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QUICKSILVER DEPOSITS OF THE OPALITE DISTRICT, MALHEUR COUNTY OREGON, AND HUMBOLDT COUNTY, NEVADA

BY

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By Robert G. Yates

ABSTRACT

The Opalite district, in Malheur County, Oreg., and Humboldt County, Nev., produced 22,174 flasks of quicksilver between January 1927 and January 1941. Nearly all of this was taken from the Opalite and Bretz mines, in Oregon; but the Cordero mine, in Nevada, should contribute materially to production in the near future.

The rocks in the district are flat-lying Miocene lavas, ranging from basalt to rhyolite in composition, and overlain by late Miocene tuffaceous lake beds. All these rocks are cut by steep normal faults, which locally have acted as channelways for rising hydrothermal solutions. The tuffs and lake beds were silicified in places by these solutions into lenticular masses of chalcedony, producing a rock locally called "opalite." The ore mineral, cinnabar, occurs partly in these chalcedony zones and partly in unsilicified rocks immediately adjacent to them. All the ore bodies mined were within 100 feet of the surface. Siliceous ore mined in the past has yielded an average of 6 pounds of quicksilver to the ton; nonsiliceous ore has yielded about 19 pounds to the ton.

Reserves in the district are estimated to be more than 3,000 flasks of quicksilver, but minable ore containing several times as much as this might be found by further exploration. New deposits may be discovered by prospecting tuffs and lake beds near faults along which quicksilver-bearing solutions may have risen.

INTRODUCTION

The Opalite quicksilver district includes two deposits with a considerable past production, one deposit with a small production, and one unproved prospect. These deposits are located along the circumference of a semicircular area that extends from a short distance west of McDermitt, Nev., for about 20 miles along the Oregon-Nevada State boundary. (See fig. 34.) The area thus includes parts of Humboldt County, Nev., and Malheur County, Oreg.; almost the entire production has been derived from the portion in Oregon. The approximate center of this semicircular area is about 15 miles west of McDermitt, Nev., the nearest town.

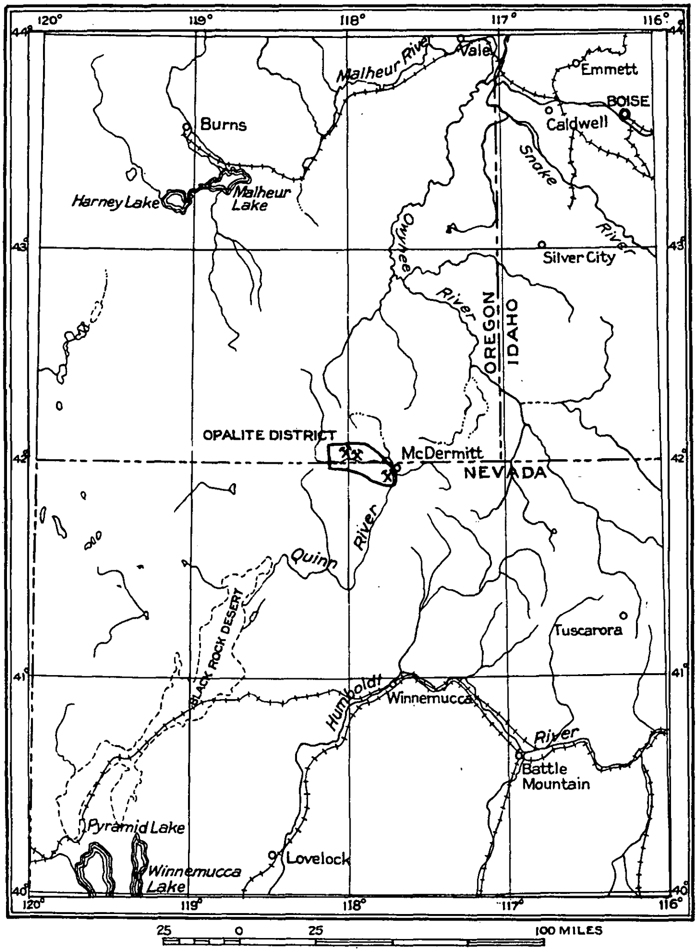


Figure 34.—Index map of parts of Oregon and Nevada showing the location of the Opalite district.

McDermitt is on the Oregon-Nevada State boundary and can be easily reached from Winnemucca, Nev., 74 miles to the south, over Nevada State Highway No. 8. The nearest railway is at Winnemucca. All of the deposits are accessible over gravel or dirt roads except for short periods during the winter.

The district is in the southern part of the White Horse Mountains where altitudes range from 4,400 feet (in the McDermitt Valley) to more than 7,500 feet. All drainage is into McDermitt Creek, which with a few of its larger tributaries is the only permanent stream. The vegetation consists mainly of abundant sagebrush; aspens grow along the permanent streams. Where the narrow valley floors are arable, hay is raised as winter feed for stock, which is pastured in the higher parts of the mountains during the summer.

The only detailed description of the district that has appeared is by Schuette.[1] As is evident from the following discussion, the writer is not in agreement with Schuette's geologic interpretation.

History and production

Mining is still active in the district, which has produced over 22,000 flasks of quicksilver since 1926. Cinnabar was first discovered in July 1917 by William Bretz near the location of what was to be known later as the Bretz mine. As assessment work over a period of years failed to reveal any high-grade ore in the discovery workings, Bretz continued to prospect the surrounding country, and in 1924 he discovered the Opalite ore body. He soon sold the ground containing this ore body to F. W. Bradley, who, in April 1925, formed the Mercury Mining Syndicate and began development of the Opalite mine. Late in 1926 a reduction plant was completed at the property. In 1931 Bretz discovered some very high grade ore just south of his original workings and leased this ground to the Bradley Mining Co., the successor of the Mercury Mining Syndicate. This property, now known as the Bretz mine, was worked intermittently during the years 1931-36, and the ore was treated at the Opalite furnace. In 1936

1/ Schuette, C. N., Lahontan quicksilver: Eng. and Min. Jour., vol. 134, pp. 329-332, 1933; Quicksilver in Oregon: State of Oregon, Dept. Geology and Min. Industries, Bull. 4, pp. 147-153, 1938.

Bradley's option to purchase the Bretz mine expired and the property reverted to the discoverer. Since then no ore has been removed from these early Bretz workings. During the summer of 1940, however, the Bradley Mining Co. was extracting ore from an open pit--referred to in this report as the 1940 Bretz workings --about half a mile west of the original Bretz mine.

The Cordero mine (also called the McDermitt mine) was discovered in 1924 by Tomas Alcorta of McDermitt. For several years Alcorta and his partner, Eusebio Agnarez, explored the ground by digging surface pits and trenches. During 1935 the Bradley Mining Co. leased the property and sank an inclined shaft into the main ore body. It is reported that 50 tons of sorted ore treated at the Opalite plant yielded 48 pounds of quicksilver to the ton. Since the spring of 1940, the Cordero Mining Co. of Nevada, associated with the Horse Heaven Mining Co. of Portland, Oreg., has been exploring the property preparatory to actual mining.

The fourth place at which cinnabar occurs is near Disaster Peak, at a prospect owned by Stive Crutcharray and P. Apesteguy, in the western part of the area mapped (fig. 34). Up to September 1940, assessment work had not revealed any promising ore body, though 2 tons of ore is estimated to have been mined from the property.

The following table shows the production of quicksilver from the district:

Quicksilver production from the Opalite district, 1927-40, inclusive 1/

Mine	Years	Ore (tons)	Tenor (pounds per ton)	Quicksilver (flasks of 76 pounds)
Opalite	1927-1940	154,531	5.96	12,124
Bretz	1931-1940	39,885	18.84	10,019
Cordero	1935	(?) 50	(?) 48	31
				22,174

1/ From the records of Mr. Worthen Bradley, president of the Bradley Mining Co., San Francisco, Calif. No production prior to 1927.

Field work and acknowledgments

The writer, assisted by James Pollock, was engaged in field work from July 5, 1940 to September 8, 1940. The district was revisited briefly in October of that year and again in March 1941. The regional geology was mapped on aerial photographs, and the geologic map, plate 52, was compiled from these photographs, controlled by a plane-table triangulation net. Maps of the principal mineralized areas were made by plane-table telescopic-alidade surveys.

The field work was under the guidance of Clyde P. Ross, and thanks are due to him not only for advice in the field but also for help in preparing the manuscript. E. B. Eckel's and H. G. Ferguson's criticisms of the manuscript are also greatly appreciated, as are those of F. C. Calkins.

Messrs. Worthen Bradley, of the Bradley Mining Co., and O. L. Cash, superintendent of the Bretz and Opalite mines, cordially cooperated with the writer, giving him free access to the company's maps, assays, and production figures, as well as providing living accommodations at the mine. Messrs. S. H. Williston and Albert O. Bartell also extended similar favors at the Cordero mine. To all these men the writer offers hearty thanks.

GEOLOGY

The steeply scarped, plateaulike character of the Southern White Horse Mountains is the result of block faulting in a thick sequence of nearly horizontally bedded Miocene lavas (see pl. 52), and the basinlike drainage area of McDermitt Creek, which includes most of the Opalite district, roughly coincides with a down-faulted block of lavas. No rocks older than Tertiary are exposed in the area mapped, but immediately to the southwest the lavas rest upon the eroded surface of a granitic complex. The lavas, which range from rhyolite to basalt in composition, are locally interbedded with tuffs. The lavas are overlain by thin-bedded upper Miocene lake sediments, which contain the Opalite and Bretz ore bodies. These sediments probably accumulated in a depression that was being deepened from time to time by faulting, and were faulted down to their present position during the Pliocene.

Mineralization probably began during or shortly after the Pliocene faulting. Hydrothermal silica-bearing solutions locally ascended along the faults, and as they approached the surface they silicified lenticular masses of the more permeable rocks. During and after the late stages of this silicification, rising quicksilver-bearing solutions deposited cinnabar both in previously silicified rocks and in unsilicified rocks.

After the lake beds had been faulted down to their present position, and after the cinnabar had been deposited, streams that headed in the adjacent upfaulted block eroded the upper beds and covered the surface thus produced with a mantle of alluvium. After the streams had established meandering courses across the nearly level graded surface, their former power of downcutting was rejuvenated to such an extent that they now flow through narrow winding canyons, whose sinuous courses were inherited from this earlier graded condition. The dying stages of mineralization, in the form of hot spring activity, were contemporaneous with the accumulation of the alluvial mantle.

Miocene lavas

The dominant rocks of the area consist of over 3,000 feet of lava flows, which range in composition from basalt to rhyolite. Intrusive rocks appear to be scarce, but some of the rocks mapped as extrusive may be intrusive--for example, the rhyolites near the Disaster Peak prospect. The rocks in the western part of the area are in general more basic than those in the eastern part. The silicic lavas range from obsidian to porphyritic rhyolite and in general exhibit well-developed flow banding. They are locally associated with tuffs. The basaltic and andesitic lavas are darker than the rhyolite and are generally in thinner flows. They are characterized by vesicularity, columnar structures, flow brecciation, and porphyritic texture. The flows are either horizontal or nearly so, except where they have been locally tilted by faulting. Individual flows are from a few feet to more than 100 feet thick.

Late Miocene lake sediments

Late Miocene lake sediments are distributed over a considerable part of the McDermitt Creek Basin (see pl. 52), and they probably once extended over a much larger area from which they have been removed by erosion. In places they are more than 200 feet thick. They consist mainly of well-bedded tuffs, shales (including clayey, carbonaceous, tuffaceous, and diatomaceous varieties), and sandstones, but include small lenses of conglomerate. They are mostly light-colored, varying from white to light brown, except that the carbonaceous shales are dark chocolate brown. The constituent fragments are dominantly of volcanic origin. Some beds contain carbonaceous plant fragments and fossil wood; and fossil leaves, fish, and fresh-water gastropods were collected at several places. On the basis of the fossils these beds have been correlated with the Miocene Trout Creek beds of Malheur County, Oreg.

These beds were believed by Schuette [2/] to have been deposited in Pleistocene Lake Lahontan, but this belief is controverted by several facts: The beds are not within the boundaries of Lake Lahontan as originally mapped by Russell, [3/] although the headwaters of McDermitt Creek were traversed by the Russell party; and the highest Lahontan beach visible near Winnemucca

2/ Schuette, C. N., op. cit.
3/ Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, 1885.

is 1,200 feet lower than the lake beds at the Bretz mine.[4] Diatoms collected from lake beds at the Bretz mine were determined by K. E. Lohman [5] as contemporaneous with the Trout Creek diatom flora, which has been assigned to the upper Miocene on fossil plant evidence; and the diatoms studied by Lohman were deposited in a lake of pure fresh water whereas the waters of Lake Lahontan were saline. Determinations of the age of fossil leaves by R. W. Brown [6] and of fresh water gastropods by F. S. MacNeil [7] also indicate Miocene age.

The scarcity of conglomerate in the lake beds is evidence that they did not accumulate at the base of the abrupt slopes which now bound the basin but have been faulted down into their present position. If the lake had been coextensive, or nearly so, with the present McDermitt Creek Basin, the lake beds at the mouths of canyons now entering the basin would contain much fan gravel. This is so far from being true that the distribution of gravel in the lake beds is wholly unrelated to the situation of the present canyon mouths. The fact that there are local unconformities between individual beds in areas of known faulting suggests, moreover, that faulting was in progress during deposition of the lake sediments.

Quaternary deposits

Two kinds of Quaternary deposits were mapped. The younger consists of the gravel, sand, and silt that are accumulating on fans and in valleys at the present time. The older, mapped on plate 52 as the precanyon gravels, consists of rubble cappings on the eroded surfaces of the lake beds in the interstream areas. This capping, which now varies from a thin scattering of angular rock fragments to local accumulations of loose porous material

4/ Ferguson, H. G., personal communication.
5/ Lohman, K. E., letter of May 29, 1941.
6/ Brown, R. W., personal communication.
7/ MacNeil, F. S., personal communication.

more than 40 feet thick, has aided in the preservation of the soft lake sediments. It is younger than the cinnabar mineralization, for it contains cinnabar-bearing boulders and is not impregnated with cinnabar where it overlies the Bretz ore bodies. Its topographic relations, on the other hand, clearly show that it is older than the canyon cycle of drainage history. Calcareous sinter is interbedded with the older gravels, showing that hot-spring activity continued after the cinnabar mineralization was complete.

Structure

The structure of the Opalite district is simple. Flat-lying lavas have been displaced, with little tilting, along steep normal faults, of which the steep scarps that outline the flat-topped Southern White Horse Mountains are a direct expression. Direct evidence of this faulting is given by the presence of fault breccia, drag warps, and silicified rocks along the scarp bases; similar features at various distances outward from the scarps indicate that the displacements were distributed on step faults. The throw on any single break cannot be measured, but the aggregate displacement, which accounts directly for much of the relief in the area, was more than 2,000 feet.

The McDermitt Creek Basin is a result of such distributed faulting, and all the quicksilver deposits of the district are related to faults within or along the borders of this graben-like area. The faults within the basin are arranged in no particular pattern and are of small displacement--probably none has a throw greater than 100 feet. In many places the lake beds that overlie the faulted lavas have adjusted themselves to the faulting by merely bending along the breaks in the lavas; but in some places the displacement in the underlying lavas has been great enough to fault the lake beds also, as may be seen, for example, where the fault east of the Opalite mine crosses Cherokee Creek.

In general the lake beds have been eroded away from the boundary faults. At the Bretz mine, where the lake beds are still in place near the bounding faults, the presence of minor folds and angular unconformities between beds indicates that faulting began shortly after the extrusion of the lavas and continued during the deposition of the lake beds. But this faulting must have been on a small scale, for otherwise the sediments would be more varied in texture than they are. The scarcity of conglomerates or other coarse deposits in the lake beds indicates, moreover, that the beds could not have accumulated at the bases of the 2,000- to 3,000-foot scarps which now partially enclose the basin. The major movement, therefore, must have occurred after the deposition of the lake beds.

The faults indicated on plate 52 include not only those that are exposed but also those that are inferred from physiographic evidence. The fault shown as extending north from the Cordero mine is mapped by inference, because of the very straight scarp just south. This fault may be younger than the precanyon gravels, and if so it would explain the incision of the streams that cross McDermitt Creek Basin.

Photographs used in the areal mapping were of great use in tracing faults, for such indications of faulting as minor differences in soil color, abrupt terminations of lava flows, and inconsistencies in stream patterns were often much more apparent on the photographs than on the ground.

In all of the mineralized areas there are minor structures related to the major faulting. At the Opalite mine (see pls. 53 and 54) a tabular body of chalcedony has been broken in several places by small faults. It is believed that the lavas beneath the lake beds are traversed by a fault, the movement along which has merely warped the soft lake beds but has caused the rigid and brittle chalcedony to adjust itself by fracture. Thes breaks, many of which are open, downward-pinching fractures, appear to have followed zones of earlier fracturing in the chalcedony. At the Opalite deposit also the lake beds have been faulted, notably along the borders of the chalcedony mass.

The lake beds that enclose the Bretz ore bodies are locally inclined to the south at angles as high as 45°, a result of drag along a fault which lies just north of the ore bodies. An anticlinal roll in these tilted beds has controlled the concentration of cinnabar at the 1940 Bretz pit (fig. 35).

At the Cordero mine also the tuffs that enclose the ore body are inclined, probably also by drag on a fault that is inferred to lie beneath the alluvium to the north.

ORE DEPOSITS

The known deposits of quicksilver ore (see pl. 52) in the Opalite district are at three separate localities. A minor showing of cinnabar occurs at a fourth locality, the Disaster Peak prospect in the western part of the area mapped. All of these occurrences except the Bretz deposit are in silicified rock, and all are believed to be genetically associated with the hydrothermal processes that have produced chalcedony zones in permeable lake beds and tuffs. The principal ore mineral, cinnabar, is mixed with the silica in the chalcedonic ore bodies and forms disseminated crystals in the unsilicified rocks. The deposits, being shallow and roughly tabular, are most easily mined by surface methods.

Mineralogy

Although the principal ore mineral in the Opalite district is cinnabar (mercury sulfide), native mercury (quicksilver) and the relatively rare oxychlorides of mercury are also present.

The gangue minerals in the siliceous ores are chalcedony, quartz, and opal. The chalcedony, which is the most abundant, is hard and dense and ranges from white to dark gray. Opal is mixed with the chalcedony in minor quantity and also forms white or gray layers in the lake beds and tuffs. Small veinlets of comb quartz, up to half an inch wide, commonly fill fractures in the chalcedony. Calcium carbonate occurs as fine needles of aragonite lining vugs in the chalcedony, and more massive aragonite is mixed with silica. The shales at the Bretz mine contain large clear plates of gypsum. Montmorillonite occurs at the Bretz mine, and halloysite or some other mineral of that group occurs at the Opalite mine. These two clay minerals were determined by Mr. Clarence S. Ross, of the Geological Survey.

Cinnabar.--The cinnabar of the district occurs in three forms: Disseminated as small crystals in the lake sediments at Bretz, intimately mixed with silica in chalcedony, and coating slip and joint faces as a pulverulent "paint" which may be of supergene origin. As the cinnabar in the chalcedony blackens rapidly when exposed to sunlight, it is not easily recognized except in freshly broken rock.

The cinnabar in the chalcedony is closely related to fractures and to irregularly distributed zones and swarms of microscopic inclusions, of which some appear to be clay minerals and others appear to be liquid. These inclusions are abundant in the cinnabar-bearing chalcedony but rare or absent in the barren rock. The presence of liquid, either included in the chalcedony or absorbed by the clay, may account for the fact that drilling in the ore is almost dustless, whereas drilling in the barren rock is very dusty. The cinnabar that has been introduced by replacement forms embayments leading from the small fractures and small globular clusters, which are not connected with the fractures but apparently associated with swarms of inclusions.

Native mercury.--Native mercury was observed only in the open pit at the Opalite mine, where it is associated with terlinguaite and cinnabar, but it has been reported at the Cordero mine. It is common in some of the Opalite ore as globules that fill cracks and small vugs in the chalcedony. The richness of some of the Opalite ore was due to appreciable amounts of native mercury and accompanying terlinguaite.

Terlinguaite.--Terlinguaite (Hg_2ClO), an oxychloride of mercury, occurs with native mercury at the Opalite mine. It is a canary-yellow powder which rapidly turns green and then black when exposed to air and sunlight. It was formed later than the cinnabar and is found in vugs and along open cracks.

Eglestonite.--Eglestonite (Hg_4Cl_2O) is said to occur in association with native mercury and cinnabar at the Cordero mine.

Realgar.--Realgar (AsS) was observed in a small cut just east of the 1940 Bretz workings, where well-formed crystals up to a centimeter in length are distributed along the bedding planes of carbonaceous shale.

Pyrite.--Pyrite (FeS_2) was noted at the Disaster Peak prospect and in small quantities at the Opalite mine, but it is nowhere common. Iron sulfates present in the lower levels of the Opalite mine were probably derived from pyrite.

Rock alteration

The dominant effect of hydrothermal alteration on the rocks of the district was silicification, which was accompanied by kaolinization.[8] All the ore deposits are either in or in contact with silicified rocks, and it is believed that the quicksilver was deposited at a late stage of the hydrothermal activity that produced the silicification. Both the lavas and lake beds were silicified, but only the lake beds were kaolinized. The lavas

8/ Kaolinization is used here in the sense of alteration to clay minerals rather than to the mineral kaolinite.

were less susceptible to replacement by silica than the more open-textured lake beds and consequently were altered only along faults and breccia zones, whereas alteration in the sediments was more widespread and was not confined to zones of fracture. Many flat tabular masses of the lake sediments were completely converted by siliceous hydrothermal solutions to hard dense chalcedony (see pls. 53, 54, and 55). This conversion is exemplified in the tuffs at the Cordero mine, in the coarsely clastic conglomeratic tuff above the Bretz workings, and in tuffs at the Disaster Peak prospect. Where erosion has removed the overlying lake sediments the chalcedony--or "opalite," as the rock is commonly termed--crops out in low rounded knobs.

The silicified masses are elongate and domelike or lenticular in form, and are roughly parallel to the strata that enclose them. They range in length from less than 100 feet to more than 1,000 feet. The silicified mass that contained the ore body at the Opalite mine is 1,200 feet long, 800 feet wide, and a little over 100 feet in maximum thickness.

The chalcedony or opalite ranges in color from grayish white to dark gray. Mottled, banded, and brecciated rock shows contrasts of color and may be due to the varying quantities of included clay minerals. The chalcedony at the Opalite mine shows light and dark bands, crenulated in places but mostly wavy. The banding in the chalcedony resembles the bedding in the lake sediments in general attitude and in spacing.

In places the chalcedony is brecciated, and angular fragments of it are tightly cemented by quartz. It is in the zones of intense brecciation that the ore bodies occur, the cinnabar being mixed with the quartz cement. The breccia may be coarse or fine, but the coarse and fine portions are not so distributed as to suggest an origin by fault movement, the brecciation being apparently due to the shrinkage of opal in the process of dehydration and conversion to chalcedony. In places, however, the breccia has been fractured by post-ore movements.

In places where brecciation was not followed by cementation or where later leaching of silica took place, the rock is porous and vuggy, containing some openings more than a foot across. Locally there are discontinuous porous bodies of limonite-stained rubble of broken blocks and fragments. Some vugs and cracks are lined with aragonite needles, and some openings in the chalcedony at the Opalite deposit are filled with granular to dense calcium carbonate.

The chalcedony commonly grades into unsilicified lake beds, through a zone several feet in width. At the base of the chalcedony the contact is sharp in places, but more commonly there is an alternation of silicified and unsilicified beds, the silicified beds increasing in number upwards. At the top of the chalcedony, silicification has progressed outwards along certain beds more readily than along others, so that in places, notably in the lower workings of the Opalite mine, the silicified and unsilicified beds interfinger. In general silicification has progressed along the bedding, but locally thin silicified sheets cut across the bedding. Some contact zones consist in part of small irregular nodules of chalcedony in an unaltered matrix of tuffs or shales. Nodules of chalcedony and quartz, or both, ranging from a few inches to a few feet in diameter, are distributed at random in the unsilicified lake beds surrounding the silicified masses at both the Opalite and Cordero mines.

Clay, presumably formed by thorough kaolinization of the lake beds, which, of course, originally consisted partly of claylike material, is abundant beneath the masses of chalcedony, and some of it, especially near zones of disturbance produced by faulting, is in sheets that crosscut the bedding of the sediments. The clay is massive or bedded and ranges in color from white to rusty brown. It is almost free from grit and when wet is very plastic.

Some calcium-carbonate rock has been formed by hydrothermal processes. At the west end of the chalcedony mass at the Opalite mine calcium carbonate appears both to have filled in and to have partially replaced what was once a porous part of the chalcedony mass, and a dikelike body of fine-grained porous calcium carbonate north of the west end of the chalcedony mass appears to have filled a fault fissure in the lake beds and to have partially replaced its walls. The relationships of the calcium-carbonate rock mapped at the Bretz mine are not clear. Some of the rock is a surficial calcium-carbonate sinter that formed after the silicification of the conglomeratic tuff to the north and apparently during the accumulation of the fan gravel exposed in the south wall of the pit (see pl. 56), for this gravel contains both tongues and nodules of calcium carbonate. The calcium carbonate probably fills the pore of, and to some extent replaces broken and crushed lake beds. This rock, which is a mixture of calcium carbonate and silica, probably becomes more siliceous downward, for the rock in the now-caved tunnels below the pit is said to have been harder than that near the surface.

Ore bodies

All of the ore bodies are associated with, and genetically related to, masses of silicified rock. The Opalite ore body is all within the chalcedony except for a minor quantity of "paint" cinnabar in the faulted sediments below the chalcedony. At the Cordero mine there is ore in both the chalcedony and the adjoining unsilicified tuffs. The ore bodies that have been mined at the Bretz pits were in unsilicified lake beds but were in contact with silicified rock.

There are two distinct types of ore, that in the chalcedony zones, where the cinnabar is intimately mixed with silica, and that in the unsilicified beds, where crystalline cinnabar fills openings along joints and bedding planes in the shales and is deposited between the grains in coarser rocks. The siliceous ore, locally known as the opalite type, is a hard brittle rock, composed of chalcedony and quartz, which is traversed by networks of small fractures filled with a mixture of silica and cinnabar. Microscopic examination reveals that the cinnabar is not confined to these fractures but extends from them, replacing the rock in irregular tongues that apparently follow swarms of small inclusions. In weathered outcrops of the opalite type of ore the cinnabar is black, but when the ore is freshly broken it is red, the intensity of the red depending upon the amount of admixed silica. At the Opalite mine native mercury and terlinguaite, associated with cinnabar, fill small vugs and fractures.

The gangue of the second type of ore as represented at the Bretz mine consists of shale and sandstone. Small crystals of cinnabar occur along partings in the shale and between grains in the sandstone. The cinnabar in the tuffs at the Cordero mine is much finer in grain size and not as apparent as that at the Bretz mine.

Both the siliceous and the nonsiliceous ore bodies are irregular in shape. The general dimensions of the Opalite ore body are indicated by the pit shown on plate 53. This ore body is roughly conformable to the shape of the chalcedony mass. Development work at the base of the chalcedony proved that the deposit extended less than 100 feet from the surface. The ore decreased in grade downward, and only traces of cinnabar were found at the base of the chalcedony. The Bretz ore bodies were equally shallow, as shown by shafts sunk below the mine workings in the ore. Cinnabar is widely disseminated in the lake beds surrounding the pits, but not abundantly enough to constitute ore. The ore body at the Cordero mine is more elongate and more steeply tilted than the one at the Opalite mine. Development work up to March 1941 had proved that it extended at least 80 feet below the surface.

The average grade of the ore sent to the furnace from the Opalite and Bretz mines is given in the table on page 322, and the grade of the Cordero ore is discussed under reserves and in the description of the mine. The figures for the Cordero mine in the table on page 322 refer to carefully sorted ore and thus are not representative of the whole mass of the deposits.

Origin

The history of the ore deposits may be summarized as follows:

1. Formation of steep normal faults.
2. Period of hydrothermal activity, with solutions rising along open parts of the fault fissures and spreading out into the more porous rocks near the surface.
   - (a) Advent of silica-rich solutions which converted the porous lake beds and tuffs into opal.
   - (b) Dehydration and crystallization of the opal into chalcedony and quartz, resulting in brecciation. (This may have been followed by the entry of siliceous solutions that replaced undehydrated opal with chalcedony and extended the silicified zone farther into the sediments.)
   - (c) Introduction of mercuric sulfide solutions, which deposited cinnabar in openings in both the silicified and unsilicified rocks.
   - (d) Final stages of thermal activity with the deposition of calcium carbonate in vugs and fracture openings, and as surficial calcareous sinter.

This sequence of events is best illustrated at the Opalite mine. At the Bretz deposit, on the other hand, ore bodies apparently did not form in the silicified rocks but did form in the adjoining unsilicified rocks. This anomaly may be explained by supposing that the channelway for the ore-forming solutions was opened by movement that occurred along the fault at some time between the earlier silicification and the quicksilver mineralization.

The chalcedony zones are believed to have been formed by replacement of lake sediments and tuffs through the action of hot siliceous solutions that rose through the volcanic rocks along fault fissures. It seems possible that some, if not most, of the silica in solution may have been derived from leaching of the wall rocks through which the solutions passed. The tuffs and lake sediments, because of their great porosity and fineness of grain, would be more readily leached--and, for the same reason, more readily replaced--than the most vesicular and fractured lavas. If the silica was derived from this source it was carried upward for only a short distance before it was redeposited.

The hypothesis of local silica transfer is supported by the presence of clays, presumably hydrothermal in origin, immediately below the chalcedony mass at the Opalite deposit. Hydrothermal conversion of the lake sediments into clays would have necessitated a removal of silica, which would have been available for the silicification of higher beds. It is remarkable that the chalcedony masses were formed within the lake beds and not on the immediate contact between the lake beds and the underlying lavas, for the contact would seem to have been a likely place for silica to be deposited, since this is the horizon at which the rising hydrothermal solutions first encountered a sudden change in the character of the rock as they approached the surface.

The fact that silicification has a short vertical range suggests that the ascending solutions had encountered some decisive change of environment at their place of deposition. This change could not have been entirely a change in character of wall rocks, for the beds below the chalcedony, except where kaolinized, are very similar to the beds that were silicified. As the bottoms of the chalcedony masses are conformable in general to the underlying beds, it seems reasonable to assume that the agency that localized the silicification was also controlled by the generally low angle of the bedding. The most available agency for such control would be a sheet of ground water from close to the surface that was moving down the dip of the beds toward topographic lows. Such water would have cooled and diluted the thermal solutions, and possibly would have changed their chemical nature.

The silica probably was introduced originally as opal, which later was dehydrated and crystallized as chalcedony. Dehydration of opal with consequent shrinkage cracking would explain brecciation in the chalcedony that cannot be ascribed to structural movements. It is possible that, after the dehydration and consequent crystallization of some of the opal, the remaining opal as well as more of the lake beds were replaced by chalcedony, thus causing an increase in the size of the silicified zone. This concept, however, would imply that the shrinkage cracks were held open during this wholesale replacement of the opal by chalcedony; but such a condition hardly seems probable, for the cracks were not filled until the time of cinnabar mineralization, when only a small amount of silica was added.

It seems certain that the cinnabar mineralization took place during the last stages of silicification. It is not certain, however, whether silicification went on continuously up to and through the period of cinnabar mineralization, or whether the major silicification was separated from the cinnabar mineralization by a pause in thermal activity. The fact that silicification accompanied cinnabar mineralization favors the concept of a continuous, but dwindling, silicification.

The distribution of cinnabar within the chalcedony was controlled by fractures, which probably were kept open by repeated movements. Where fracture zones were absent or where the channelways to them had been closed the cinnabar was deposited elsewhere, as for example at the Bretz deposit, where the ore bodies are in the soft lake beds. The closing and shifting of channelways could likewise account for the fact that not all of the chalcedony masses are ore bearing.

Calcium carbonate, deposited as a surficial sinter at the Bretz mine and as filling in fractured chalcedony at the Opalite mine, represents a final stage of hydrothermal activity.

The above concepts of origin are not in agreement with those expressed by Schuette.[9] Schuette describes the cinnabar of the Opalite deposit as occurring in a surficial deposit of siliceous hot-spring sinter which accumulated as a mound upon the shores of Lake Lahontan. Beds overlying the mound are described as having accumulated during a high-water stage of the lake. Aside from the fact that the lake beds are late Miocene, and also much higher than the highest known level of the Pleistocene Lake Lahontan, the gradational contacts of the silicified body, the interfingering of silicified and unsilicified beds, and the character of the chalcedony fail to support this hypothesis of surficial origin.

SUGGESTIONS FOR PROSPECTING

In prospecting the Opalite district for new ore deposits, zones of silicification should be looked for carefully. Areas adjacent to the faults shown on plate 52 are favorable prospecting ground for silicified and altered rocks. A more comprehen-

9/ Schuette, C. N., op. cit.

sive search than was possible during the field work for this report will doubtless reveal areas of silicification other than those shown on plate 52. These chalcedony zones may project through the alluvial mantle and crop out as low knobs, or they may be exposed only in stream cuts with lake beds or alluvium overlying them.

Each body of chalcedony that is prospected should be carefully examined for zones of brecciation, which in turn should be carefully examined for cinnabar. As the cinnabar does not have the characteristic bright-red color on weathered rock surfaces, the chalcedony should be chipped to reveal unweathered surfaces.

Ore bodies of the Bretz type may be discovered in unsilicified tuffs and lake beds that are in contact with or adjacent to barren silicified zones, where quicksilver solutions presumably came up the same channelways that the silicifying solutions followed but were diverted into unsilicified rocks as they approached the surface. Ore bodies of this type can most effectively be looked for by panning the sediments around the silicified zones. Panning of the sediments at outcrops where the beds are contorted and have steep dips might lead to the discovery of new deposits, as steeply dipping beds may indicate the presence of faults in the lavas beneath. Cinnabar in the chalcedony is not amenable to panning because of the admixed silica, but even small quantities of the crystalline cinnabar that is characteristic of the Bretz type of deposit can be detected by this method.

Favorable geologic conditions exist between the old Bretz pits and the 1940 pit (see pl. 56) and near the three small outcrops of silicified rock a quarter of a mile southeast of the old Bretz pits. Another place that seems to deserve further exploration is the area of silicified rocks 1½ miles south of the Opalite mine. All the tuffs and sediments adjacent to the silicified rocks at the Disaster Peak prospect are also possible host rocks for cinnabar.

The Cordero Mining Co. has delimited the silicified zone at the Cordero mine by means of the resistivity method of geophysical surveying. This method of exploration may prove to be useful in discovering and tracing faults that are buried by alluvium and in discovering and delimiting silicified zones in other parts of the district.

Past mining operations indicate that none of the ore bodies probably extends much more than 100 feet below the outcrop, although the Cordero deposit, because of its dip of over 40°, may prove to be an exception to this rule. Below this depth it is likely that the ore bodies, if still present, may narrow down to veins along crushed zones in faults.

These shallow deposits probably can be mined most economically by means of open pits. If assays are to be used as a guide in mining, numerous samples should be taken, because the grade of the ore varies greatly within very short distances. Exploratory drilling in the hard, dense chalcedony would be expensive, and closely spaced holes would be necessary in order to determine the grade of an ore body. Where the alluvial cover is thin, scraping with a bulldozer would be an efficient manner of prospecting the surface.

RESERVES

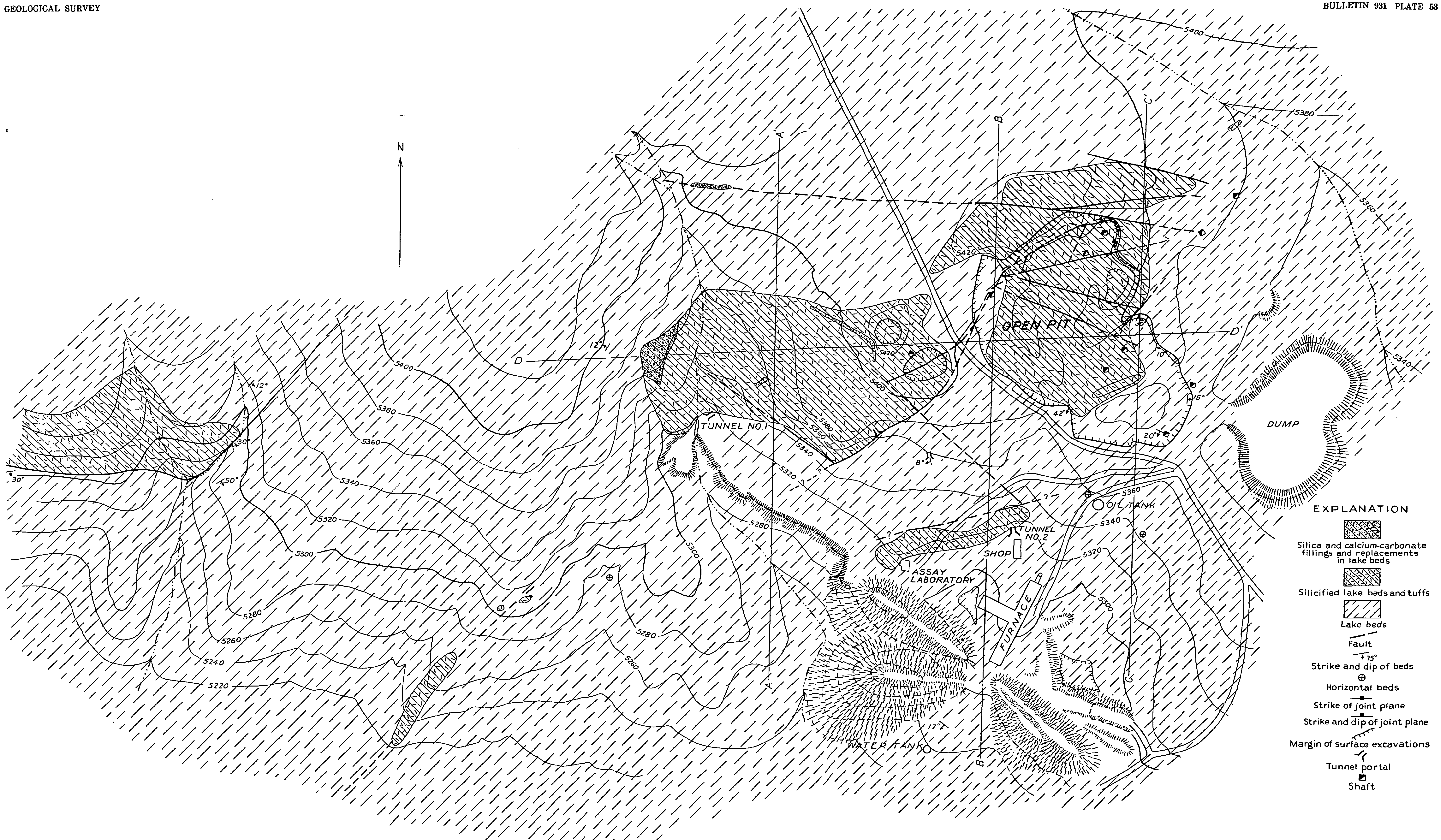
The ore bodies of the Opalite and Bretz mines had been almost exhausted by April 1941. The known reserves of the district, therefore, are confined to the recently explored ore body of the Cordero mine.

The management of the Bradley Mining Co. believed in March 1941 that the ore remaining in the chalcedony at the Opalite mine was not in excess of 5,000 tons with an average tenor of 2 pounds of quicksilver to the ton. It is possible, however, that the life of the mine may be extended by the mining of ore in cinnabar-bearing lake beds that are exposed in the lower winze (see pls. 53 and 55), though the grade and extent of that ore is problematical.

No body of commercial extent or grade is now known in the vicinity of either the old or the new Bretz workings. There are several showings of cinnabar that have been prospected since the field work for this report was done.

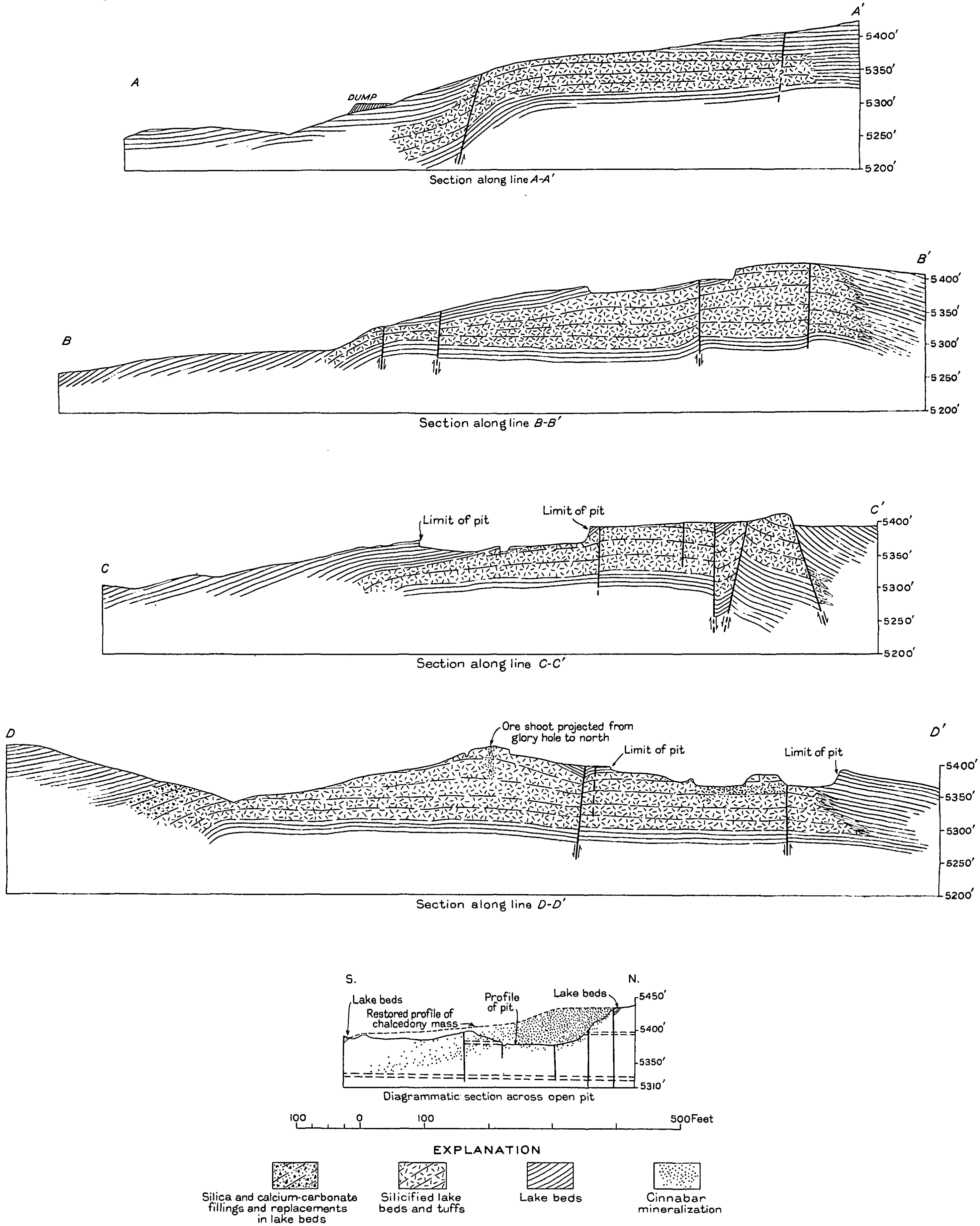
In the Cordero mine about 15,000 tons of ore has been blocked out that will average 15 pounds of quicksilver to the ton, or about 3,000 flasks. This ore body has been carefully explored and its tenor has been estimated by means of numerous assays. Surface and underground exploration indicates that the property has potential reserves of from 50,000 to 100,000 tons of ore, averaging about 5 pounds of quicksilver to the ton. These figures, however, are based upon broad generalization, and further explorations may reveal ore that will justify a higher estimate. It seems certain, at any rate, that the property can produce at least 3,000 flasks of quicksilver and perhaps several times that amount at 1941 prices.

At the Disaster Peak prospect development work has not yet revealed any ore body. Very little cinnabar can be seen in the outcrops of the silicified rocks, whereas in all other known deposits of this type in Nevada and Oregon cinnabar was relatively abundant in the outcrops and decreased in grade downward. It is therefore doubtful whether the chalcedony contains a deposit of any considerable size. However, the unsilicified rocks beneath and adjacent to the chalcedony mass are probably worthy of further prospecting in the hope that deposits similar to the Bretz may be discovered.



GEOLOGIC MAP OF THE OPALITE MINE AREA

Geology and topography by Robert G Yates and James Pollock



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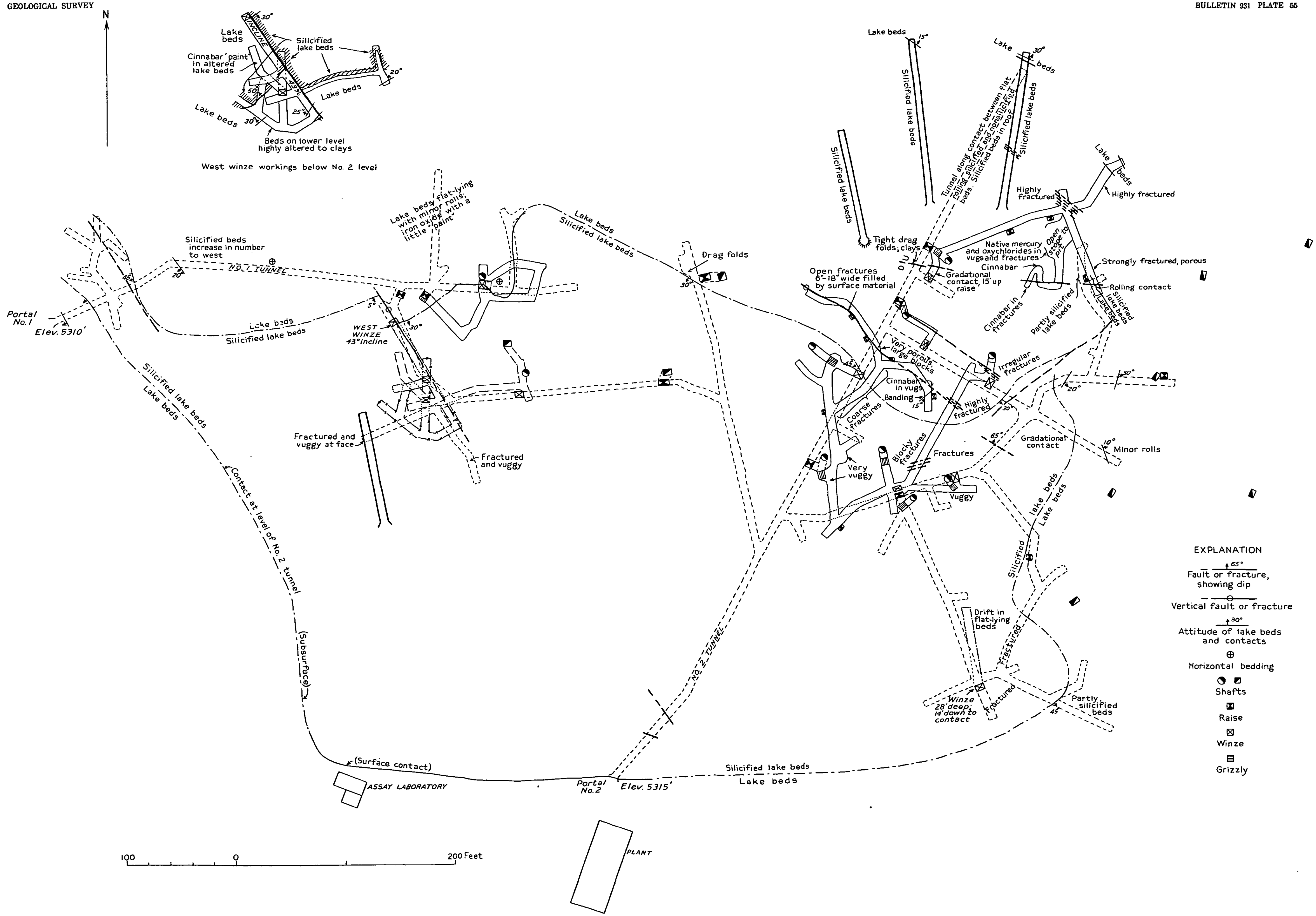
GEOLOGIC SECTIONS OF THE OPALITE MINE



PLAN OF WORKINGS OF THE OPALITE MINE

Modified from map of Bradley Mining Co.

MINES

Opalite mine

The Opalite mine is about 20 miles west of McDermitt, in sec. 33, T. 40 S., R. 40 E., in Malheur County, Oreg. It is owned and operated by the Bradley Mining Co. of San Francisco, Calif. A rotary furnace capable of treating over 100 tons a day of ore from the Opalite mine is in operation on the property. Ore from the Bretz mine has also been treated in this furnace, but because of the wet character of this ore less than 50 tons of it can be burned in a day.

Since 1927 the Opalite mine has produced over 12,000 flasks of quicksilver. The mine has been developed by means of a glory hole, with the main haulageway about 100 feet below the outcrop of the ore body. If it had been known beforehand that the deposit did not persist at depth it could have been mined more economically from the surface.

The lower workings (tunnels 1 and 2) follow, in general, the contact between the unsilicified beds and the overlying chalcedony. There are traces of cinnabar in the chalcedony of these lower workings (see pl. 55), and a little low-grade ore has been stoped from the soft lake beds on the southeast side of the west winze, which was sunk on a northwest-striking fault. The pulverulent cinnabar here present may be of secondary origin; if so, it will probably not prove to be extensive.

The main ore body was in the northern part of the east pit, and in general the present borders of the pit coincide with the limits of this ore body. The chalcedony is much brecciated and the best ore occurs where the brecciation is most intense. Ore from the Opalite mine has averaged a little less than 6 pounds of quicksilver to the ton. Some high-grade ore, which contained native mercury and the oxychloride in addition to cinnabar, yielded as much as 40 pounds of quicksilver to the ton, but the rest of the ore produced in the past cannot have averaged more than 4 pounds to the ton.

Most of the ore has been removed from the east pit, but the former presence of two ore shoots to the west is indicated by the two glory holes represented in plate 53. These two ore shoots did not extend to the lower level, and the chalcedony east of the surface workings contains only traces of cinnabar.

Bretz mine

The Bretz mine is about 13 miles by a graveled road from McDermitt and lies in sec. 3, T. 41 S., R. 41 E., in Malheur County, Oreg. It is leased and operated by the Bradley Mining Co. of San Francisco. Cinnabar was first discovered in the district in the silicified conglomeratic tuff just north of the Bretz pits (see pl. 56), but no ore has been mined from these rocks. All the ore that has been mined at Bretz was from the soft lake beds south of the silicified rocks.

The ore occurs in two separate zones, the location of which is marked by the east and west pits (pl. 56). The northern limit of the ore was an east-trending fault. This fault, adjacent to which the lake beds showed steep drag folds, was probably the channelway for the ore-forming solutions and the solutions that silicified the rocks to the north. Some porous sinter, consisting of calcium carbonate and silica, was deposited on the surface between the two ore bodies after the ore zone had been partially eroded. This sinter is said to have extended downward along the faulted zone and to have increased in hardness with depth. A tunnel (now caved) about 75 feet below the rim of the pits is reported to have crosscut siliceous calcium-carbonate rock that contained cinnabar.

The ore bodies in both the east and west pits are almost completely mined out, only a little ore remaining in the walls, but traces of cinnabar are found in the lake beds for several hundred feet to the south and west of the pits.

During the fall and summer of 1940 the only ore that was being burned at the Opalite furnace was from a small opening, half a mile west of the old Bretz pits (see pls. 56, 57, and fig. 35), referred to as the 1940 Bretz pit. The ore here is probably related to the same east-trending fault as the similar ore at the old Bretz pits. The ore body extends along the crest of a southwest-plunging anticline. Several small pockets of ore containing as much as 30 percent of cinnabar were mined from

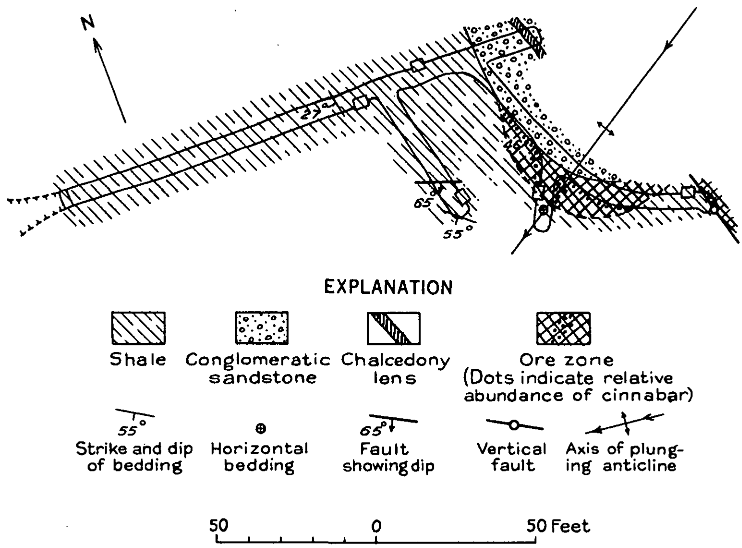


Figure 35.--Geologic map of the underground workings of the 1940 Bretz pit.

this pit. The rocks here are thin-bedded, brown-black carbonaceous shales overlying a buff conglomeratic sandstone. Most of the ore was in the shale, but some of the high-grade pockets filled the pores in lenses of tuffaceous shale. By the end of 1940 this ore body had been exhausted, after yielding about 5,000 tons of ore averaging 12.8 pounds of quicksilver per ton. The ore from the soft lake beds was too wet either to mine or to burn during the winter months.

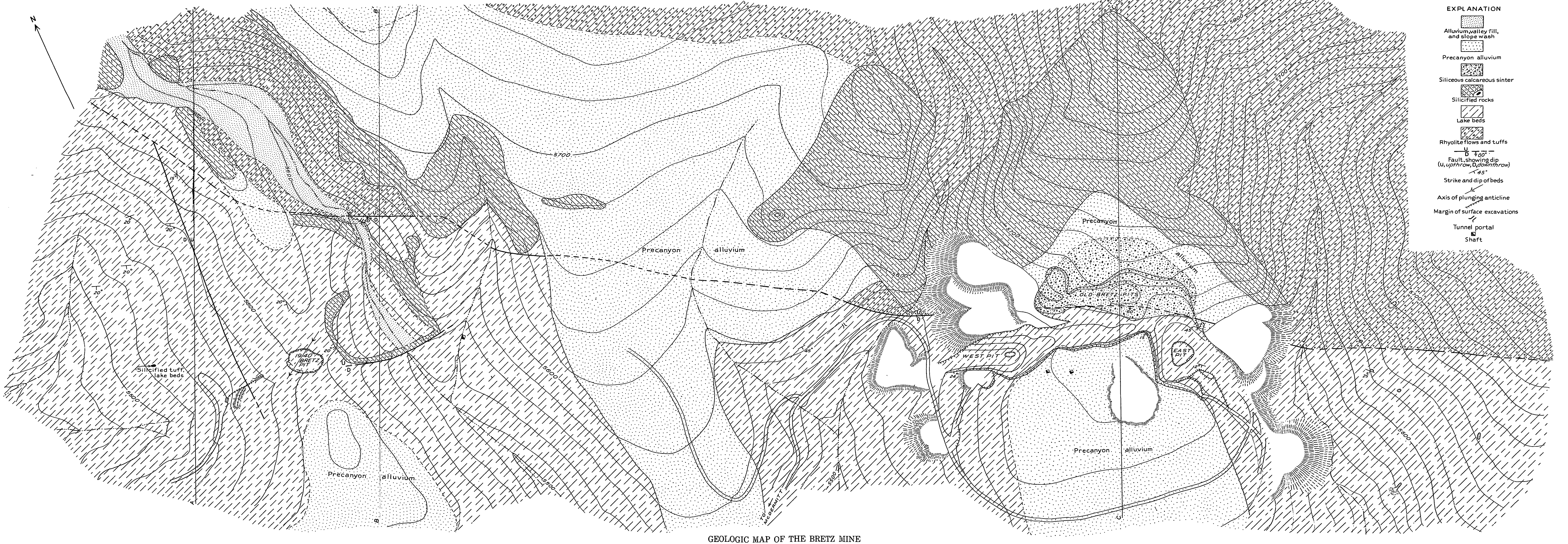
A tunnel (shown on pl. 56) in rhyolitic lavas and tuffs about 500 feet north-northeast of the 1940 pit explores a fault along which cinnabar occurs in fractures in opalized rocks. Near the portal of this tunnel cinnabar is present in chalcedonized tuffs.

The area about the 1940 Bretz pit has been explored by the Bradley Mining Co. by means of pits 100 feet apart and ranging in depth from 4 to 20 feet. West of the spur on which the 1940 pit is located none of the pits revealed any ore, but on the east side of the spur, directly in line with the old Bretz pits, there are good showings of cinnabar and exploration was being carried on here during the winter of 1940-41.

Cordero mine

The Cordero mine is in Humboldt County, Nev., about 11 miles by road southwest of McDermitt. The deposit was discovered in 1931, but only 40 tons of hand-sorted ore, burned at Opalite in 1935, has been treated. In the spring of 1940 the mine was taken over by the Cordero Mining Co., which has since conducted extensive explorations. This company installed a 50-ton Herreshoff furnace in the spring of 1941 and had on the property a gasoline power shovel which will be used in open-pit mining.

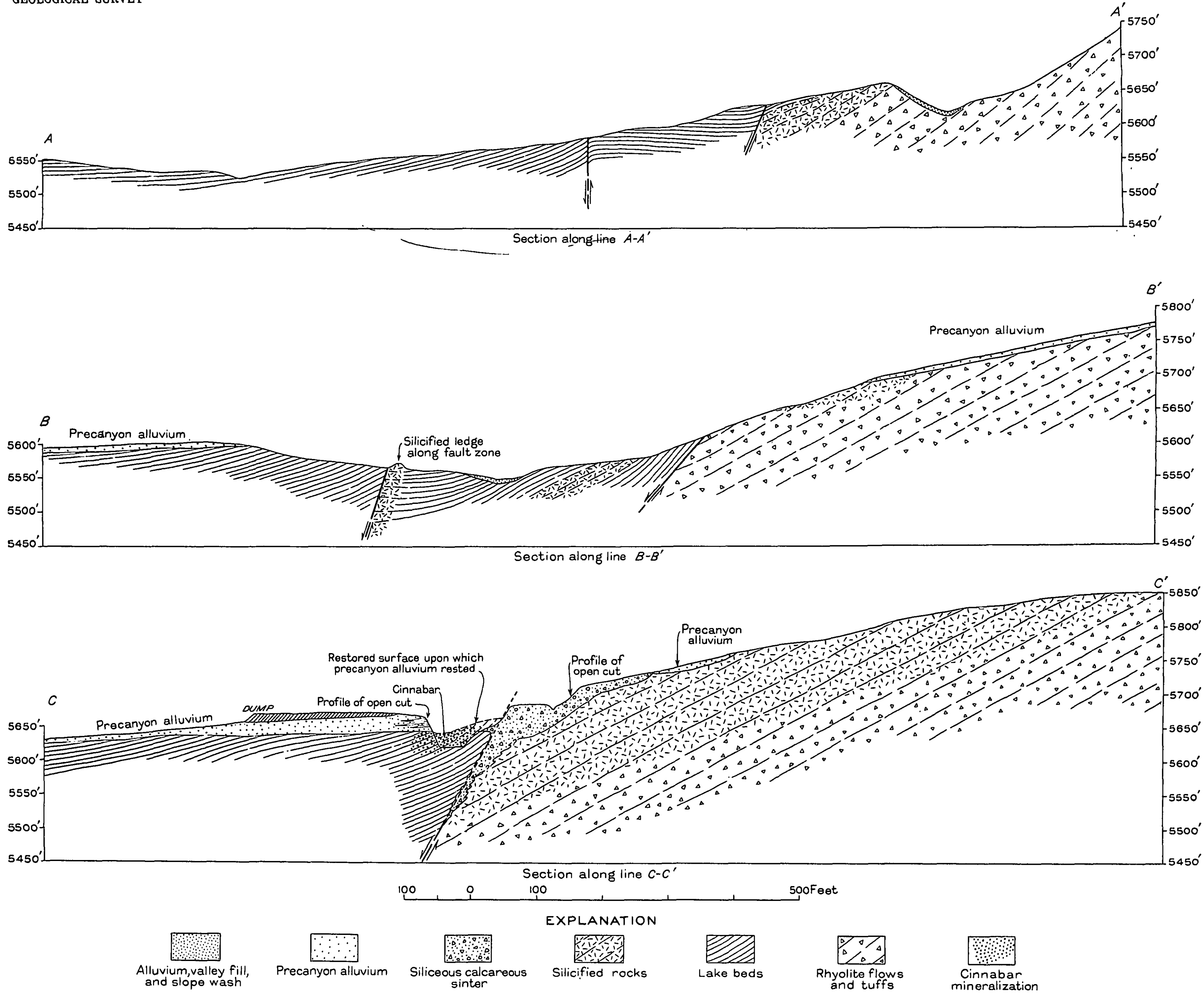
Cinnabar is here distributed sporadically over a northeast-trending area about 300 feet wide and 3,500 feet long (pl. 58). The only natural rock exposures in this area are small knobs of chalcedony. All these outcrops are surrounded by an alluvial mantle, locally 15 feet or more in thickness, of volcanic detritus that was derived from the immediate slopes and canyons to the southeast. Trenching through the alluvial mantle has indicated that there are two principal zones of mineralization, one at the southwestern end of the property and the other at the northeastern end. The southwestern area has more and better ore than the northeastern area and for this reason will be mined first.



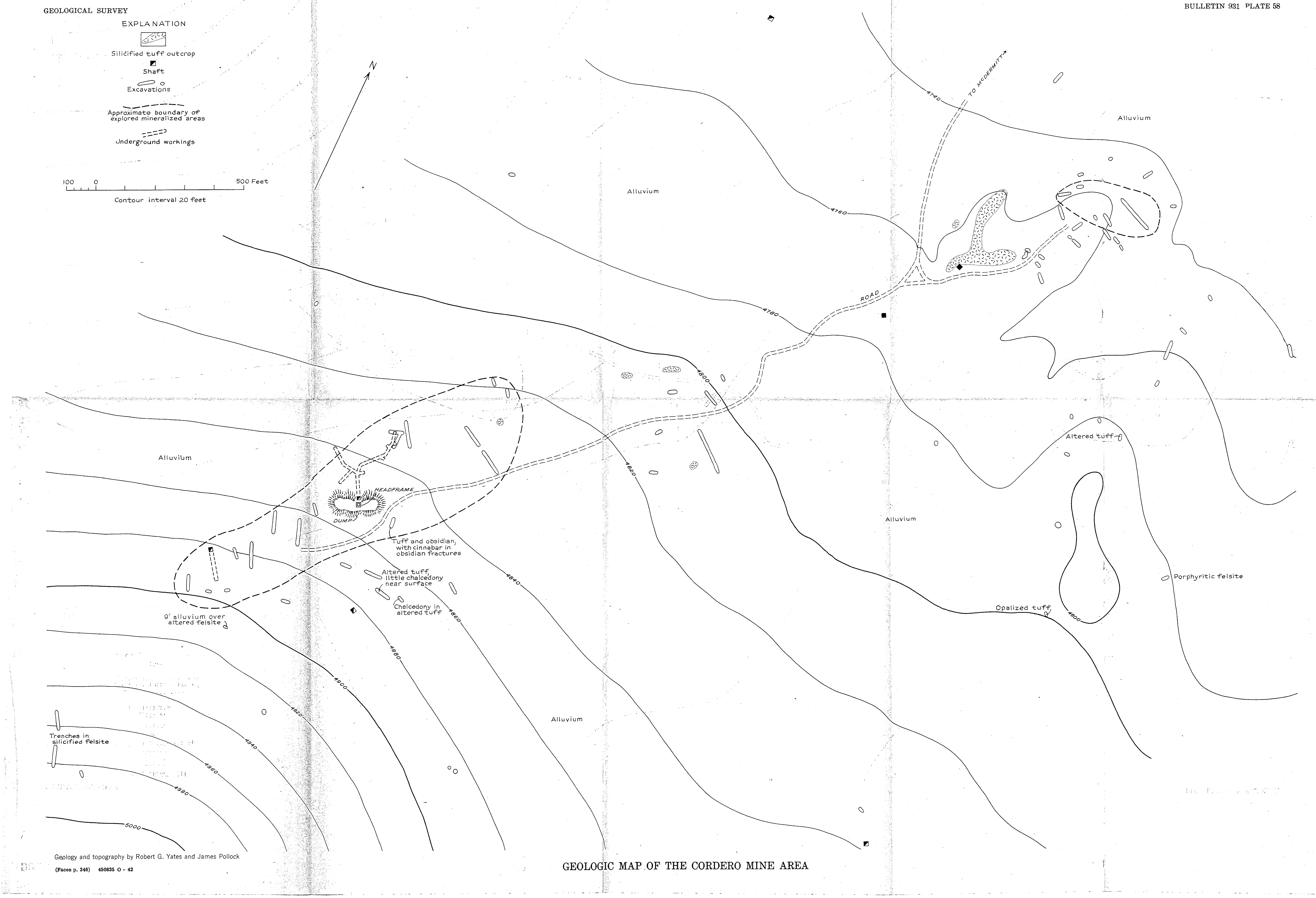
GEOLOGIC MAP OF THE BRETZ MINE

500 0 500 Feet

Contour interval 20 feet



GEOLOGIC SECTIONS OF THE BRETZ MINE



Geology and topography by Robert G. Yates and James Pollock

GEOLOGIC MAP OF THE CORDERO MINE AREA

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Figure 36 represents the underground workings as they were in September 1940. Since that time additional exploration has increased the total workings to over 1,200 feet. These have explored a distance of 250 feet along an ore body that ranges from 15 to 50 feet in width and extends at least 80 feet below the

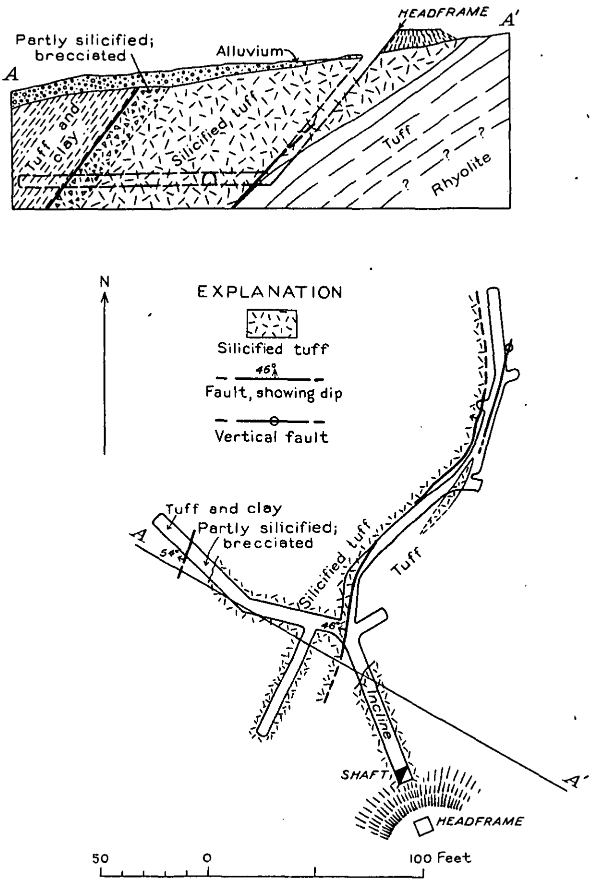

Figure 36.--Sketch map and section of the underground workings of the Cordero mine.

surface. It is estimated that at least 15,000 tons of 15-pound ore had been blocked out by this development.

This ore body is in clays and tuffs which overlie rhyolitic lavas. The beds dip steeply to the northwest, probably as the result of drag on a fault which is inferred to be under the alluvium a short distance to the northeast of the mineralized zone. Because of the indefinite location of this fault, it is not shown on plate 58, although it is shown on plate 52. The tuffs have been selectively silicified along the bedding, to form a body of chalcedony similar to that in the Opalite mine. Channel samples taken every 2 feet along the workings show abrupt changes in grade of ore from less than 1 pound to over 80 pounds to the ton. Cinnabar occurs in the chalcedony and also in the clays and tuffs. High-grade zones occur along slightly faulted contacts between the silicified and unsilicified rocks. A pit southeast of the head frame (see pl. 58) shows cinnabar deposited in fractured obsidian.

Geophysical surveying in the vicinity indicates that there may be two or more silicified zones, any of which may contain cinnabar.

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