Quicksilver Deposits in the Southern Pilot Mountains Mineral County Nevada

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By DAVID A. PHOENIX and JAMES B. CATHCART

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A report on the geology and on the occurrence of cinnabar in the area

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By DAVID A. PHOENIX and JAMES B. CATHCART

ABSTRACT

The Pilot Mountains quicksilver district is in the southeastern part of Mineral County, Nev. Cinnabar was first discovered in 1913, and intermittent production to the end of 1949 yielded about 5,000 flasks of quicksilver.

Sedimentary and volcanic rocks of Mesozoic age underlie most of the area and are locally overlain and intruded by Tertiary igneous rocks. The sedimentary formations include the Middle Triassic Excelsior formation, the Upper Triassic Luning formation, and the Lower Jurassic Dunlap and Dunlap (?) formations. Jurassic thrust faulting and Tertiary normal faulting have produced moderately complicated structures.

The cinnabar mines and prospects, with one exception, are all below northward-dipping, low-angle thrust faults, the Cinnabar Canyon and Lost Steers thrusts. These faults probably constitute the major structural control for the cinnabar mineralization in the district. The cinnabar, the only important ore mineral, occurs as fillings of fractures and is disseminated in the gouge of the faults and through various country rocks. Most of it has filled open spaces, but some has replaced the more limy sediments.

All the known ore bodies lie within an area of about 4 square miles in the central part of the Pilot Mountains. Because the grade and character of each ore body reflect its environment, the deposits have been grouped into the following categories: (1) Deposits localized by normal faults in limestones at the head of Cinnabar Canyon. These deposits are the largest and the richest of the district; they include the Mina Development Co. and Drew mines, which together have produced 80 percent of the quicksilver of the district. (2) Deposits in sandstone and conglomerate near Dunlap Canyon. These ore bodies, though smaller, are rich; they are localized beneath rolls in normal faults and are generally in the footwall side. (3) Deposits in chert on the south flank of the Pilot Mountains. Although these deposits are the smallest in the district, they are rich. They are localized along faults by a change in dip or strike at the intersection of faults with bedding planes, and they occur where the chert is most broken.

There are no appreciable reserves of low-grade ore in the district. Some mines have small amounts of known high-grade ore, and development work along the controlling structures, as well as additional prospecting in the district, may lead to the discovery of other ore bodies. The district should produce at least a few hundred flasks of quicksilver annually during periods of high prices.

INTRODUCTION

LOCATION AND ACCESSIBILITY OF AREA

The Pilot Mountains quicksilver district is in the central part of the Pilot Mountains about 12 miles southeast by east of Mina, Nev. (fig. 15). The ore deposits are all in T. 6 N., R. 36 E., Mount Diablo meridian, in the eastern part of Mineral County. The dis-

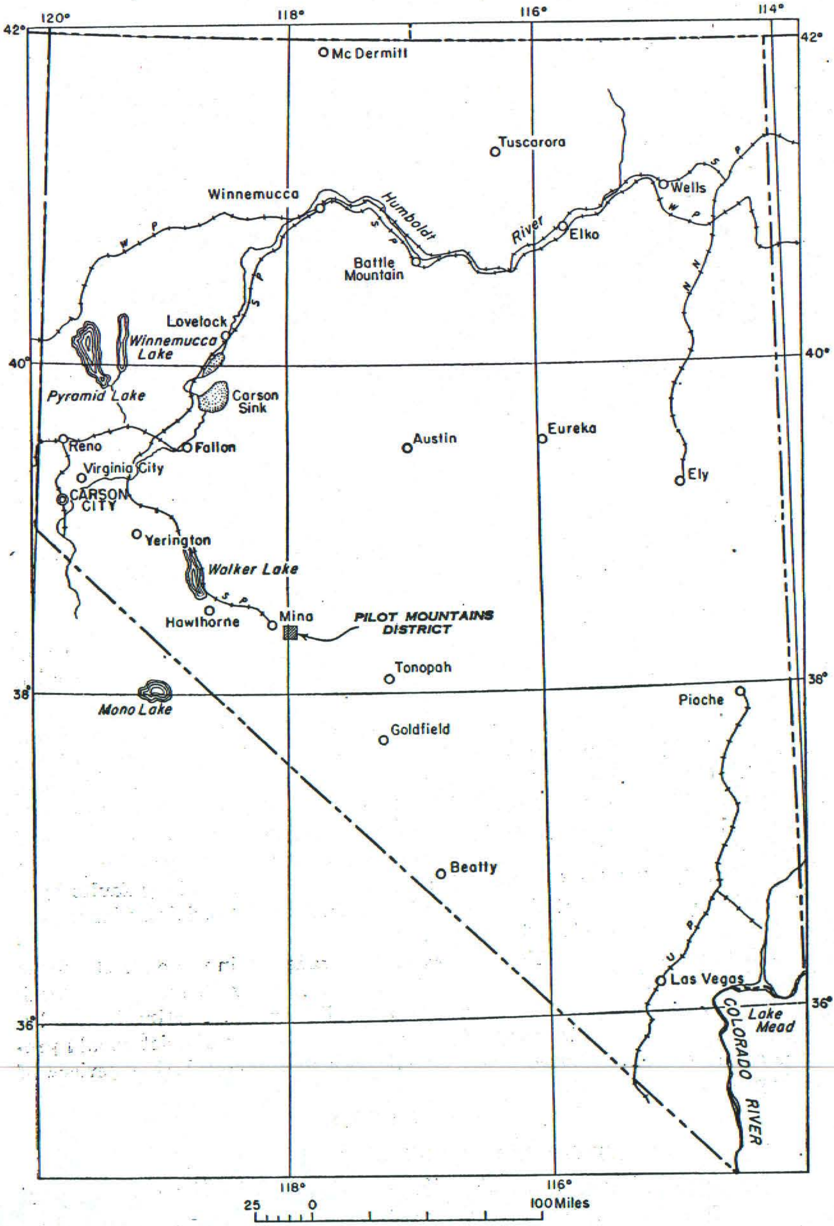

FIGURE 15.—Index map of Nevada, showing the location of the Pilot Mountains quicksilver district in Mineral County.

trict is in the western part of the area covered by the Tonopah quadrangle topographic map.

The mines are at altitudes of 7,000 to 8,000 feet, but most of them are readily accessible by good gravel roads except after an occasional heavy snow. Springs with flows of no more than 5 gallons a minute supply the only available water but are adequate for small mining operations. The soil cover is thin and supports only a sparse growth of juniper and sage, so that exposures are abundant.

HISTORY AND PRODUCTION

The first discovery of cinnabar in the district was made in June 1913, at the Lost Steers mine, by Thomas Pepper and Charles Keough.

On the day of discovery [according to Knopf (1916, p. 59)] Thomas Pepper and Charles Keough had been tracking two stray steers, when near nightfall the trail led over an old prospect in which a face of limestone traversed by small veinlets of red mineral was exposed. The red mineral was recognized by Keough as cinnabar. After finding the steers and taking them to Mina the two discoverers returned to Cinnabar Mountain, as the hill on which they had made the find has since been named, where they spent 10 days in careful search and located 17 claims.

Since then, prospecting and mining have been carried on intermittently, the periods of greatest production reflecting, in general, the times of highest quicksilver prices.

The total production from this district has been about 5,000 flasks of quicksilver, and 80 percent of it came from two mines—the Mina Development Co. and the Drew (table 1). Most of the ore bodies have been small but comparatively rich, and, according to Foshag (1927, p. 119), "some of the ore charged into the retorts has been almost pure cinnabar, and 10 percent ore was not uncommon." Consequently, the ore has been treated in either retorts or small rotary furnaces.

FIELD WORK AND STUDY

Previous geologic reports on the area include one on the stratigraphy (Muller and Ferguson, 1939) and one on the geology (Ferguson and Muller, 1949), the latter including a detailed study of the structural geology of the Pilot Mountains (pp. 29-38). The quicksilver deposits have been discussed by Knopf (1916), Ransome (1921), Foshag (1927), and Bailey and Phoenix (1944).

The present report is based on 3 months' field work in the fall of 1942. The areal geology was plotted on a single aerial photograph enlarged to a scale of about 1,400 feet to the inch (pl. 19). The results of this plotting coincide essentially with those obtained by Ferguson and Muller (Muller and Ferguson,

TABLE 1.—*Recorded quicksilver production, in flasks,*[1] *from the mines of the Pilot Mountains, Nevada, 1914–48*[2]

Year	Mina Development Co. (inc. Lost Steers)[3]	Drew[3]	Allen[3]	Mammoth[3]	Reward[3]	Betty, Inman[3]	Cardinal[3]	Hitt[3]	Sullivan[3]	Chong Wong[4]	Fletcher[4]	Coveney[3]	Keg[5]	Red Wing[5]
1914														
1915	344	724												
1916														
1917														
1918														
1919	628	136												
1920														
1921	120	10				3								
1922	255													
1923														
1924				17										
1925	135			9										
1926	15					15								
1927	163					14								
1928	15				4	3								
1929	20		14	4	41	3								
1930	30	4	12	8	23		65							
1931	4		2	5	36		30							
1932		1	6		137		30							
1933	1	7			54									
1934			2		9	2								
1935	1		2		14	8								
1936	1				2									
1937			1	2	3	2	4							
1938			5			5	4							
1939	3		4		7	8								
1940	1,146	6			33	22		6				6		
1941	187	4		5	18	24		40	5					
1942	1			(4)	132	(6)	(6)		1					
1943–48				[7] 10				[7] 10						
Total	3,069	896	48	50+	513	109+	133+	46+	6	(?)	(?)	6	30 ±	30 ±

[1] A flask contained 75 lbs. from June 1904 to Jan. 1928; it has since contained 76 lbs.

[2] Compilation of figures from Mineral Resources of the United States and other sources.

[3] Production figures used with permission of owners.

[4] Production unknown, probably small.

[5] Production reportedly about 30 flasks.

[6] Worked by lessors; production unknown.

[7] Combined production from Mammoth and Hitt mines.

1939, pl. 3; Ferguson and Muller, 1949, pl. 2), and the writers have freely used their field maps to interpret structure and stratigraphy and as topographic control for the accompanying cross sections. All the mine owners and operators were most cordial and helpful, but special thanks are due A. J. Anderson and L. B. Spencer, of the Mina Development Co. The writers are indebted, also, to H. G. Ferguson, S. W. Muller, and E. H. Bailey, of the Geological Survey, and to Howel Williams, professor of geology at the University of California, for helpful advice and criticism during the field work and the preparation of the report.

GEOLOGY

The rocks of the Pilot Mountains quicksilver district are dominantly sedimentary, volcanic, and intrusive rocks of Mesozoic age, but locally they are overlain and intruded by Tertiary igneous rocks (pl. 19).

The major structural features of the mining district are two thrust faults, the Cinnabar Canyon and Lost Steers thrusts (pl. 19). It is significant that the two mines in the district with the greatest production, the Drew and Mina Development Co. mines, have obtained the largest part of their ore from immediately below these faults and that several other small prospects likewise are located along them.

Isoclinal folding is associated with the thrusting; younger folds and normal faults, together with igneous intrusives, further complicate the structure.

STRATIGRAPHY

The stratigraphic nomenclature in this report follows that of Muller and Ferguson (1939, p. 1582). The formations shown on the geologic map and briefly described in the text are the Middle Triassic Excelsior formation, the Upper Triassic Luning formation, and the Lower Jurassic Dunlap and Dunlap (?) formations. The Tertiary volcanic rocks have been less thoroughly studied and are referred to only by compositional names—for example, hornblende andesite.

TRIASSIC ROCKS

EXCELSIOR FORMATION

The Excelsior formation consists of more than 10,000 feet of sedimentary and volcanic rocks, but only the upper part of this section is included in the mapped area.

Two types of volcanic rocks are included at the top of the formation. One, light brown on the weathered outcrop, is altered hornblende andesite. Within the altered andesite are contorted local beds of red to brown chert that are probably silicified tuff. The thickness of the altered andesite is estimated to exceed 1,600 feet. The other type of volcanic rock, a dark-brown hornblende andesite with phenocrysts of hornblende generally an inch or more in length, is included in the formation because it may be of equivalent age, although possibly it is contemporaneous with late Jurassic intrusions. The presence of epidote along the joint planes makes it unlikely that it is a Tertiary intrusion. It is further possible that the unaltered andesite is merely a phase of the light-brown altered andesite. Although a distinction between these two igneous rocks is indicated in the field, the investigation was not sufficiently detailed to clarify their probable origin.

The sedimentary rocks are mostly chert, although in places it is interbedded with siliceous slate and thin beds of brownish sandstone. The chert is easily distinguished by its hardness and its light-gray to dark-brown color on the weathered outcrop. According to Foshag (1927, pp. 115 and 122) and Hill (1915), the chert is partly of tuffaceous origin.

The sedimentary rocks immediately below their contact with the overlying andesites are brecciated and locally altered to clay minerals. Farther away, the cherts are tightly folded and contorted in places. Movement has undoubtedly occurred along the contact, although the displacement is not believed to be great enough to warrant mapping it as a fault.

LUNING FORMATION

The Luning formation, of Upper Triassic age, is divided into three members that here have an aggregate thickness of about 8,000 feet. Throughout the mapped area, however, the lowermost part of the section is generally cut out by faulting.

The lower member is mostly thin-bedded limestone with minor amounts of carbonaceous and sandy shale. The limestone, seen underground at the Chong Wong property, is coarsely crystalline and locally sandy.

The middle member consists of interbedded brown slates and fine conglomerates. The conglomerates are composed of angular to subangular chert pebbles in a siliceous matrix, and at the head of Cinnabar Canyon, where they are best developed, pebbles make up about half the member. Here the middle member is in thrust contact with the Lower Jurassic Dunlap formation. East of the Drew mine, it rests with a gradational contact on the lower member.

The upper member, found only in the northern part of the map area, consists of thickly bedded dark limestone and dolomite and minor amounts of shale. An abrupt change in lithology marks its contact with the underlying slate and conglomerate member.

JURASSIC ROCKS

DUNLAP FORMATION

The Dunlap formation, of Lower Jurassic age, is a heterogeneous assemblage of dominantly nonmarine sediments with only a few lenses of marine limestone and some tuffaceous beds. In the western part of the map area, the thickness of the formation exceeds 5,000 feet; in the eastern part it is less than 1,500 feet, but the upper part of the section is here cut off by thrust faults. The Dunlap formation rests with an angular unconformity of 10° to 70° on the Excelsior formation. A thin, siliceous basal conglomerate composed of small subrounded to subangular fragments of chert derived from the Excelsior formation, with interbeds of brown quartzitic sandstone, marks this contact.

In the central part of the area, near the head of Cinnabar Canyon, the lower 750 feet of the formation consists dominantly of red and brown sandstones and shales that grade downward into brown sandstones and chert conglomerates. Overlying these lower sedimentary rocks and separated from them by a slight unconformity is about 300 feet of bluish marine limestone with considerable interbedded sandy shale and conglomerate. The conglomerate contains many chert pebbles and also limestone pebbles derived from the Luning formation during the early stages of folding (Ferguson and Muller, 1949, p. 31).

DUNLAP (?) FORMATION

Yellow, limy shale with local lenses of bluish limestone overlies the bluish marine limestone, sandy shale, and conglomerate. These beds are well exposed in the vicinity of the Mina Development Co. mine, where they are thrust over the interbedded limestone, sandy shale, and conglomerate. Because of their lithologic similarity to other beds in the Dunlap formation, these beds are thought to be a part of that formation, but their exact stratigraphic position is unknown.

In a section through the ridges west of Dunlap Canyon the sequence is somewhat different. Here the lower part of the formation consists of more than 3,000 feet of brown sandstone, lenticular beds of conglomerate, and local beds of white, sandy limestone. These sediments locally contain thin flows of greenstone, and near the Red Wing prospect they are intruded by small dikes of gabbro possibly of Cretaceous age. The upper part of the formation, which crops out on this ridge west of the map area, is composed of about 2,000 feet of poorly bedded conglomerates and fanglomerates containing abundant limestone pebbles derived from the Luning formation.

CRETACEOUS (?) AND TERTIARY IGNEOUS ROCKS

INTRUSIVE ROCKS

Small dikes of gabbro, possibly of Cretaceous age, were mapped near the Red Wing prospect. These dikes are intrusive into the sedimentary beds of the Dunlap formation.

A small intrusion of hornblende andesite cuts rhyolitic extrusive rocks and the Dunlap and Luning sedimentary formations in the northwestern part of the area. It shows strong vertical columnar jointing and weathers to gray. Phenocrysts of hornblende and plagioclase feldspar, one-quarter to one-eighth inch long, lie in a light-gray microcrystalline groundmass. At the intrusive contact the adjacent shale and sandstone have been altered, possibly by baking, to varicolored clays. Farther south, on the ridge at the head of Dunlap Canyon and about half a mile west of the Sullivan prospect, is another small intrusive body of the same rock. The two are probably related, and both may well have been intruded along the normal faults adjacent to and paralleling the general trend of Dunlap Canyon.

EXTRUSIVE ROCKS

A series of interbedded rhyolitic flows, with a microcrystalline or glassy groundmass (vitrophyres), and tuffs is exposed between Cinnabar and Dunlap Canyons on the west and north sides of the andesite intrusive in the northwestern corner of the map area. The flows contain phenocrysts of quartz, orthoclase, and some biotite and are red; the vitrophyres are dark; and the interbedded tuffs are white. All these volcanic rocks dip at low angles to the south and are probably in fault contact with the Luning formation in Cinnabar Canyon.

Near the head of Dunlap Canyon, an irregular dark-colored flow of vesicular basalt caps the Dunlap formation. A light-brown andesite, containing numerous large phenocrysts of plagioclase feldspar and sparse hornblende phenocrysts, caps the small intrusive body of hornblende andesite half a mile west of the Sullivan prospect.

QUATERNARY ROCKS

The rocks mapped as Quaternary are alluvial deposits found in the bottom of the main stream canyons. Locally, as at the Inman mine, these sediments have been prospected for placer cinnabar.

STRUCTURE

As the rocks have been folded and faulted, the geologic structure in the district is somewhat complex. The central part of the area consists of tilted and slightly folded sediments of the Dunlap formation, unconformably underlain and nearly surrounded by the cherts of the Excelsior formation, which are highly contorted in places. In the northern part of the area the Luning formation is isoclinally folded and overturned to the south and is thrust over the older Excelsior and younger Dunlap formations.

THRUST FAULTS

Two major thrust faults lie within the map area, the Cinnabar Canyon thrust and the Lost Steers thrust a few hundred feet below (pl. 19). In addition, half a mile south of the Lost Steers mine and near the head of Dunlap Canyon, a less extensive and probably sympathetic thrust fault has disrupted the Dunlap formation just above its contact with the Excelsior formation. The trends of the two major thrust faults are parallel; both strike about N. 60° E. and dip 30°-35° N. Moreover, both have been offset by steep normal or reverse faults. On the east side of the map area and just east of the Drew mine, they terminate against a northwestward-trending, nearly vertical fault along which displacement is sufficient to offset their eastward continuation at least 7,000 feet to the south. From the Drew mine westward for about 2½ miles, their trace is nowhere greatly offset until in the center of the map area and on the east side of Dunlap Canyon both thrusts are offset to the north, for a distance of about 2,100 feet, by a reverse fault that dips steeply to the west. From here they strike across Dunlap Canyon and again terminate against an eastward-dipping normal fault along which displacement is sufficient to throw any further trace of them to the north and out of the map area.

The Cinnabar Canyon thrust, probably of early Jurassic age (Muller and Ferguson, 1939, p. 1619; Ferguson and Muller, 1949, p. 34), is of sufficient magnitude to cause the Upper Triassic Luning formation to override the Lower Jurassic Dunlap formation. Below this fault, shales of the Dunlap formation have been extensively crushed and sheared, whereas, in the upper plate, slates and conglomerates of the Luning formation have been isoclinally folded and overturned. The Lost Steers thrust, of equivalent age, is within the Dunlap formation and locally separated from the Cinnabar Canyon thrust by as much as 500 feet of highly contorted yellow limy shale (pl. 21). Where it truncates limestone beds it has brecciated them for nearly 50 feet normal to its trace;

elsewhere it can be followed by gouge and shear zones in the softer sediments.

The thrust faults assume considerable significance when the distribution of the most productive mines in the district is considered. All the ore in the Drew mine was extracted from highly brecciated limestone lenses lying immediately below the Cinnabar Canyon thrust fault, and, although cinnabar mineralization is localized chiefly along normal faults in the Mina Development Co. mine, the ore deposits as a whole lie only a few tens of feet below the Cinnabar Canyon thrust.

NORMAL FAULTS

The oldest normal faults are believed to be older than the Dunlap Canyon thrust fault, for in the Mina Development Co. mine area the Cinnabar Canyon thrust has apparently overridden them.

Following the period of thrusting, steep northward-trending normal faults of considerable magnitude were developed. These faults offset the thrust faults and appear to have allowed movement during several periods. The last movement is dated as Tertiary because the faults locally offset Tertiary volcanic rocks; earlier movement is suggested by the general alinement in Dunlap Canyon of the Tertiary andesite intrusions along the trend of the major northward-trending faults (pl. 19). Small faults, possibly genetically related to the major normal faults, preceded mineralization and provided channelways for ore-bearing solutions.

Movement after mineralization along the Keough fault, a transverse zone of closely spaced normal faults at the Mina Development Co. mine, is indicated by a slight offset of the ore body (pl. 20). Renewal of movement along old faults is indicated by the presence of slickensided cinnabar in the gouge of the faults. The total throw of any of the faults that postdate mineralization is small.

ORE DEPOSITS

OCCURRENCE OF MINERALS

The only important ore mineral in the deposits is cinnabar. It fills fractures and also is disseminated through the country rock. Two types are common: a deep-red crystalline variety and a bright-scarlet earthy variety that is found most abundantly in deposits that occur in limestone, such as those at the Drew, Lost Steers, Keg, and Mina Development Co. mines. The crystalline variety is most commonly found as a filling in fractures, as isolated crystals in calcite veinlets, and as massive bodies replacing the limestone. It is frequently associated with massive stibnite. The earthy variety, although widely distributed as partial fillings in fractures, is found most abundantly at the Drew mine. Here this variety of ore occurs in large masses replacing what were once believed to be discontinuous limestone lenses. The ore is friable and earthy but is held together by numerous tiny, irregular veinlets of calcite and quartz. Intimately associated with this cinnabar is lemon-yellow stibiconite in sufficient abundance that upon casual examination the hand specimen has a characteristic bright-orange color. Valentinite, in pearly-gray crystals and masses pseudomorphous after stibnite, also was found intimately mixed with the cinnabar, as well as calamine, azurite, malachite, and sparse crystals of sphalerite.

The minerals of the ore deposits were deposited from mineralizing solutions rising along faults and fissures. In the deposits characterized by massive crystalline cinnabar, the first minerals to be deposited were pyrite, quartz and calcite, and—later—stibnite and cinnabar. In the deposits that contain the earthy cinnabar mixed with the oxidation products of stibnite, sphalerite, and possibly mercurial tetrahedrite, the order of deposition is not known. The earthy variety of cinnabar may be due to redeposition of the crystalline variety. Foshag (1927, p. 116) suggests that it may owe its origin to the oxidation of mercurial tetrahedrite; a further source may be mercurial galena (Hewett, 1931, pp. 81-82) or stibnite, as suggested to the authors by D. E. White.

Here follows a summary of the occurrence of minerals in the ore deposits. They are arranged according to Dana's system of mineral classification.

Minerals of the ore deposits of the Pilot Mountains mines, Mineral County, Nev.

	Composition	*Remarks*
Native elements:		
Sulfur[1]	S. Native sulfur.	Reported at Lost Steers mine (Foshag, 1927, p. 116).
Gold[1]	Au. Native gold.	Reported at Drew mine (Foshag, 1927, p. 120).
Mercury[1]	Hg. Native mercury.	Reported by Foshag (1927, p. 116).

[1] Scarce.

Minerals of the ore deposits of the Pilot Mountains mines, Mineral County, Nev.—Continued

	Composition	Remarks
Sulfides:		
Stibnite[2]	Sb_2S_3. Antimony sulfide.	Found in abundance at Lost Steers mine and present in some quantity at Drew and Mina Development Co. mines. Associated with cinnabar and antimony oxides (stibiconite and valentinite).
Sphalerite[1]	ZnS. Zinc sulfide.	Found only at Drew mine.
Metacinnabarite[1]	HgS. Black mercuric sulfide.	Reported from workings on Keg claims (L. B. Spencer, personal communication).
Cinnabar[3]	HgS.	Only important quicksilver ore mineral. Occurs as crystalline masses and as earthy powder in limestone deposits.
Pyrite[1]	FeS_2. Iron sulfide.	Sparingly present at Lost Steers, Drew, Mina Development Co., Betty, Allen, and Chong Wong properties.
Haloid:		
Calomel[1]	HgCl. Mercurous chloride.	Reported by Foshag (1927, p. 116) from Lost Steers mine.
Oxides:		
Quartz[2]	SiO_2. Silica.	Associated with cinnabar in mines in chert.
Pyrolusite[1]	MnO_2. Manganese oxide.	Associated with cinnabar in mines in chert.
Cuprite[1]	Cu_2O. Cuprous oxide.	Found with malachite and azurite and red powdery cinnabar at prospect near Reward mine.
Stibiconite[1]	$H_2Sb_2O_5$. Hydrous oxide of antimony.	Lemon-yellow masses in stibnite or powdery fillings in cavities.
Valentinite[1]	Sb_2O_3. Antimony oxide.	Pearly-gray crystals and masses pseudomorphous after stibnite.

1 Scarce. 2 Common. 3 Abundant.

Minerals of the ore deposits of the Pilot Mountains mines, Mineral County, Nev.—Continued

	Composition	Remarks
Oxides—Continued		
Limonite[2]	$2Fe_2O_3.3H_2O$.	In varied amounts at all properties.
Oxygen salts:		
Carbonates:		
Calcite[3]	$CaCO_3$. Calcium carbonate.	In veinlets associated with cinnabar in mines in limestone, sandstone, and conglomerate.
Malachite[1]	$CuCO_3.Cu(OH)_2$. Basic cupric carbonate.	From prospects near Reward mine. Also found on dumps at Drew mine.
Azurite[1]	$2CuCO_3.Cu(OH)_2$. Basic cupric carbonate.	Found at Reward and adjacent prospects. Reported from Drew mine.
Silicates:		
Calamine[1]	H_2ZnSiO_5. Hydrous zinc silicate.	At Drew mine with sphalerite and earthy cinnabar.
Clays[3]	Hydrous aluminum silicates.	Found in fault gouge of all mines. Associated with cinnabar.
Chrysocolla[1]	$CuSiO_3.2H_2O$. Copper silicate.	Reported at Drew mine (Foshag, 1927, p. 117).
Antimonate:		
Bindheimite[1]	Hydrous antimonate of lead.	Reported by Foshag (1927, pp. 117, 120) at Drew mine.
Sulfates:		
Barite[2]	$BaSO_4$. Barium sulfate.	Sparingly present at Lost Steers, Chong Wong, and Reward mines.
Brochantite[1]	$CuSO_4.3Cu(OH)_2$.	Reported at Drew mine (Foshag, 1927, p. 117).

1 Scarce. 2 Common. 3 Abundant.

LOCALIZATION OF ORE

All the known ore bodies lie within an area of about 4 square miles. The nature of each is largely dependent on the character of the host rock; hence three types are distinguishable: ore bodies in limestone, ore bodies in sandstone, and ore bodies in chert. For each type, general conclusions as to the character, grade, and localization of the ore and the size of the ore bodies can be drawn.

Regional as well as local structural controls have governed the distribution and emplacement of the ore. The Cinnabar Canyon and the underlying Lost Steers thrust faults are believed to have played an important role in the regional distribution of the cinnabar ore bodies, for these occurrences of cinnabar, with the exception of the Chong Wong property, are below either one or both of them (pl. 19). The Mina Development Co. mine, which has had the largest production in the district (table 1), lies less than 100 feet below the Lost Steers thrust, and the Drew mine, which has had the second-highest production for the district, has explored a crushed zone not over 200 feet below the mapped position of the Cinnabar Canyon thrust. The Keg and Coveney prospects likewise are adjacent to and below this fault.

The ore bodies in the chert of the Excelsior formation, with the exception of that mined from the Cardinal mine, are only 200 or 300 feet below the contact of the chert and the hornblende andesite of the formation. Since the chert just below this contact is sheared and locally altered to clay minerals, it is possible that it has also produced conditions favorable for regional cinnabar localization.

Locally, the ore deposits appear to be most closely related to small normal faults that are probably contemporaneous with the major normal faults of the area. Other features that may control the concentration of cinnabar to form ore bodies are structural traps, favorable beds and areas of brecciation, and—possibly—changes in the temperature and pressure of the mineralizing solutions.

Ore bodies in the limestone at the head of Cinnabar Canyon have yielded the principal production of the district, and those in the Mina Development Co. and Drew mines have been the largest and richest. The ore shoots at the Mina Development Co. mine were as much as 50 feet long, 35 feet wide, and 25 feet high; they probably averaged at least 50 percent cinnabar. The ore shoots at the Drew mine, although smaller, were equally rich. A few small bodies of ore in these mines were essentially solid cinnabar. The ore in the limestone was localized along steep normal faults and relatively flat bedding shears (pl. 21). The faults strongly shattered the limestone, and the cinnabar partly filled the open spaces and partly replaced the limestone of the breccia. Moreover, it was deposited along bedding shears for distances up to 10 feet away from the zone of brecciation.

Ore bodies in the sandstone and conglomerate in Dunlap Canyon, as explored by the Reward, Mammoth, Hitt, and Allen mines, have yielded more than 10 percent of the total production of the

district. These ore bodies are much smaller and not as rich as those in the limestone; not uncommonly, however, they contain as much as 20 percent cinnabar. Most of them lie under rolls along small normal faults. Locally, the cinnabar-bearing solutions migrated along bedding planes in the sandstone, and, where the sediments are porous, some cinnabar was disseminated through the sandstone.

Ore bodies in the chert of the Excelsior formation, explored by the Sullivan prospect and the Betty, Inman, and Cardinal mines, have yielded less than 10 percent of the quicksilver of the Pilot Mountains district. They are the smallest concentrations of ore in the district, but small bodies of solid cinnabar have frequently been encountered, so that the ore has averaged from 15 to 20 percent cinnabar. The most favorable conditions for ore concentration are found along steep normal faults where there is a change in dip or strike, although the ore is often localized by bedding planes. Cinnabar cements fault breccia and occurs in cracks and fissures in the chert adjacent to the faults on either the hanging-wall or footwall side.

AGE OF ORE BODIES

The age of the ore bodies is unknown. Possibly they are late Tertiary, as are most of the Nevada quicksilver deposits. The writers found no colors in pannings from several of the more promising places in the Tertiary volcanic rocks, although Foshag (1927) quotes reports that some cinnabar is present in them. Possibly the ore solutions were closely associated with the emplacement of the Tertiary hornblende andesite intrusion found between Dunlap and Cinnabar Canyons.

RESERVES

All the ore occurs as relatively small but rich bodies that, in the past, have yielded as much as 50 to 60 pounds of quicksilver to the ton. There are no reserves of low-grade ore on any of the properties. Further exploration along the controlling structures may reveal new ore bodies in many of the mines, but their size is likely to preclude large-scale operations. Production from the district depends upon the prevailing price of quicksilver. With prices at less than $125 a flask, the district will probably produce somewhat less than 100 flasks of quicksilver a year. During times of higher prices, however, the output may be increased several fold.

SUGGESTIONS FOR PROSPECTORS

The Pilot Mountains quicksilver district is believed to have been rather thoroughly prospected. Some new ore bodies may be discovered in the cherts of the Excelsior formation south of the Sullivan prospect on the south flank of the range, and further exploration in the Luning formation, particularly to the east of the Drew mine and south of the Chong Wong prospect, might be profitable. During the course of the field mapping several unexplored occurrences of cinnabar were noted. Midway between the Drew mine and the Coveney prospect, the limestone of the Dunlap formation was mapped adjacent to and beneath the Lost Steers thrust fault. Small specks of crystalline cinnabar were found in this limestone. In addition to this occurrence, cinnabar was found as veinlets in limestone of the Dunlap formation about 2,100 feet southwest of the portal of the Mina Development Co. mine. Because no ore has been found in any of the volcanic rocks, they should be regarded as the least favorable for prospecting. Additional prospecting in the larger mines might be advisable, as, in contrast to the smaller mines in the district, they have been characterized by fairly continuous ore bodies and evident structural controls. They also have the added advantage of being adjacent to the Dunlap Canyon thrust fault.

MINES AND PROSPECTS

MINES AND PROSPECTS IN LIMESTONE

MINA DEVELOPMENT CO. MINE

The Mina Development Co. mine is owned by L. B. Spencer and A. J. Anderson. The 13 unpatented claims of the property are at the head of Cinnabar Canyon, in the central part of the Pilot Mountains, at an altitude of about 7,400 feet. The mine was worked intermittently for more than 20 years prior to 1940, and during this period various owners and lessors are said to have recovered about 1,800 flasks of quicksilver from high-grade pockets. About 1,200 flasks of quicksilver were taken from a small high-grade ore body during 1940 and 1941 by the present owners. There was no production from 1941 to 1948.

The workings of this mine, as shown on plate 20, consist of about 5,000 feet of drifts and crosscuts on seven levels; the lower two were flooded while the writers were at the mine. The ore-bearing rock is massive, bedded limestone of the Dunlap formation. Its distribution is shown on plates 21 and 22, where it is designated as the "upper" limestone.

Faults of three ages are distinguishable in the mine. The oldest is the northward-dipping Lost Steers thrust fault, which is probably subsidiary to the major Cinnabar Canyon thrust. This thrust brings yellow shale above the "upper" shale of the mine workings and the ore-bearing "upper" limestone. The ore-bearing limestone is cut by nearly vertical normal faults that predate mineralization and trend southwestward. These normal faults, on which movement appears to have taken place during several periods, are later than the Lost Steers thrust fault; they in turn are offset by a transverse zone of closely spaced normal faults—the Keough fault—that postdates mineralization. Measurement of the displacement was attempted only along the normal faults, and it is nowhere greater than 60 to 80 feet, a composite of movement both before and after mineralization. Movement on these normal faults has been taken up in part by small displacements along bedding planes.

Cinnabar is the only ore mineral of quicksilver seen on the property. It is associated with stibnite, the antimony oxides stibiconite and valentinite, pyrite, barite, and quartz. It replaces limestone and occurs as high-grade pods in the broken limestone, as crystals in calcite stringers cutting the limestone, as films on the slickensided surface of the fault plane, and as disseminated crystals in fault gouge.

The ore bodies are localized along the southwestward-trending normal faults that predate mineralization and in bedding slips adjacent to these faults. No ore has been found above the Cinnabar Canyon thrust fault; therefore it is possible that the zone of gouge developed along this thrust, together with the so-called "upper" shale of the mine workings, acted as a barrier to the upward migration of the ore solutions. In summary, localization of the mineralizing solutions required the preexistence of steep normal faults, the presence of a favorable limestone bed, and probably the barrier effect of the "upper" shale and the thrust gouge.

Three closely associated types of ore body have been exploited. In the first, cinnabar partly filled cracks and partly replaced the limestone; this type was exceptionally rich and yielded most of the quicksilver. In the second type, which was lower in grade, cinnabar only filled cracks in the limestone. In the third type, cinnabar was concentrated in gouge along the normal faults.

LOST STEERS MINE

The Lost Steers mine is on the same group of claims as the

Mina Development Co. mine but lies south of it, nearer the top of the ridge. During nearly 25 years prior to 1941, about 450 flasks were reportedly recovered by various owners and lessors. The last production was in 1941, when about 50 flasks were recovered by the present owners.

Most of the ore came from a small glory hole (40 feet long, 25 feet wide, and 30 feet deep) and several small adjoining crosscuts. The main workings explored a jointed, broken limestone lens in the Dunlap formation, but a lower haulage level has been driven in a brown sandy limestone and shale lying conformably beneath the limestone. Several small faults, seen only underground, and a well-developed vertical fault that crops out east of the main workings cut the limestone.

Cinnabar is the only ore mineral seen on the property by the authors, but Foshag (1927, p. 116) reports the occurrence of calomel. Associated with the cinnabar are stibnite and its oxidation products stibiconite and valentinite; also calcite, quartz, and probably some barite. The cinnabar occurs (1) as crystals in calcite veinlets in the limestone, (2) as an earthy variety filling cracks and cavities in the limestone, (3) as crystals associated with calcite in the fault gouge, and (4) as crystals replacing stibnite.

The only ore body consisted before mining of small, scattered, discontinuous veinlets of cinnabar in broken limestone. It was localized in a fractured area in the limestone, and at its bottom was the nearly flat limestone-shale contact. Near the main workings, many cinnabar-bearing calcite stringers cut the limestone adjacent to small faults, but they are not sufficiently numerous to form ore.

DREW MINE

The Drew mine is owned by Mrs. E. Drew Wagoner, of Mina, and is under lease to the Mina Development Co. The property, consisting of eight unpatented claims, is at an altitude of nearly 8,000 feet, about a mile east of the Mina Development Co. mine. Its past production is reported to have been about 1,000 flasks of quicksilver.

The open underground workings consist of an inclined shaft 70 feet deep and about 120 feet of drifts and crosscuts (fig. 16). Two lower levels, 150 feet and 200 feet below the surface, have been inaccessible for several years, as the inclined shaft is caved. The country rock, a yellow limy shale with lenses of limestone, is thought to be a part of the Dunlap formation. The rocks are crushed and sheared because of their proximity to both the Cin-

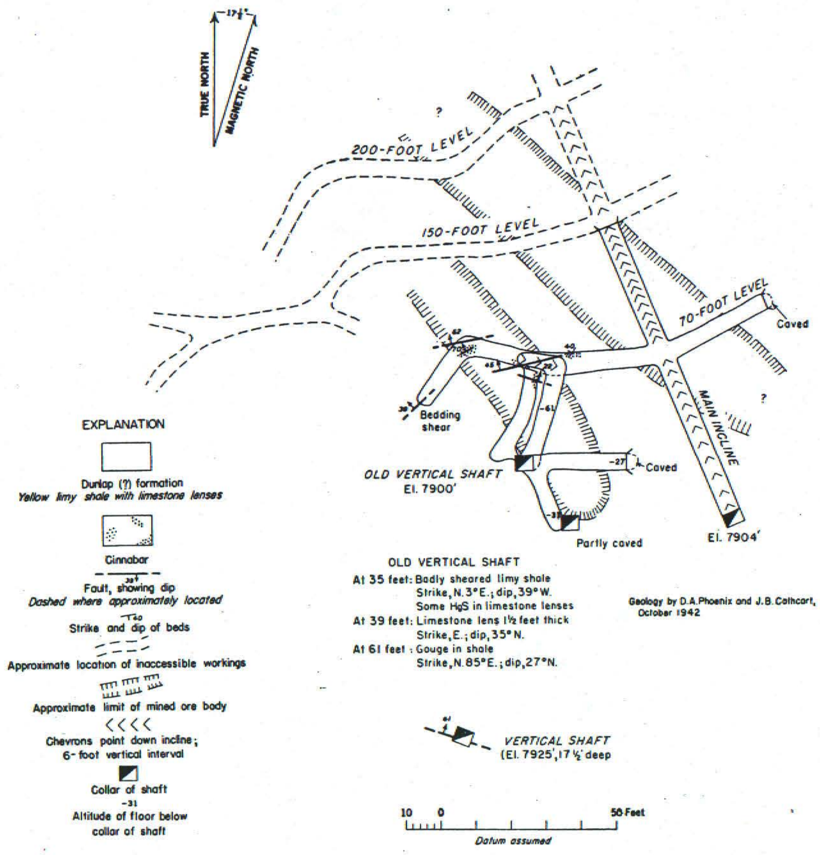

FIGURE 16.—Geologic map of the Drew mine, Pilot Mountains district, Nev. Inaccessible workings plotted from a survey by L. B. Spencer.

nabar Canyon thrust fault and a strong normal fault of later date.

A scarlet, earthy variety of cinnabar is the only ore mineral seen on the property. It is associated with stibiconite, valentinite, quartz, calcite, and—according to Foshag (1927, pp. 117, 118)—sphalerite, calamine, and bindheimite, the antimonate of lead. Various copper minerals, including azurite and malachite, also occur on the property. The powdery nature of these minerals and the fact that they fill cavities suggest a supergene origin.

The richest ore body discovered was a tubular shoot that started a few feet east of the collar of the inclined shaft and was mined to the west side of this inclined shaft on the 200-foot level.

A similar ore body was discovered about 50 feet west of the incline on the 70-foot level; reportedly, it was never found on the 200-foot level. The ore bodies were formed by the replacement of limestone lenses and favorable shale beds and were very high-grade.

KEG PROSPECT

The Keg prospect, on a group of five unpatented claims north of and adjacent to the Mina Development Co. claim, is owned by A. J. Anderson and L. B. Spencer, of Mina. Production figures are not known, but, judging from the workings, they must be small.

Development consists of a short inclined shaft about 75 feet long. The country rock is crushed and sheared yellow limy shale of the Dunlap (?) formation lying directly under the Cinnabar Canyon thrust fault. Powdery cinnabar and possibly metacinnabarite occur with calcite in and near a small, flat, northwestward-trending fault that displaces the Cinnabar Canyon thrust.

COVENEY PROSPECT

The Coveney prospect, owned by Clay Coveney, of Mina, is about half a mile west of the Drew mine. Its production is reported to have been 6 flasks of quicksilver.

Less than 100 feet of workings have explored a steep normal fault in the crushed and sheared yellow limy shale of the Dunlap (?) formation beneath the Dunlap Canyon thrust fault. Cinnabar, the only ore mineral, was observed in only small amounts in the gouge of the small normal fault.

CHONG WONG PROSPECT

The Chong Wong prospect is about a mile to the north of the Drew mine at an altitude of about 7,800 feet. It is on a group of five unpatented claims owned by the Chong Wong Estate, Jung Wong, Executor, Reno, Nev., and under lease to H. W. Bell, also of Reno. Records of past production are not available, but probably little quicksilver has been produced. At the end of 1942, the lessee was installing a two-pipe retort and expected to start retorting ore from the dumps.

Development consists of two adits on the same level with about 350 feet of drifts and crosscuts. The country rock is the coarsely crystalline lower limestone member of the Luning formation; this is the only mine in the upper plate of the Cinnabar Canyon thrust fault. Steep normal faults localized the ore.

Cinnabar, the only ore mineral seen on the property, occurs (1) in alluvium, as scattered crystals and fragments in open-cuts directly above the underground workings, (2) in cracks and veinlets associated with calcite, and (3) disseminated in the limestone. Gangue minerals are calcite, barite, and pyrite. The ore bodies mined were small and high-grade; they occurred in and near steep normal faults and at fault intersections.

MINES AND PROSPECTS IN SANDSTONE AND CONGLOMERATE

REWARD MINE

The Reward mine, on a group of nine unpatented claims, is owned by Dallas H. Gray, Jr., and the C. A. Bonner Estate, of San Francisco, Calif., and is under lease to the Pacific Placers Co. It is in Dunlap Canyon, at an altitude of nearly 7,000 feet, about 11 miles southeast of Mina. Production to 1942 is reported to have been 513 flasks of quicksilver.

Development consists of two adits, one north of the other, on about the same level (pl. 23). The southern adit has about 350 feet of drifts and crosscuts and a large stope that extends to the surface; the northern adit contains about 50 feet of workings, including a small inclined winze 20 feet deep.

Cinnabar is associated with stibnite, calcite, and barite. The ore body mined was high-grade and mainly localized beneath a roll in the fault, though in places it extended into the hanging wall.

MAMMOTH MINE

The Mammoth mine, on a group of 12 unpatented claims, was under lease in 1942 to Elko Zeradi, of Mina. It is on the west side of Dunlap Canyon, about a mile north of the Reward mine, at an altitude of about 7,000 feet. The production to 1941 was 50 flasks of quicksilver. The mine was in operation in the fall of 1942, and ore was being treated in a small retort. A. J. Anderson reports a production of about 10 flasks of quicksilver from the Mammoth and Hitt mines together for the period 1941 to 1948.

Development consists of two adits, one 55 feet above the other; they are connected by a stope and raise, with about 380 feet of drifts and crosscuts (fig. 17). The mine workings explore a northeastward-trending fault that dips 55° SE. The workings are in the Dunlap formation, which here consists of interbedded red conglomerate, red and brown sandstone, and minor amounts of shale, overlain by white quartzitic sandstone.

Cinnabar, the only visible ore mineral of quicksilver, is associated with clays in the gouge of the fault and elsewhere with calcite in cracks and fissures. The ore body in the underground workings was small, high-grade, and localized beneath a flat curve along the strike of the fault.

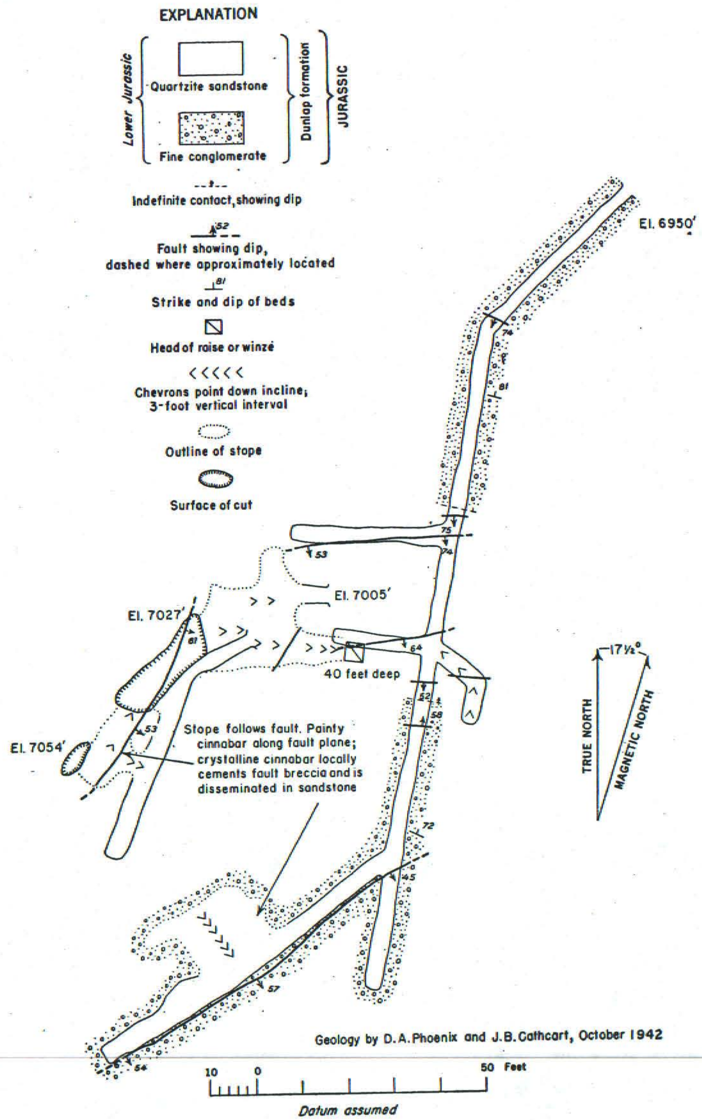

FIGURE 17.—Geologic map of the Mammoth mine, Pilot Mountains district, Nev.

HITT MINE

The Hitt mine, owned by Bert Hitt, of Mina, is in a small canyon on the west side of Dunlap Canyon, about 1¼ miles west of the Mina Development Co. mine and about 10 miles southeast of Mina. The recorded production to the end of 1941 was 46 flasks of quicksilver.

The underground workings consist of two adits with about 400 feet of drifts and crosscuts and small stopes. The upper adit connects with a small glory hole (fig. 18). The rocks of the area consist of interbedded red and brown sandstone and red conglomerate of the Dunlap formation. They strike east of north and dip 34° NW. The workings explore a northwestward-trending fault that dips 57° SW.

Cinnabar, associated with calcite, manganese, and clays, (1) is disseminated in the gouge of the vertical fault; (2) occurs along bedding planes in the sandstone; (3) fills cracks and fissures in the sandstone; and (4) is disseminated in the more porous sandstone.

ALLEN MINE

The Allen mine, located in 1919 by the present owner, Ed E. Allen, of Mina, is about 1,000 feet southwest of the Hitt mine in a small canyon west of Dunlap Canyon. The recorded production to the end of 1941 was 48 flasks of quicksilver.

The mine workings consist of two adits, one about 250 feet west of the other and at about the same level, with 510 feet of drifts, crosscuts, and stopes. The workings have been driven in sandstone and conglomerate of the Dunlap formation. The easterly adit explored a steep northwestward-trending fault zone along which a stope extends to the surface.

Crystalline cinnabar, the only ore mineral, is associated with calcite, pyrite, and clay minerals. The ore bodies were localized at the intersection of two normal faults and occurred as smaller bodies along the main fault, which trends N. 30° W. through the workings.

RED WING PROSPECT

The Red Wing prospect, between the Hitt and Mammoth mines, is owned by G. J. Barry, of Los Angeles, Calif. Complete records of production are not available, but the small dumps and incomplete records suggest a production of about 30 flasks of quicksilver.

Development consists of six small surface pits, a small shaft, and one adit about 70 feet long with a 20-foot winze. Develop-

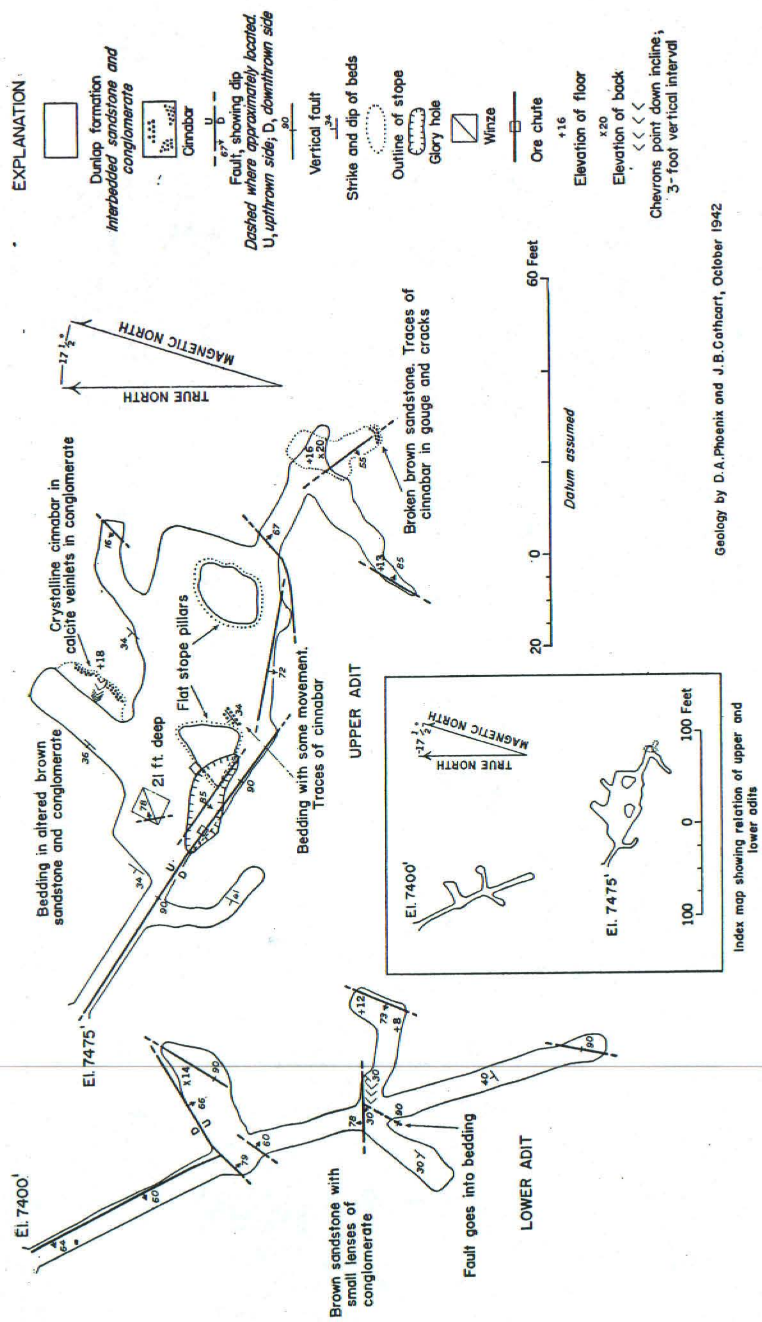

FIGURE 18.—Geologic map of the Hitt mine, Pilot Mountains district, Nev.

ment work during the fall of 1942 yielded some ore. The country rocks are red and brown sandstone and conglomerate, overlain by a fine-grained, partly silicified white limestone of the Dunlap formation. The mine workings explored two steep normal faults in the silicified limestone. Cinnabar occurs with quartz and calcite in fault gouge and fills cracks and fissures in the locally silicified limestone.

MINES AND PROSPECTS IN CHERT

CARDINAL MINE

The Cardinal mine, owned by L. V. Cornelius and his son, of Mina, is reached by traveling along the crest of a high ridge southwest of the Drew mine for about half a mile. The poor road that connects the two mines is practically impassable in the winter months. The mine workings are on the southeast side and just below the crest of the ridge. Since the deposit was discovered by Henry Ott in 1930, various owners and lessors have recovered about 133 flasks of quicksilver.

Major development work has been confined to the vicinity of a steep fault that cuts transversely across a ridge of chert in the Excelsior formation. A small glory hole, which has explored the main ore zone at the surface, is connected to a drift about 120 feet lower on the hillside that cuts the fault at depth. The east slope of the ridge also has been explored, and minor faults containing some cinnabar have been found in the chert. In all, there are about 650 feet of drifts and crosscuts.

Cinnabar, the only ore mineral, was found with quartz and calcite, filling cracks and fissures in the chert, and in gouge and breccia along the fault. The ore bodies, which were small and high-grade, were localized as pods along the major fault zone. The junction of the major fault with bedding shears in the chert seems to form the most favorable zones for ore bodies.

INMAN MINE

The Inman mine, owned by Fred Inman, of Tonopah, Nev., is on the southeast flank of the Pilot Mountains at an altitude of about 7,950 feet. It is reached by traveling 16.8 miles south from Mina on the old Tonopah road to Summit Springs. The first turnoff to the east past Summit Springs leads to the mine, a distance of 4.4 miles. Originally discovered in 1916 by Carl Reik and Ed Messenger, the property consists of a group of 16 claims, called the Red Wing group; it formerly included the present Betty and Inman properties. The recorded production from the Red Wing group from 1921 to 1941 was 109 flasks of quicksilver.

The underground workings, which consist of 750 feet of drifts, crosscuts, and stopes (pl. 24), follow a fault that trends northeastward and dips about 70° SE. Pockets of rich cinnabar ore have been encountered in exploring along this fault, above the main drift, by means of about 120 feet of stoping. The country rocks are broken iron-stained chert and chert conglomerate that strike northeast and dip 40° SW. The bedding planes between the chert layers are locally sheared and contain gouge, and where they are adjacent to faults they contain cinnabar.

Cinnabar formed high-grade crystalline pods along the normal fault, before mining, and filled fractures in the chert on both the hanging-wall and footwall sides. About 250 feet to the east, below the main workings, a small adit and stope explore Quaternary gravel containing small nuggets of cinnabar concentrated on the chert bedrock.

BETTY MINE

The Betty mine, owned by E. Messenger and H. Betty, adjoins the Inman property on the south flank of the Pilot Mountains.

The underground workings, which are at an altitude of about 7,800 feet, consist of approximately 570 feet of drifts and crosscuts with a connecting stope to the surface (fig. 19). The rocks in the vicinity consist of folded chert and chert conglomerate of the Excelsior formation. Above the mine workings, thick beds of altered volcanic rocks and hornblende andesite overlie these cherts. Two nearly vertical, northward-trending normal faults cut the chert, forming breccia zones half a foot to 2 feet wide.

Crystalline cinnabar fills small fractures in the highly broken chert and has formed high-grade pods in the porous breccia of the faults. Locally, mineralizing solutions are believed to have migrated out from the faults and deposited cinnabar along bedding shears in the chert.

FLETCHER PROSPECT

The Fletcher prospect, which is on a group of six claims just west of the Betty property, is owned by Fred Fletcher, of Mina. No production records are available, but little quicksilver has been produced.

Development consists of about 150 feet of underground workings that explore highly broken cherts, shales, and altered volcanic rocks of the Excelsior formation. No cinnabar was seen.

SULLIVAN PROSPECT

The Sullivan prospect, on two claims, is owned by C. E. Sullivan and L. V. Cornelius, of Mina. It is at the head of Dunlap

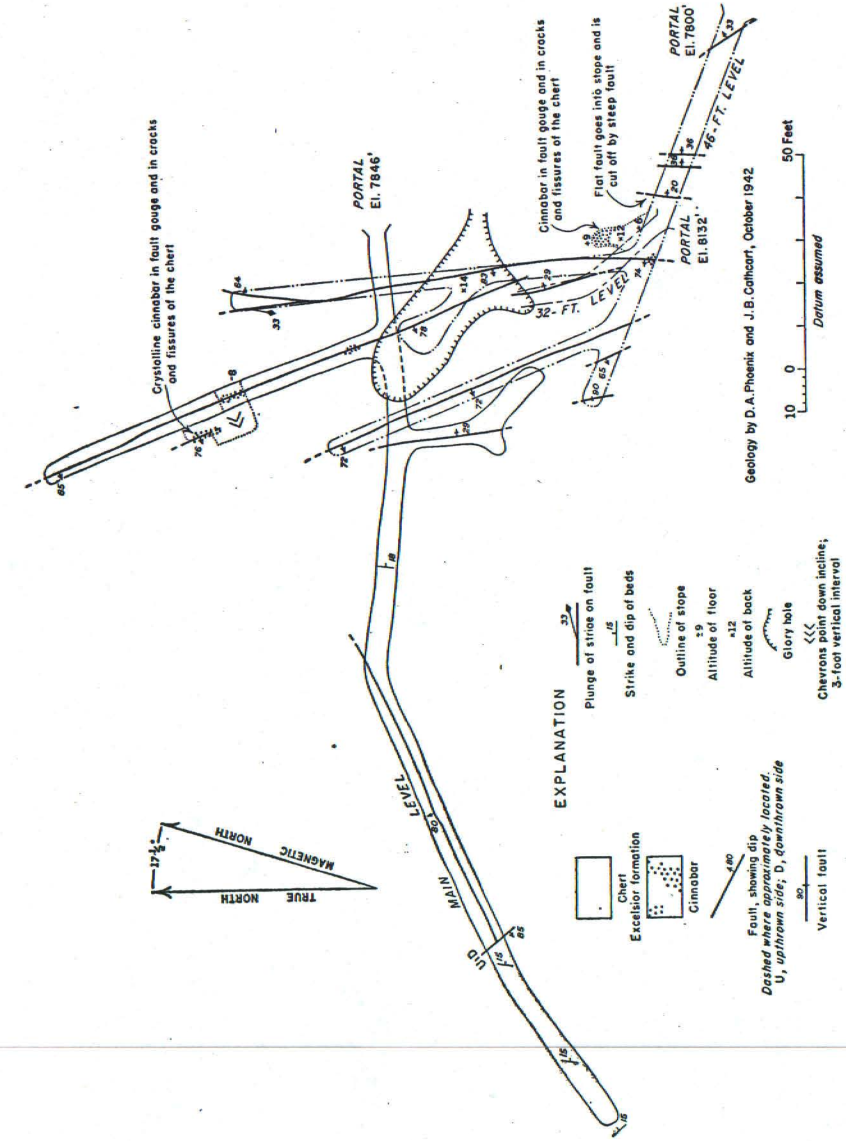

FIGURE 19.—Geologic map of the Betty mine, Pilot Mountains district, Nev.

Canyon, about 2½ miles south of the Reward mine. The claims were located in 1940, and 6 flasks of quicksilver were produced in the course of development work.

The workings consist of a series of trenches and pits that extend in a northwesterly line for 135 feet. The rocks of the area are beds of chert and chert conglomerate of the Excelsior formation that strike northwest and dip 10°-40° N. Small steep normal faults cutting relatively flat bedding shears formed loci for ore deposition.

Crystalline cinnabar was the only ore mineral seen. It occurs in clays in the flat bedding shears and in cracks and fissures in the chert, and it is associated with quartz, calcite, pyrite, and pyrolusite.

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