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REPORT ON

THE GROOM PROPERTY

YAVAPAI COUNTY, ARIZONA

Edward H. Wisner
Durand A. Hall

October, 1950

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SUMMARY AND RECOMMENDATIONS

SUMMARY: The salient feature of the Groom copper property, 16 miles East of Wickenburg, a railroad point and supply center, consists of two strong veins, parallel and some 300 feet apart and traceable on the surface for over 9,000 feet. The limited exploration, mainly for gold rather than copper, has been confined to the East vein and its branches. Judging from the surface, the East vein is decidedly the weaker of the two, its average width being 8-11 feet, contrasted with an average width of 20-30 feet for the West vein. The outcrops of both veins show residual chalcopyrite and abundant cellular limonite derived from chalcopyrite, but that of the West vein is more persistent, has a greater average width, and shows longer stretches of promising gossan. Since all of the West vein, a number of other veins, and most of the East vein are virtually unexplored, the Groom property is still a prospect. Judging by the length and width of the veins and the nature of their outcrops, the prospect, however, is an exceptionally attractive one.

These veins are thoroughly oxidized and leached at the surface and show only sporadic copper minerals, a condition which seems likely to prevail to a depth of over 500 feet. The property presents a somewhat expensive exploration risk, based almost solely on geology, for the discovery of a large medium- to high-grade copper mine amenable to relatively low-cost underground operation. Its location with respect to transportation and supplies is favorable, and it is distant only 12 miles airline from power.

Any present estimates as to size and grade of potential ore are avowedly speculative, based as they are upon judgment of outcrops.

However, two to three millions tons of 5 to 6% primary copper ore is a reasonable guess as to the immediate stakes involved. Several times this size operation is within the scope of reasonable conjecture. Should a zone of secondary enrichment exist much higher grade ore is possible.

Success of a venture here would depend primarily upon the following conditions:

a. The depth to which oxidation and leaching of the veins have taken place.

b. The character and grade of primary sulphide ore at depth, below the oxidized and leached zone represented by surface exposures.

c. The width, depth and lateral extent of potential ore shoots represented by outcrops, and the existence of possible "blind" ore shoots.

d. The persistence in depth of the vein structures themselves.

Important likewise, but less critical is the degree of secondary copper sulphide enrichment which may be encountered below the bottom of oxidation.

Since the depth of leaching and oxidation (in the East vein at least) exceeds 500 feet, the above vital questions can be answered only by deep exploration, either by diamond drilling, by underground exploration from a shaft, or by a combination of the two.

It is pertinent to enquire why such impressive outcrops as those on the Groom property have not been thoroughly tested for their copper possibilities at depth, considering especially the advantageous location of the property with regard to transportation and power, and its presence in a

region noted for its important copper deposits. A review of the camp's history, and of the extent of exploration may serve to answer this question and is included in this report. Briefly, the history of operations at the Groom consists of one short and misdirected campaign by a major company followed by 'shoestring' attempts to exploit the spotty gossan gold ores. The sulphide zone, if it exists, has never been reached. Exploration was confined to the East vein and its branches, while the stronger West vein remains virgin.

Clearly the attractiveness of an exploration venture at the Groom property depends upon the interpretation in terms of primary and secondary copper sulphides of the oxidized and leached outcrops of this extensive vein system. And yet with the exception of Henry Mulryan, an associate of Beals, there is no evidence that a geologist trained in the interpretation of such outcrops ever spent more than a few hours on the property. There is no record of any geologist visiting the property between 1928 and 1950, when the writers spent two days there. The Groom Mine lay neglected during World War II, in spite of the active search for copper during those years; a brief report dealing only with the road situation to the Groom Mine was issued by the Bureau of Mines in 1942.

RECOMMENDATIONS: Our study of the Groom outcrops convinces us that over important stretches there is substantial evidence of the former existence in the veins of primary copper sulphides sufficient to have constituted good grade ore. The width, great structural strength of the veins, and their extent on strike strongly suggest their persistence to depths well below the probable bottom of oxidation and leaching. Inasmuch, however, as exploration of whatever sort would involve cutting

the veins at depths exceeding 500 feet, we believe that the planning of such long-range exploration should be preceded by more detailed field study than we have thus far made.

Our present recommendations are, therefore, limited to field study and mapping under the direction of a competent mining geologist thoroughly familiar with copper outcrops. Such a study should be completed in a maximum of 60 days. Provision should be made for a certain amount of surface trenching in conjunction with the geological work, and probably the reopening of one short adit on the West vein. None of this work would require machinery, the work would be purely an aid to geological investigation and should be planned and directed in the field.

Housing is available at the camp, both for this preliminary work and for the initial stages of actual exploration.

The geological study recommended might conceivably deem the property. The writers believe this result unlikely and consider the preliminary study rather as a necessary prerequisite to determine the nature and location of the next exploration step, whether the latter consist of drilling, shaft sinking, a combination of the two, or whatever.

Fortunately, the deal on the property is such as to afford ample time for thorough investigation before any financial commitments, either as actual work or payments, fall due.

REPORT ON THE GROOM PROPERTY

Yavapai County, Arizona

GEOLOGY
(Refer to Surface Plan)

The Groom property lies on the western slope of the Bradshaw Mountains, made up mainly of the Bradshaw granite, pre-Cambrian in age. Within the granite are areas of schist, presumably representative of the cover intruded by the granite. Aplite occurs in abundance, especially just southwest of the West vein.

The Groom vein zone may be traced continuously by surface exposures for more than 9,000 feet in a northwest-southeast direction. Along this zone two major, steeply-dipping parallel structures predominate -- the East and West veins. In addition there are several strong veins branching still more to the northwest but also to the southeast from the main zone, as shown on the Surface Plan.

Both the East and the West veins occupy faults of strong displacement; this is shown on the Surface Plan by successive offsets of the quartz porphyry dike near the northwest end of the property. That the vein fissures are also important faults speaks well for their persistence, in depth as well as laterally. They are not gash veins.

The East and West veins are persistently accompanied by hydrothermally altered diabase (?) dikes which in places occupy the structures to the exclusion of the veins. Again, this speaks well for the persistence of these fault-veins in depth.

Both veins appear to be dislocated by cross faults of moderate

horizontal displacement, as suggested on the Surface Plan. The great width of the West vein on the southeast side of one such cross fault, near the Groom shaft, contrasted with its meagre outcrop on the northwest side of this fault, suggests that the cross-fault was pre-mineral or active during the mineralization; it may have localized the intense mineralization southeast of the fault. This fault and other probable cross faults displace the West vein but not the East vein, or displace the East vein to a less extent, suggesting that the East vein with its fissure formed after most of the cross faulting had ceased. Here again is evidence for activity of the cross faults during metallization; they may have had effect on localization of potential ore, and should not be overlooked in planning exploration.

Strike faulting also occurred along the East and West veins; such faulting also seems to have been active during mineralization as evidenced by successive fracturing, filling of the fractures with vein-matter, and refracturing, especially in the West vein. Such intermineral fracturing is associated with the formation of ore bodies throughout the world.

In places strike faulting, probably post-mineral, appears to have caused gaps in the continuity of the veins.

The Groom area shows therefore close time relationships between fissuring, faulting, intrusion and metallization; such a combination is a universal feature of important ore districts.

MINERALIZATION

Since underground workings are now inaccessible, the following first-hand description applies to outcrops only.

The chief gangue of the veins is quartz, typically pitted, to varying degrees, the pits frequently exhibiting residual, cellular limonite typical of the oxidation of chalcopyrite in a siliceous gangue. Occasionally coarsely crystalline calcite occurs. Manganese as pyrolusite appears in considerable amounts. Specular hematite, largely or wholly primary, is common, especially in the so-called "Iron veins" (e.g. Glory Hole vein - See Surface Plan) carbonates and oxides of copper are not uncommon, especially in the East vein; they are sparser, harder to see, but nonetheless present in the West vein.

Remnant chalcopyrite, chalcocite and pyrite are sparser still, but definitely present in both veins, especially the East vein in its narrower stretches. Using East vein specimens, every gradation may be traced between fresh copper sulphides, partly oxidized sulphides, and limonite representing former copper sulphides. Application of these results to the West vein outcrop leads to the conclusion that the West vein carried far more copper than the East vein; sufficient residual copper sulphides are to be seen in the West vein to confirm this line of reasoning. As might be expected with a stronger, wider, more brecciated vein structure, the West vein is more thoroughly leached than all but the wider stretches on the East vein.

The relatively rare remnants of chalcopyrite are therefore significant in that they permit the tracing of the oxidation process from the original sulphide to the cellular limonite-filled cavities found throughout the better-looking croppings. Mr. R. L. Banks, who operated the property during most of its active history, reports that residual sulphides were not uncommon both underground and in surface workings on the East vein, but were found underground mainly where fault gouge protected

the vein from oxidation.

Our examination covered in some detail about two-thirds of the exposed length of the Green vein zone. Of this distance, we considered there to be at least 1,000 feet of nearly continuous outcrop on the West vein, and lesser distances on other veins, which in our opinion represent former copper sulphides with only minor amounts of pyrite. As shown on the Surface Plan, this promising segment of the West vein averages over 30 feet in width; chalcopyrite-limonite may be found in varying amount throughout this width.

Elsewhere along the outcrops examined evidence of former pyrite was greater, that of former copper sulphides correspondingly less. This does not mean that more pyritic portions of the veins are necessarily valueless - it does mean that the oxidation of large amounts of pyrite tends to obscure evidence of former chalcopyrite. At any rate, these "pyritic" stretches of outcrop are considered less promising than those carrying typical chalcopyrite-type limonite structures.

Beside the two types of bold outcrop mentioned, there are considerable stretches along the East, West and other veins where the outcrops are "subdued", being largely covered by detritus or soil. While such outcrops may mean sparse mineralization, they may also signify the former presence of heavy sulphides with a minimum of quartz gangue and so are worthy of careful prospecting.

Possible Grade of Primary Ore: Estimates as to grade of the primary copper ore would be based on a quantitative determination of the relative amount of limonite-filled cavities ascribable to former chalcopyrite. Such a detailed study has not yet been made, and our est-

imate is therefore little more than an experienced guess. Croppings in other districts familiar to the writers and comparable to the 1000 feet plus of heat-looking croppings on the Groom property have overlain 5 to 7% primary copper ore. The better Groom croppings are strikingly typical of the outcrops of known high grade copper veins.

Secondary Enrichment: The chance for an important zone of secondary enrichment at the bottom of oxidation cannot be overlooked. Copper has been thoroughly leached from the major veins, perhaps to an average depth exceeding 300 feet below the present surface. Vein walls are tight and should tend to prevent dissipation of copper in solution out into the walls. However, formation of an enriched secondary chalcocite zone depends not only on suitable structure but also upon a suitable erosion cycle. At the Groom mine the water level within the veins seems to have risen since original oxidation took place. It is impossible, therefore, to determine whether conditions were originally favorable for the development of an enriched zone, and, if they were, whether such a zone still remains or was destroyed by later oxidation and leaching. The chance is perhaps 5 to 1 against the presence of an enriched zone, but considering the high stakes involved, these are favorable odds: with copper at 20¢ a pound, each increase of 1% copper over the primary content of ore represents an additional $4 per ton.

HISTORY

The history of the camp, as related to the writers by R.L. Beals, operator of the property between 1925 and 1940, starts with the end of the last century. During 1898-1900, a man named Middleton is said to have sunk the Middleton shaft (see Surface Plan and Composite

Plan, Middleton Workings) and driven parts of the 130 and 350 ft. levels. His objective seems to have been gold; the upper horizons of the East and Glory Hole veins here were later mined for gold. No primary ore was encountered, but fault-drag vein fragments containing chalcocite and chalcopyrite were found on the 350 ft. level.

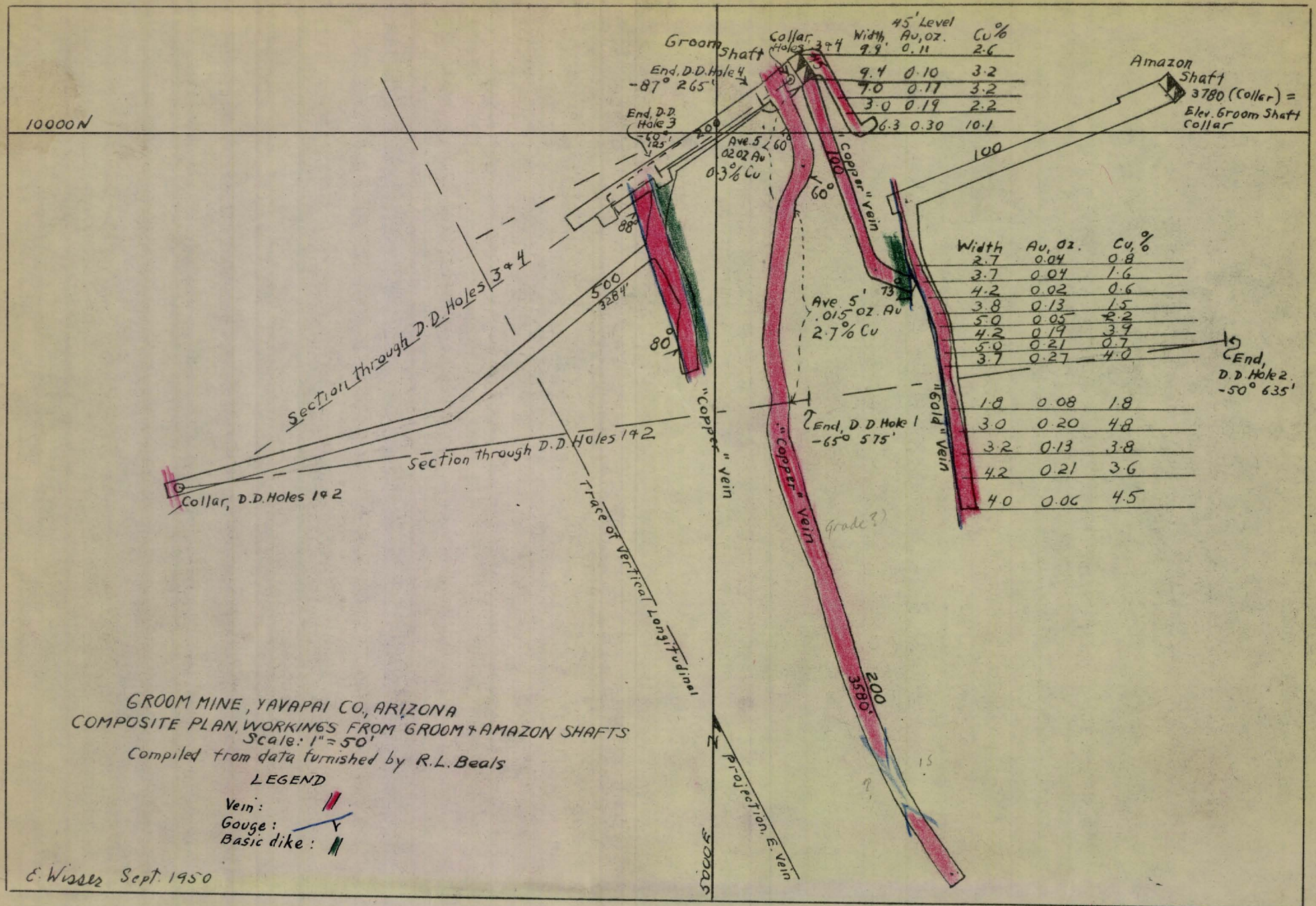
Middleton stopped operations, whether through discouragement or lack of capital, about 1900. The property lay idle until 1925.

In 1925, R. L. Beals in partnership with Walter Arnstein (who formerly had controlled the Bully Hill copper-zinc mine in Shasta County, California) obtained an option on the Groom mine. During that year they sank the Groom shaft 50 feet and drove the 45 ft. level in ore averaging 0.16 oz. Au and 3% Cu. (See Composite Plan, Groom and Amazon Workings.)

In 1926, on the strength of favorable examinations by Tom Hamilton and Julius Kruttschnitt (now Board Chairman, Mt. Isa Mines Ltd., Australia) the American Smelting & Refining Co. undertook development of the property. They sank the Groom shaft to 500 ft., drifting for 300 ft. on the 200 level, and for 75 ft. on the 500, as shown on the map cited.

As suggested on the Vertical Section through D.D.Holes 1 & 2 facing ~~this~~ next page, the East vein seems to split going down, near the Groom shaft, the eastern split ("Gold" vein) carrying fair values in gold and copper, the Western split carrying low gold but fair copper. All A.S.&R. work was done on the western split or "Copper" vein.

By sinking to the 500 level the A.S.&R. had hoped to get below the leached, oxidized zone, and into the sulphide zone. On the 500 the vein was still thoroughly oxidized, about 8 ft. wide and carrying, according to Beals, about 3% copper as carbonates, etc.

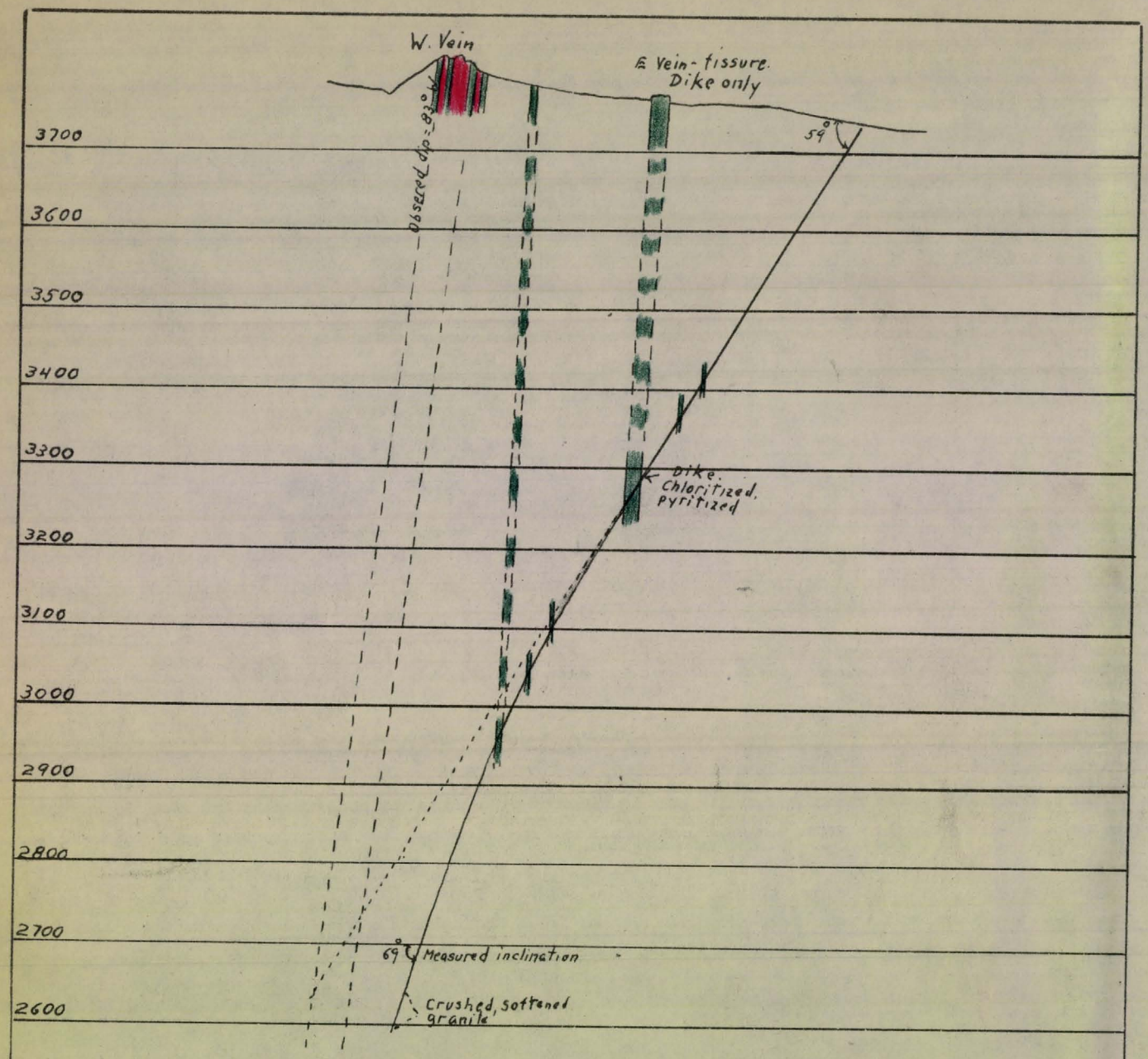


GROOM MINE, YAVAPAI CO., ARIZONA
COMPOSITE PLAN, WORKINGS FROM GROOM + AMAZON SHAFTS
Scale: 1" = 50'
Compiled from data furnished by R.L. Beals

LEGEND

Vein:
Gouge:
Basic dike:

E. Wisser Sept. 1950



GROOM MINE, YAVAPAI CO., ARIZONA
VERTICAL SECTION THROUGH D.D. HOLE 5

Scale: 1" = 200'

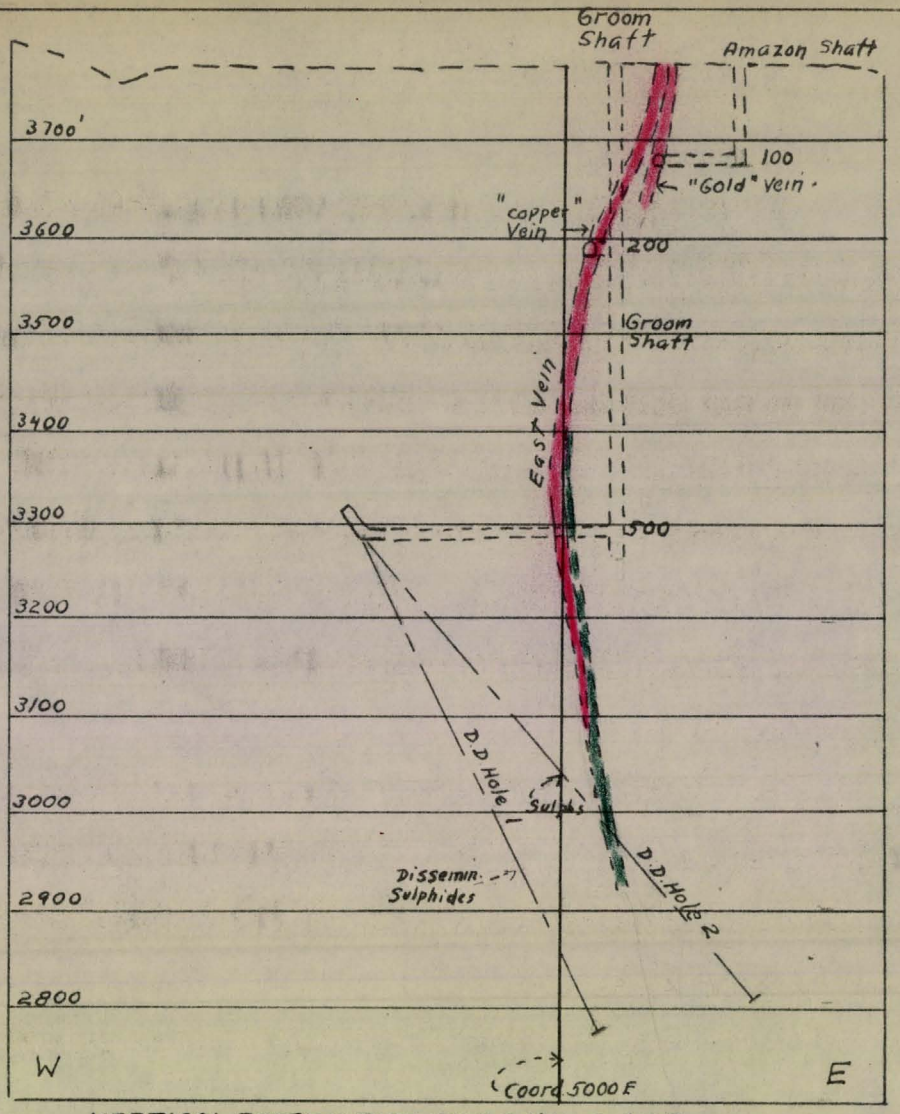
From R. L. Beals data

LEGEND

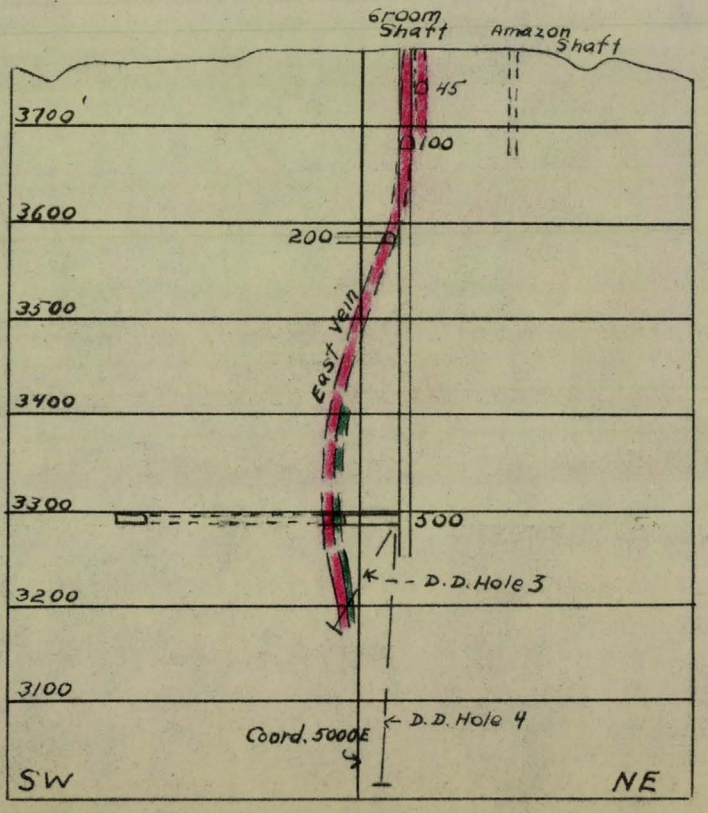
Vein:

Dike:

E. Wisser Oct. 1950



VERTICAL SECTION THROUGH D.D. HOLES 1 & 2



VERTICAL SECTION THROUGH D.D HOLES 3 & 4.

GROOM MINE
YAVAPAI CO., ARIZONA
CROSS-SECTIONS, GROOM SHAFT AREA
Scale: 1" = 200'
For location of sections, see Composite Plan, Groom-Amazon Workings & Surface Plan

LEGEND
Vein :
Dike :
Compiled from R.L. Beals data.

E. Wissel Sept. 1950

In 1928 sinking and drifting were suspended and diamond drilling undertaken in an attempt to penetrate the sulphide zone. The west crosscut 500 level was extended as shown on the Composite Plan, and Hole 1, indicated on the plan and on the Section facing this page, put down. The presumption had been that the East vein dipped west; but as shown on the Vertical Section, the vein turned over to the east, confirming its observed attitude on the 500 level. Hole 2, along the same course but flatter, was then drilled, but cut the vein fissure where it contained only dike and gouge.

The drill was then moved to the shaft station, in the East wall of the vein, and Hole 3 drilled, which duly cut the vein. Where cut the vein showed oxidised quartz and was similar in character to its exposure on the 500 ft. level.

Obviously the shaft station as a collar for drill holes was crowded too close to the vein; nevertheless an attempt was made from this station to cut the vein at a deeper horizon (Hole 4). The attempt failed, since vein and hole were practically parallel, as shown on the Section through D.D.Holes 3 and 4.

The A.S.& R. made a final attempt to find a sulphide zone, this time on the West vein, and drilled Hole 5 from the surface. (See Surface Plan and Vertical Section through D.D.Hole 5, facing this page.) Hole 5 cut the East vein where only dike and gouge occupied the fissure; but as shown on the Surface Plan and on the Vert. Longitudinal Projection, East vein, the East vein-fissure carries only dike above where it was cut by Hole 5.

Hole 5, drilled 1300 ft. almost certainly failed to cut the West vein. Observed dips on the West vein in the area of Hole 5 are all steeply west, averaging 83°. Hole 5 was surveyed and found to have steep-

east from 59° at the collar to 69° at the bottom, as shown on the Vert. Section through Hole 5. The East vein dike and another dike correlate between the surface and the hole, but the four persistent dikes that follow the West vein on the surface were not cut in the hole.

Inspection of the cores of this and other holes suggested to Beals that general oxidation in the country rock and oxidation of basic dikes ceases at about 700 ft. below the present surface. Doubtless oxidation in the strong veins may extend somewhat deeper.

After completion of Hole 5 in September, 1928, the A.S.& R. dropped the property.

Between September, 1928 and January 1929, the 100 ft.level, Groom shaft was driven by Beals (See Composite Plan, Groom & Amazon Workings.) Sorted ore from this drift was shipped for copper.

In 1930 a 25 ton mill was built by Beals and associates to handle gold ore from the Glory Hole vein and the East vein in the Middleton area. (See Surface Plan, Composite Plan of Middleton Workings, and Vert. Longit.Projection, East vein.) The Adit level was driven, a winze sunk from that level to the 55 ft. level, and a drift run on the 55 ft. level from the winze. No figures on production are available but apparently about 15,000 tons of ore were stoped. The milling method (amalgamation followed by sulphidization and flotation) failed to yield results, and regular milling ceased in 1931. Between 1931 and 1937, the mill was used as a pilot plant to test metallurgy of the ores being developed.

In 1938 the California-Engels Mining Co. undertook further development of the Groom property. They reopened the Middleton shaft and advanced the 130 and 350 ft. levels. They sank the Amazon shaft in the Groom area (the Groom shaft had caved in 1932) and drifted 100 ft. on the

"gold" vein. This company lacked capital for the undertaking of deep development; they tried to make a go of the high-level gold ore and failed, ceasing operations in 1940.

The above exploration developed, according to Beals, the following tonnages of proven and probable ore:

East Vein, Middleton area - 13,000 tons 0.22 oz.Au.,2.5% Cu.

East Vein, Groom area - 47,000 " 0.15 " " 2.5% "

Glory Hole Vein, Middleton area -- 12,000 " 0.20 " " -

Total shipments to smelters, 1928-1940, amounted to 444 tons averaging 0.126 oz. Au and 5.8% Cu.

SUMMARY AND RECOMMENDATIONS

Summary: The salient feature of the Groom copper property, 16 miles East of Wickenburg, a railroad point and supply center, consists of two strong veins, parallel and some 300 feet apart and traceable on the surface for over 9,000 feet. The limited exploration, mainly for gold rather than copper, has been confined to the East vein and its branches. Judging from the surface, the East vein is decidedly the weaker of the two, its average width being 8-11 feet, contrasted with an average width of 20-30 feet for the West vein. The outcrops of both veins show residual chalcopyrite and abundant cellular limonite derived from chalcopyrite, but that of the West vein is more persistent, has a greater average width, and shows longer stretches of promising gossan. Since all of the West vein, a number of other veins, and most of the East vein are virtually unexplored, the Groom property is still a prospect. Judging by the length and width of the veins and the nature of their outcrops, the prospect, however, is an exceptionally attractive one.

These veins are thoroughly oxidized and leached at the surface and show only sporadic copper minerals, a condition which seems likely to prevail to a depth of over 500 feet. The property presents a somewhat expensive exploration risk, based almost solely on geology, for the discovery of a large medium to high-grade copper mine amenable to relatively low-cost underground operation. Its location with respect to transportation and supplies is favorable, and it is distant only 12 miles airline from power.

Any present estimates as to size and grade of potential ore are avowedly speculative, based as they are upon judgment of outcrops. However, two to three millions tons of 5 to 6% primary copper ore is a reasonable guess as to the immediate strains involved. Several times this size operation is within the scope of reasonable conjecture. Should a zone of secondary enrichment exist much higher grade ore is possible.

Success of a venture here would depend primarily upon the following conditions:

a. The depth to which oxidation and leaching of the veins have taken place.

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Housing is available at the camp, both for this preliminary work and for the initial stages of actual exploration.

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Durand A. Hall

Edward H. Wiener

San Francisco, California

October 18, 1950

PHOTOGRAPHS

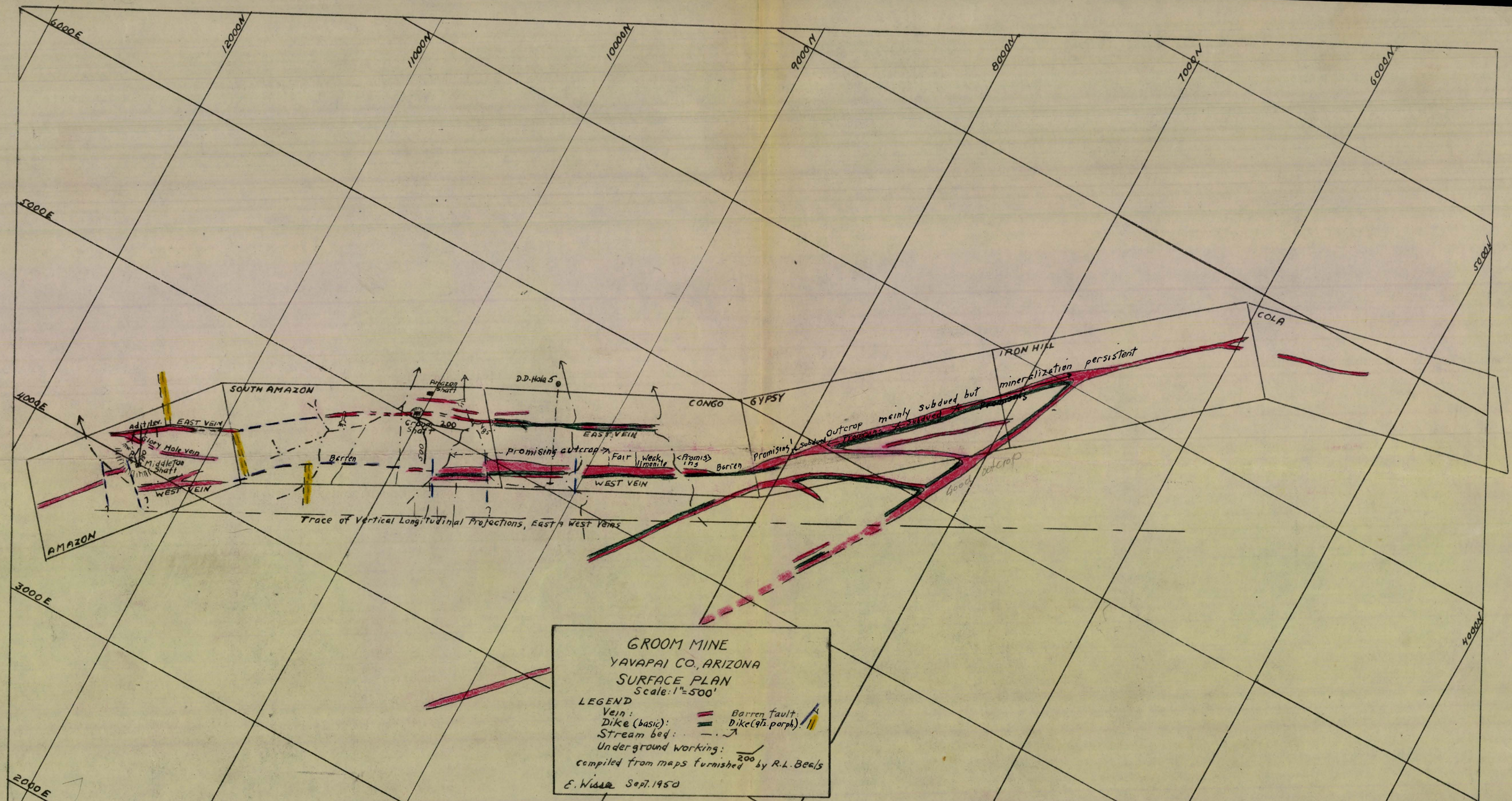
1. West Vein Outcrop. Looking Northeast; 750 ft. South of Groom Shaft; 125 ft. South of D.D.H.#5. Part of promising section.

2. West Vein Outcrop. Looking Southwest from above location of Photo #1. 1000 ft. South of Groom Shaft. Promising section.

3. West Vein Outcrop. Northern section. Looking Northwest from a point South of Middleton Shaft.

4. East Vein Outcrop. Looking Southeast. 500 ft. South of Groom Shaft.

5. West Vein Outcrop. Looking Southwest. 500 ft. South of Groom Shaft.



GROOM MINE

YAVAPAI CO., ARIZONA

SURFACE PLAN

Scale: 1" = 500'

LEGEND

Vein:

Dike (basic):

Barren fault:

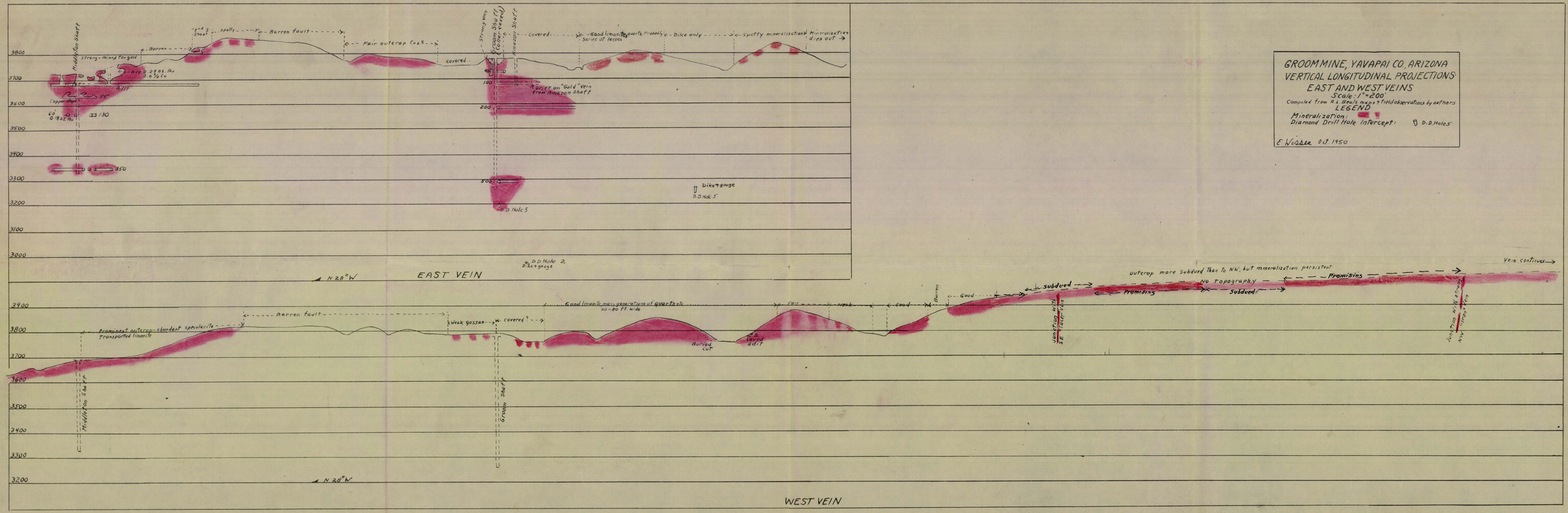
Dike (qtz. porph.):

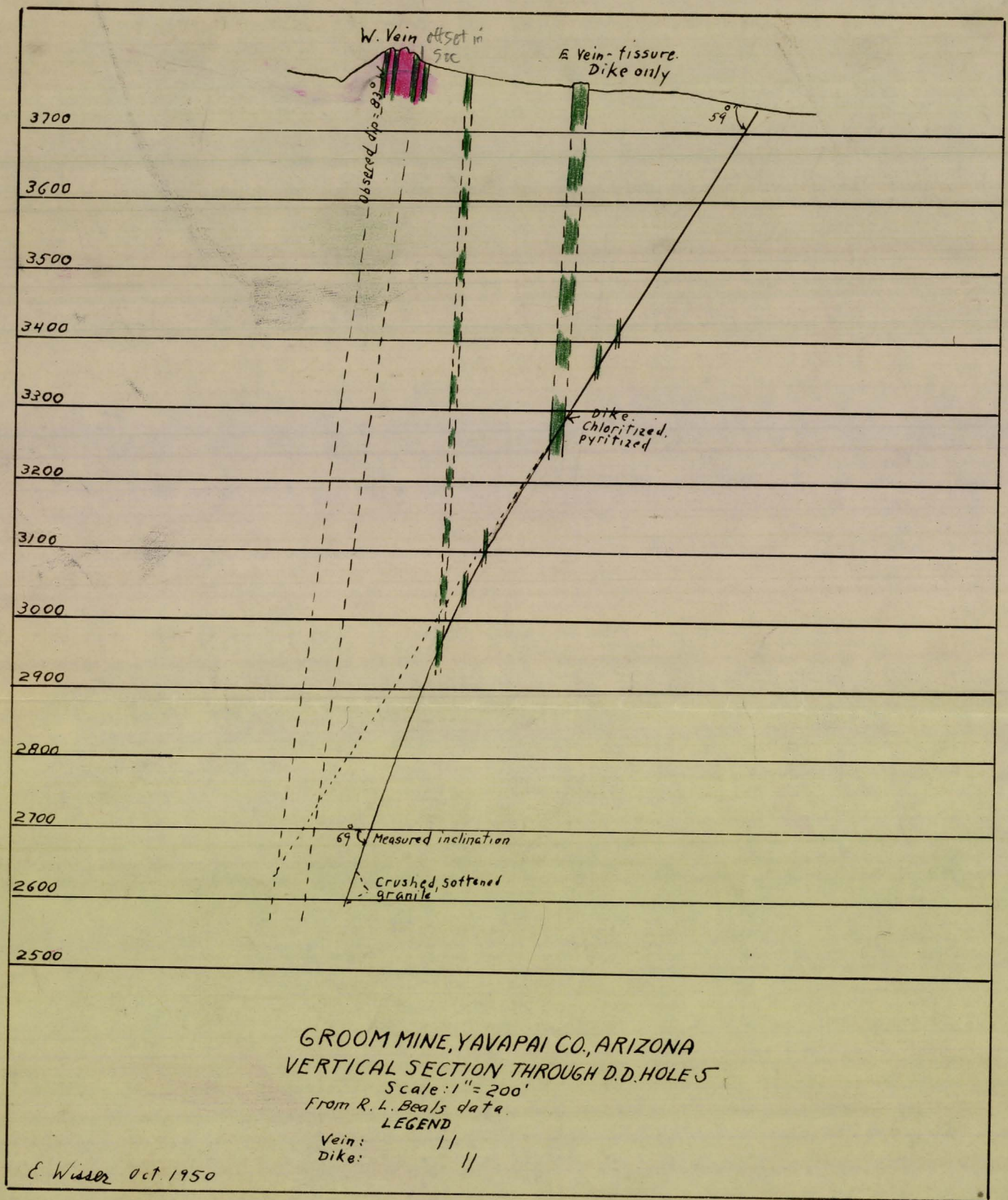
Stream bed:

Underground working: 200

compiled from maps furnished by R.L. Beals

E. Wisser Sept. 1950


GROOM MINE, YAVAPAI CO., ARIZONA
VERTICAL LONGITUDINAL PROJECTIONS
EAST AND WEST VEINS
Scale: 1" = 200'
Compiled from R.L. Beals maps + field observations by authors
LEGEND
Mineralization:
Diamond Drill Hole Intercept:
D.D. Hole 5
E. Wissee Oct. 1950
EAST VEIN
WEST VEIN
Middleton Shaft
Barren fault
Fair outcrop Cu2S
Strong-mined for gold
Ave 0.29 oz. Au
3.0 % Cu
Adit
Copper stain
0.18 oz Au
Spotty
Barren
Strong vein
Groom Shaft (Collar caved)
Amazon Shaft
Covered
Good limonite, quartz Probably Series of lenses
Dike only
Spotty mineralization
Mineralization dies out
Drift on "Gold" Vein from Amazon Shaft
D.D. Hole 5
Dike + gouge
D.D. Hole 2
Dike + gouge
N 28° W
Prominent outcrop - abundant specularite
Transported limonite
Weak gossan
Covered?
Good limonite, many generations of quartz etc
30-80 ft. wide
Buried cut
Caved adit
Fair
Weak
Good
Barren
Good
Subdued
Promising
Junction with S.E. lacer vein
outcrop more subdued than to NW, but mineralization persistent
No topography
Subdued
Promising
Junction with strong NW "iron" vein
Vein continues
Groom Shaft
3800
3700
3600
3500
3400
3300
3200
3100
3000
3900



GROOM MINE, YAVAPAI CO., ARIZONA

VERTICAL SECTION THROUGH D.D. HOLE 5

Scale: 1" = 200'

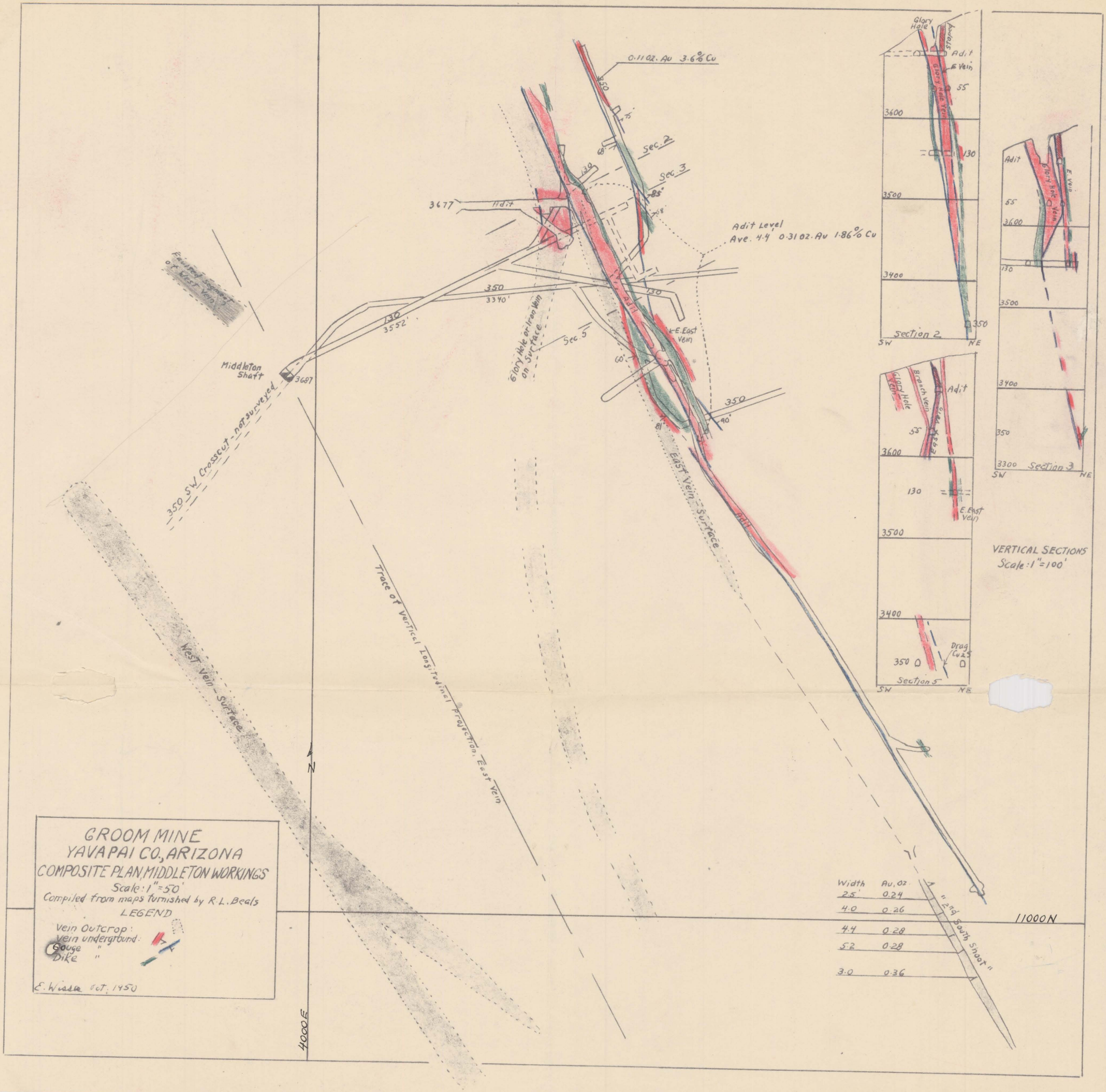
From R. L. Beals data

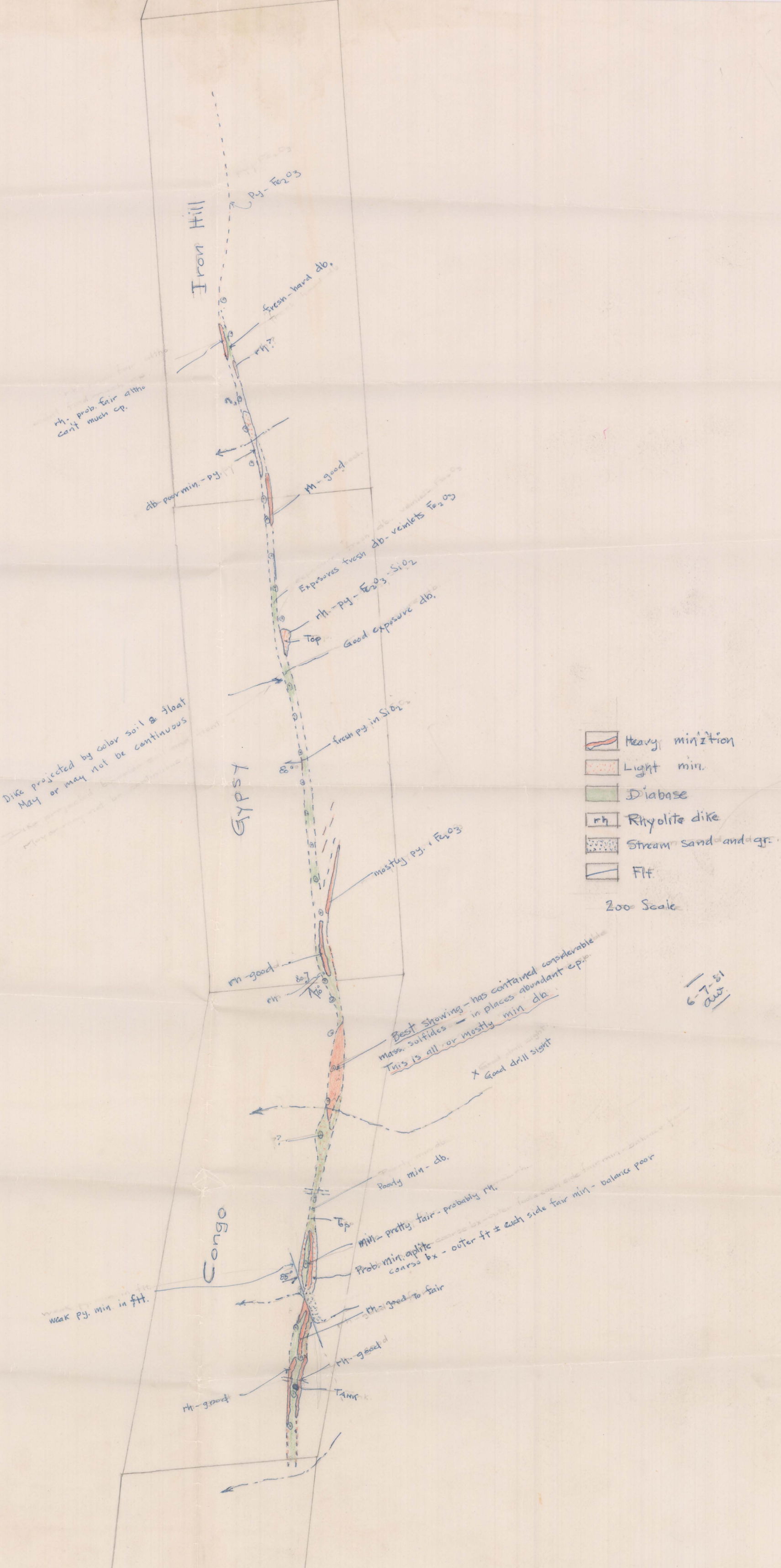
LEGEND

Vein: //

Dike: //

E. Wisser Oct. 1950


GROOM MINE
YAVAPAI CO., ARIZONA
COMPOSITE PLAN, MIDDLETON WORKINGS
Scale: 1" = 50'
Compiled from maps furnished by R.L. Beals
LEGEND
Vein Outcrop:
Vein underground:
Gouge "
Dike "
E. Wisse Oct. 1950
0.11 oz. Au 3.6% Cu
Sec. 2
Sec. 3
Sec. 5
3677
Adit
Adit Level
Ave. 4.4' 0.31 oz. Au 1.86% Cu
Faulted Segment of West Vein
Middleton Shaft
3687
350 SW Crosscut - not surveyed
Glory Hole or Iron Vein on Surface
E. East Vein
East Vein - Surface
West Vein - Surface
Trace of Vertical Longitudinal Projection, East Vein
N
4000E
11000N
"2nd South Shoot"
Width Au, oz.
2.5' 0.24
4.0 0.26
4.4 0.28
5.2 0.28
3.0 0.36
Glory Hole
Stoped
Adit
E Vein
Glory Hole Vein
Section 2
SW NE
Branch Vein
East Vein
Section 3
Drag Cu 2.5
Section 5
VERTICAL SECTIONS
Scale: 1" = 100'


Iron Hill
Py - Fe2O3
fresh - hard db.
rh.
rh: prob. fair altho
can't much cp.
db- poor min. - py.
m - good
Exposures fresh db - veinlets Fe2O3
rh. - py - Fe2O3 - SiO2
Top
Good exposure db.
fresh py in SiO2
Dike projected by color soil & float
May or may not be continuous
Gypsy
mostly py. + Fe2O3
m - good
rh
Best showing - has contained considerable
mass. sulfides — in places abundant cp.
This is all or mostly min. db.
X Good drill sight
Poody min - db.
Top
min - pretty fair - probably rh.
Prob. min. aplite
coarse bx - outer ft ± each side fair min - balance poor
rh - good to fair
rh - good
rh - good
Top
weak py. min in ftt.
Heavy mineration
Light min.
Diabase
rh Rhyolite dike
Stream sand and gr.
Flt
200 Scale
6-7-51
AWT

SIGNIFICANCE OF OUTCROPS AT THE GROOM MINE, ARIZONA, IN TERMS OF COPPER ORE AT DEPTH.

Edward Wisser and Durand A. Hall

February 13, 1951

Yavapai, County

SIGNIFICANCE OF OUTCROPS AT THE GROOM MINE, ARIZONA, IN TERMS OF COPPER ORE AT DEPTH.

INTRODUCTION

To mining scouts familiar with the surface expressions left behind by copper sulphides which have been leached by surface waters and removed from the place in which they formed the Groom vein outcrops tell a simple story: these cellular outcrops represent bodies of what was formerly commercial copper ore. Processes of weathering and oxidation have removed the original copper and much of the original iron from the upper portions of these ore bodies, and transported these metals downward. Much of the copper may have been redeposited within the veins below the zone of oxidation; if the original ore bodies extend down below the zone of oxidation and leaching, primary ore of commercial grade should exist there. The leached outcrops therefore may indicate copper ore bodies below them, despite the fact that they exhibit next to no copper themselves.

Leached outcrop interpretation is an exploration technique built up by intensive study over many years; what is clear to those who have worked with it for years is naturally far from clear to those who have not. There follows a very elementary exposition of the subject, and an attempt to apply the technique to an interpretation of the Groom outcrops in terms of possible copper ore below them.

OCCURRENCE OF METALS IN THE EARTH'S CRUST

The crust contains all the metals scattered through it in minute amounts; but it is only where commercially valuable metals are concentrated in bodies of sufficient size and richness to yield a profit that these metals can be mined. Such concentrations are called ore bodies, and have a variety of forms. They may lie in quartz veins, occupying only portions of the vein; they may be found in limestone beds; their metallic particles may be disseminated sparsely but evenly through igneous rock (porphyry

copper deposits); they may take on still other forms.

Metals in the crust occur usually not in the pure form but as compounds, most commonly as their sulphides. Among the commoner metallic sulphides are:

Pyrite, FeS_2, iron sulphide
Galena, PbS, lead sulphide
Sphalerite, ZnS, zinc sulphide
Chalcopyrite, $CuFeS_2$, copper-iron sulphide
Chalcocite, Cu_2S, copper sulphide

WEATHERING OF ORE BODIES

Most ore bodies, whatever their shape, were formed originally at some distance below the surface existent at the time. After ore formation erosion, which works constantly to lower the surface, in time exposes the ore bodies (Figure 1). Sulphide ore bodies exposed to air and percolating ground water charged with air suffer chemical and physical changes; the zone in which this "weathering" takes place extends from the surface down some tens, hundreds or in places even thousands of feet. It is called the zone of oxidation (Figure 1).

Since erosion normally wears the surface gradually downward, the zone of oxidation works on downward with it; so long as erosion and oxidation take place at the same rate the oxidized zone maintains a constant depth below the outcrop; but where erosion suddenly accelerates its pace there may not be sufficient time for complete oxidation and ore metals may be caught in or near the outcrop. Where erosion is retarded and the water table lies deep (see below) oxidation may extend to considerable depths, particularly in arid climates such as that of the Southwest.

The lower limit of the zone of oxidation roughly coincides with

the water table, an undulating surface, above which crevices in the rock form channels for circulating water,and below which all openings are permanently filled with water.

Some metals such as lead resist weathering; where the surface of erosion penetrates a lead ore body, lead, commonly as lead carbonate, appears in the outcrop. Ore is therefore found at the surface and is readily found by prospectors. On the other hand other metals, notably copper, in a similar situation tend to be completely removed by leaching from the outcrop and throughout much of the zone of oxidation (Figure 1). These metals may be redeposited,in enriched form, at depth, and they may be preserved in their original or primary form below the zone of oxidation; but the finding of such hidden ore bodies beneath their barren outcrops may be long delayed. They may never be found unless a prospector recognizes in their leached outcrops the characteristic traces which the vanished metal such as copper leaves behind.

Oxidation, Solution and Sulphide Enrichment of Copper Ores.- Metallic sulphides are especially unstable under weathering. Most copper sulphide ores contain more or less pyrite; oxidation of the pyrite provides the most powerful dissolving agents, in the form of ferric sulphide and sulphuric acid, which transform the copper in the normally insoluble copper sulphides chalcopyrite, chalcocite etc. to the soluble copper sulphate ($CuSO_4$). A further product of oxidation of such mixtures is limonite (fine-grained oxides of iron of variable composition).

The limonite tends to remain in the outcrop while the copper as copper sulphate tends to be leached out and downward. It has been found that limonite derived from pyrite associated with zinc sulphide has a different appearance from that of limonite of a different origin,

such as that derived from a mixture of chalcopyrite and pyrite. Thus the various limonites are distinctive, and diagnostic of the sulphides which produced them.

As the sulphate solutions trickle dow nward through the zone of leaching (Figure 1) they may drop a part or all of their metallic load toward the bottom of that zone and form oxidized ore deposits,especially in rocks with alkaline reaction such as limestone.

Where the sulphate solutions pass through the zone of oxidation and penetrate the water table,their copper may be precipitated as secondary sulphides (chalcocite and others) to form a zone of secondary sulphide enrichment (Figures 1,2,3 and 4). This zone commonly coincides with the topmost horizon of original,primary,unaltered sulphides. The secondary chalcocite deposits in cracks within and between masses of the original sulphide, which is often chalcopyrite. These secondary-primary ores may be exceedingly rich in copper,since they result from accumulated leaching of copper from an oxidized zone of considerable vertical range, and compressing of the copper within a narrow vertical range which contains as well primary copper ore.

Finally, as shown in Figure 1, the lower part of the original ore body, unaffected by oxidation and leaching,forms the zone of primary ore.

Thus the effect of weathering of copper ore bodies is to render barren their upper parts, often to enrich, in compensation,their middle parts,and to leave unaltered that portion of an original ore body lying below and beyond the reach of oxidation processes.[1]

1. A.M.Bateman: Economic Mineral Deposits,John Wiley & Sons,New York, 1950, 245-252

W.H.Emmons: The Enrichment of Ore Deposits.U.S.Geol.Surv. Bull. 625, 1917, 11-12 and 44-68.

W.Lindgren: Mineral Deposits, McGraw-Hill Book Co.Inc.New York 1933, 813-818 and 831-838.

H.E.McKinstry: Mining Geology, Prentice-Hall Inc.New York,1948, 251-257.

Examples of the Oxidation of Copper Ore Bodies.-

1. Mine in Southwestern United States (Figure 2). Figure 2 is a longitudinal section through a mine,the name of which Blanchard could not publish because his illustration came from a private report. Drilling beneath the leached outcrop passed through 300 ft.of leached oxidized material barren of copper and entered the sulphide ore lens below. Subsequent exploration from a shaft discovered the leached body that fails to crop out; underground drilling below this barren but "promising" mass of leached limonite discovered the right-hand sulphide lens. In the first case, the surface of erosion had cut into the site of the original ore body and a leached outcrop formed; in the second case,the top of the original ore body,now marked by limonite, still lies beneath the surface,so that the outcrop above the ore body gives no hint of the ore below.

2. Butte, Montana (Figure 3). The Butte district, although it has produced over two and one-half billion dollars worth of copper,is no exception to the rule: copper was almost wholly leached from the outcrops of its veins. Reno Sales, formerly Chief Geologist, Anaconda Copper Mining Co. says[2]: "Almost without exception the copper

2. Reno H. Sales: Superficial Alteration of the Butte Veins.ECON. GEOL. Vol.5,1910, 15-21.

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veins are barren of copper at the outcrop, this being true also of the zone of oxidation below. There are no visible copper minerals

of any kind, oxides, carbonates or silicates,and it rarely occurs that an assay of copper in the oxidized portions of the veins will show mor than a trace of copper...Taking a broad view of the entire copper producing area, it can be stated that there is but little, if any, positive evidence to be found in those portions of the veins nearest the surface, that is, the oxidized material, to indicate the existence of copper in commercial quantities or otherwise at greater depths."

Sales' final statement,made 40 years ago,no longer holds;if the Butte deposits still lay virgin, they would be discovered from surface evidence alone, because the limonite in the vein outcrops can now be translated in terms of the copper sulphides associated with its formation.

3. Superior, Arizona.(Figure 4). The sulphides involved in the above examples are mainly chalcocite, enargite and others;chalcopyrite is sparse. At the Magma Mine, Superior,Arizona in contrast, nearly half the primary ore is chalcopyrite, the remainder being bornite (Cu_5FeS_4), similar in composition. The outcrop above the ore body is strongly leached of copper and shows but little limonite.It is inconspicuous and has nothing of the strong rusty limonite "gossan" or "iron hat" characteristic of outcrops over copper ore elsewhere.

The present depth of the leached zone is 400 ft.,but the authors believe the country to have been tilted down to the east since oxidation,as suggested in Figure 4,so that the lower limit of oxidation lay roughly horizontal before tilting. The original depth of oxidation, before the tilting,is thought to have been about 1500 ft..

Many other examples could be given; it is thought that the above will suffice for present purposes.

INTERPRETATION, IN TERMS OF POSSIBLE COPPER ORE, OF SPECIMENS COLLECTED FROM THE GROOM MINE, ARIZONA.

The Groom copper property, Yavapai County, Arizona, is described in the report by Durand A. Hall and the writer of October, 1950. The present paper is an appendix to that report,to which the reader is referred for a description of the vein system.

Hall has made three trips to the property, the writer one. Specimens of vein outcrops were collected on all three trips to make up the suite discussed below. Hall, who has had extensive experience in the interpretation of leached copper outcrops, is mainly responsible for the following observations,which have however been checked and concurred in by the writer.

The Problem at the Groom.- No mining prospect can be judged solely on the basis of a collection of specimens, no matter how complete, because specimens fail to convey a notion of relationships in the field. The present specimens are mainly from vein outcrops,"gossan"; but they do not show the relative proportions of various types of gossan material in the outcrops as a whole.They are qualitative,not quantitative, and without knowledge of field relationships even qualitative conclusions are subject to error. The careful, detailed field mapping needed to furnish conclusive data is as yet undone. A far larger suite of specimens studied as an adjunct to field mapping should give a definitive interpretation of the Groom outcrops in terms of possible ore.

Except for limited workings on the East vein,the Groom is essentially an unexplored prospect. It lacks,therefore,standards to use in judging outcrops: no primary sulphide ore bodies have been developed from which the course of oxidation may be traced upward from the top of the sulphide zone to the outcrop and vice versa. The sparse remnant

copper sulphides found in the vein outcrops help to trace the process of oxidation from original chalcopyrite through partly oxidized sulph into limonite and finally into the cavities remaining after even limonite has been washed away;but such sporadic evidence is not to be compared with that offered by an actual copper sulphide ore body oxidized in its upper parts.

For this reason interpretation of the Groom outcrops must rest largely on sources outside the district: direct comparison of Groom material with that from districts where the relationship between original sulphide ore and oxidized outcrops has been established by minin or comparison with descriptions in the literature of leached outcrop technique, or by both. Broad experience is more vital in judging the G Groom outcrops than it would be in an explored district where standard of comparison have been established.

The problem at the Groom is this: what was the nature of the primary ore, now represented only by the barren gossan in the outcrops? As will be shown,the gossan indicates the former presence,in what is now the outcrop, of chalcopyrite. How certain is this indication, and if justified,did the primary ore contain enough chalcopyrite to be commercial? If so,is there primary,and possibly secondary ore, at depth beneath the surface showings? Chalcopyrite ore is almost always accompanied by greater or smaller amounts of pyrite; on the other hand,pyrite bodies frequently occur with little or no chalcopyrite. Was the original Groom mineralization mainly pyrite with only insignificant chalcopyrite,or was it chalcopyrite with subordinate ~~xxxxxxxx~~ pyrite? An attempt is made to supply at least suggestive answers to these vital questions.

Leached Outcrop Interpretation.- Correlation of leached, barren outcrops with the sulphides that gave them birth was first initiated, on a sound basis, by Augustus Locke[3], who devoted most of his attention, however, to outcrops of disseminated copper deposits. It remained for Roland Blanchard and P.F.Boswell, coworkers with Locke on the original enterprise, to develop techniques for the interpretation of leached outcrops of other types of ore bodies, such as those of the quartz-copper veins at the Groom mine. The following generalizations are taken from the Blanchard-Boswell paper with which the Groom problem is most nearly concerned [4]. For reasoning and chemistry refer to original paper, appended to this report.

3. Augustus Locke: Leached Outcrops as Guides to Copper Ore. Williams & Wilkins Co., Baltimore, 1926.

4. Roland Blanchard & P.F.Boswell: Notes on the Oxidation Products derived from Chalcopyrite. ECON. GEOL. vol.20, 1925, 613-638.

Oxidation products from chalcopyrite and chalcopyrite-pyrite mixtures where the surroundings are chemically neutral ("Inert gangue" such as the quartz in the Groom veins) differ from those where the surroundings contain neutralizer (e.g. limestone). The following conclusions refer to inert surroundings only.

Three types of limonite form in neutral environments:

1. Coarse cellular: shows a limontic, siliceous honeycomb with sharp, angular pattern. Cells are often parallel; cell walls are rigid; cell diameters range from 0.2 mm. to 5 mm. Coarse cellular limonite is especially common where nodules of chalcopyrite have been leached from quartz veins. In no case has the chalcopyrite from which this type of limonite forms been found without some admixture of pyrite, but there is

usually less pyrite than chalcopyrite.

This coarse cellular limonite develops as follows: in the primary sulphide before the start of oxidation minute silica veinlets ramify through the nodular mass,following tiny fractures. As oxidation of the chalcopyrite proceeds,these silica veinlets advance and eat their way into the purer portions to make a connected webwork throughout the sulphide mass,with unoxidized or partly oxidized sulphide filling the intervening spaces. These extensions of the veinlets are not white like the original silica,but consist of brown, yellowish or reddish jasper.

As oxidation of the chalcopyrite goes further,the sulphide residuals within the webwork become completely oxidized,leaving behind the cellular honeycomb mentioned. In some cases the cell walls are coated with fine, powdery limonite;in other cases the cells are completely empty. In the latter case the original sulphide nodules carried a higher percentage of pyrite than in the former case. Where however the original sulphide was entirely pyrite no cellular limonite results;the resulting cavity is free from limonite of any type.

2. Fine Cellular. This type often grades into the coarse cellular type. It differs from the latter as follows:

Cells smaller,up to o.5 mm.or less. No white silica veinlets;boxwork made up wholly of limonitic jasper. Most of the cells are thickly coated with compacted fine dusty limonite on their walls and carry limonite within the cells themselves. The total iron left in the cavity as limonite from pure chalcopyrite usually represents from one-fourth to one-third the amount of iron of the original sulphide. This amount decreases with increase in pyrite content of the original sulphide until,when equal molecular ratios of pyrite and chalcopyrite exist in the original

sulphide the cavity left upon oxidation is devoid of limonite.

This fine cellular limonite type is the only one with a characteristi color:it is a deep yellow orange (ochreous).

Chalcopyrite is not the only sulphide which on oxidizing leaves cellular limonite within the space formerly occuppied by the sulphide ("indigenous limonite").But as between chalcopyrite and pyrite oxidizing in an inert environment,it is the only one ordinarilly leaving it.

3. Glassy,compact type. Limonite varnish or pitch is confined too closely to the vicinity of unoxidized chalcopyrite to have a bearing on the present problem.

Analysis of the Groom Gossan Specimens.- This report is intended to be read while the suite of Groom specimens, referred to by number, is at hand. Less satisfactory is the use of the photos,which carry corresponding numbers. Where the specimens themselves are available, a hand-lens is needed to detect some of the smaller features described.

The suite is divided into a series of groups, representing stages of oxidation.

Group 1. Relict Sulphides Present.

Specimens from a surface cut on the East Vein about 1000 ft.north of the Groom shaft.

104. Oxidation of a large nodule of chalcopyrite,as shown by remnants of chalcopyrite. Note cellular development of limonite and thin cell walls of secondary as well as primary silica,as described by Blanchard & Boswell. In a few places sufficient limonite has been removed to show structure of the cells. Nodular forms taken by the limonite are typical of this stage of chalcopyrite oxidation.

101. More relict sulphides than in 104. Compare with Plate I-B, Blanchard-Boswell paper cited on page 9 and appended;the photo shows original triangular shape of the chalcopyrite nodules,similar to those in Spec.101. Compare these nodules of limonite with the open spaces in Specimens 202, 301.

106. Similar,but enriched with sedondary chalcocite,apparently deposited on fracture faces.

Group 2. No Relict Sulphides Left, but Cavities Still Undeveloped.

201. East Vein outcrop 1000 ft.north of Groom shaft. No chalcopyrite left, but compare the limonite with that of 101, 104, 106, which show chalcopyrite in process of oxidation. Note in 201 development of cellular boxwork in the limonite.The thin cell walls are limonitic jasper as described by Blanchard & Boswell.

Compare the structure of 201 with the finer-grained structures of 302,from Group 2 and the West Vein. 302 shows the same angular,cellular pattern, but with much of the limonite removed by solution. 205 (see below) shows an intermediate phase.

202. Similar to 201 but shows a "skin",which marks the actual surface of the ground, and which shows completely leached cavities;but here the removal of limonite may have been due to simple washing out by rain water rather than chemical leaching. 202 is from the same area as 201.

204. West Vein outcrop. Shows gradation from limonite to cellular cavities typical of the better-looking outcrops on the West Vein.

205. From central part of best-looking segment of West Vein outcrop. This type of cropping is the most conclusive to be found on the West Vein outcrop. Except for the actual presence of chalcopyrite,all the steps of oxidation described by Blanchard & Boswell and above, by the present writers, are shown. It is likely that a polished surface of the specimen would show relict chalcopyrite under the microscope. Some oxidized copper still remains.

Compare 205 with 104, 101, 106, where relict chalcopyrite is preserved.

208. From a Branch vein off the West Vein, near the junction. Shows fine cellular limonite with specularite (iron oxide). The limonite is typical of the oxidation of chalcopyrite which had only minor admixed pyrite, Were equal amounts of pyrite and chalcopyrite present the cells would be nearly empty (see pages 10-11). If the original sulphide had been entirely pyrite, no limonite would remain.

Note that the limonite is the typical dark yellow-orange mentioned by Blanchard & Boswell as the one color always characteristic of a chalcopyrite origin. (See page 11).

The large amount of primary specularite suggests that the ore-forming solutions were deficient in sulphur, for otherwise pyrite would have formed. This is an added argument in favor of low pyrite in the original copper ore.

208,with the similar 308 (see Group 3) represent in our opinion original chalcopyrite ore of very high grade.

Group 3. Leaching farther Advanced. Limonite derived from Chalcopyrite and probably also from Pyrite.

302. South end of West Vein croppings, at north end of Red Hill. Shows typical coarse cellular limonite, and is characteristic of the best-looking stretches of the West Vein outcrop. Note the sharply angular pattern of the cell walls and their thinness. Compare 302 with the photo of coarse cellular limonite derived from chalcopyrite shown in the appended paper by Blanchard: "Significance of the Iron Oxide Outcrop at Mount Oxide, Queensland", Proc. Australasian Institute of Mining and Metallurgy, 1939, (Figure 8).

The small amount of limonite remaining in the cells suggests the presence of some pyrite in the original chalcopyrite ore (up to 1:1), affording sufficient acid etc. to remove the iron. Compare with 208, 308, where much dark ochreous limonite remains, indicating a lack of much pyrite in the original ore. However, as with 202 (page 12) soft limonite could be removed at the very surface by rain water scouring.

302 is thought to represent an original ore running 10% to 15% copper.

301. West Vein, best section. Like 302, but with still coarser pattern of cellular limonite. Typical chalcopyrite-limonite.

307. West Vein Croppings. Fine cellular limonite, but of a color and pattern not too certainly derivable from chalcopyrite.

303. West Vein Outcrops, south end, on the north slope of Red Hill. Likewise indeterminate. May have derived from coarse-textured pyrite with only minor chalcopyrite. Specimen taken a few feet from 301, 302.

309. Suggests also original pyrite: cell walls thick compared with those of the chalcopyrite-limonite specimens, and the angular, straight-line pattern of the latter is less evident. Compare with 301, 302.

CONCLUSION

The suite of specimens described are believed to be reasonably representative of long stretches of Groom vein outcrops. If the interpretation in the field and in the laboratory, that the writers have attempted is correct, namely, that these stretches represent former copper sulphide ore which averaged from 3% to 6% in copper, the Groom would appear to be well worthy of exploration. The probable great depth of oxidation, perhaps 500 to 700', makes an exploration venture expensive. For this reason all the corroborative information that can be gathered in the field and in the laboratory should be focused on the problem before any program of drilling or shaft sinking is embarked on.