear to be sufficiently numerous to increase the average tenor of any considerable length of breccia vein to more than 1\(\frac{1}{2}\) percent. In the Ambrose mine, on one of the best veins in the district, the tenor of the ore in the stopes must have been approximately 6 percent. Probably no ore body containing more than a few tons will average above 5 percent antimony, and mining on larger scale must be done on ore averaging less than 1\(\frac{1}{2}\) percent.

Quicksilver

The quicksilver reserves of the Stayton district are comparatively small. Assuming that new ore bodies similar to those that have been stoped will be found along unprospected segments of vein zones adjacent to the mines, a future production of more than 1,000 flasks may be expected. The Stayton mine is probably capable of yielding nearly 100 flasks per year for a few years if operated on a larger scale. The other mines of the district can be expected to add very little.

Although the mines of the district are estimated to contain only slightly more than 1,000 flasks, the chances of finding new ore bodies are rather good. Between the Stayton and Gypsy mines a part of the vein zone has been prospected, but further prospecting might uncover additional shoots of medium-grade ore. There is also a good possibility that additional ore will be found in the area lying west and south of the present workings of the Stayton mine. The edge of what may be a large ore body, said to average 2 pounds to the ton, is exposed in the western workings of the Stayton mine. Such ore might be worked profitably by large-scale stripping operations with prices only slightly higher than $185 per flask. The chances of finding quicksilver deposits elsewhere in the area seem more remote.
SUGGESTIONS FOR PROSPECTING

Additional quicksilver deposits in silica-carbonate rock should be sought in the northwestern corner of the district and farther north and west outside of the area mapped. The best place to prospect the eastern antimony veins for cinnabar is at higher altitudes immediately below the contact between the two volcanic units or below the projection of this contact where it is now removed by erosion.

The most favorable place to prospect for cinnabar ore along the exposed fault zones in basalt is between the Gypsy and Stayton mines. The Stayton vein is not exposed above the mine road, but the faulting of the contact between the two volcanic units indicates that the fault zone at least crosses the ridge to the south. The projection of this vein immediately below the andesitic agglomerate is also worth investigating. An ore body might be found in the pre-Tertiary sedimentary rocks below the Stayton vein, but the estimated depth to these rocks below the surface, about 1,300 feet, makes the chance for finding ore rather remote. Small amounts of good ore were found southeast of the Mariposa mine, and perhaps other small pockets might be found along this same zone.

No quicksilver ore is known to occur in the andesitic agglomerate or in andesite and rhyolite intrusives in the district; these rocks may be regarded as the least favorable in which to prospect.

DESCRIPTION OF MINES

Antimony Mines

Of the several small antimony mines in the district, only one, the Ambrose, was open in the spring of 1941 when the field work was done.

Ambrose Mine. The Ambrose mine, also known as the Rip Van Winkle mine (see fig. 2), is in sec. 30, T. 11 S., R. 7 E. in the northeastern corner of San Benito County. The mine has not been operated for more than 20 years, and production probably has not exceeded 100 tons of antimony. The lowest level could not be examined because it was flooded; if any large stopes exist along this flooded level they would increase the estimate of past production. Hand-sorted ore shipped from the mine averaged 38-50 percent antimony.

The only ore mineral is stibnite which, together with a little milky quartz, forms a nearly continuous vein that strikes N. 20° W. and dips 65° SW. in and close to the southern border of an andesitic intrusive body. The vein, which is split at several places, swells from almost nothing to a width of 10 inches within short distances, but in the main stope the average width perhaps exceeded 5 inches. The wall rock is kaolinized adjacent to the vein for only a few feet and contains minor amounts of disseminated pyrite.

The vein pinches in the roof of the upper level and may die out upward, for it could not be found on the hillside immediately above; however, at the top of the ridge along the continuation of the altered zone, a 4-inch vein of nearly pure stibnite is exposed in a small trench. On the second level the stibnite vein ends 200 feet from the portal, but the fracture continues as far as it has been prospected, a distance of about 50 feet. Whether the vein continues southward into the surrounding Franciscan rocks is not known as exposures are poor, but the decreasing width of the vein southward in the mine suggests that the mineralization is confined to the intrusive rock.

5—3163
Fig. 2. Geologic map of the Ambrose mine.
Only small reserves are in sight in the mine. The presence of undiscovered ore bodies along the vein in any direction, except possibly downward, seems improbable. The ore near the portal between the two upper levels cannot be expected to yield more than a few tons of antimony.

*Blue Wing Mine.* The Blue Wing mine, owned by Mr. R. B. Knox, is in sec. 5, T. 12 S., R. 7 E., a few hundred yards southwest of the Stayton mine. It is believed to have produced a few tons of hand-sorted ore. As the mine is now flooded the following information is that offered by Mr. Knox, supplemented by the authors’ examination of the rock on the small dump.

The workings consist of a vertical shaft approximately 75 feet deep with a drift to the north and a short, shallow drift to the south. The ore is in northward-trending quartz-stibnite veins in basalt. The vein is apparently discontinuous, but locally it contains lenses of nearly pure stibnite slightly less than a foot thick. Cinnabar was found in vugs and along fractures in the upper 20 feet of the stibnite vein, but it did not occur below this level.

The vein was carefully prospected a few years ago, and at that time was considered of too low grade to be worked for either antimony or quicksilver. A few tons of ore containing nearly 50 percent of stibnite remains on the dump.

*Shriver Mine.* The Shriver mine, located in sec. 31, T. 11 S., R. 7 E., had been caved for a number of years prior to 1941. The vein has been opened along two tunnels with an aggregate length of 1,200 feet. Small amounts of quicksilver ore have been found near the surface, and assayed specimens of the antimony vein have yielded $25 in gold and $17 in silver per ton. One and one-half tons of high-grade antimony ore was shipped from the mine in 1893.

*Quicksilver Mines*

Stayton Mine. The Stayton mine, owned by Mr. R. B. Knox, is in sec. 5, T. 12 S., R. 7 E. in western Merced County. Located in 1870, it has been the principal producer in the Stayton district. The first mining is said to have been for stibnite, but between 1876, when the Stayton Mining Company gained control of the property, and 1880, quicksilver was mined, and it is reported that about 1,000 flasks were produced from the Stayton and Gypsy mines. After the early eighties the mine was inactive, except for a short period in 1917-18, until 1920 when Mr. Knox began small-scale operations. Since 1920 the mine has yielded approximately 400 flasks of quicksilver. It is equipped with a 12-ton furnace and a retort.

The ore is cinnabar in veinlets that fill fractures in both fresh and kaolinized basalt along a north-trending normal fault zone which has a dip of 58° W. As is shown on the mine map, plate 65, cinnabar extends from the footwall across the fault zone and into the hanging wall for a distance of at least 75 feet. Although "paint" can be found throughout most of this distance, the minable ore is confined to several narrow veins. Minable ore was found against the footwall, 7-12 feet west of the footwall below a zone of clay gouge, and in small amounts along a series of parallel faults.

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7 Irwin, William, Jr., California State Min. Bur., 10th Ann. Rept. of State Mineralogist, p. 517, 1890.
fractures 60 feet west of the footwall on the 30-foot level. The location of
the stopes suggests that the ore was localized by slight bulges in the foot-
wall where there are changes of a few degrees in strike.

On the 150-foot level there are 775 feet of drift. The footwall is said
to steepen to nearly vertical on this level, and ore is said to occur above,
but not in, the steep portion of the fault. An inclined shaft that follows
the dip of the footwall is said to reach the 250-foot level, but all of the
workings more than 25 feet below the 70-foot level were either flooded or
filled with waste or gas during the authors’ investigation in 1941. On the
250-foot level, where the dip of the fault is less steep, additional ore is
reported.

In the northern part of the mine a vuggy quartz-stibnite vein imme-
diately above the footwall is crushed on the 70-foot level, but 250 feet
from the portal it is less thoroughly fractured and wider. Apparently
this vein exerted no control on the cinnabar mineralization. Open cracks,
as much as a foot wide and containing good quicksilver ore, are said to
occur in the southern part of the 150-foot level along this vein.

An adit, driven to intersect the vein 70 feet north of the main portal
passed through a small high-grade pocket of cinnabar along what is
probably the northerly extension of the footwall of the main Stayton vein.
A westward continuation of the crosscut exposed only thin streaks of
cinnabar.

As in most cinnabar mines, nearly all ore of furnace grade was
stoped as it was found. This fact, coupled with the inaccessibility of the
lower levels, makes any estimate of reserves difficult. The mine was being
operated in 1941 by three men who had no difficulty in taking out and
retorting enough hand-sorted ore to yield a couple of flasks of quicksilver
each month. Development work has shown that ore suitable for hand-
sorting to an average of 40 pounds to the ton occurs above and west of
the 30-foot level. The intervening 60-foot zone, between this level and the
footwall, contains many stringers and coatings of “paint” but is said to
average less than 2 pounds of quicksilver to the ton. The grade is conse-
quently too low for furnace ore at present prices ($185 per flask),
although the ore could be very cheaply mined by stripping from the sur-
face. According to Mr. R. B. Knox the ore is not bottomed at the 250-foot
level, nor do the workings run out of ore to the south. The absence of
cinnabar from the crosscut to the north of the mine indicates that the ore
does not continue in this direction. The eastern side of the footwall has
never been prospected for more than a few feet, and as the fault zone is
known to be multiple, some additional ore might be encountered east of
what is considered to be the footwall.

The best area for future development lies to the west, as the zone of
alteration and shearing is known to be at least 400 feet wide in the nearby
Yellow Jacket mine. A large amount of additional prospecting and devel-
opment work may be necessary before workable ore bodies are found, but
it seems highly probable that the future production of the mine should at
least equal its past record of about 1,000 flasks. As the mine was being
operated in 1941, development work was very slow but more than paid
for itself by the recovery of ore found in small rich stringers.

Bradley, W. W., Quicksilver resources of California: California State Mining Bur.
Bull. 78, p. 121, 1918.
Yellow Jacket Mine. The Yellow Jacket mine, owned by Mr. R. B. Knox, is in sec. 5, T. 12 S., R. 7 E., in western Merced County. The portal is slightly more than 500 feet northwest of the portal of the Stayton mine. Only a few tons of ore have been taken from the mine.

Fig. 3. Geologic map of the Yellow Jacket mine.

The main workings, as shown in figure 3, are entirely in fresh and kaolinized basalt. They consist of a 175-foot adit extending to the south and a 275-foot crosscut, most of which lies west of the adit. Cinnabar coatings on a quartz vein and rare barite in the adit 100 feet from the portal did not continue beyond short stopes in the roof and floor. In the crosscut another vein zone 55 feet west of the adit also contained a few rather thin seams of cinnabar. Several other steeply dipping quartz veins which strike a few degrees west of north were intersected in the crosscut. The veins are broken locally but nowhere highly brecciated; only in a few places do they contain any stibnite. Several zones of silicified rock parallel the veins but do not contain quartz veins.
Although some ore has been found in the mine no ore was in sight in 1941. The mine is apparently in a nearly barren zone and future development cannot reasonably be expected to reveal more than small, scattered ore bodies.

**Gypsy Mine.** The Gypsy mine, owned by Mr. R. B. Knox, is in sec. 5, T. 12 S., R. 7 E., in western Merced County. It is about 2,400 feet north of the Stayton mine on the same wide fracture zone, but probably not on the continuation of the same vein. Its production record can only be inferred; perhaps less than half of the 1,000 flasks taken from the district prior to 1880 came from this mine. The mine was recently leased, and operations on a small scale were expected to begin in the summer of 1941.

The mine workings open in July 1941 are shown in plate 10. They consist of a stope open to the surface and extending down an incline for about 100 feet, several short drifts, and two adits. An inclined shaft, reported to have reached a depth of 40 feet below the present accessible workings, is now caved.

The mine explored a silicified zone 10-17 feet thick along a normal fault which strikes N. 20° W. and dips 37°-51° SW. The country rock is a well-indurated tuff-breccia of the basaltic unit.

The silicified zone is defined by slickensided fault planes at its hanging wall and a sinuous gradational contact at its footwall. The rock of the zone apparently has been subjected to several stages of mineralization separated by intervals of movement along the fault. The earliest silicification of the tuff-breccia was accompanied by deposition of light-gray sugary quartz and small amounts of pyrite. This vein material was later fractured and cemented by drusy quartz containing a few minute needles of stibnite. Still later movements brecciated this silicified rock and formed the fractures which now contain cinnabar.

Cinnabar, the only ore mineral, occurs as light-red to deep-purple massive vein fillings in steep fractures, and as colloform coatings encrusting quartz crystals in small vugs. Light yellow-brown opal locally accompanies the cinnabar.

The ore body, composed of numerous steep fractures filled with cinnabar, was about 50 feet long and 5-10 feet thick, and extended down the dip of the fault for 75 feet. The average tenor is believed to have been about 10 pounds of quicksilver to the ton. A slight upward roll of the fault plane, involving only small changes of strike and dip, possibly localized the ore body. The fault zone in the southern workings is only slightly silicified and contains no ore, but part of the barren zone in the northern workings is thoroughly silicified.

The reserves in sight are small, but exploration of the vein zone at depth might reasonably be expected to find additional ore bodies. A clean-up of the ore in the walls would not yield more than 100 flasks of quicksilver. The segment of vein between the Gypsy mine and a resistant outcrop of the vein 500 feet to the south has not been adequately prospected and is one of the most favorable places in the district for future exploration.

**Comstock Mine.** The Comstock mine is in sec. 19, T. 11 S., R. 7 E., in the extreme southeastern corner of Santa Clara County. Forstner \(^{10}\) reported that the mine was not operated for a number of years prior to

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\(^{10}\) Forstner, William, op. cit., p. 172.
1903. A single sentence by Raymond indicates the existence of a retort in 1875. No production figures are obtainable. The grade of the ore left in the stopes together with the size of the stopes suggests that about 300 flasks may have been recovered. The lower levels of the mine were flooded in 1941 so the full extent of the workings could not be determined.

The mine is in serpentine and in silica-carbonate rock which extends along the western edge of the serpentine from the mine to one fork of Paehcoo Creek 300 yards to the south. The serpentine east of the silica-carbonate rock forms a northward-trending belt about 600 feet wide.

The major structural control for the ore body (see pl. 11) is exerted by a fault that strikes N. 55°-65° E. and has an average dip of 30° S. The serpentine on the hanging wall is highly silicified and almost everywhere converted to dense black flinty chalcedonic quartz containing disseminated pyrite. All of the cinnabar found in the mine occurs above the fault in this silica-carbonate rock. The cinnabar is closely associated with the silica; it replaces the black chalcedonic quartz, and occurs in very siliceous irregular veinlets, and to a lesser extent in small veinlets of nearly pure cinnabar cutting the quartz. Some ore is found in a series of fractures nearly parallel to the main fault. No ore is known to occur in or below the zone of gouge that lies along the main fault and is as much as 2 feet thick in places.

A secondary control for the deposition of the cinnabar is a series of irregular, nearly vertical fractures trending approximately N. 40° W. All of the best ore was found in the upper workings around the old stopes which follow these fractures.

The mine appears to be nearly worked out. Crosscuts immediately above the fault zone, the most favorable place for ore, extend 25 feet east and 85 feet west of the main incline but do not expose any ore. Some ore with metacinnabar, largely replaced by cinnabar, occurs in a vein along the eastern incline which connects with the open surface stope. A clean-up of the retort ore in sight, supplemented by any possible ore in the block between the two main inclines, probably would not yield more than 100 flasks of quicksilver.

Other small lenses of silica-carbonate rock in the first canyon west of Wildcat Canyon might be profitably prospected.

Mariposa Mine. The Mariposa mine is in sec. 28, T. 11 S., R. 7 E., in the northeastern corner of San Benito County. There is no record of production from the mine, though Forstner's report on the Stayton district indicates that the claims were staked prior to 1903.

The workings shown in figure 4 consist of a 350-foot drift and several shorter drifts. The main drift is in basalt, but material on the dump indicates that altered intrusive rock was reached in the easternmost workings. The principal shear zone, 60 feet wide, consists of a series of faults most of which strike N. 45°-70° W. and dip moderately to steeply northeast. Cinnabar is present in only very minor amounts although, according to Mr. R. B. Knox, a small ore body was taken out of a raise from the southern branch of the drift. Silicified rock is rare, and no stibnite was seen. The mine has probably produced little ore, and reserves are negligible.

Fig. 4. Geologic map of the Mariposa mine.

Approximately 1,400 feet southeast of the Mariposa mine on the same altered zone are three shafts. The timbered one is flooded to within 30 feet of the surface. About 600 feet farther to the southeast is a caved drift which may extend several hundred feet to the northwest. A shallow prospect pit, 115 feet southeast of the timbered shaft exposes a fractured zone in basalt which is faulted against intrusive andesite on the east. On the basalt side of the fault, "paint" is distributed through a 6-foot zone, the central part of which contains ore of good retort grade.
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AN INITIAL FINE OF 25 CENTS WILL BE ASSESSED FOR FAILURE TO RETURN THIS BOOK ON THE DATE DUE. THE PENALTY WILL INCREASE TO 50 CENTS ON THE FOURTH DAY AND TO $1.00 ON THE SEVENTH DAY OVERDUE.
Cinnabar only in silicified zone above fault.

Footwall exposed, strike and dip indeterminable.

Minor shears, variable dips, somewhat flatter than inclined.

Unsilicified, altered serpentine.

Cinnabar veins, showing dip.

Fault, showing dip.

Altered serpentine.

Silica-carbonate rock and silicified serpentine.

Approximate profile.