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REPORT ON THE

AFTERTHOUGHT MINE

SHASTA COUNTY, CALIFORNIA

Edward Wisser

August 23, 1947

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ILLUSTRATIONS.

REPORT ON AFTERTHOUGHT MINE, SHASTA COUNTY, CALIFORNIA.

INTRODUCTION.

The writer revisited the Afterthought mine, July 25-August 12, 1947, after an absence of fifteen months, during which time about 4700' of diamond drilling was done, and about 1800' of drifting, crosscutting and raising. Since results of this work were mainly disappointing, the writer was called back to analyse the additional data secured, in terms of possible remaining chances for ore, and to advise on the future operation, if any, of the mine.

The new drifting and crosscutting, particularly, shed much light on structural conditions, heretofor largely deduced from drill-holes alone. It seemed advisable, therefore, to restudy the structure and ore control in the mine area, largely from scratch. The accompanying Structural Contour Composite Plan and vertical sections are for that reason essentially new contributions, based on the new data and in places on a reinterpretation of old data.

GEOLOGIC STRUCTURE AND ORE CONTROL.

The dominant structural feature and ore control remains the northeast flank of the Main rhyolite mass, as may be seen by comparing the structural contour plans accompanying the writer's reports of May 2, 1946, June 28, 1946, August 20, 1946, September 4, 1946 and September 30, 1946, with the current plan. The reëntrant in the steep flank of the Main mass which contains the ore cut in D.D.Hole AS-1 and now being developed on the new 100 ft. level, is a bigger concavity than had been thought, for at date of writing ore continues on that level, going west, without meeting the main mass where the latter had been expected.

The northeast flank of the Main rhyolite mass localizes ore in the following ways, as first pointed out by Stewart, report of June 9, 1946, 17-21, and by the writer in various reports:

(1) Copper ores, occasionally high in zinc, along northwest sheeted zones in the Main mass, near the contact; exemplified by the ore bodies below the 400 near No. 3 shaft. The control of the contact over these ore bodies is well shown by Stewart's Section D-D' (not reproduced with the present report). The contact (generally coextensive with the Main fault) dips northeast while the sheeted zones dip southwest. Ore is richest near where the zones abutt on the contact, and dies out down to the southwest, away from the contact.

At higher horizons more or less the same thing is seen, and here mineralized sheeted zones appear related to replacement ore bodies in limy shale, at or close to the contact. Thus D.D.Hole AU-5, while it passed beneath the 400 Ore body still in the Main rhyolite, disclosed a strong sheeted and brecciated zone carrying very heavy pyrite and showing stretches assaying as high as 11% zinc. The sheeted zone projects up to the replacement ore in shale, lying along a vertical segment of the contact (see accompanying Section Showing Proposed D.D.Hole "H" and Composite Plan). (Incidentally, when the 400 Ore body is developed, a crosscut should be run into the Main rhyolite to examine this mineralized sheeting. Some stretches may be mineable).

Again, the sheeted zone exposed in the recent extension of the south crosscut, 200 level to the new raise to the 100' level, projects up to the north and into the 200 Ore body. Some of this material on the 200' level may be milling ore and may warrant development if stoping is started with a mill on the property.

(2) Massive sulphide replacement bodies in limy shale, high in zinc (18% plus) and possibly containing as much copper as the so-called copper ores in the rhyolite (about 3%). There are two types of shale replacement ore bodies:

(2A) Vein-like, tabular, relatively narrow ore bodies along vertican segments of the Main rhyolite flank, where the shale beds lie parallel to the Main rhyolite. An example is the 400 Ore body (see Composite Plan, Section Showing Proposed D.D.Hole "H", and Section Showing Proposed Holes A-1, A-2). As pointed out by Stewart, reference cited, 20-21, solutions presumably travelling up the Main contact where it is steep and parallel to the adjoining shale beds had little opportunity to enter and replace the shale because the shale laminae were plastered along the contact instead of butting against it as with Case 2B described below. Further, fault movements took place along and near the contact; some of these movements were premineral and along shale beds. Resulting gouge appears to have limited replacement on the side away from the Main rhyolite contact, so that the 400 Ore body on the 400 level has usually a gougy northeast wall which cuts the ore off slickly. Such ore bodies are therefore narrow and tabular.

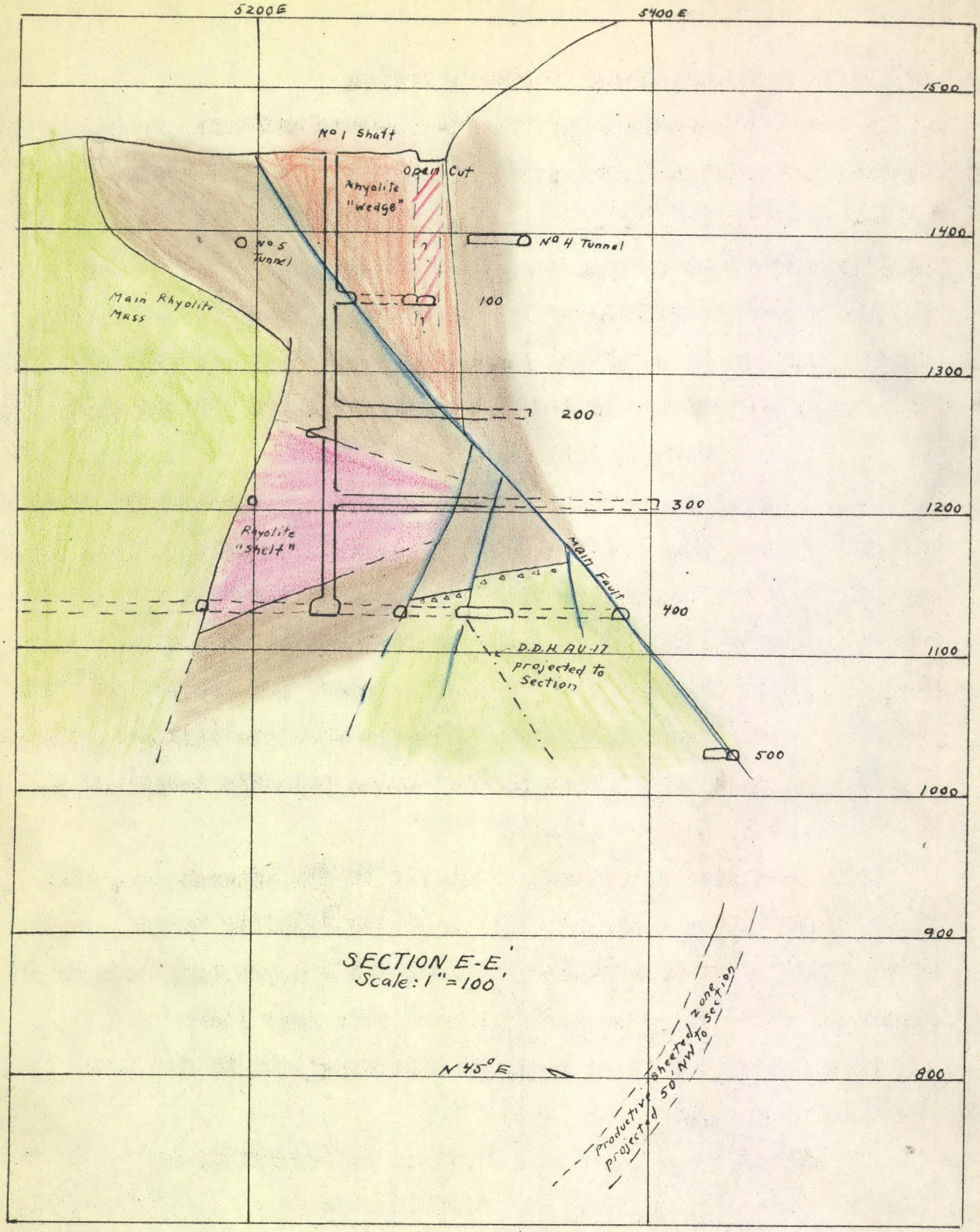
The northwest "tail" to the 200 ore body, drifted on, 200' level, is a similar example; but the 200 ore body itself probably belongs with Case 2B.

(2B). Massive sulphide replacement ore bodies in shale beds that abutt on the contact in dip and/or strike; such ore bodies appear to lie contained in concavities in the northeast flank of the Main rhyolite mass, so that the ore-bearing shale bedd abutt down their dip against a flattish shelf in the rhyolite. As pointed out by Stewart, in such a case solutions travelling up the Main contact were able to penetrate between shale laminae; an upward shove of the Main rhyolite mass (which probably occurred about the time of mineralization) would facilitate such penetration. The 200 ore body is an example of this. (See Section through D.D.Holes AU-2, AU-3, where the sill shows the dip of the sediments as well).

Another example is the ore body now being developed on the new 100' level.(See Composite Plan). Here ore occurs along steeply-dipping shale beds that probably make an acute angle in strike with the Main contact, and that abutt against a flat terrace on the Main rhyolite flank, below the 100' level.

Ore bodies of this type are wide in plan; but they suffer a molestation not so often encountered by the steep tabular ore bodies of Case 2A: the shale beds carry frequent intercalated rhyolite sills; where a series of shale beds lie parallel to a steep segment of the Main contact, ore formed along these beds will not normally be cut off by barren sills, for the latter are generally conformable with the shale bedding. With Case 2B in contrast, the intercalated sills that abutt against the Main rhyolite were in the main impervious to ore solutions; they form barren ribs within the ore body, as is well shown on the new 100' level (see Composite Plan).

The largest ore body known lay in the rhyolite "wedge", in the hanging wall of the Main fault (see Section E-E', largely reproduced from Stewart, and the Composite Plan). As pointed out by Stewart (17), this block was highly shattered and ore deposited in open spaces as well as by replacement. The No.4 tunnel appears to have been driven into the shales northeast of the rhyolite "wedge" and to have encountered shale replacement ore, probably a further examples of Case 2A, along a steep rhyolite contact. The "wedge" is probably a down-faulted chunk



5200E
5400 E
1500
1400
1300
1200
1100
1000
900
800
No 1 Shaft
Open Cut
Rhyolite "wedge"
No 4 Tunnel
No 5 Tunnel
Main Rhyolite Mass
100
200
300
400
500
Rhyolite "shelf"
Main Fault
D.D.H. AU-17 projected to Section
SECTION E-E'
Scale: 1" = 100'
N 45° E
Productive sheeted zone projected 50' NW to section

of the Main rhyolite mass (Stewart, 9-10).

A lesser structure discovered by Stewart and which recent cross-cutting and drifting has perfectly confirmed is the rhyolite "shelf", called by Stewart a "sill-like dike".(See Section E-E',Section through D.D.Holes AU-2, AU-3, Sections to show proposed holes "D" and "E-F", and the Composite Plan). The "shelf" bottomed the 200 Ore body;but the ore exposed in D.D.Holes AU-2,AU-3 is believed to make along the steep northeast corner of this shelf (see section through those holes).

CHANGES FOR FURTHER ORE.

The general zone, near the Main rhyolite contact,which contains the 400 Ore body,has now been drifted upon for nearly 900 ft. southeast of that ore body, with negative results. The Main contact has been reached by drilling in three places,each barren, along this str stretch. Drill-holes to the northeast, toward and across the Main fault, show this area to be largely great rhyolite sills,eliminating chances for major ore bodies in the shale, possibly localized along the footwall of the Main fault.

It seems extremely likely that ore in the Afterthought mine is confined to the small area north of the rhyolite "nose",and east of the 400' level main haulage tunnel. The 400 ore body ends to the southeast where it wraps itself around this nose (Composite Plan) and no ore has been found south of this nose (400 SE drift and D.D. Holes AS-3, AS-4).

No further large-scale exploration is justified; the property should be placed on a salvage basis: the ore found is high-grade and should yield enough profit to return the money invested. Once the method of realizing on the ore is determined (shipping to smelter, milling at Mt. Copper Co., mill, or in a mill at Afterthought) the

400 and 100 ore bodies will presumably be prepared for stoping. In such case, further but limited exploration in the restricted area described above will be justified as a side-line to the production of metals at a profit. In other words, present expenditures, solely for exploration, are no longer justified by existing chances to make a large mine at Afterthought. Once the mine is in production, a certain amount of exploration, paid for out of operating profits, will be worthwhile.

RECOMMENDATIONS FOR EXPLORATION.

General.- The following exploration is scheme is designed to test two kinds of structures shown in the past to be favorable for ore: (1) vertical segments of the Main rhyolite and other rhyolite contacts, such as that along which the northwest "tail" to the 200 ore body made (200 level) and that along which lies the 400 ore body; and (2) flatter segments of the Main rhyolite, or other rhyolite contacts, where these flat segments are intersected by strong sheeted, mineralized zones within the rhyolite. The accompanying Plan Showing Suggested Exploration shows most of the exploration suggested.

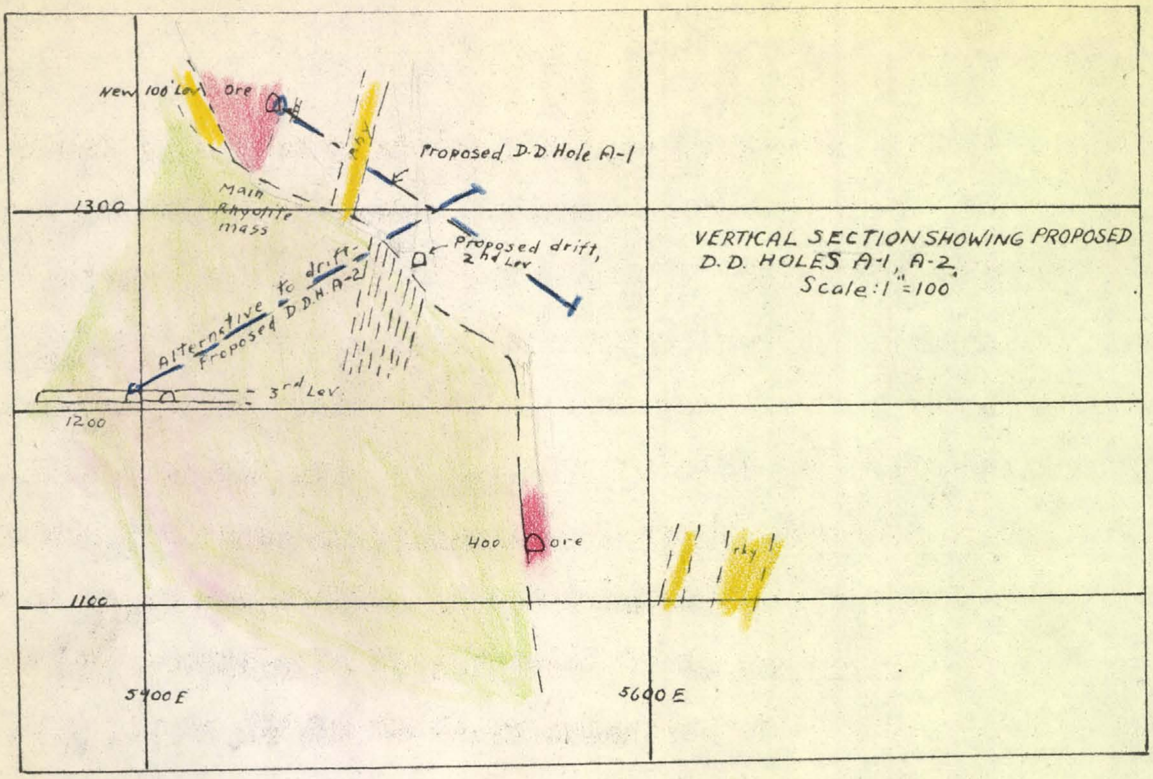
100' Level and Above.- According to latest reports the 100 ore body is still in ore to the west and to the southeast. The southeast drift is following the footwall of the ore, which makes in shale beds striking about N70°W and dipping steeply southwest. The west drift however is following the north wall of a steep rhyolite contact, and the ore there, replacing shale beds of the attitude described, strikes across the west drift at an acute angle, so that the "drift" is in part a crosscut. A rib of rhyolite separates the east drift ore from that in the west drift; this rib was cut in D.D.Hole AS-1. As shown on the Exploration Plan, ore was cut in D.D.Hole AS-1 west of the rhyolite rib and south of the west drift. Three long holes drilled into the south wall of that drift showed heavy mineralization;one hole showed good zinc ore that looks like a replacement of shale. Actually, the rhyolite rib bifurcates as shown on the plan:it is a single rib southeast of the 100' level workings,but splits near the short north crosscut west of the raise. According to D.D.Hole AS-1,there is ore south of the south fork of the rib;the ore now being drifted on to the west lies between the two forks and was not cut in Hole AS-1.

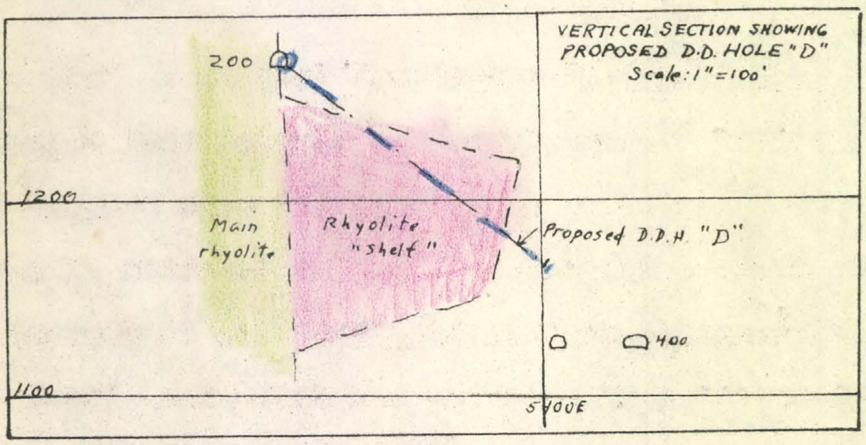
The ore on the east of the rhyolite rib was crosscut east of the raise, and its footwall is now being followed southeast. The northwest extension of this ore is unknown.

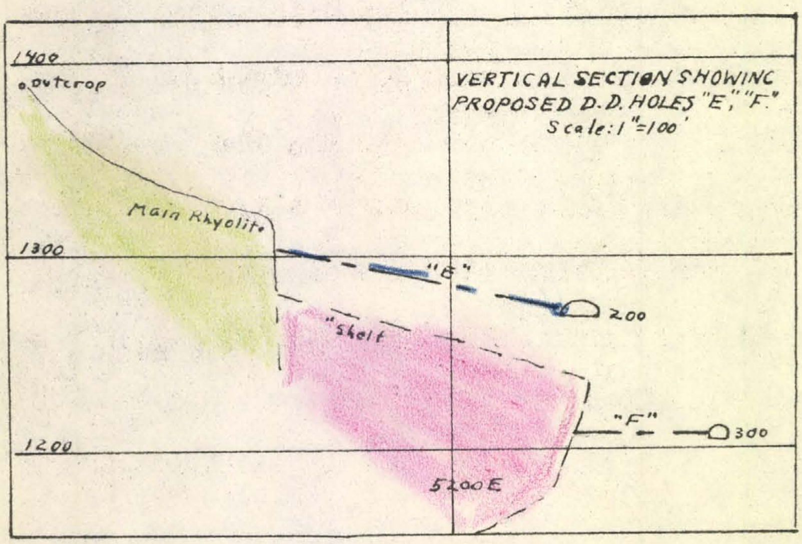
Proposed D.D.Hole "C": (See Exploration Plan). This hole is designed to explore the ground between the rhyolite rib and the Main rhyolite mass, under ore cut in D.D.Hole AS-1. It should be drilled far enough southwest to enter the Main rhyolite mass.

Proposed D.D.Hole "B": Designed to test the northwest extension of the ore east of the raise,and to explore the area between this ore and the 200 stope. This is potential ore ground,because the flat segment of the Main rhyolite contact thought to have helped localize the 100 ore body extends beneath it, and because there is ore northeast and southwest of it. A large rhyolite sill borders the 200 stope on the southeast (see large Composite Plan and Section Showing Suggested Hole "H"). This sill may have helped localize the 200 ore body and there may be more ore on its southwest side. T

The 100 ore body has emphasized the fact that barren sills or ribs may exist,with ore on either side;this fact must not be overlooked.


VERTICAL SECTION SHOWING PROPOSED D.D. HOLES A-1, A-2.
Scale: 1"=100'
New 100' Lev.
Ore
rhy
Proposed D.D. Hole A-1
1300
Main Rhyolite mass
Proposed drift, 2nd Lev.
Alternative to drift-
Proposed D.D.H. A-2
3rd Lev.
1200
400
ore
rhy
1100
5400 E
5600 E


VERTICAL SECTION SHOWING PROPOSED D.D. HOLE "D"
Scale: 1"=100'
200
1200
Main rhyolite
Rhyolite "shelf"
Proposed D.D.H. "D"
400
1100
5400E


VERTICAL SECTION SHOWING PROPOSED D.D. HOLES "E", "F."
Scale: 1"=100'
1400
outcrop
Main Rhyolite
1300
"E"
200
"Shelf"
"F"
300
1200
5200E

Proposed Adit to connect with 100 Ore body Workings: When stoping of the 100 ore body commences, a second exit will be required. Mr. Price has suggested an adit into the hill, at the elevation of No. 1 Shaft collar, as shown on the Exploration Plan (position of portal approximate). The adit would connect with a raise near the west end of the ore, and driven as high as possible in ore. The adit and raise will facilitate handling of supplies for mining, since a truck can be driven to the adit portal. The adit has exploration value as well, for it will traverse the zone of intersection of a strong sheeted zone in the Main rhyolite with the northeast flank of the rhyolite mass, as shown on the Exploration Plan.

200' Level Horizon.- The main structural feature at this horizon is the vertical segment of the Main rhyolite contact that helped localize the "tail" of the 200 ore body. Near the main 200 ore body the rhyolite contact flattens as shown on the Exploration Plan, but southeast of the steep segment, and in line with it, is a promising area, that of the intersection of a strong and well-mineralized sheeted zone with the northeast flank of the Main rhyolite mass. The counterdrift shown on the Exploration Plan might be driven to explore this area, but drilling seems preferable. The Section Showing Proposed Holes A-1, A-2, facing this page, shows alternative holes.

Proposed Holes A-1, A-2 (Alternative): A-1 appears the better hole. It would cut the shale beds at a better angle and would test as well any upward extension of the 400 ore body. Hole A-1, drilled from the 100 level, could be drilled at the same time Holes B and C are drilled. (See Exploration Plan).

The vertical segment of the Main rhyolite contact was drifted on, 200' level, southeast of No.1 shaft, but not to the northwest. The

300' level lies largely in the rhyolite "shelf", and the vertical segment under discussion is obscured on the 400/ also by this shelf (see Section E-E', facing p.5).

Exploration to the northwest, of this and possibly other contacts, has a speculative attraction, because except for the workings in the rhyolite "wedge" along the Opencut ore body, no exploration has ever been done northwest of the main haulage tunnel, 400' level. (See large Composite Plan). Recent work has emphasized, unfortunately, the ease with which barren rhyolite may cut out ore above, below and laterally: the 200 ore body is cut off a few feet above the stope back by flat-lying rhyolite ; such an ore body could have no surface expression, and similar ore bodies northwest of No.1 shaft, where the Main rhyolite contact outcrops barren would have no surface expression either.[1]

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1. Note: Proposed D.D.Hole B might well be extended to a total of 130' to test the possibility for ore above the flat rhyolite mass that cut off the 200 ore body going up.

Proposed Drift, 200 Level: See exploration plan. Drift northwest along the Main rhyolite contact as shown. The contact as followed will soon overturn, dipping southwest ; but farther northwest it must straighten up, and here might be a favorable locus for ore.

Proposed D.D.Hole E (alternative to above drift): See Exploration Plan. The drift has the disadvantage that the top of the rhyolite "shelf" lies not far below it; the shelf might rise going northwest to the horizon of the drift, cutting out chances for ore. D.D.Hole E has been designed to avoid this contingency and may be a better bet.

(See Section Showing Proposed Holes E and F, facing p.8).

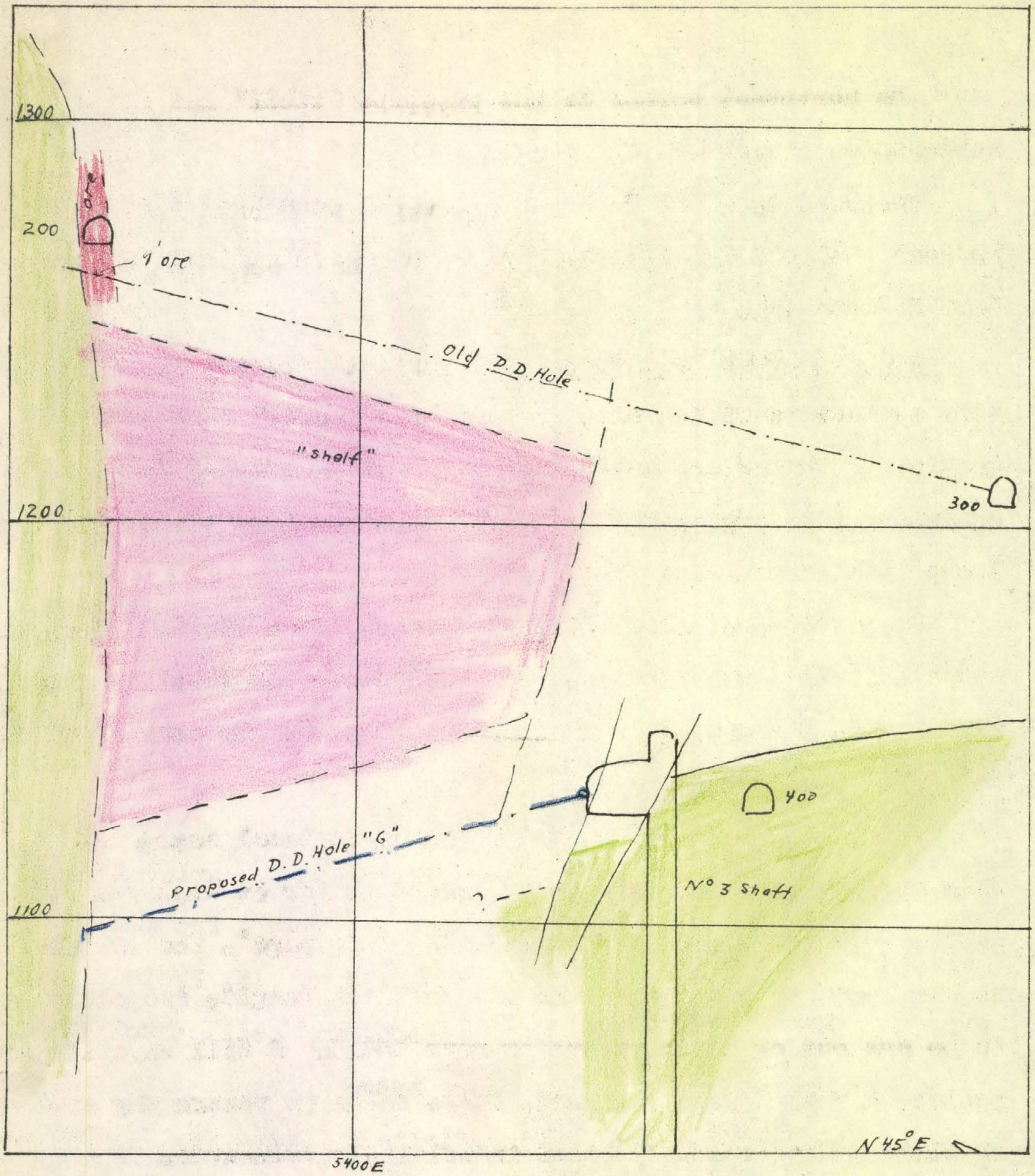
300' Level Horizon.- The horizon of the 300' level roughly bisects the nearly vertical surface marking the northeast edge of the rhyolite "shelf" and exploration of this edge will be discussed for convenience under that heading. (See Sections E-E', and Sections Showing Proposed Holes D, F, also Section through Holes AU-2, AU-3).

Both the large Composite Plan and the Exploration Plan show the anomoly connected with the ore cut in Holes AU-2, AU-3, and the northwest end of the 400 ore body. See also Section through D.D. Holes AU-2, AU-3. At the horizon of the 400' level there is no direct connection between the 400 ore body and the ore of Holes AU-3, AU-2. But above the 400 horizon, the northeast edge of the rhyolite "shelf" is continuous, going southeast, with the vertical segment of the Main rhyolite mass along which the 400 ore body made (see also, Vert. Longit. Projection, 400 ore body). It follows, therefore, that at say 1150' elevation, ore is continuous, from the Main 400 ore body on the southeast, through D.D. Hole AU-4, and to Holes AU-3, AU-2. Following this ore, at the proper horizon, northwest toward No.3 shaft, is essential.

Proposed Drift, 1150' elevation: See Exploration Plan. The drift may be started from a raise on the tail-like downward extension of the AU-3 ore, as suggested on the Exploration Plan. Possibly a preferable plan would be simply to start stoping the 400 ore body above the 400 level and pursuing the ore northwest in the stope, or by a sub-drift.

Before doing this it might be advisable to test the northwest extension of this ore along the northeast edge of the shelf, or to search for a possible second ore body along this edge.

Proposed D.D. Hole D: See Exploration Plan, and Section Showing Hole D, facing p.8.



VERTICAL SECTION SHOWING D.D. HOLE "G". (Section is part of F.H. Stewart Section D-D').
Scale: 1" = 40'

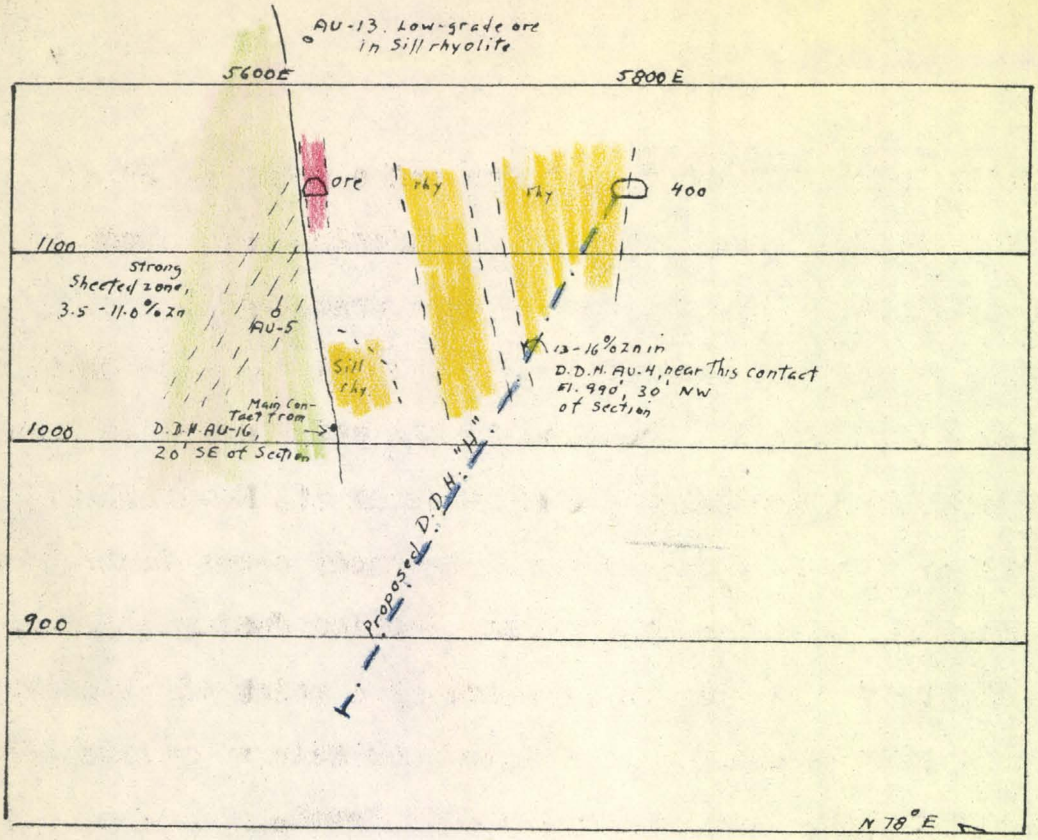
The northeast corner of the rhyolite "shelf" has never been explored northwest of No.1 shaft.

Proposed D.D.Hole F: See Exploration Plan ,and Section Showing Proposed Holes E and F, facing p.8. This hole would be attractive if Hole E found ore.

<u>400 and Lower Horizons.</u>- The vertical segment of the Main rhyolite contact persists below the rhyolite "shelf" (see Sections E-E', Section through Holes AU-2,AU-3, and Section showing Proposed Hole G, facing this page). This lower segment has been little explored and looks like a promising place for ore.

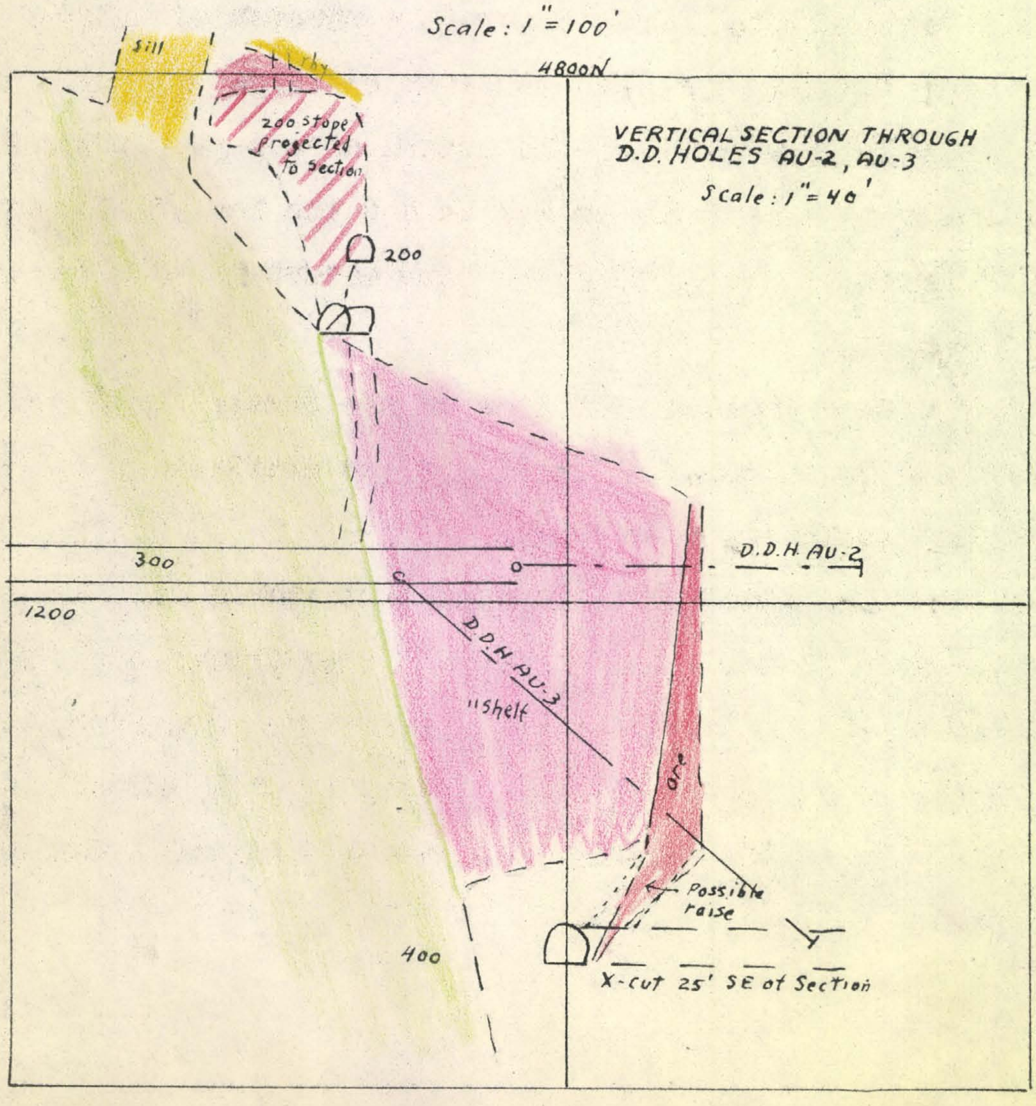
Proposed D.D.Hole G: Stewart recommended a similar hole,but to be drilled south from No.1 shaft station, 400 level.(See Exploration Plan). I prefer Hole G,since it would cut the contact within the proven ore area.

In the area of the 400 ore body,the vertical segment of the Main rhyolite contact persists downward as far as explored (see Section Showing Proposed Hole H,facing ~~this~~ page 12. The 400 ore body, as shown on the section and on the Vertical Longit. Projection,appears to be cut out at depth by one or more bodies of sill rhyolite plastered against the Main rhyolite mass. There seems no reason why such sill rhyolite bodies should persist indefinitely downwards. If they do not,the Main contact,if still vertical beneath them,would appear to be an especially favorable locus for ore;indeed,the present 400 ore body might represent merely "leakage" ore,deposited by solutions that managed,while ascending the Main contact,to sneak past bodies of sill rhyolite. The real mine might lie at depth. This is pure speculation, but it seems to me a shame not to test this chance.



VERTICAL SECTION SHOWING PROPOSED D.D. HOLE "H"

Scale: 1" = 100'



VERTICAL SECTION THROUGH D.D. HOLES AU-2, AU-3

Scale: 1" = 40'

Diamond Drill Hole AU-5 cut toward its end a total of 6' of 13% to 16.6% zinc ore (see Composite Plan). Unfortunately study of this and other drill-holes of this part of the area, together with that of crosscuts recently driven on the 400' level suggests that this ore lies in a rhyolite sill next to a thin wafer of shale separating the first sill from another one southwest of it. Neverthless, some further exploration of this possible small ore body seems desirable.

Proposed Hole H: (Exploration Plan and Section Facing this Page).

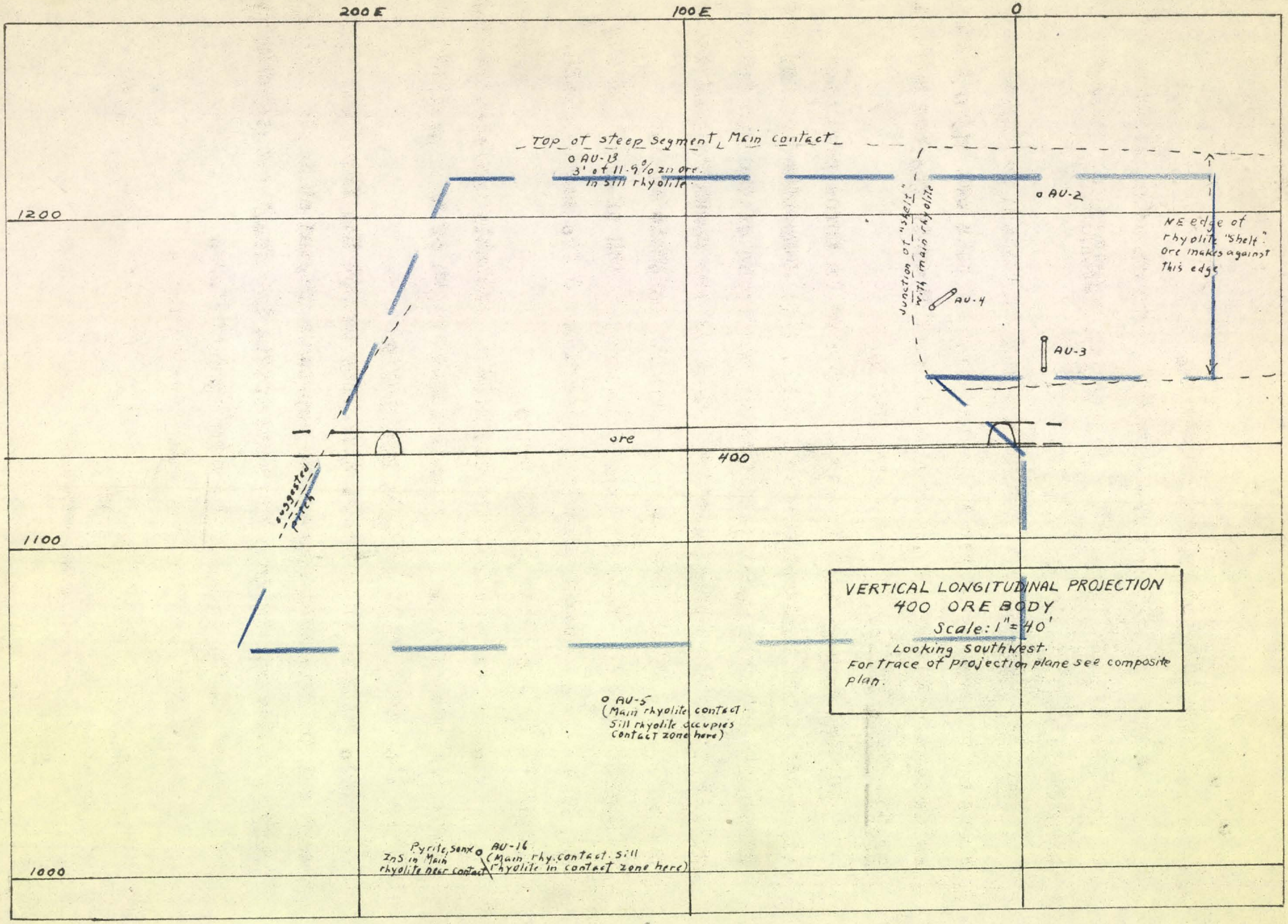
The hole would cut the same shale wafer at a point 45' southeast of where cut in Hole AU-5 and 60' higher, and the Main r hyolite contact at a point some 250' below the ore on the 400' level.

Exploration of Old Ore Exposures.-

100' Level: North of No.1 Shaft there is a stretch of solid sulphides, including ZnS, 35' long and at least 5' long. The drift is caved at each end of this stretch, so the length of ore may be greater. This should be investigated; if the ground is not too heavy, an attempt might be made to retimber the caved parts and ascertain the size of this sulphide ore body.

200' Level: Price estimates 2600 tons of ore remaining, in the top and sides of the 200 stope. The "tail" of ore drifted on, 200 level, should also be developed, by a raise.

450 Stope: Zinc ore remains at the southeast end of this stope. Stewart suggested a drill-hole, S82°E from the transformer station, 400 level, to explore the southeast extension of this ore. Since Price estimates 4200 tons of ore between the top of this stope and the 400 level sill, the southeast extension may be explored and mined during stoping.



VERTICAL LONGITUDINAL PROJECTION
400 ORE BODY
Scale: 1" = 40'
Looking southwest.
For trace of projection plane see composite plan.

ESTIMATE OF PROBABLE TONNAGE.

Development of known ore is not far enough advanced to permit of any precise estimate, but the order of magnitude of tonnage possibilities may be guessed at.

400 Ore Body.- The Vertical Longit. Projection facing this page shows my conception of the shape and size of this ore body. Assuming an average width of 8 ft. and a density of 9 cubic ft. per ton gives 29,000 tons. (Dilution not considered).

100 Ore Body.- This is best considered in three portions: (1) east of the bifurcated rhyolite rib (see Composite and Exploration Plans, and refer to p.6-7); (2) between the forks of the rib (present west drift is exploring this); (3) south of the south fork of the rib, and under the first stretch of ore cut in D.D.Hole AS-1.

(1) The east crosscut has disclosed a width of about 30 ft. for this body. Assuming a strike length of 90 ft. and a vertical height of 50 ft. gives 15,000 tons.

(2). The ore body between the ribs is probably narrower; 15 ft. width has been assumed; with an assumed length of 50 ft. and height of 50 ft., there would be 4000 tons here.

(3). Nothing is known of this body except the first ore intercept cut in Hole AS-1 appears to represent it, and at least one of the drifter holes put in from the west drift, 100 ft. level, seems to have penetrated it. The body might contain 5000 tons.

Possible total, 100 Ore body: 24,000 tons.

Resumé, Possible Ore. (Figures other than above from Price).

	Tons	
200 Stope	2600	
450 "	4200	(top of stope to 400 sill).
400 ore body	29000	
100 " "	24000	
	59800	

The tonnage found and mined may be disappointingly lower; I distrust both the 400 and 100 ore bodies, largely because of the unpredictable ability of barren sill rhyolite to cut out ore. On the other hand, the same sill rhyolite may have hidden ore shoots from us that we may later find; this possibility must be kept firmly in mind during stoping operations. In general, stoping usually discloses some unexpected ore, and most mines, after stoping actually starts, yield more ore than estimates have indicated. Even where not masked by ribs or other bodies of sill rhyolite, the Afterthought ore in shale is commonly surrounded by barren shale suggesting in no way the nearby presence of ore. Thus on the 400' level one may stand a foot away from the north wall of the 400 ore body, in a crosscut, and see no sign of ore. In the very ore-zone itself, a few feet away from the northwest or southeast tip of the ore body, only barren shattered shale is visible, with no more calcite stringers than in hundreds of other places in the mine.

Taking all this into consideration, nevertheless in my opinion the Afterthought mine will yield not much over 60,000 tons at best, and probably not less than 40,000 tons. If D.D.Hole H should be drilled and reveal presently unsuspected possibilities of ore at depth, this picture would be radically changed.

ESTIMATE OF PROBABLE GRADE.

The writer has attempted no averaging of samples at this time because no samples have as yet been taken of the 400 and 100 ore bodies, except for drill-hole samples. Averages by others of samples from the drill holes and from the back of 200 stope suggest the following rough figures:

Au, oz/ton	Ag,oz/ton	Cu,%	Pb,%	Zn,%
0.04	8.0	3.0	4.0?	20.0

I understand that the presence of barite in the ore invalidated much of the assaying for lead; Mr. Price gave me the figure for the zinc average; otherwise these values correspond to those calculated in your Los Angeles office.

E. W.

San Francisco, August 23,1947 Edward Wisser

REPORT ON THE DONKEY MINE, SHASTA COUNTY, CALIF.

Introduction.- The following report is based on one day's field work, August 8, 1947, preceded by brief visits on two occasions in April, 1946. The deeper underground workings shown on the accompanying plan are from a map by E.D.Linton dated 1917.

General Geology.- The Donkey workings appear to lie entirely within the same rhyolite massive that appears at the Afterthought mine; both mines lie along the northeast edge of the mass. The Donkey mine might lie a mile and a half southeast of Afterthought.

As shown on the plan, the rhyolite-shale contact at the Donkey is not a simple one: it may contain either deep embayments of shale in rhyolite, or shale roof pendants. It appears that the north crosscut, 200 level, may have reached the shale contact nearest the mine.

The rhyolite in the area of the mine is dominantly fissile,the planes of fissility striking E-W to N60°E as a rule; zones of fissility are separated by ribs of massive rhyolite. Some of the rhyolite is brecciated, with coarse sheeting traversing the breccia. Curiously, the attitude of the shale beds corresponds with the fissility in the rhyolite.

Mineralization.- Mild silicification, iron-staining and manganese staining are scattered almost throughout the mapped area. The major mineralization however is confined to a well-defined zone north of the shaft, and exposed in the opencut NNE of the shaft and in the two tunnels northwest of the shaft. Along this zone the strong fissility strikes about N70°E,wheareas that in the rhyolite south of the zone strikes nearly E-W. Gougy slips are common in the mineralized zone and it seems probable that the zone is a locus of faulting.

What is called on the plan the "Main Structure" is almost certainly a fault, and probably a reverse fault.

The zone shows intense hydrothermal alteration, sporadic cellular limonite, common copper-stain and occasional manganese stain. G.C. Taylor is said to have shipped high-grade silver ore from the opencut NNE of the shaft. In the westernmost tunnel a 6" streak of nearly massive sphalerite, galena and some chalcopyrite is exposed.

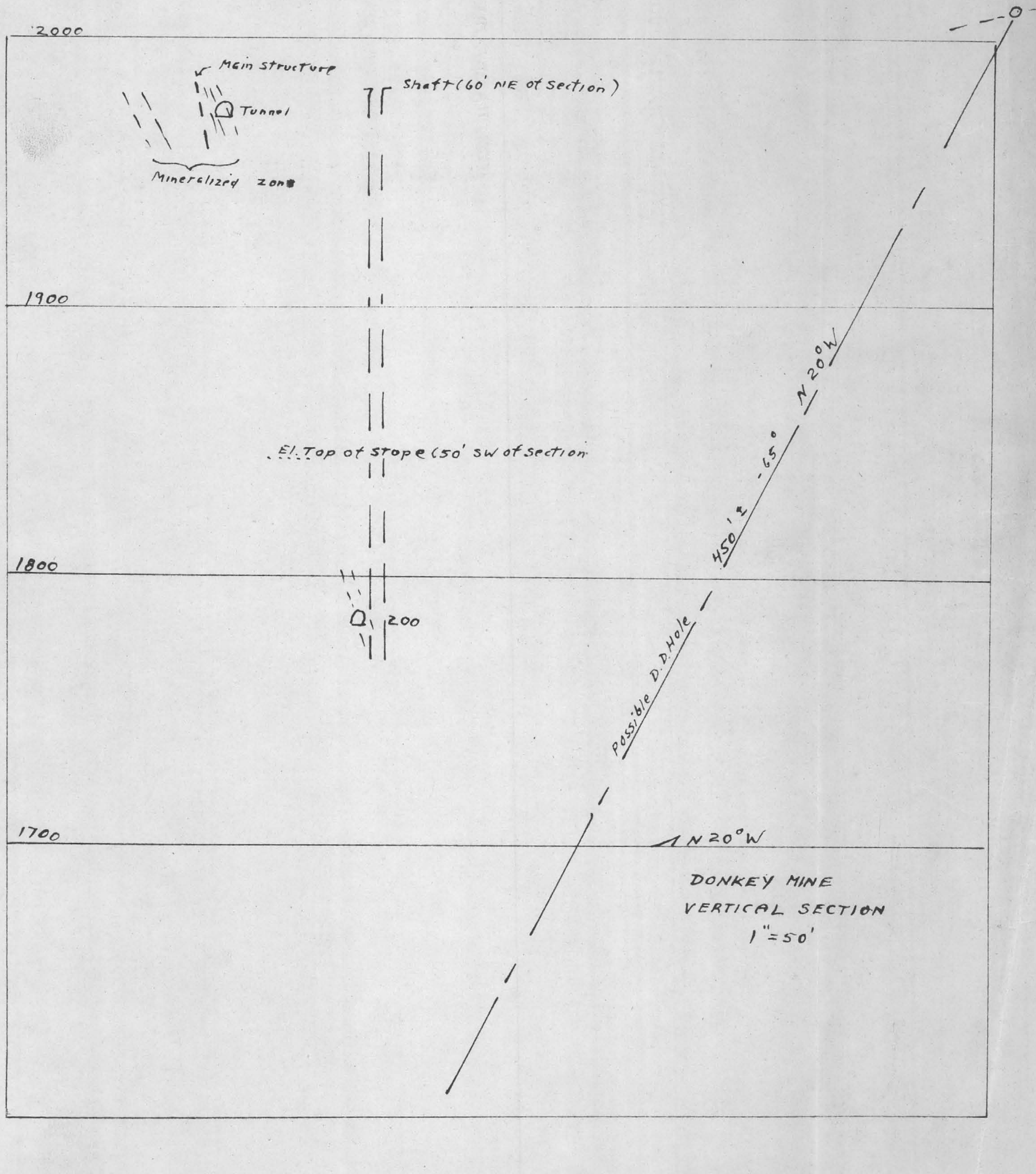
On the 200 level, the westerly working from the shaft is probably a drift on this zone, as suggested on the accompanying Section. A little stoping was done, but whether this represents the entire Donkey production is not known.

The 6" streak of sulphides in the west tunnel ends abruptly on the east; mineralization exposed in the opencut NNE of the shaft is pinching to the west as suggested on the plan. The ore occurrence is thought to be as small lenses along this mineralized zone. The plan shows a northwest crosscut, 75' level, from the shaft; this must have traversed the mineralized zone and apparently it found nothing. A longer north crosscut, 200' level not only crossed the mineralized zone but probably reached the shale contact. Finally, I am told that long after this work was done the mine was unwatered, cleaned out and examined, with apparently discouraging results.

<u>Conclusions</u>.-The possible diamond drill hole shown on the Section would be about 450' long; it would cut the mineralized zone at a poor angle. To get the same depth with a proper angle of intersection would require a 600 ft. hole or longer. The hole laid out has no particular objective other than to cut the mineralized zone where it looks strongest near the surface, and roughly below the ore above the 200 level. I do not recommend this hole, nor any work on the Donkey.

E.W.

San Francisco, Aug. 26, 1947 — Edward Wisser


2000
Main Structure
Shaft (60' NE of Section)
Tunnel
Mineralized zone
1900
El. Top of stope (50' SW of section
1800
200
450' ± -65° N 20° W
Possible D.D. Hole
1700
N 20° W
DONKEY MINE
VERTICAL SECTION
1" = 50'

September 30, 1946

Mr.J.L.Bruce
1206 Pacific Mutual Bldg.
Los Angeles 14, Calif.

__SUGGESTED__ __UNDERGROUND__ __EXPLORATION__ __AT__ __AFTERTHOUGHT__ __MINE__.

Refer to accompanying composite plan, and sections.

There are three ore showings, presumably each a unit ore body, to be developed, and two or three areas of speculative promise to explore. The ore showings are discussed first.

__AU-6__ __Ore__ __Body.__-It is assumed the ore showings in Holes AU-2,3,4 and 6 are continuous. This ore zone is projected to the 4th level horizon (~~gray~~ yellow on the plan) and to the 3rd level horizon (~~yellow~~ gray on the plan). Beside these projections, refer, in Stewart's report, to his vertical sections through Holes AU2-3, AU-4; to Sections through AU-5 and AU-6, facing page 5, my Interim Report of August 20,1946; t Section N75°E through collar of Hole AU-5, my letter to yourself of August 28, 1946; and to Longitudinal Projection,AU-3-AU-6 Sheeted Zone, facing page 5 of my report, Afterthought and Rising Star Mines Compared, September 4, 1946.

The sum of what these data show is this: near Holes AU-3, AU-4, the rhyolite contact is vertical or overhanging,and the ore may be expected to descend to the horizon of the 4th level. Southeast of this area,the contact flattens, and since the sheeted zone along which the ore occurs dips southwest into the rhyolite,the ore probably pinches going southeast on the 4th level horizon. (See especially the sections through Holes AU-5, AU-6, mentioned above). As shown on the longitudinal projection mentioned, the line of intersection of the sheeted zone and the rhyolite rises near Holes AU-5, AU-6, so that ore on the 4th level horizon if any, will be narrow here; but farther southeast the rhyolite drops away again, as viewed in the plane of the ore zone, so that ore on the 4th level horizon may widen again.

Thus, while the 4th level appears in general a little low for maximum ore on this zone, it seems for that very reason an ideal level for exploration because, if I am correct, it lies close to the bottom of ore and so would make a perfect extraction level.

Recommendation.- 4th Level. From point shown on plan, crosscut S10°E 100 ft. to get under ore in Hole AU-3. Drive southeast and northwest on the ore zone. Regarding possibilities for the NW drift, see my report of June 28, 1946, p.6. Best chances at present appear to be to the southeast. The main rhyolite contact should be followed; if ore should pinch out, a raise should be put up, in the sediments close to the contact, but a few feet out from the rhyolite; the inclination of the raise should parallel the dip of the contact. (See sections through Holes AU-5, AU-6).

x x x x x x x x x x x x x

The area prospected toward the bottom of Hole AU-5, while a speculative prospect, is best discussed here. When or if the southeast drift, 4th level, on the AU-6 ore zone reaches the line of Hole AU-5, a chance will be offered to reach this area. If arrangements can be made to keep a drill at the mine, it would be greatly preferable to drill the area in question, since the 4th level may be too high. See Vertical Section through Point 5800E, 4745N (N25°E) accompanying my letter to you of September 16 last. Otherwise drive the crosscut shown on the plan with this report.

If the AU-6 ore zone has a reasonable vertical extent, the 3rd level should show more ore along it than the 4th.

Recommendation, 3rd Level.-From face of NE crosscut shown on plan, crosscut N65°E about 35 ft. to cut the ore zone,and drive southeast and northwest along the zone, crosscutting and raising where such work seems indicated.

x x x x x x x x x x x x x

200 Ore Body.- The southeastern extension of this ore body has not been reached; although the southeastend of the stope is not too encouraging, some exploration to the southeast is justified,especially since other ore lenses may occur along this zone (see my report of August 20 last, p.4, and accompanying map).

Recommendation, 2nd Level.- As shown on the plan, retimber SE drift and drive southeast along the northeast wall of the ore,crosscutting SW if appreciable ore is encountered.

Recommendation,200 Stope.- It is important to determine the upper limit of this ore shoot. Hence raise where shown, keeping close to the rhyolite footwall.

Recommendation, 2nd Level.- The ore lens probably pinches out to the northwest,but if the short S25°W crosscut should disclose ore, about 40 ft. additional length of ore would be indicated.

x x x x x x x x x x x x

AS-1 Ore Body.- Before starting any tunelling or raising on this prospect, more information should be gained as to the shape and extent of the ore body. Drilling seems indicated here, and two alternative holes are shown on the plan and the accompanying sections. Possible Hole A, upper section, may be drilled up from the 3rd level or down from the surface. To save time I have used a N-S section through

Hole AS-5, already prepared; but actually I should drill the surface hole along a course S20°W, or the underground hole, N20°W, becamme the ore zone probably strikes NW (see plan).

The alternative Hole B is shown on the lower section. It would be drilled from the 2nd level. It is slightly more risky than A, because it takes a bigger bite, demanding a greater extension of ore NW of Hole AS-1; Hole A seems pretty well designed to test the vertical extent of the ore. However, I rather prefer B.

x x x x x x x x x x x

Speculative Prospects.- If Hole AS-10, now running, should find ore, the only way I can think of to get at it would be to extend the main Afterthought tunnel several hundred feet NE, or drive a lower tunnel a greater distance. The trouble is that the south end of the 2nd level, while near this "embayment" where the latter shows on the surface, is far below any possible ore that might be cut by Hole AS-10 (1269 ft. vs. 1500 ft. elevations). However, if as I have suggested elsewhere, the embayment is much deeper, with steeper sides, than I have drawn it on the accompanying plan, then the 2nd level might be a feasible site for exploration. Hole AS-10 may give enough data to decide this.

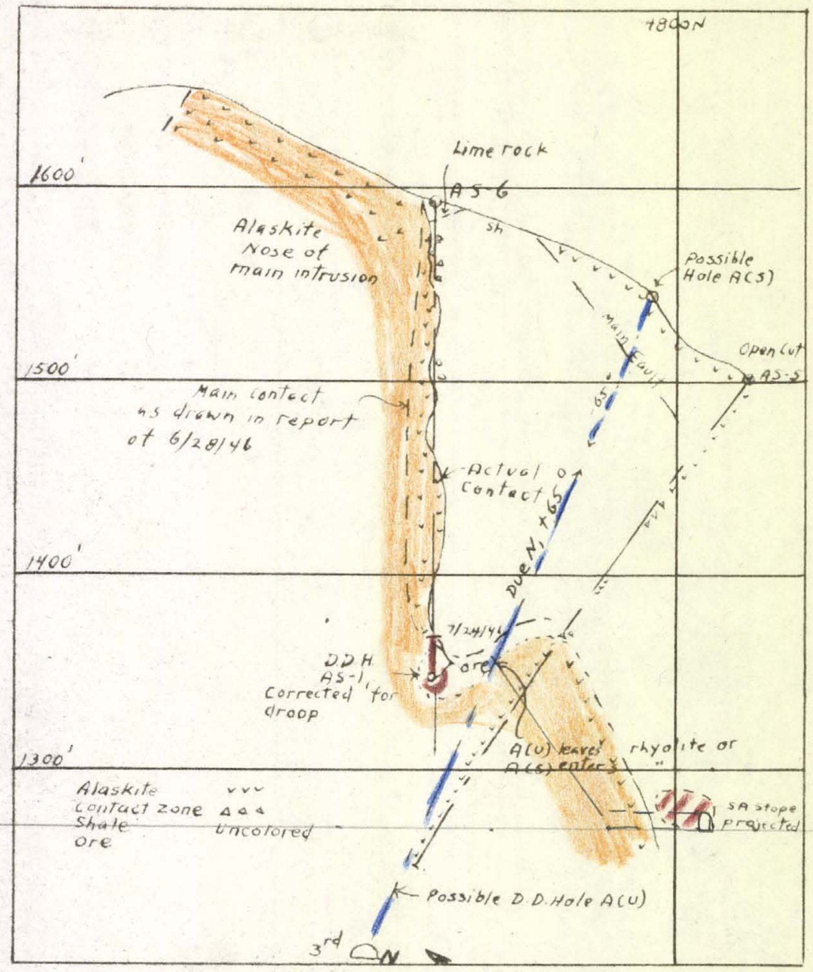
In spite of the barren extension of Hole AU-4, I still think that driving SE on the Main Shear Zone, 5th level, into the sedimentaries, is a good bet.

General.- These suggestions are of necessity hastily made and subject to revision.

Yours truly

E.W.

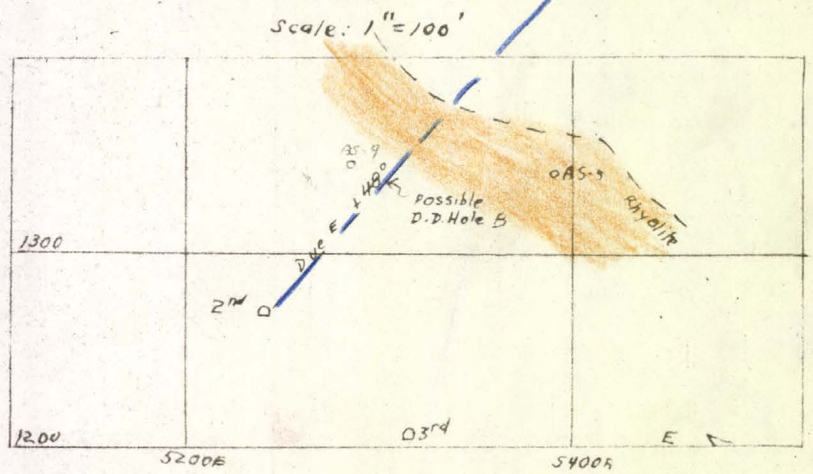
Edward Wisser



AFTERTHOUGHT MINE, SHASTA CO., CALIF

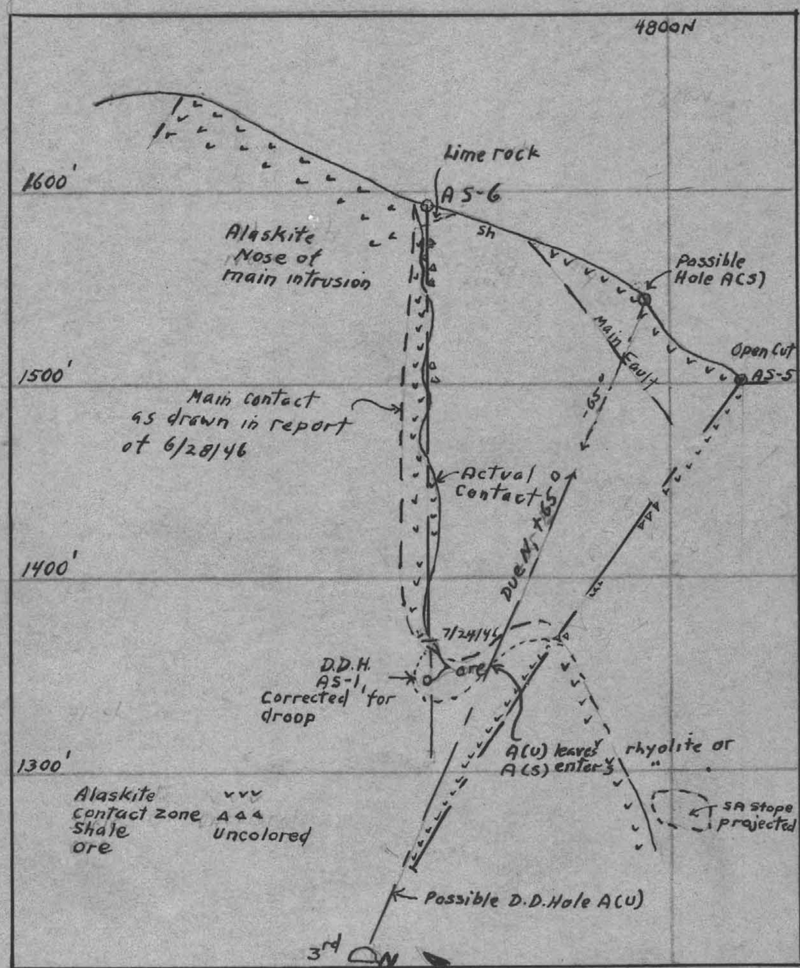
VERTICAL SECTION THROUGH D.D. HOLES AS-5, AS 6, Possible Hole A
(Revised Section D-D', Wisser Report of 6/28/46)

Scale: 1" = 100'



Vertical Section through Possible Hole B

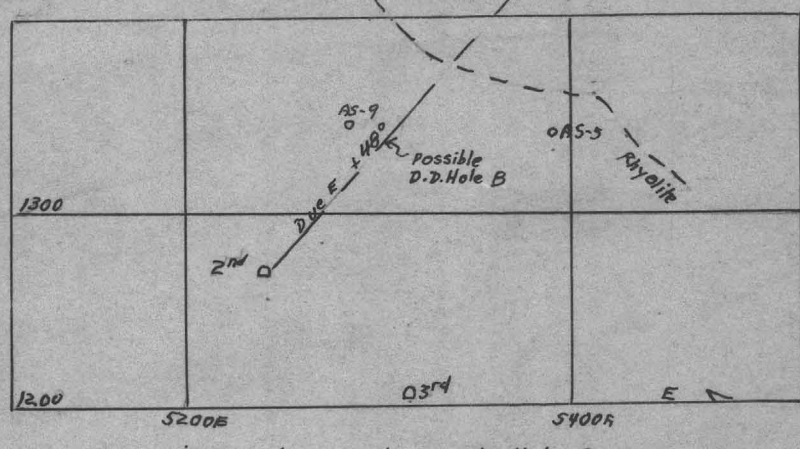
Scale: 1" = 100'



AFTERTHOUGHT MINE, SHASTA CO., CALIF.

VERTICAL SECTION THROUGH D.D.HOLES AS-5, AS-6, Possible Hole A
(Revised Section D-D', Wisser Report of 6/28/46).

Scale: 1" = 100'



Vertical Section through Possible Hole B

Scale: 1" = 100'

Wisser

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY AND ORE DEPOSITS OF THE AFTERTHOUGHT MINE

SHASTA COUNTY, CALIFORNIA

SPECIAL REPORT 29

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GEOLOGY AND ORE DEPOSITS OF THE AFTERTHOUGHT MINE

SHASTA COUNTY, CALIFORNIA

By JOHN P. ALBERS
Prepared in cooperation with the
United States Geological Survey

as well as its depth, is conjectural. Whatever the original source of the hydrothermal solutions, they probably made their way upward through the earth's crust along sheared and fractured zones in the Bully Hill rhyolite, and in the sedimentary rocks of the Pit formation. Here and there the physical condition of the host rocks was such that the mineralizing solutions had relatively easy access to the host rocks. Where the temperature and composition of the visiting solutions and host rock were favorable, a chemical reaction occurred, and the host rock was slowly replaced by sulfide minerals. The size of the resulting sulfide bodies was dependent in part upon the volume of host rock that was accessible to the solutions and also upon the length of time that the solutions were active in the area.

AREAS FAVORABLE FOR EXPLORATION

Known ore bodies, of which possible extensions may be found, are:

1. Northwest extension of the Copper Hill No. 1 ore body between the surface and the 200 level. According to Lindberg (1919, p. 11) the northwest face of the old 100 level is in part massive sulfide; and high-grade sulfide appears on the dump of the No. 4 adit.

2. Downward extension of the Copper Hill No. 1 ore body. There is no record of what was mined from this ore body between the 100 and 200 levels. The ore body has a maximum width of 35 feet on the 100 level, and the favorable zone should extend at least half way to the 200 level before intersecting the Main fault.

3. Southeast extension of the 220 ore body. Drill-hole data indicate that the soda rhyolite bench extends for at least 100 feet farther to the southeast. The sedimentary rocks probably dip southwest into the soda rhyolite bench, and the area of this extension thus has the same geologic environment as that above the 120 and 220 ore bodies.

4. Extension of the 412 mineralized zone southeast below the 400 level, and northwest above the 300 level. Bodies of sulfide along this zone, which is marked out by veinlets filled with quartz and calcite, are apt to be small, but there may be several of them. The 412 fault zone projects downward toward the mineralized zone encountered in diamond-drill hole AU 44, and upward toward the 220 ore body.

5. Southeast extension of the 450 ore body between the 500 and the 600 levels. The top of this ore body seems to be controlled in part by an anticlinal fold in the shale and plunges southeast at an angle of about 40°. From the distribution of caved 500-level workings, and from the presence of sedimentary rocks below the 500 level in diamond-drill holes AU 4 and AU 5, the writer infers that the mineralized zone continues to plunge southeast below the 500 level.

6. Possible downward extension of the 800-level mineralized area. This is a strongly pyritized zone, which includes a lens 15 feet wide and at least 40 feet long that assays more than 4 percent copper (based on observations by F. W. Stewart). Although the writer has not examined these workings, it seems possible that the material exposed on the 800 level may be part of the pyritic halo that characteristically surrounds sulfide bodies in the soda rhyolite shear zones. If so, the core of the sulfide body is probably below the level.

7. Almost all the ore bodies enclose layers of unreplaced rock, and in some places these "false faces" might be mistaken for the true wall of an ore body. Therefore the walls of all stopes, especially the shale wall, should be explored at regular intervals.

Geologically favorable blocks, other than extensions of known ore bodies, include the following:

1. The block southeast of and below the 500-level workings is geologically favorable because a nearly horizontal body of soda rhyolite underlies sedimentary rocks that are known to be mineralized in diamond-drill holes AU 5 and AU 44. Furthermore, shear zones that probably served as feeder channels for the 420 and 450 ore bodies extend downward into the soda rhyolite in this vicinity.

2. The block of sedimentary rocks southwest of the No. 3 shaft between the 400 and 500 levels is geologically favorable because the sedimentary beds dip southwest toward a mineralized fault contact with soda rhyolite. This fault contact is the same one along which the 420 ore body is localized farther southeast.

3. Mineralized shear zones are probably present in the soda rhyolite below the 800 level. Bodies of high-grade sulfide similar to the 700b ore body may reasonably be expected where such shear zones intersect the shale contact.

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GEOLOGY AND ORE DEPOSITS OF THE AFTERTHOUGHT MINE, SHASTA COUNTY, CALIFORNIA*

By JOHN P. ALBERS **

OUTLINE OF REPORT

* Publication authorized by the Director, U. S. Geological Survey. Prepared in cooperation with the California State Division of Mines.

** Geologist, U. S. Geological Survey.

ABSTRACT

The Afterthought mine is in Shasta County, California, 24 miles northeast of Redding. It is primarily a zinc-copper mine. Between 1905 and January 31, 1951, it produced 158,525 tons of crude sulfide ore that assayed an average of about 16 percent zinc, 2.7 percent copper, 2 percent lead, 5.0 ounces of silver, and 0.04 ounce of gold.

The chief rocks in the mine area are folded shale and tuff beds of Triassic age, underlain by, and also intruded by, soda rhyolite and soda rhyolite porphyry. Rock contacts and bedding strike northwest and in most places dip steeply northeast; a weak cleavage strikes northwest and dips steeply southwest. Volcanic breccia of Pliocene age overlies the older rocks unconformably. Four types of faults are present—(1) low-angle thrust faults, (2) steep normal faults that strike northwest and dip southwest, (3) steep normal faults that strike northeast, and (4) faults that dip northeast. An important and unusual structural feature is the benchlike contact between soda rhyolite and shale.

Along certain zones the rocks have been carbonatized, pyritized, silicified or sericitized.

The ore bodies are sulfide replacement deposits that occur (a) in sheared and fractured soda rhyolite, (b) as a replacement of shale along premineral fault contacts between soda rhyolite and limy shale, and (c) in limy shale. About 15 sulfide bodies of minable size are known in the mine. The largest of these, the Copper Hill No. 1, now mined out, is estimated to have contained more than 50,000 tons of ore, but all the other ore bodies are considerably smaller. The chief structural controls of the ore bodies are: sheared and broken zones in the soda rhyolite; high-angle faults between soda rhyolite and shale; soda rhyolite benches; a reverse fault that dips northeast; and drag folds in the sedimentary rocks. The ore is a mixture of sulfides and gangue minerals. The sulfide minerals are pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, and bornite, with minor amounts of luzonite, covellite, and chalcocite. Gangue minerals are calcite, quartz, and barite. Oxidation extends only a few feet below the surface.

All the known ore bodies in the mine, except the Afterthought shear zone ore bodies, are in a block that is 600 feet long, 500 feet wide, and 700 feet deep. It is in this block that the irregular, benchlike contact between soda rhyolite and shale is found, and several good prospecting areas along this contact in the upper part of the mine are indicated. There is also evidence that the benchlike contact between soda rhyolite and shale plunges southeast at a low angle; therefore the writer believes that wildcat prospecting in the mine area should be directed downward toward the southeast below the 500 level.

INTRODUCTION

The Afterthought mine is in Shasta County, California, on U. S. Highway 299 E, 24 miles northeast of Redding. The property lies in secs. 10, 11, and 15, T. 33 N., R. 2 W., Mount Diablo base and meridian. It is near the eastern end of the East Shasta copper-zinc district. (See fig. 1.)

The maximum relief within the mine area is about 800 feet, and the canyon of Little Cow Creek, a permanent stream that flows southwest and provides an ample supply of water for the mine, is the dominant topographic feature. The mine plant and main haulage level are on the east bank of Little Cow Creek at an altitude of 1,125 feet. The hillslopes surrounding the mine rise rather steeply to an elevation of 1,800 feet, where the topography becomes much more subdued, owing to the presence of a Tertiary erosion surface capped by a permeable volcanic tuff breccia. (See pl. 1; fig. 2.)

The Afterthought mine is owned and operated by the Coronado Copper & Zinc Co., and the property is said to include approximately 1,800 acres of patented mineral claims consolidated into one block (Lindberg, 1919, p. 3). Of this total, less than 60 acres is underlain by mine workings.

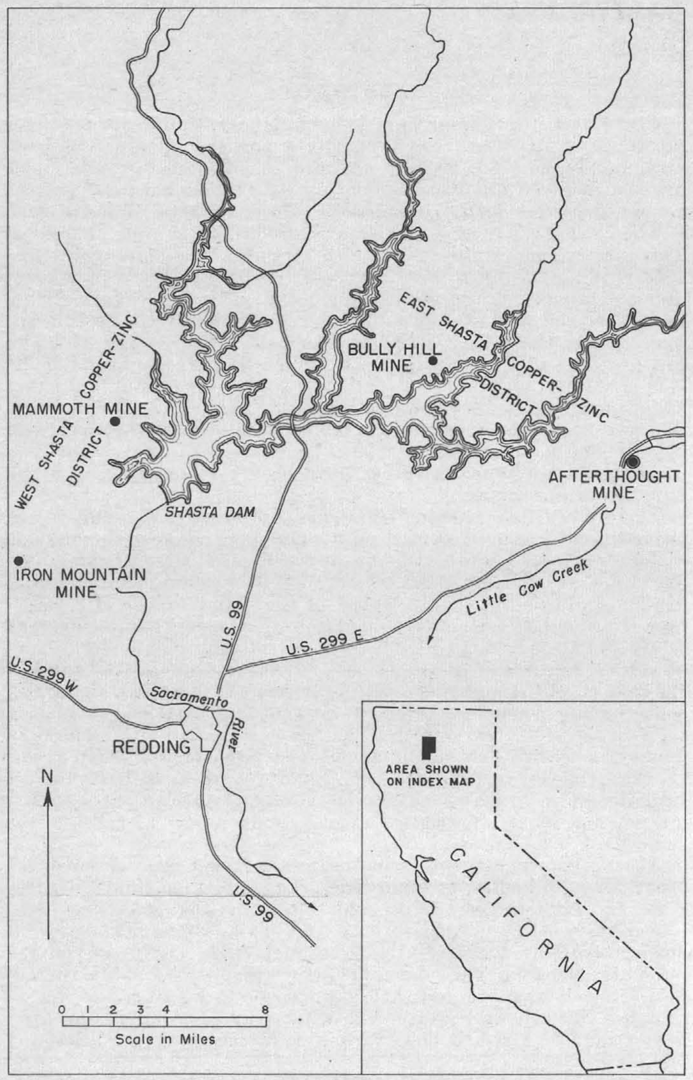


FIGURE 1. Index map showing the location of the Afterthought mine and the East Shasta and West Shasta copper-zinc districts.

The mine is developed by nine levels extending through a vertical distance of 729 feet. The 400 level, which is the main haulage level, extends 2,910 feet into the hill. At a distance of 1,450 feet from the portal a 329-foot shaft, the No. 1 shaft, connects the 400 level with the surface. Two underground shafts, one 300 feet deep, and one 400 feet deep, connect the 400 level with deeper workings. The mine workings total 18,700 feet: 16,500 feet in drifts, crosscuts, and stopes and 2,200 feet in raises and shafts. (See pl. 2.)

At the time of this study 9,790 feet of the mine workings were mapped. An additional 3,200 feet of workings, now inaccessible, were mapped in 1946 by F. W. Stewart, consultant for the Coronado Copper & Zinc Co., and these maps were available to the writer. The remaining 5,710 feet of workings were inaccessible, and geologic data on them are either inadequate or nonexistent.

The study of the Afterthought mine is part of a larger project that includes studies of the entire East Shasta and West Shasta copper-zinc districts (fig. 1). The field work in the Afterthought mine area was begun in June 1949 and discontinued in September of the same year. Critical areas in the mine were re-examined and new workings were mapped during November and December 1950. E. M. MacKevett assisted with the underground mapping, and operated the plane table during the 1949 work, and J. F. Robertson assisted with various phases of the work during 1950. A. R. Kinkel, Jr., and W. E. Hall of the U. S. Geological Survey spent two days mapping in the mine during 1949.

The writer wishes to acknowledge the many courtesies and fine cooperation extended by officials of the Coronado Copper & Zinc Co., especially by Messrs. M. G. Grant, R. W. Moore, Lyttleton Price, K. C. Richmond, B. W. Stewart, and Jack Widauf. The underground photographs that appear in this report were taken by M. G. Grant. Dr. James A. Noble of the California Institute of Technology kindly loaned the writer nine polished sections of the ore for study.

HISTORY AND PRODUCTION

The history of the Afterthought mine dates from about 1862, when the Copper Hill claim was staked (Frank and Chappell, 1881, pp. 23-25). Apparently very little work was done on the claim until 1873, when H. M. Peck bought the property. Peck and his employees at first carried sacks of ore on their backs to the top of the hill, where it was loaded on wagons and hauled to Stockton. At Stockton it was transferred to ships that carried it to Baltimore, Maryland, and to Swansea, Wales.

About 1875 Peck erected a reverberatory furnace and attempted to smelt the ore. This venture was not successful, and in 1903 he sold the property to the Great Western Gold Co.

The erection of a 250-ton blast furnace in 1905 resulted in the first successful reduction of the ore at the property. Between 1905 and 1927 several different companies operated the mine for short periods, and several different methods of extracting the metals from the ore were used. Although the ore carries a high percentage of zinc and considerable lead, only copper, gold, and silver were recovered from the ore prior to 1925.

FIGURE 2. Afterthought mine plant from U. S. Highway 299 E. Little Cow Creek in foreground.

later were partly altered to covellite. In general, chalcopyrite is somewhat more abundant in ore bodies that have replaced soda rhyolite than in ore bodies that have replaced shale.

Bornite appears in polished section as small veinlets and as small, irregular patches in sphalerite. It commonly shows mutual boundary relationships with chalcopyrite, but one polished section shows numerous islands of chalcopyrite in a sea of bornite. Bornite seems to be a minor constituent of sulfide bodies at all levels in the mine, and on the upper levels it is partly altered to supergene covellite and chalcocite.

Tetrahedrite is closely associated with galena. In polished section, it appears typically admixed with galena as irregular patches interstitial to sphalerite, but in a few places small areas of tetrahedrite occur without galena. Less commonly tetrahedrite is interstitial to pyrite. Tetrahedrite shows mutual boundary relationships with galena; but where the two minerals occur as admixed areas in sphalerite the tetrahedrite most commonly occupies sheltered embayments or coves along the irregular boundary of the area.

Galena is interstitial to pyrite, sphalerite, and chalcopyrite, but shows mutual boundary relationships with bornite and tetrahedrite. It also appears in polished section as irregular, alined patches in sphalerite and chalcopyrite. These patches of galena commonly coalesce, giving the sulfide a banded appearance.

Luzonite, a pink variety of enargite, was identified in a polished section of ore from the 122 stope. It is a rare constituent of the ore and appears as anhedral grains in chalcopyrite.

Covellite occurs in the upper ore bodies of the mine as an alteration of bornite. As seen in polished section, it characteristically penetrates bornite along fractures and grain boundaries. Covellite is not an abundant mineral and has not been seen as an alteration product of chalcopyrite.

Chalcocite is rare, but it is intimately associated with covellite in a few specimens. It seems to be most abundant near the southeast end of the 120 ore body. Covellite and chalcocite, along with azurite, malachite, and limonite, are supergene minerals.

Gangue Minerals

Gangue minerals, mainly calcite, quartz, and barite, are intimately mixed with sulfide minerals. In polished section the gangue minerals commonly appear as large areas enclosing euhedral grains of pyrite or small irregular patches of the other sulfide minerals; less commonly they appear as irregular patches in a sea of sphalerite or chalcopyrite. The writer believes that the barite, calcite, and part of the quartz were introduced, whereas the rest of the quartz is probably residual.

Quartz and Calcite Veins. In the Afterthought mine calcite and quartz commonly occur as numerous small veins. Quartz and calcite occur together and appear to be intergrown in most of the veins. Admixed calcite and quartz, in veins as much as a foot wide, are common along fault contacts between soda rhyolite and shale. Less common are veins of pure calcite in shale, or pure quartz in soda rhyolite.

The veins are small fissure-type veins that range from a fraction of an inch to more than a foot in thickness. Most of the veins strike northwest and dip steeply either northeast or southwest, but a few nearly horizontal veinlets are present in sulfide and in highly fractured zones.

The veins were formed during and after the deposition of the sulfides, and probably the fractures along which the veins formed also served as channels for sulfide-bearing solutions. The 420 ore body, for example, fades into a network of quartz-calcite veinlets in shale at its northwest end. Similarly, the 412 sulfide bodies are lenses of sulfide that replace shale along the hanging wall of a fracture filled with intergrown quartz and calcite. The calcite-quartz vein itself continues for scores of feet beyond the 412 sulfide lenses but gives no other indication of its close association with sulfide. Similar relationships between unimportant-looking quartz-calcite veins and small sulfide lenses are seen at other places in the mine.

Barite. Barite is closely associated with sulfide minerals in several of the Afterthought ore bodies. Although its distribution is spotty, it seems to be generally more abundant in ore bodies above the 200 level. According to Brown (1916, pp. 760-761) the average ore, evidently from the Copper Hill No. 1 ore body, contained 7.4 percent barite. This is in agreement with a statement by Diller (1904, p. 176) that the ore contains less than 5 percent gangue, most of which is barite.

In a brief examination of polished sections of ore from the upper level the writer has noted barite, along with quartz, calcite, and unreplaced rock. Barite may also occur in minor amounts at lower levels, but information is inadequate.

The paragenesis of minerals associated with the ore deposits is given in table 1.

Oxidation and Supergene Enrichment

The oxidized zone is very shallow, and supergene enrichment of the sulfide ore bodies has been insignificant. Sulfide ore in the Afterthought shear zone is capped by only 2 feet of gossan, and the Copper Hill No. 1 sulfide body, where now exposed in the open cut, could not have had more than 3 or 4 feet of gossan capping. Minor amounts of azurite and malachite, in addition to limonite, are found in the surface zone of oxidation. According to Brown (1916, p. 761) the oxidized ores of the Copper Hill lode were very rich in gold, and were mined for their gold content alone during the early days. Apparently the workings from which the gold was mined consisted only of surface pits and trenches.

Supergene sulfide minerals include covellite, chalcocite, and secondary(?) chalcopyrite. These minerals occur as deep as the 420 stope, but in such minor amounts that they do not perceptibly increase the grade of the ore. The supergene sulfide minerals were most abundant in the west end of the 120 stope and near the east end of the 122 stope.

Genesis of the Sulfide Bodies

The sulfide bodies at the Afterthought mine were formed after the period of orogeny in late Jurassic time and before the deposition of late Cretaceous sedimentary rocks. The mineral assemblage is characteristic of the mesothermal class of mineral deposits, and from this assemblage the writer concludes that the ore bodies were formed at moderate depth, probably 1 to 3 miles. Presumably, hydrothermal solutions emanated from a parent magma somewhere below; but the nature of the magma,

Table 1. Paragenesis of epigenetic minerals at the Afterthought mine.

(Dash lines indicate that few or no data on age relationship are available.)

HYPOGENE — SUPERGENE

Rock-alteration stage — Sulfide-replacement and vein-forming state

Kaolin

Cryptocrystalline quartz

Calcite

Montmorillonite and nontronite

Radial quartz and veins of milky quartz

Pyrite

Barite

Sphalerite

Luzonite

Chalcopyrite

Bornite

Tetrahedrite

Galena

Calcite-quartz veins

Covellite

Chalcocite

Secondary chalcopyrite

Azurite

Malachite

Limonite

The Coronado Copper & Zinc Co. purchased the Afterthought property in 1946, and after new ore bodies had been located by exploratory drilling, the company constructed a 100-ton selective flotation plant. Mining was started in October 1948 and continued until July 1949, when the operation was stopped owing to a drop in the price of metals. In July 1950 the mine was reopened, and was operated continuously until August 1952. The crude sulfide ore is ground to 94 percent minus 200 mesh, and two concentrates are made by selective flotation. One, a copper-lead concentrate, is shipped to a smelter at Tooele, Utah; the other, a zinc concentrate, is shipped to a smelter at Great Falls, Montana.

Accurate records of the production of the Afterthought mine extend back to 1905. Between 1905 and January 31, 1951, the mine produced 158,525 tons of crude sulfide ore that assayed an average of about 16 percent zinc, 2.7 percent copper, 2 percent lead, 5.0 ounces of silver, and 0.04 ounce of gold.

Following is a summary of highlights in the history of the Afterthought mine:

1862: The Copper Hill claim was staked.

1873: H. M. Peck bought the property for $6,000 and named it the Peck mine.

1875: First local attempt was made to treat the sulfide ore by direct smelting in a reverberatory furnace (Tucker, 1924, p. 425).

1903: Great Western Gold Co. acquired the property and erected a 250-ton water-jacketed blast furnace, which operated successfully from 1905 to 1907 (Lindberg, 1919, p. 3).

1909: Property was acquired by the Afterthought Copper Co. (Tucker, 1924, p. 425).

1918-1919: Afterthought Copper Co. used the Harwood process to reduce the ore. In this method the sulfide was first pre-roasted in a reverberatory furnace, and then treated by flotation (Averill, 1939, p. 174). This process was not successful (Lyttleton Price, company engineer, personal communication).

1925: The California Zinc Co. acquired the property and erected an 8½-mile aerial cable tram to transport ore from the Afterthought mine to the Bully Hill mill for treatment (Averill, 1939, p. 174). This tram operated until 1927, when the mine was closed down.

1946: Coronado Copper & Zinc Co. acquired the property, and diamond-drill holes totaling several thousand feet were put down. New ore bodies were found.

1948: A 100-ton flotation plant was constructed and the mining of new ore bodies found during the 1946 diamond-drilling program was begun.

GENERAL GEOLOGY

The Afterthought mine is in Triassic volcanic and sedimentary rocks that belong to two formations—the Bully Hill rhyolite and the overlying Pit formation. The contact between the two formations, and the bedding in the Pit formation, strike about N. 45° W. and in general dip steeply northeast. The mine is located on the northeast flank of a large anticline whose axis appears to be almost horizontal. Most of the small folds in the mine area appear to be drag folds on the limb of this major structure.

Secondary cleavage strikes northwest and dips steeply southwest; it is not everywhere present. At many places throughout the East Shasta district the cleavage parallels the axial planes of minor folds.

Numerous premineral faults and shear zones are found in the mine area and more than 90 percent of them strike northwest. No postmineral faults have been recognized, but one premineral fault may have a slight amount of postmineral movement.

At least five main types of hydrothermally altered rocks occur in the mine area. Most conspicuous are the zones of carbonatized rock, or "lime rock," which in a few places are closely associated with sulfide bodies. Areas of silicified and pyritized rocks commonly occur as halos around sulfide bodies in the Bully Hill rhyolite. Sericite and several clay minerals are rather widespread.

The highest hills in the vicinity of the Afterthought mine are capped by the Tuscan tuff, a Pliocene volcanic tuff breccia (Anderson, 1933, p. 223; Anderson and Russell, 1939, pp. 231-235) that rests unconformably upon the older rocks. The Tuscan tuff has little economic significance except insofar as it masks the geology of the potentially ore-bearing older rocks.

Triassic Rocks

Bully Hill Rhyolite

General Description. The Bully Hill rhyolite was named by Diller (1906, p. 8). Later Graton (1910, p. 82) concluded that these rocks were intrusive alaskite and alaskite porphyry and discarded the geographic name "Bully Hill" as unnecessary. The writer, however, considers these rocks largely extrusive soda rhyolite and soda rhyolite porphyry and is, therefore, here restoring the name "Bully Hill rhyolite" as a formal stratigraphic term. A full discussion of the origin of the Bully Hill rhyolite, including a description of the evidence leading to the conclusions summarized above, is beyond the scope of this report, but will be given in a future report on the East Shasta copper-zinc district.

The formation name Bully Hill rhyolite is applied to a sequence of volcanic and intrusive rocks that are composed principally of quartz and sodic plagioclase with little or no potash feldspar. The Bully Hill "rhyolite" is therefore not a normal rhyolite, but rather a soda rhyolite, or quartz keratophyre. The terms soda rhyolite, and soda rhyolite porphyry will be used in this report, except when the full formation name is used.

The Bully Hill rhyolite crops out in the western part of the Afterthought mine area. It is a hard light-gray aphanitic rock that in some places contains quartz and feldspar phenocrysts. In some parts of the area the Bully Hill rhyolite is massive and has a weak cleavage; in other parts of the area it has a strong cleavage; and in still other parts it is brecciated. These differences are due partly to original variations in the rock and partly to later changes wrought by tectonic forces. The main types of Bully Hill rhyolite that occur within the limits of the Afterthought map area are described below.

Soda Rhyolite. Approximately 70 percent of the Bully Hill rhyolite shown on plate 1 is a light-gray aphanitic rock without quartz or feldspar phenocrysts. Except where strongly sheared it is very hard, and it commonly breaks with a smooth conchoidal fracture. Company engineers who have logged the core of diamond-drill holes that penetrated this soda rhyolite have described it as "hard water colored rhyolite."

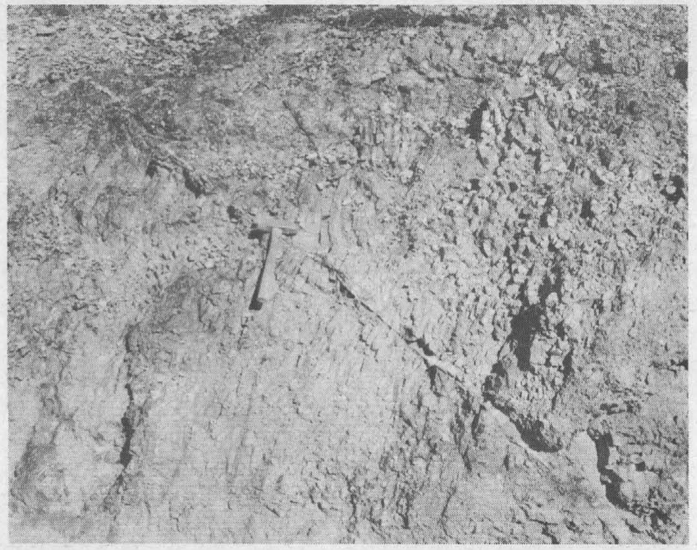


FIGURE 3. Prismatic and brecciated Bully Hill rhyolite near the Afterthought mine.

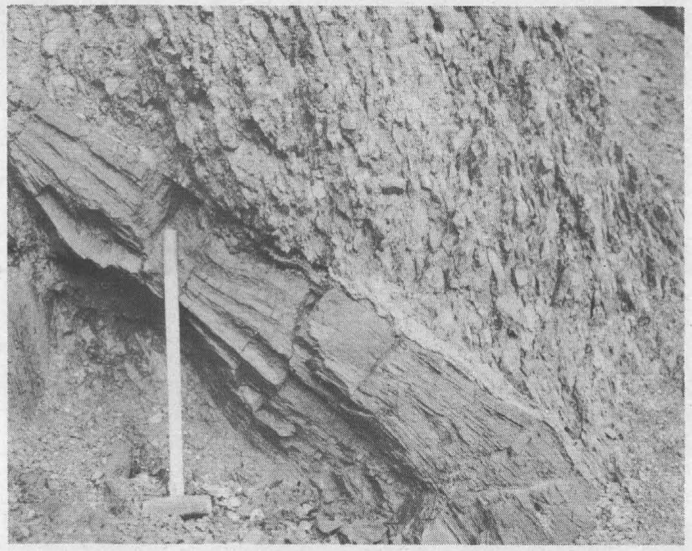


FIGURE 4. Banded sulfide ore overlain by puddinhead breccia in Copper Hill open cut.

Thin sections show the soda rhyolite to be composed primarily of a fine feltlike mass of quartz and sodic plagioclase, with a few larger grains of albite as much as 0.1 mm in diameter. Most of the soda rhyolite is seen under the microscope to be somewhat altered to sericite and clay minerals, and the degree of alteration is more or less proportional to the intensity of shearing.

Soda Rhyolite Porphyry. About 30 percent of the Bully Hill rhyolite in the Afterthought mine area has phenocrysts of quartz or feldspar in a light-gray aphanitic groundmass, and is mapped as soda rhyolite porphyry. The phenocrysts range in size from 1 to 4 mm and are irregularly distributed. In some areas the porphyry contains several phenocrysts per square inch of rock surface, whereas in other areas it contains an average of only one or two phenocrysts per square foot of rock surface.

Contacts between the soda rhyolite facies and the soda rhyolite porphyry facies are sharp in some places but more commonly they are gradational. Possibly those bodies of soda rhyolite porphyry whose contacts are sharply defined were separate flows or intrusions, whereas those with gradational borders may have formed in the inner part of a thick body of silica-rich lava where the rate of cooling was slow enough to permit the growth of phenocrysts.

Prismatic Structure. Small prismatic columns occur at many places in both the soda rhyolite and the soda rhyolite porphyry. Most columns are 1 to 2 inches in diameter and are four-, five-, or six-sided. In some areas the columns are fairly straight, but in other areas they are crooked or irregular. In some places the straight columns can be traced for a distance of 10 feet, but the crooked or irregular columns commonly fade out or grade into a breccia within 2 or 3 feet. Most columns within a given outcrop are oriented about the same direction, but in another outcrop only a few feet away the columns may be oriented in a different direction. Although the prismatic structure is developed in both the soda rhyolite and the soda rhyolite porphyry, the structure is most common in the uppermost part of the soda rhyolite, within about 200 feet of its contact with the overlying Pit sedimentary rocks. The prismatic structure is probably the result of contraction on cooling of the crystallizing rock.

Breccias. Four main varieties of breccia are found in the Bully Hill rhyolite of the Afterthought mine area. One of these is considered to be volcanic in origin, two others are probably both intrusive and tectonic, and the fourth appears to be tectonic. These varieties are designated as: volcanic breccia, prismatic breccia, tectonic and volcanic puddinhead breccia, and tectonic breccia.

The volcanic breccia is a coarse soda rhyolite breccia that consists of angular fragments of soda rhyolite as much as a foot in diameter, surrounded by soda rhyolite matrix. It crops out along Little Cow Creek in the southwestern part of the map area. The fragments are commonly closely packed and constitute the bulk of the rock. They are diversely oriented and are of two types of rock, flow-banded soda rhyolite and massive soda rhyolite. The banding in the fragments is evidently the result of a color variation, as no difference in grain size between the adjacent bands, or layers, is apparent in hand specimens.

The boundaries of this breccia are in some places sharply defined, but in other places the breccia grades into large areas of unbrecciated soda rhyolite, either flow-banded or massive. Although examination of outcrops of this breccia yielded no certain clue as to its origin, the writer interprets it as volcanic flow breccia.

The prismatic breccia is seen at many places in the mine area as patches of soda rhyolite with prismatic structure. These patches form islands in a sea of brecciated soda rhyolite (fig. 3). The prismatic structure fades into breccia, and many of the fragments in the breccia have the same size, cross-sectional outline, and composition as the adjacent columns. It seems obvious that this breccia formed when the small, brittle columns were broken up by mechanical processes into a jumbled mass of fragments. The breaking may have occurred while the soda rhyolite was being intruded, or later as a result of tectonic stress. The writer believes that most Bully Hill rhyolite with prismatic structure is intrusive because in some parts of the mine it appears to cut across beds of the Pit formation.

a roll in the structure similar to that which localized the 420 ore body. The 122, 420, and AU 40 sulfide lenses all plunge southeast at a very low angle.

The 120, 220, AS 6, and AU 5 ore bodies are localized in sedimentary rocks above soda rhyolite benches. These ore bodies are not in contact with the soda rhyolite, but are commonly separated from it by several feet of relatively barren sedimentary rock that dips into the benches. The soda rhyolite on the 200 and 300 levels, down dip from the 120, AS 6, and 220 ore bodies, is locally sheared, and the shear zones contain disseminations and stringers of pyrite and chalcopyrite. Thermal solutions probably ascended along these shear zones and into the easily accessible beds of shale that dip into the soda rhyolite benches. Why sulfide bodies were formed when the solutions reached the shale is not evident. The chemical composition of the calcareous shale may have been an important factor, but a fold in the sedimentary rock about 75 feet above the 120 and AS 6 ore bodies may also have been influential.

The AU 5 ore body is in sedimentary rock and lies in a crude synclinal structure that plunges southeast at an angle of about 35°. Diamond-drill hole AU 44, located 60 feet northwest of the AU 5 ore body, penetrated soda rhyolite at a relatively shallow depth, and from this information the writer infers that a gently dipping contact with soda rhyolite may project into the area beneath the AU 5 ore body.

The 412 sulfide lenses are in shale along the hanging wall of a premineral fracture. The reason for the localization of the individual lenses of sulfide is not known.

The largest body of sulfide in the Afterthought mine was the Copper Hill No. 1 ore body, now mined out. This ore body appears to have had a length of about 400 feet, a width of at least 125 feet, and a maximum thickness of 35 feet. The Copper Hill No. 1 ore body, now exposed only in the glory hole and for a short distance on the 100 level, was in shale in the hanging-wall side of the Main fault near a soda rhyolite contact. It has a steep southwest dip that is essentially parallel to the dip of the contact and also parallel to bedding in the shale. The ore, where exposed in the glory hole, is banded parallel to bedding in the shale host rock (fig. 4). The bottom of the ore body is apparently a short distance above the 200 level where the ore zone intersects the Main fault. According to the writer's interpretation, sulfide solutions rose along the Main fault, and in the vicinity of the soda rhyolite wedge they fed upward into bedded shale and sheared soda rhyolite. This is a structurally favorable area because the beds dip steeply southwest into the Main fault, and thus were easily accessible to the mineralizing solutions.

The Copper Hill No. 2 ore body was also in the hanging wall of the Main fault and replaced a portion of the soda rhyolite wedge. Only the remnant of the top of this ore body is now exposed in the glory hole; at this exposure it appears to be a very pyritic sulfide body about 20 feet wide that comes to a rather blunt top beneath two intersecting premineral fractures. A polished section of the sulfide collected from the glory-hole exposure is composed of more than 85 percent pyrite, less than 5 percent chalcopyrite, and about 10 percent gangue. A cross section drawn by F. W. Stewart in 1946 suggests that the area below the glory-hole exposure was stoped; if so, it must be assumed that a higher percentage of chalcopyrite was present in the stoped area. Hence, the pyrite seen in the glory-hole exposure is here considered as part of a pyritic halo that surrounded a copper ore body. The highly pyritized soda rhyolite in the hanging wall of the Main fault on the old 100 level may be part of the same pyritic halo. The small lens of sulfide exposed in the No. 7 adit is in the hanging wall of the Main fault and has a structural environment similar to that of the Copper Hill No. 2 ore body.

Mineralogy and Paragenesis

The primary sulfide minerals composing the ore bodies of the Afterthought mine are, in approximate order of decreasing abundance, sphalerite, pyrite, chalcopyrite, galena, tetrahedrite, bornite, and luzonite. Gangue minerals are calcite, quartz, and barite; supergene minerals are covellite, chalcocite, chalcopyrite(?), azurite, malachite, and limonite.

The pyrite is in the form of cubes, pyritohedrons, and anhedral grains that range in size from 0.05 mm to 5.0 mm. Where the mineral is abundant, as it commonly is in and near ore bodies that replace soda rhyolite, the individual grains may be so closely packed that in polished section they appear as large patches of solid pyrite. On the other hand, pyrite in high-grade banded zinc ore appears in polished sections as sparse, small grains in large areas of sphalerite, or as very small grains that are grouped together, with much interstitial material, to form pyrite-rich layers. Pyrite also occurs as disseminated grains scattered through large areas of soda rhyolite, and as granular layers a fraction of an inch thick that parallel the bedding in shale. The pyrite is commonly strongly corroded by sphalerite, but is not much replaced by chalcopyrite.

The sphalerite is dark gray and probably rather high in iron. In polished section it appears as large patches that include both idiomorphic and irregular areas of all other sulfide minerals. Sphalerite has commonly replaced pyrite; and in some polished sections it has a mottled appearance, owing to the presence of numerous small, rounded, crudely alined blebs of chalcopyrite. Such blebs of chalcopyrite are interpreted as exsolution bodies formed by the unmixing of a solid solution of sphalerite and chalcopyrite. Much of the banded sulfide ore in polished section shows sphalerite to contain very numerous, rather small, irregular, elongated patches of galena, or tetrahedrite, or both minerals together. These patches are all elongated in the same direction, and are largely responsible for the finely banded appearance of the ore. In a few places sphalerite appears in polished section as islands in a sea of galena, but this relationship is not common because sphalerite is generally much more abundant than galena.

Chalcopyrite appears in polished section as interstitial fillings around pyrite grains; as irregular patches in sphalerite; as large areas with islands of both pyrite and sphalerite; as small exsolution bodies in sphalerite; as small patches in bornite; and, rarely, as discontinuous septa between galena and sphalerite. Chalcopyrite also occurs as small disseminated grains in gangue and in soda rhyolite. In one polished section of ore from the 220 stope, chalcopyrite appears as blades in bornite and is closely associated with covellite. The writer is not certain whether this is supergene chalcopyrite or whether it indicates an exsolution intergrowth of chalcopyrite and bornite that

Structural Control of the Ore Bodies

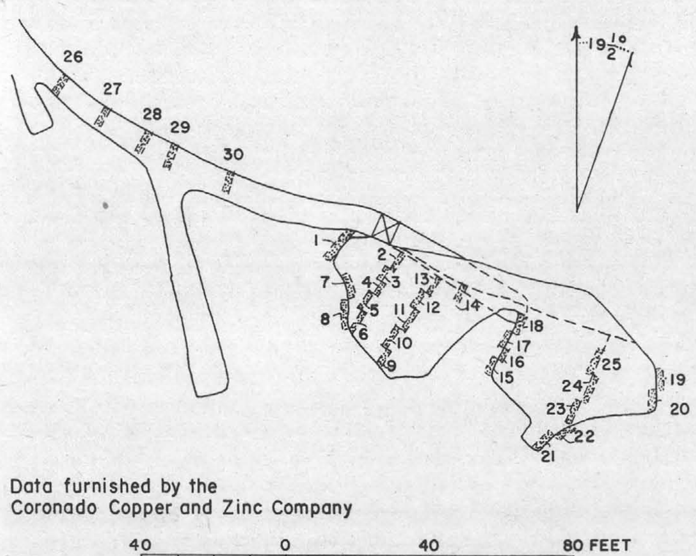
Four structural features have played important parts in the localization of ore bodies at the Afterthought mine. They are shear zones in the Bully Hill rhyolite that dip southwest; the irregular benchlike contact between the Bully Hill rhyolite and the Pit formation; the Main fault and the 412 fault; and drag folds in the sedimentary rocks and bows, or convexities, in steep fault contacts between soda rhyolite and shale.

The ore bodies below the 400 level are in sheared and fractured zones in the soda rhyolite. These shear zones strike northwest and dip southwest; the overlying shale contact and the Main fault strike northwest but dip northeast, and thus intersect and offset the shear zones. The ore bodies are below these intersections. The lower part of the 450 ore body is a replacement of soda rhyolite, whereas the upper part appears to be a replacement of shale. The southeast end of the 450 ore body is controlled by a fold in the overlying shale that plunges about 40° SE., and the top of the 450 ore body at its northwest end is bounded by the Main fault. The unusually high grade of the 450 sulfide body may be a result of concentration of the mineralizing solutions in that area, caused by the two overlying structures.

The Afterthought open-cut sulfide lens is in a soda rhyolite shear zone similar to the shear zones found below the 400 level. Both the shear zone and the sulfide lens end beneath the Northeast fault, and it is thought that the fault was a rather impervious wall which deterred the rising thermal solutions sufficiently to cause them to react with and replace the underlying sheared and fractured soda rhyolite. The No. 2 adit and the 400 southeast drift explored lower parts of the Afterthought shear zone, but the records do not show whether or not sulfide was encountered. A lenticular body of shale bounded by faults was found in the No. 2 adit, and it is possible that a body of sulfide was localized in this shale below the level of the No. 2 adit.

The 420, AU 40, and 122 ore bodies are rather narrow lenticular replacement bodies localized along irregular, steep fault contacts between soda rhyolite and shale. The sulfide formed mainly as a replacement of sheared and broken shale, but the soda rhyolite and the discontinuous screen of lime rock between the shale and the soda rhyolite was replaced to some extent by sulfide stringers and disseminations. The dip of the fault contact between shale and soda rhyolite makes a roll at several places, from northeast to southwest and back again; the sulfide bodies occur in places where this contact is convex to the southwest and soda rhyolite overhangs shale. In such areas the shale was apparently more fractured and therefore more easily accessible to mineralizing solutions. In places where the contact is convex to the northeast, a layer of mixed calcite and quartz, or, rarely, a thin band of sulfide, marks out the mineralized zone. The top of the 420 ore body is controlled in part by drag-folded beds in the sedimentary rocks (fig. 8). The 122 sulfide body is localized along a steep, southwest-dipping fault contact between soda rhyolite and shale, but several feet below it is a soda rhyolite bench. The shale beds are much broken and sheared, and dip into the soda rhyolite bench. The top of the 122 ore body may be partly controlled by drag-folded beds at the northwest end. The AU 40 sulfide lens is localized along

Sample number	Horizontal width	% Zn.	% Cu.	% Pb.	Oz. Au.	Oz. Ag.
1	9.6′	14.0	1.68	1.1	0.05	4.0
2	4.6′	28.0	3.50	3.8	0.04	5.4
3	5.4′	32.2	2.27	1.9	0.04	7.0
4	3.7′	19.6	1.55	3.0	0.04	6.2
5	4.6′	4.6	2.82	2.4	0.04	5.2
6	6.0′	1.6	2.54	0.8	0.02	7.6
7	8.1′	1.8	1.11	0.6	0.01	0.8
8	8.1′	1.2	2.58	0.3	0.02	4.4
9	6.0′	7.7	2.30	0.2	0.02	9.7
10	6.0′	20.0	3.25	2.4	0.04	7.7
11	6.0′	3.5	6.72	4.0	0.01	40.2
12	6.0′	0.3	5.73	1.3	0.03	12.4
13	7.0′	20.5	5.80	2.2	0.13	13.6
14	4.7′	10.1	3.15	0.7	0.04	6.2
15	3.8′	8.4	3.40	0.5	0.06	9.6
16	5.1′	15.3	3.28	2.0	0.08	6.6
17	6.4′	35.1	1.10	5.8	0.08	5.5
18	6.4′	27.0	0.95	4.9	0.03	4.4
19	6.0′	14.6	1.68	2.4	0.08	5.6
20	6.1′	22.7	2.46	1.1	0.08	7.0
21	6.2′	28.2	1.30	2.3	0.05	5.5
22	6.7′	19.2	5.60	1.5	0.04	7.2
23	7.0′	30.7	11.03	4.5	0.06	11.9
24	7.0′	31.2	3.58	5.0	0.07	13.7
25	7.0′	31.2	3.80	1.9	0.08	13.9
26	2.7′	10.0	0.55	0.6	0.03	1.6
27	4.0′	27.0	2.46	2.6	0.06	7.4
28	3.0′	25.3	3.30	6.6	0.06	18.0
29	4.8′	25.0	2.70	3.3	0.06	19.8
30	6.8′	22.5	2.05	4.3	0.06	14.4



Data furnished by the Coronado Copper and Zinc Company

FIGURE 9. Assay map of the 220 ore body.

Puddinhead breccia is a local term applied by miners to rock that consists of angular to sub-rounded soda rhyolite fragments in a matrix of dark-gray to black, soft, commonly slickensided argillaceous material (fig. 4). Many of the soda rhyolite fragments have the same size and cross-sectional outline as prismatic columns in nearby areas, and they seem to be fragments of columns.

A thin section of the shaly matrix of the puddinhead breccia shows that its dark color results from the presence of a considerable amount of carbonaceous material. Other constituents of the matrix are quartz and clay minerals. The writer concludes that the matrix is sheared mudstone.

The puddinhead breccia is distributed irregularly and occurs only in areas very near, but not always adjacent to, shale of the Pit formation. Its contacts with the shale are commonly sharp, and appear to be faults of small displacement. Observed contacts between puddinhead breccia and massive soda rhyolite also are faults, but contacts with prismatic breccia are commonly gradational.

The largest observed body of puddinhead breccia is on the 400 level a short distance northeast of the No. 1 shaft. Here it has an outcrop width of 40 feet and a strike length of at least 140 feet. Other areas of puddinhead breccia occur on the surface in the glory hole and on the 300 level near the No. 1 shaft.

The tectonic breccia occurs north of the mine buildings (pl. 1); it consists of sparse fragments of hard massive soda rhyolite in a matrix of softer sheared soda rhyolite. The fragments are subrounded and slightly elongate and average less than an inch in diameter. They are somewhat lighter in color than the sheared matrix and therefore stand out in rather sharp contrast to it; except for the lack of platy minerals in the fragments, there is no difference in composition between fragments and matrix. The platy structure of the matrix fades into the fragments; it does not wrap around them. Observed contacts between this type of breccia and the unbrecciated rocks around it are gradational. Brecciated zones cross contacts between soda rhyolite and soda rhyolite porphyry.

Origin of the Bully Hill Rhyolite. The origin of the Bully Hill rhyolite, like the origin of the Balaklala rhyolite in the West Shasta copper-zinc district, has long been a subject of controversy. Diller (1906, p. 8) described the Bully Hill rhyolite as a series of flows alternating with tuffs that dip beneath shale of the Pit formation; but he also states that it locally cuts the shale and envelopes its fragments. Fairbanks (1892, p. 32) likewise had noted the tuffaceous character of the rhyolite, and evidently he also considered it to be mainly extrusive.

Graton (1910, p. 82), after larger-scale studies, concluded that the "Bully Hill rhyolite" was intrusive into the surrounding rocks, and he renamed it "alaskite" and "alaskite porphyry." Most geologists who have worked in the area since Graton have followed his views (Boyle, 1915, p. 69; Hinds, 1933, p. 107; Stewart, 1946; Wisser, 1946).

The writer believes that most of the Bully Hill rhyolite originated as an accumulation of siliceous volcanic rocks extruded into the sea immediately prior to the deposition of the Pit formation. Moreover, the numerous beds of rhyolitic tuff interbedded with shale of the Pit formation are evidence that volcanism continued during Pit time.

Associated with the various extrusive facies of the Bully Hill rhyolite are several intrusive bodies, one of which is the prismatic soda rhyolite that intrudes the lower part of the Pit formation in the Afterthought mine area. The presence of these intrusive bodies does not invalidate the extrusive origin thesis proposed above, because feeder dikes, sills, and other intrusive forms are to be found in almost all volcanic areas. The local intrusions of soda rhyolite that occur in the lower part of the Pit formation are here regarded as shallow intrusive manifestations of the volcanic activity that continued while Pit sediments were burying most of the old volcanic field (pl. 5, secs. AA′ and BB′).

Age and Thickness. The Bully Hill rhyolite has yielded no fossils, but from its relationships with adjacent rocks it is considered to be middle or late Triassic in age.

The thickness of the Bully Hill rhyolite in the Afterthought mine area is probably about 1,100 feet. This thickness is deduced from exposures about half a mile southeast of the Afterthought mine where the Bully Hill rhyolite lies with apparent conformity between the older Dekkas andesite and the younger Pit formation. Both contacts dip northeast at a steep angle, and the thickness of the intervening soda rhyolite is approximately 1,100 feet.

Pit Formation

General Description. The shales and tuffs that crop out in the northeast portion of the Afterthought map area belong to the Pit formation. The formation was first described by Smith (1894, p. 592), who called it the Pitt shales. Later, Diller (1906, p. 4) renamed it the Pit formation, and described it as being composed largely of dark-gray shale, thin-bedded sandstone, and many layers of tuff, and conformably underlying the Hosselkus limestone on the east and overlying the andesites and rhyolites of the volcanic belt on the west.

The writer is in agreement with Diller's statement, and would add that the tuff layers are especially abundant in the lower 500 feet of the Pit formation. It is this tuffaceous lower part that crops out in the Afterthought mine area; tuff underlies a considerably larger part of the mapped area than shale, mudstone, and siltstone (hereafter grouped as shale for convenience) (pl. 1).

Shale. The shale of the Pit formation is medium gray to black and in the Afterthought mine area it is indistinctly bedded. It effervesces slightly in dilute hydrochloric acid. It commonly has a prominent secondary cleavage that in some places parallels bedding but more commonly does not. Under the microscope the shale is seen to consist predominantly of very fine-grained quartz and kaolin, with dark-gray to black carbonaceous material, and a few angular grains of detrital quartz 0.1 mm and less in diameter. Calcite and clay minerals are present as alteration products. The shale was especially hospitable to mineralizing solutions, as shown by the fact that most of the ore bodies in the Afterthought mine are replacements of shale.

Tuff. More than half of the Pit formation underlying the Afterthought mine area is tuff. The tuff occurs as beds interlayered with shale, and commonly the individual beds of tuff differ slightly from one another in color, grain size, and composition. The most common variety of tuff is light gray and poorly bedded, and consists mainly of fine chlorite, crystals of quartz and feldspar, and small rock fragments, generally less than half an inch in diameter. Some of the tuff beds contain shale fragments up to a foot long. The tuff in a few of the beds is well layered, sandy or gritty looking, and is composed almost entirely of broken crystals and small particles of rock.

Most of the tuff in the Pit formation is of rhyolitic composition; but a relatively small percentage is dark gray or brown, does not contain quartz crystals, and is probably close to andesite in composition. The best exposures of tuff occur near the northern edge of the mapped area, along the road to the Donkey mine.

In thin section the rhyolite tuffs are seen to consist of broken fragments and whole crystals of quartz and plagioclase in a cryptocrystalline groundmass of fine chlorite and calcite. In some thin sections the ghostlike outlines of probable glass fragments can be seen, but the rock is so altered that precise identification of these fragments is not possible.

Age and Thickness. The Pit formation was indicated to be of Middle and Late Triassic age by J. P. Smith (1914, p. 4). The age assignment was based on fossils collected from the upper part of the formation.

A thickness of about 2,000 feet was assigned to the Pit formation by Diller (1906, p. 4). A thickness of about 500 feet is exposed in the Afterthought mine area.

Tertiary Volcanic Rocks

Tuscan Tuff

The top of the ridge that lies at the eastern edge of the Afterthought mine area is covered by the Tuscan tuff, a tuff breccia of Pliocene age, capped in some places by flows of basalt. The Tuscan tuff is an extensive formation that crops out along the eastern side of the Sacramento River valley. It has been well described by Anderson (1933) and Anderson and Russell (1939), who studied it on a regional scale.

Talus and Rock Mantle

The bedrock geology in the Afterthought mine area is masked by a thin cover of talus and soil on many hillslopes. The presence of this material makes correlation of geology between outcrops difficult, especially in the eastern part of the map area, where the underlying rock consists of folded lenticular beds of shale and tuff.

ROCK ALTERATION

Four alteration processes have affected the rocks in the Afterthought mine area. The processes are carbonatization sericitization, pyritization, and silicification. Pyritization, silicification, and carbonatization appear to be genetically related to the sulfide mineralization, whereas sericitization apparently occurred at a somewhat earlier date.

Carbonatization. Several tuffaceous layers of the Pit formation and small masses in the Bully Hill rhyolite have been carbonatized, and the resulting calcareous rock is known locally as lime rock. On the surface the lime rock derived from tuff forms bold, dirty-gray outcrops, and it contains rather coarse calcite crystals that have incompletely replaced the various constituents of the tuffaceous host rock. The amount of calcite in the rock is extremely variable, and every gradation from slightly carbonatized tuff to rock composed of more than 90 percent calcite can be found. The lime rock occurs in elongate zones that generally parallel the bedding; some of the zones are as much as 100 feet wide and several hundred feet long.

Smaller zones of lime rock are found between sulfide ore bodies and soda rhyolite wall rock; in such places the calcite seems to have replaced soda rhyolite, and although these zones are generally much more limited in extent than the zones of carbonatized tuff, they are probably more important as indicators of ore.

Thin sections of the lime rock show that the calcite occurs as subhedral grains 1 to 5 mm in diameter and as irregular patches as much as several centimeters in diameter. Calcite replaces all the principal constituents of the rock—quartz, kaolin, and feldspar—apparently without regard for mineral boundaries. It has been replaced in turn by later quartz and pyrite, and veinlets of clay minerals cut across grains of calcite.

Sericitization. Almost all rocks in the mine area have been slightly sericitized, and where the rocks are strongly sheared this type of alteration is prominent. The sericitic alteration is not restricted to the mineralized areas.

Pyritization and Silicification. The Bully Hill rhyolite has been pyritized and silicified along some shear zones and in a few areas where the rock is broken and brecciated. The pyritized areas are somewhat more extensive than the silicified areas, but the two are closely related. The pyrite occurs as separate subhedral crystals that are commonly arranged in layers or bands parallel to the cleavage in the rhyolite. In silicified rock the quartz occurs as radial growths that fan out from a center of granular quartz, or from a pyrite crystal, like spokes from the hub of a wheel.

Copper-zinc ore bodies that occur in the soda rhyolite, principally those bodies below the 500 level, are surrounded by a halo of heavily pyritized rock a few feet to a few tens of feet thick. The weakly pyritized and silicified soda rhyolite on the 200 and 300 levels is in a shear zone located down dip from the 120, 122, and 220 ore bodies, and this zone may be a channel along which the sulfide-bearing solutions traveled.

STRUCTURE

Secondary Cleavage

Secondary cleavage, as distinguished from parting along bedding planes, is present in both the Bully Hill rhyolite and the Pit formation, but it is not equally developed in all places. Most commonly it consists of approximately parallel cleavage planes spaced a few millimeters or a few tenths of a millimeter apart, with platy minerals developed along the cleavage plane. In some zones the cleavage planes are so closely spaced and platy minerals, principally sericite, are so abundant that the rock has been called a schist. Contrasted with these strongly sheared zones are large areas where the rocks have only an incipient cleavage, or no cleavage at all. Every gradation between the two extremes can be found in the Afterthought mine area.

The cleavage strikes northwest and dips an average of about 70° SW. It is parallel to the axial planes of minor folds in a few places in the mine area and in many places throughout the East Shasta district. In general, cleavage

the host rock. Locally the edges of sulfide bodies replaced folded shale beds and are partly controlled by them. In such places the banding in the sulfide is concordant with the shape of the folded beds, and small drag folds may be traceable in the sulfide for several inches inward from the shale contact (fig. 8). Examples of this kind of banding were seen near both ends of the 420 ore body, and at the southeast end of the 450 ore body.

Large horses of unreplaced shale in the sulfide bodies are not common, but thin septa of unreplaced shale are present at many places along the walls of sulfide bodies. Commonly these septa are only a fraction of an inch thick, whereas the intervening layers of banded sulfide have a thickness several times as great. Because of their continuity and the absence of disseminated sulfide minerals, these marginal shale septa are easily mistaken for the true wall of an ore body.

Contacts between sulfide and soda rhyolite host rock in many places have the same types of irregularities as contacts between sulfide and shale described above, but they are more commonly gradational than sharp. Also, the banding in sulfide that replaces soda rhyolite parallels cleavage rather than bedding; and in a few places where the host soda rhyolite is weakly sheared the massive sulfide is not banded.

Where closely spaced stringers or disseminations of sulfides have replaced sheared soda rhyolite or shale the

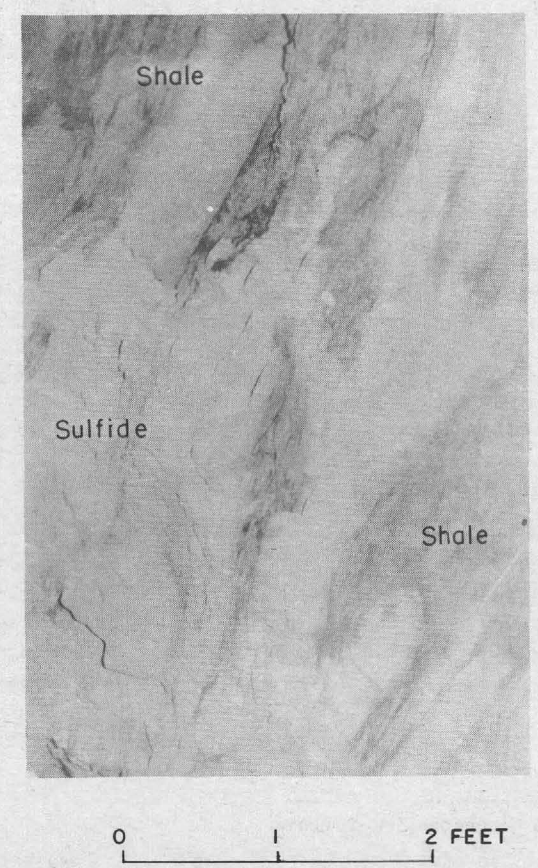


FIGURE 7. Photograph showing interfingering relationship between sulfide and shale at the northwest end of the 120 stope.

FIGURE 8. Sketch showing the top of the 420 ore body near its northwest end where it is controlled by drag-folded beds.

deposits are commonly not rich enough to be considered as ore. This type of sulfide deposit is most commonly found in sheared soda rhyolite, and intersections of these mineralized shear zones with shale contacts are favorable places to look for massive sulfide ore. Some zones of closely spaced sulfide stringers in shale or in lime rock have an average grade high enough to make them minable, and in some places these zones pass into bodies of massive ore within a short distance along strike.

The average assay of all ore mined up to January 31, 1951, was approximately 16 percent zinc, 2.7 percent copper, 2 percent lead, 5.0 ounces of silver, and 0.04 ounce of gold. This average represents the over-all grade of ore mined from about 13 separate ore bodies. The grade of the 120, 122, 220, and 420 ore bodies approximated this average, but the grade of the 450 ore body was much higher, whereas the grade of ore bodies in shear zones in soda rhyolite was lower. Furthermore, the grade of ore within each sulfide body is not uniform. As a general rule the richest ore is near the center of the sulfide lenses and the poorest is near the edges, but the type of rock replaced is also a controlling factor. For example, the zinc content of ore that has replaced shale is almost always higher than the zinc content of ore that has replaced soda rhyolite, but the copper content is about the same in both. Figure 9, an assay map of the 220 ore body, illustrates the changes in grade that are common within ore bodies of the Afterthought mine. The sulfide has replaced shale except near the southwest corner of the ore body, where partly carbonatized soda rhyolite was the host rock. The assays of zinc are lower in samples 6, 7, 8, and 9 than in samples 3 and 4 taken near the middle of the stope, but the assays of copper are not significantly different. Sulfide represented by samples 6, 7, 8, and 9 replaced soda rhyolite and lime rock, whereas sulfide represented by all other samples replaced shale and lime rock.

The metasomatic origin of the sulfide deposits is indicated by banding in the ore that parallels bedding where shale is the host rock and parallels cleavage where soda rhyolite is the host rock; by preservation in the banded ore of drag folds and monoclinal flexures inherited from the host rock; by the presence of residuals of unreplaced shale within ore bodies—the bedding shows that these shale residuals are oriented parallel to each other and parallel to bedding in shale adjacent to the ore bodies; by interfingering, or sawtooth relationship of sulfide and shale at the top, bottom, and ends of ore bodies; by gradational contacts between some ore bodies and country rocks, chiefly soda rhyolite; and by the presence of disseminated sulfide minerals in altered soda rhyolite and in lime rock.

Outlines of most of the 15 known ore bodies in the Afterthought mine are shown in plan on plates 1, 3, 4, and 6 and in section on plates 5 and 6 and in figure 5. For convenience, all the ore bodies have been given a name or a number. The Afterthought, Copper Hill No. 2, 600, 700a, and 700b, and 800 ore bodies occur in soda rhyolite; whereas the Copper Hill No. 1, 120, 122, AS 6, 220, 412, 420, 450, AU 5, and AU 40 ore bodies occur in shale or along the contact between soda rhyolite and shale. If ore bodies existed in the Main fault zone between the 200 and the 400 levels they were probably in shale. The minable ore bodies range in size from a few hundred tons to more than 50,000 tons. In addition to the sulfide bodies of minable size and grade there are numerous smaller lenses of sulfide and bodies of low-grade disseminated sulfide.

Characteristics of the Ore

Sulfides are present in the Afterthought mine as massive ore that is commonly banded owing to thin layers of differing composition; as stringers that replace sheared soda rhyolite or shale; as disseminated grains in soda rhyolite or shale; and, rarely, as small veinlets that fill fractures.

The massive ore and banded ore consist of fine-grained, intimate mixtures of pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, bornite, calcite, quartz, and barite, with minor amounts of luzonite, covellite, and chalcocite. The bands or layers in the banded sulfide ore average a small fraction of a millimeter in thickness, but a few bands are as much as 2 mm thick. Calcite and quartz occur, in some places, as tiny veinlets oriented about normal to the banding in the sulfide; but more commonly these minerals are intimately mixed with the sulfide, or occur as veins along the walls of sulfide bodies, especially along contacts between sulfide and soda rhyolite. Barite is not visible in hand specimens of the ore.

Contacts between massive banded sulfide and shale host rock are everywhere sharp, and no halo of disseminated or low-grade sulfide is present. The same condition holds, in a few places, for contacts between massive sulfide and soda rhyolite host rock. More commonly, however, the massive sulfide that replaces soda rhyolite in the lower levels of the mine is surrounded by a halo or casing of pyrite. According to Stewart (1946, p. 15), replacement of the host rock is nearly complete at the cores of these ore bodies, but the degree of replacement decreases in all directions away from the core, and massive sulfide grades outward into zones of numerous parallel stringers of barren pyrite. Where zones of lime rock lie adjacent to massive sulfide, as near the southwest sides of the 120, 220, and 420 ore bodies, the contacts between massive sulfide and lime rock are gradational and irregular.

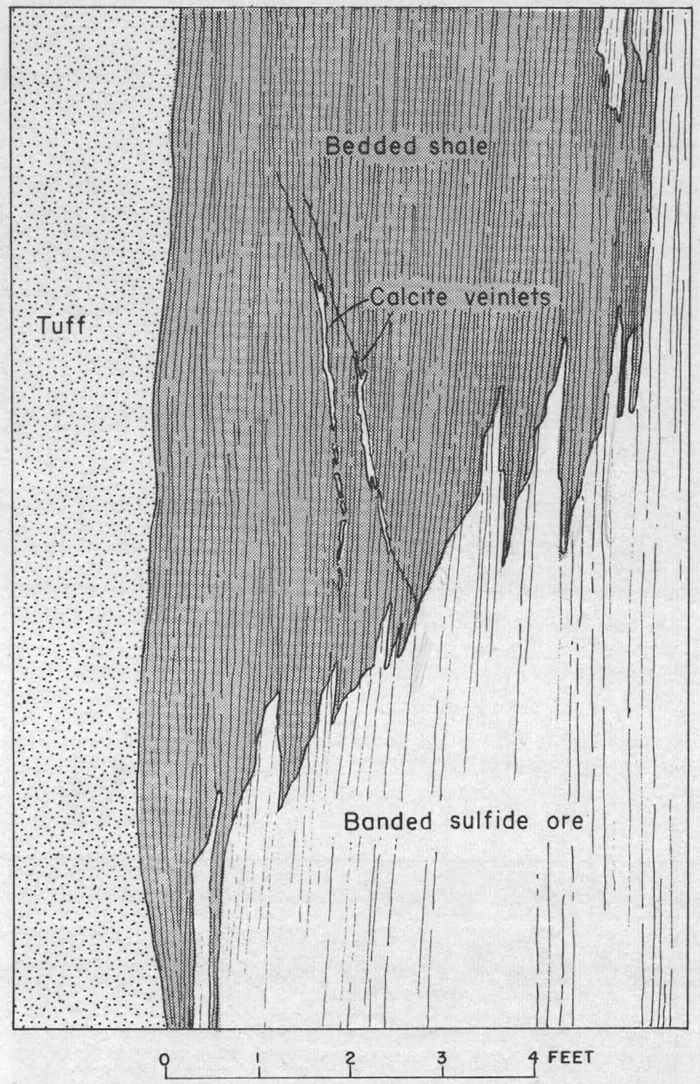


FIGURE 6. Sketch showing sawtooth relationship between sulfide and shale at the northwest end of the 412 stope.

In many places the contact between massive sulfide and shale at the edges of sulfide bodies has, in cross section, a sawtooth form. In such places, the shale layers increase in width at the expense of the sulfide until the sulfide layers pinch out in sharp ends (fig. 6). Commonly these marginal sulfide layers are banded, and the banding tends to parallel the edges of an individual sulfide layer all the way to its apical contact with the shale.

In other places at the edges of the sulfide bodies the contact between sulfide and shale host rock may be described as interfingering; that is, the shale widens at the expense of the sulfide, but the ends of the sulfide layers are blunt and rounded rather than sharp (fig. 7). The banding in sulfide parallels the length of the fingers but is truncated by the contact at the blunt ends of the fingers. The banding parallels either bedding or cleavage in the shale host rock, and evidently was inherited from

is most strongly developed in the incompetent tuffs and shales. Very siliceous rocks, especially the siliceous soda rhyolite with prismatic structure, commonly have no cleavage at all.

Folds

The shales and tuffs of the Pit formation were locally deformed during the intrusion of soda rhyolite and were later folded and squeezed during a period of orogeny. The folds that resulted are grouped into three general types: overturned and recumbent folds, irregular asymmetrical folds, and small asymmetrical drag folds. The asymmetrical drag folds can be seen at several places in the mine area, but folds of the other two types are indicated only by the attitude of the bedding in various places.

Overturned and recumbent folds in the sedimentary rocks near the contact between the Bully Hill rhyolite and the Pit formation have wave lengths that range from a few tens to a few hundreds of feet. These folds apparently formed in two stages. In the first stage, very viscous soda rhyolite pushed its way into incompetent sediments of the Pit formation. The intrusion was partly concordant and partly discordant: where concordant, the sediments were wrapped around the intruding rhyolite; where discordant, the sediments were cut or torn by the rhyolite. The second stage in the formation of these folds occurred in probable late Jurassic time, when the rocks were tilted and folded into their present form. The massive soda rhyolite acted more or less as a buttress, with the result that sediments near the soda rhyolite contact were squeezed and contorted into disharmonic structures.

Wave lengths of the irregular asymmetrical folds average less than a hundred feet. These folds are in harmony with the structural pattern of the region, and they apparently formed during the period of deformation in probable late Jurassic time. Overturned and recumbent folds and irregular asymmetrical folds are illustrated in cross section AA′ on plate 5.

Asymmetrical drag folds exposed in the mine are developed on the northeast flank of a large anticline. Wave lengths of the folds range from 3 to 12 feet. Axes of these folds plunge either northwest or southeast at angles of as much as 25°. The best folds can be seen in the No. 10 adit near the top of the B raise, on the 100 level a few feet west of the collar of diamond-drill hole AU 21, and in the No. 4 adit near the portal (pl. 4).

Faults and Shear Zones

Four main classes of faults are found in the mine. They are, from oldest to youngest: (1) low-angle thrust faults, (2) high-angle normal faults and shear zones that dip southwest, (3) normal faults that strike northeast, and (4) faults that dip northeast. All the faults are premineral in age, and more than 90 percent of them strike northwest.

Low-Angle Thrust Faults. Most of the low-angle thrust faults dip southeast or southwest at angles ranging from 10° to 25°. The best exposures of these faults are in the soda rhyolite on the 200 and 300 levels, where the faults are clearly younger than the cleavage, but are offset by high-angle faults. Calcite and quartz are found along some of the low-angle faults, and along nearly horizontal fractures that occur at a few places in the mine. The low-angle thrust faults and fractures are the result of thrust movements during the later stages of orogeny. The amount of displacement along most of these faults is probably not more than a few feet.

High-Angle Normal Faults and Shear Zones that Dip Southwest. Faults of this class strike northwest and have dips that range from vertical to 45° SW. In places these faults are closely spaced, and the rock between the faults is intensely sheared. These shear zones occur in soda rhyolite, in sedimentary rock, and locally along the contact between soda rhyolite and sedimentary rock. They can be seen on every level in the mine but are most prominent in the soda rhyolite on the old 100 level northeast of the No. 1 shaft, and on the 500, 600, 700, and 800 levels. In all these places the shear zones are strongly mineralized. On the 200, 300, and 400 levels the shear zones are weakly mineralized. The most important of these faults and shear zones are the 420, 220, and 122 faults, and the 450, Copper Hill, and Afterthought shear zones. Displacement is difficult to measure because of the lack of markers in the rocks. However, if the contact between the Bully Hill rhyolite and the Pit formation is used as a marker horizon, the vertical displacement on the 420 fault is about 250 feet, on the 220 fault 85 feet, and on the 122 fault 150 feet (pl. 5, sec. BB′). The displacements of this contact observed in a few places suggest that most of the other faults in this class have a normal movement measurable in feet or tens of feet.

Normal Faults that Strike Northeast. Less than 10 percent of the faults in the mine belong to this class. Most of them dip southeast at moderate angles. They offset faults of the first two classes but are themselves offset by reverse faults that dip northeast. The Northeast fault, as mapped on the surface, seems to be a normal fault with a net displacement of more than 75 feet. Underground measurements of the direction and amount of movement along the faults that strike northeast are scarce, but the faults are regarded as normal faults of relatively small displacement.

Faults that Dip Northeast. The youngest faults strike northwest and dip northeast. Faults of this class are few, but two of them—the Main fault and the 412 fault—are of considerable economic importance.

The Main fault strikes N. 45° W., dips 45° to 60° NE., and is the most continuous fault in the mine. In some places, as on the 200 level, it is a shear zone as much as 12 feet thick; in other places, as on the surface above the No. 4 adit, it is a shaly breccia zone less than a foot thick, bounded by slickensided surfaces. Mullions on the slickensided fault surfaces plunge directly down the dip. The Main fault is interpreted as a premineral reverse fault with slight postmineral movement.

The age of the Main fault is deduced to be premineral from the fact that calcite-quartz veinlets can be seen in the fault zone where it is now exposed on the 200 level, on the 300 level, and in the No. 7 adit; and also from the fact that sulfide in the hanging wall of the Main fault in the No. 7 adit is not broken or slickensided and appears to have formed after the fault. The gangue minerals are closely related to sulfide in other parts of the mine, so the presence of calcite-quartz veinlets within the fault zone suggests that the fault may have formed prior to the deposition of sulfides. Indirect evidence leading to the same conclusion lies in the fact that the Main fault was explored at six different levels by hundreds of feet of workings, now for the most part inaccessible; although no records exist for the inaccessible workings, it seems valid to assume that at least small lenses of sulfide were encountered along the fault zone in a few places.

A minor amount of postmineral movement on the Main fault is postulated, because in a few areas the calcite-quartz veinlets within the fault zone are somewhat crumpled.

Evidence regarding the direction of movement along the Main fault is scarce, but the fault appears to be a reverse fault with a dip slip of at least 450 feet. This conclusion is based on the premise that the wedge-shaped segment of Bully Hill rhyolite in the hanging wall of the fault is an upthrown segment of the soda rhyolite nose that forms the footwall of the fault below the 400 level. Above the 400 level a block of sedimentary rock of the Pit formation forms the footwall of the fault. This block gradually widens toward the surface, because the average dip of the contact between soda rhyolite and sedimentary rock is less than the dip of the Main fault. Under such circumstances, if the Main fault were a normal fault, there would be no source for the soda rhyolite of the hanging wall.

It is of course possible that above the present erosion surface the contact between Bully Hill rhyolite and the overlying Pit formation dipped at a higher angle than the Main fault. Under these conditions the wedge of soda rhyolite could have been dropped down from above with normal movement on the Main fault. These relationships are illustrated in plate 5, sections AA′ through DD′.

The 412 fault is in shale in the general area of the 412 stope (pl. 5., sec. CC′). It appears to be a weak fault, and is marked by a zone of calcite-quartz stringers that ranges from a fraction of an inch to several inches in width. The 412 fault can be traced from the 300 level down to the 500 level, but above the 300 level it apparently dies out. It is probably a normal fault of small displacement.

Bench Structure

In general, the contact between the Bully Hill rhyolite and the Pit formation in the vicinity of the mine strikes northwest and dips steeply northeast. Within the mineralized area, however, the contact is alternately steep and nearly horizontal, and assumes benchlike forms. Five distinct benches have been recognized. They range in width from 20 feet to more than 200 feet; the length is somewhat greater than the width. The benches occur through a vertical range of 500 feet. Most of them slope gently toward the southeast.

In some places the bedding in the sedimentary rocks adjacent to soda rhyolite follows the shape of the benches and wraps around them like a carpet on a stairway, whereas in other places beds of sedimentary rock dip directly into a soda rhyolite bench and are truncated by it. This relationship is seen beneath the 120 ore bodies where the rocks are fairly well exposed in mine workings (pl. 6). Here the beds of sedimentary rocks dip toward a soda rhyolite bench for a distance of about 75 feet across strike. At least one layer of shale projects downward several feet into the soda rhyolite. Thus, the contact does not have the shape of a low-angle fault surface. In view of these contact features and the absence of low-angle faults in this area, the writer concludes that the beds of sedimentary rock were truncated as a result of the intrusion of the soda rhyolite. Where the sedimentary rocks were truncated or pushed aside during the intrusion of the soda rhyolite, contacts were irregular and angular. Later, during orogeny, these irregularities were modified by tilting and faulting, and molded into their present benchlike form. The bench structure is illustrated on plate 5, sections AA′ through EE′.

A notable example of the bench structure is the blunt wedge of soda rhyolite that protrudes 150 feet into the sedimentary rocks between the 200 and the 400 levels. Both the top and the bottom of this wedge are nearly horizontal, and the blunt eastern end of the wedge is vertical. The beds of sedimentary rock appear to wrap around this blunt soda rhyolite wedge, and thus are in the form of a crude recumbent fold.

GEOLOGIC HISTORY

The geologic history of the area around the Afterthought mine is summarized as follows:

(1) During middle or late Triassic time the Bully Hill rhyolite, a soda rhyolite, was extruded into the sea. The basin of deposition was slowly depressed and the soda rhyolite was covered by several thousand feet of shale and tuff.

(2) Dikes and sills of soda rhyolite were intruded into the Bully Hill rhyolite and into the lower part of the Pit formation, either while Pit and younger sedimentary rocks were still being deposited or shortly afterward. These intrusive bodies were emplaced at shallow depth and were later manifestations of the same igneous activity that formed the Bully Hill rhyolite and the rhyolitic tuffs in the Pit formation.

(3) After middle Jurassic and prior to late Cretaceous time the rocks were folded, faulted, and slightly metamorphosed.

(4) The rocks were hydrothermally altered along some zones, and shortly afterward the sulfide ore bodies were formed.

(5) The area was eroded during Cretaceous and early Tertiary time, and a surface of rather low relief was formed. On this surface the Tuscan tuff was deposited during late Tertiary time. Finally, after still another period of uplift, the present valleys were cut during Quaternary time.

ORE BODIES

General Features

The ore deposits at the Afterthought mine are sulfide replacement deposits in shale and in sheared, altered soda rhyolite. The ore is commonly banded, and is typically a fine-grained mixture of pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, and gangue minerals. Sulfide bodies that replace shale are in general richer in sphalerite than those that replace soda rhyolite. The ore bodies are slightly elongate lenses that plunge southeast at an average angle of less than 10°. Some ore bodies are surrounded by a halo of heavily pyritized rock, and some are partly surrounded by a halo of carbonatized rock. The carbonatized rock is most commonly found between sulfide bodies and soda rhyolite wall rock. It was formed partly as a replacement of soda rhyolite and partly as a replacement of tuffaceous sediments.

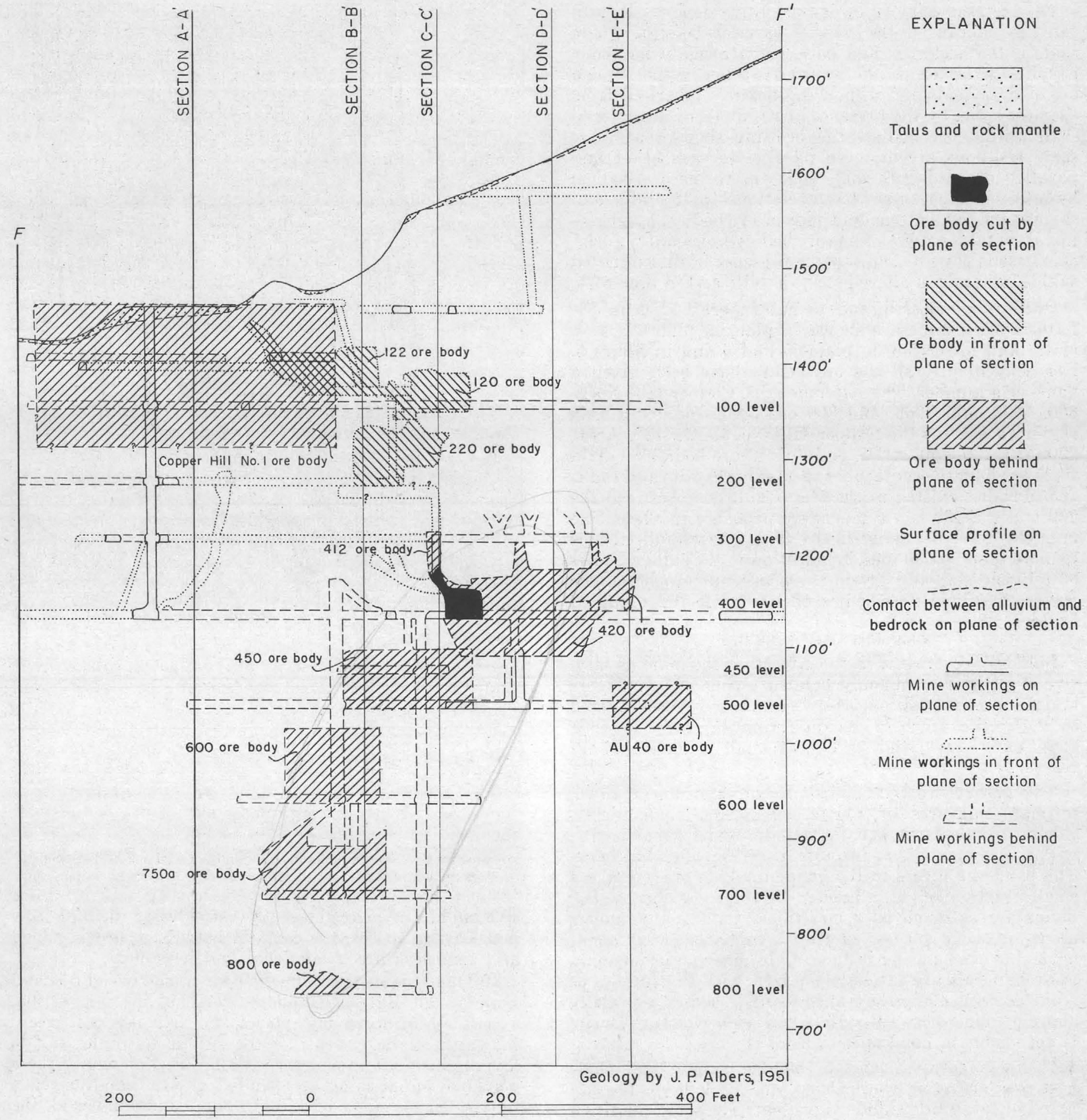


FIGURE 5. Longitudinal projection of the Afterthought mine showing relative positions of the known ore bodies.

INTERIM OFFICE REPORT ON AFTERTHOUGHT MINE,

SHASTA COUNTY, CALIF.

Edward Wisser

August 20,1946

INTERIM OFFICE REPORT ON AFTERTHOUGHT MINE,

SHASTA COUNTY, CALIFORNIA.

INTRODUCTION.

Since starting this report notice has been received that the next underground hole will be that proposed by Mr.Mudd,drilled up 60°, course nearly south, from a point near the collar of Hole AU-5, and that the next surface hole will be drilled from the open cut,at a point 40 feet northwest of the collar of Hole AS-5, down 25°,direction S45°W.

The underground hole was discussed in my letter to Mr.Bruce of July 31 last,where I pointed out (1) that rhyolite is unfavorable for high grade ore at Afterthought and (2) that since this hole would cross any supposed southeast extension of the AS-1 ore body in rhyolite,and would remain in rhyolite for the first 300 feet,chances for ore in this hole were very slim.

The surface hole was discussed in the same letter,where I showed that such a hole would enter rhyolite at 135 feet,and only about 100 feet below the surface.

I shall point out below three instances,with a probable fourth, where my predictions regarding structure (and ore) were checked by drilling; it might be supposed from this that my notions of Afterthought structure and ore control are in general not far from correct but unfortunately from my standpoint, no attention has been paid to these ideas in the drilling program, and where holes laid out have met with my approval,the reason has in the main been coincidence.

Self-respect demands that I give you,with entire cordiality and absence of ill-feeling,my honest opinions at all times. This right has been freely given me, and I shall presume on it further to ask this: if the underground hole is barren, and stays in rhyolite for about the first 300 feet,and if the surface hole is barren and enters rhyolite at about 135 feet,then I ask,if any more exploration is done, that my ideas be given the consideration I think they will then merit.

One thing I wish to state with all emphasis: I cannot say that these holes will not find ore; they may. But if they prove barren, that fact has no bearing on the value of the Afterthought mine,barring the possible necessity of the AS-1 ore body going as far as the location of either hole to make a mine,a necessity which I strongly doubt.

THE PRESENT PICTURE IN TERMS OF ORE CONTROL.

In my petrographic report of August 7 last, I outlined a modification in previously expressed ideas of ore occurrence: hitherto the ore bodies in limey shale were thought to be similar to replacements in limestone,in that they favored certain limey beds near the main rhyolite contact,were only conditioned by sheeted zones in a secondary way,and hence differed markedly from the rhyolite ore lenses in the lower levels, which are controlled entirely by such sheeted zones. The thin-section work showed that fracturing in the host rock controls the amount of calcite present in the rhyolite;review of detailed drill logs taken by the writer suggests strongly that the same holds for ore in the limey shale:that the shale,really brittle hornfels,fractured more readily than the rhyolite,permitting introduction of abundant calcite.(This will be checked by thin-section work to be done on the ore in limey shale in Hole AS-1). The microscopic work already done shows plainly that pyrite, the earliest metallic mineral, replaced calcite almost exclusively (only fine, dusty cubes in the rhyolite groundmass)and that sphalerite replaced both calcite and pyrite,but also steered clear of the rhyolite. This replacement on a very fine scale accounts for the peculiar,obscure appearance of the sphalerite (or more likely, marmatite). Due to this close association of calcite (with minor quartz, by the way), pyrite and marmatite,the time relations are thought to be very close, i.e. pyrite followed calcite and was in turn followed by sphalerite or marmatite within a very short interval. This accounts for the high iron in the sphalerite.

It follows that the ore shoots in limey shale do have a close affiliation with those in rhyolite,and that therefore the prospect, which I have repeatedly urged, involving driving southeast along the Main shear zone,on say the 500 level,and following this zone into the shale,is an excellent one;this is strongly indicated by the high grade ore in shale, at the southeast end of the 450 stope. What prevented this fact from being obvious before(namely,the influence of sheeted zones on ore in the shale)is the circumstance that the shale brecciated rather than sheeted, under stress.

The accompanying Horizontal Projection of Sheeted Zones brings out these points. Refer also to the accompanying sections through Holes AU-6, AU-5 respectively. The more important zones are discussed below.

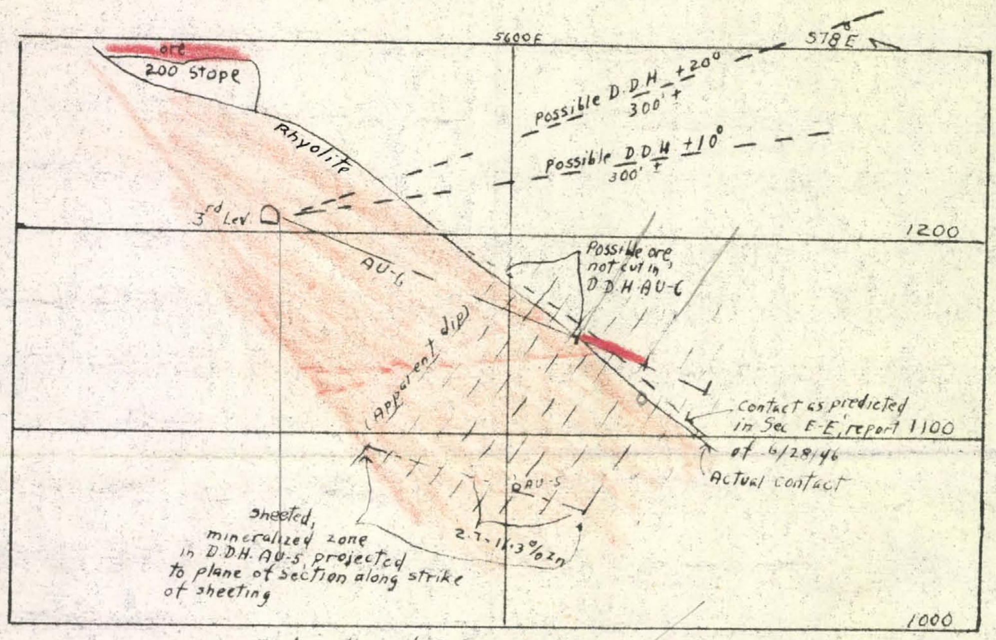
<u>AS-1 Ore Body.</u>- No particular sheeting system was noted in the ore; but Hole AS-5,passing directly beneath the ore (in rhyolite) showed strong,barren sheeting which would project up into the ore. This fact supplies <u>Proof 1</u> that rhyolite is unfavorable for ore.

This sheeted zone, shown at the bottom of Hole AS-5, dips steeply southwest. It was very likely cut in Hole AS-3 (shown at 4600N coordinate) and if so, carried pyrite and calcite, but was otherwise barren there, although in sediments, not rhyolite, at that point. Hence one of the main ore controls of the AS-1 ore body has probably already been tested, southeast of the rhyolite nose, and the rhyolite appears as much a barrier to ore southeast of that ore body as it does below the ore body (Hole AS-5).

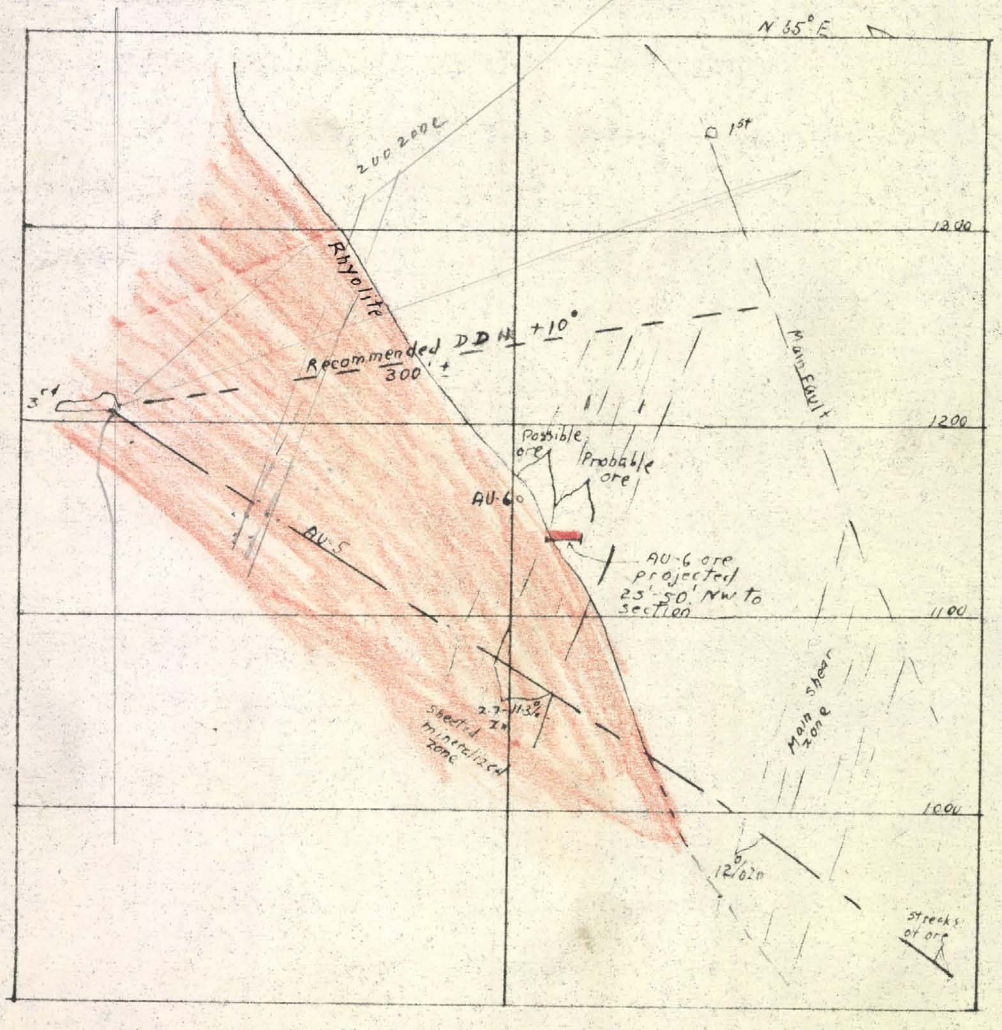
A strong sheeted zone, parallel to the one mentioned, occurs along the west margin of the AS-1 ore body; where Hole AS-1 cut the ore, the two zones are one; but due to the flatter dip of the second zone, they separate at depth, hence are widely apart at the projection plane, 1140' elevation. This southwestern zone, and still another, broader zone southwest of it, project into the deep "valley" in the rhyolite, southwest of the nose, and because at least a little ore was found on the north rim of this valley, the latter is a good prospect. It was not explored by Hole AS-4.

200 Ore Body.- No sheeted zone has been definitely identified with this ore shoot, but the narrow zone shown about 80 ft. northeast of the collar of Hole AU-5, if it continues northwest, would project up directly into the stope. Barrenness of this zone to the SE is proof 2 that rhyolite is unfavorable for ore.

AU-3-4-5-6 Ore Body.- No sheeted zone was noted in Holes AU-2-3-4, probably owing to the fact that the ore lies in sediments along a vertical, brecciated segment of the rhyolite contact. But Hole AU-5 shows a strong sheeted zone in rhyolite, carrying marginal ore; Hole AU-6 shows the same zone, associated with high grade ore in sediments (see sections through those holes); this fact affords



Section through D.D.H. AU-6
1" = 100'



Section Through D.D.H. AU-5
1" = 100'

proof 3 that rhyolite is unfavorable for ore. Incidentally, the section through Hole 6 shows how closely I predicted the point of emergence of the hole from the rhyolite; there is no reason why the ore body there should not be much wider than the hole shows it, as the section explains. This is check 1 on my notions of structure. With regard to Hole AU-5, extrapolating the structural contours on the stereogram accompanying my report of June 28 will show that I predicted the point of emergence of Hole AU-5 at 1050 ft., whereas the actual elevation of the point of emergence was 1025 ft. Check 2.

Main Shear Zone.- This zone carried all the principal ore bodies in the lower levels; the ore was in rhyolite except for the southeast end of the 450 stope. Hole AU-5 cut the southeast extension of this zone, in the sediments. The hole disclosed about 10ft. of 12% zinc ore along the hanging wall of the zone; this showing may represent a fraying-out to the southeast of a major ore body, perhaps 200 ft. long; or the hole may have cut the zone at the top or bottom of a longer shoot.

The Main shear zone is so strong, and fractured the rhyolite so strongly, that it bore commercial zinc ore in rhyolite, something that happened practically nowhere else. So much the better for the chances of this zone in sediments.

Unexplored Segments of Sheeted Zones.- Obviously chances are good along the Main shear zone, between the 450 stope and Hole AU-5, and along the AU-6 zone southeast of the ore in that hole. The AS-1 ore body will probably follow the steeper shear zone connected with it, northwest into the "flat" in the rhyolite shown on the plan. While Hole AS-7 will cut this zone, starting at about 410 ft. (if the hole goes that deep) it will cut it in rhyolite and the zone where cut will probably be barren. Incidentally, in my letter of July

31st last, I predicted this hole would enter the rhyolite at 180'. I have the log to 210 ft. only, but at 192 ft. the hole entered rhyolite and remained in that rock to the then bottom. If the hole stays in rhyolite, this will furnish another check on my notions of structure. Check 3: the third positive check to date is furnished by Hole AS-6. Section D-D', my report of June 28 last, shows that AS-6 should have entered rhyolite at 1060' elevation; it did so at 1025'.

The southeast extension of two strong sheeted zones into the "valley" southwest of the rhyolite nose has been mentioned on page 4.

RECOMMENDED EXPLORATION.

There are at the present indications of four separated ore zones, each on its respective sheeted zone: (1) As-1; (2) 200 ore body; (3) AU-3-4-5-6 ore body; (4) Main shear zone. For the AS-1 shoot, the writer recommended a surface hole to explore its northwest extension (letter of July 31 last, page 2, Possible Hole (c)). I have no present plan for exploration of the 200 ore body; this should probably await "tunnelling" if any. The remainder of this report deals with exploration on the AU-6 and Main shear zones. First however, it may be asked, What tonnage are we shooting at, and What are the chances of reaching that figure?

Minimum Tonnage Required.-A figure of 400,000 tons has been given me, informally, but it seems to me a lesser figure might suffice. If the grade should prove anything like as good as that in Hole AS-6, a $5 profit per ton would be the lowest conceivable. With a 200-ton mill, 300,000 tons of ore would provide a five year operation and a total operating profit of $1,500,000. Allowing $500,000 to return expenditures for property, for building mill and money already spent, leaves $1,000,000 net profit, returned at the rate of $200,000 per year. If the Afterthought makes a mine, this is the writer's measure of its probable size.

<u>Optimum Tonnage of Known Ore Zones.</u>- Can this tonnage be found? If the writer's notions of ore controls are correct, certain maximum possible figures for the various ore zones can be guessed at. Under present exploration methods, which are strictly geometrical, basing the next hole solely on ore or no ore in the last, no calculations of optimum tonnage are possible.

AS-1 Ore Body.

Hole AS-6 has shown a vertical dimension of 20 ft. for this; but since the hole was drilled right down the vertical brow of the rhyolite nose and found the ore only because the brow had a "cave" in it, the thickness is unreliable. (See section accompanying my letter of July 31st last, which however shows the "cave" too high: the log shows that the hole went from rhyolite through 6" of shale and into ore). This ore <u>might</u> extend up 50'. If the ore body occupies the "valley" shown on the plan, its horizontal area will be 100' x 100'. Total volume 500,000 cu.ft., and at 10 cu.ft. per ton, 50,000 tons.

200 or SA Ore Body.

No basis for calculation exists here; the ore shoot might have a horizontal area about 130 x 40; if it goes up 100', it would contain another 50,000 tons.

AU-6 Ore Body.

As shown on the plan, Hole AU-6 was drilled at an acute angle to the strike of this vein-like ore body (assuming the ore in AU-6 connects with that in AU-4). But the accompanying section through AU-6 shows that the ore here may be much thicker than the hole indicates. Some extension southeast must be allowed for as well. Guessing at an average width of 20' and a length of 250', then with a height of 150' (which might go with the length assumed), 75,000 tons <u>might</u> be found here.

Main Shear Zone.

The principal hope for tonnage seems to lie here. The sediments form a wedge;one side is the footwall of the Main fault,the other, the rhyolite contact. The wedge is open to the southeast; the northwest cutting edge pitches down to the southeast like the prow of a racing boat,so that the southeast end of the 450 stope is in shale (point of wedge),while lower levels,southeast of this point, are still in rhyolite. That mineralization exists in this wedge toward its open or southeast part is shown by the ore and streaks of ore sulphides near the bottom of Hole AU-6. For the purpose of this estimate, assume that the 450 ore maintains its width of 20' on entering the wedge,and that the shoot persists 200 ft. southeast. A vertical dimension of 200 ft. seems not unreasonable in this strong shear zone. Such a shoot would contain 80,000 tons.

Summary,Optimum Tonnage.

As-1............	50,000
200.............	50,000
AU-6............	75,000
Main Shear Zone..	80,000
	255,000

This figure seems not unreasonable to me; if 300,000 is sufficient tonnage, I think the mine has a good chance of making it. Stewart suggests direct shipping of the ore,and I have seen mention of this possibility in recent correspondence. If that is possible, the Afterthought,with 300,000 possible tons of ore, is certainly a good venture.

To block out any such tonnage would take more time than appears available; but if say two of the above four possibilities should be punctured, the mine would no longer look attractive and could be tranquilly dropped. The following two drill-holes are designed with this thought in mind.

Continuation of Hole AU-4.- To test the Main shear zone; already discussed and I urge it again.

Hole from Collar of AU-5.-The hole to test the AU-4-6 zone, proposed previously by myself, was up 20° along the course of AU-6. The present map shows that this hole too nearly parallels the sheeted zone. I propose the hole shown in accompanying section through Hole AU-5the length would be no greater (about 300') and the hole would cut the sheeted zone at a bigger angle.

CONCLUSIONS

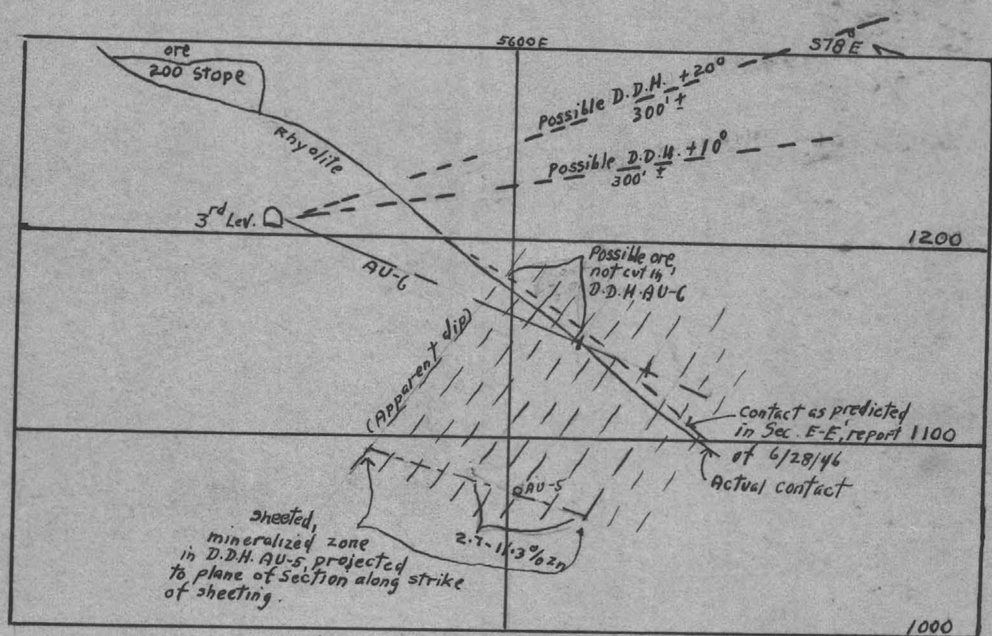
It seems to me that these two holes are well adapted to assist a decision on the forthcoming due payment. If they are barren, don't pay it ;if both find ore, take the risk and make the payment. If one finds ore but not the other, decision might be difficult; I should say, drop the property unless the width of ore cut was much larger than anticipated.

This is a clean-cut, unfuzzy program and I am not ashamed of it.

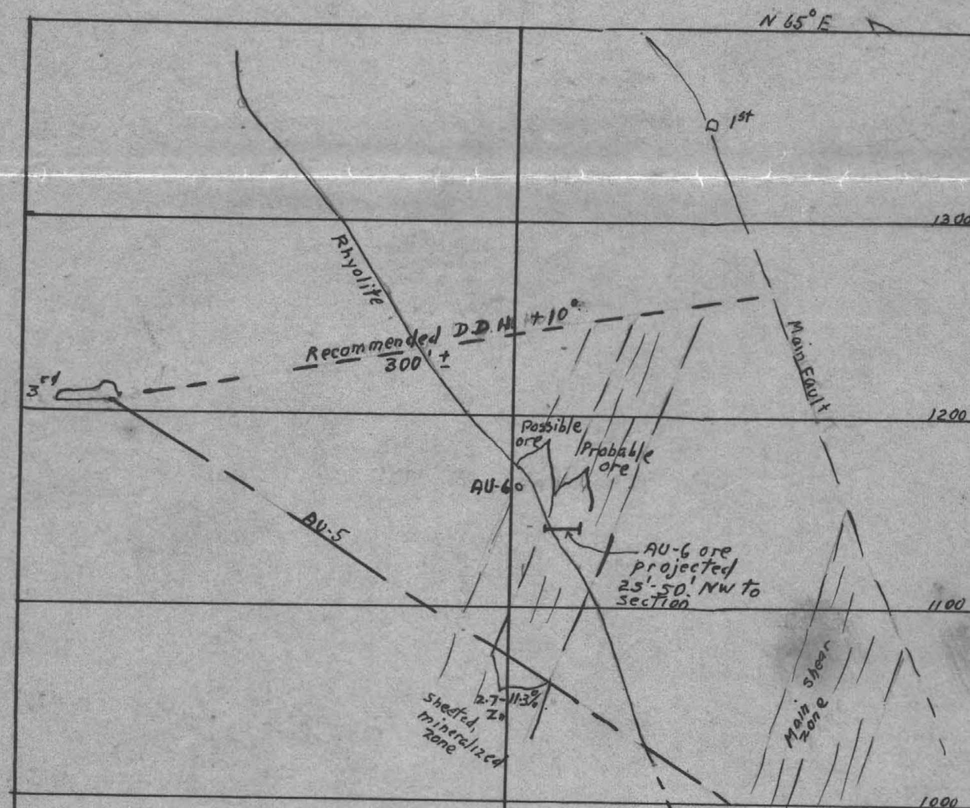
E.W

San Francisco
August 20, 1946

Edward Wisser



Section through D.D.H. AU-6
1" = 100'



Section Through D.D.H. AU-5
1" = 100'