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PRECIOUS METALS WITH A VOLCANOGENIC BASE METAL DEPOSIT: THE UNITED VERDE EXTENSION MINE, JEROME, ARIZONA

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A paper presented at the 1988 N.W.M.C.

ABSTRACT

From 1915 to 1938 the UVX produced 3.9 million tons of 10.2% Cu, 0.04 oz/t Au, and 1.7 oz/t Ag. This production came from three distinct types of ore bodies: i) About 3.0 million tons averaging 12% Cu, .03 oz/t Au, and 1.2 oz/t Ag. This occurred in the main orebody and a couple satellitic bodies, each massive chalcocite/cuprite grading downward into chalcopyrite/pyrite and ultimately near barren pyrite. The main orebody occurs above a quartz eye rhyolite traversed by a stockwork of chalcopyrite veinlets flanked by dense black chlorite. The copper mineralization is overlain by chert, volcaniclastic rocks, and basalt flows. The nature of this base metal occurrence is the principal evidence for a volcanogenic origin. ii) 850,000 tons averaging 6% Cu as chalcocite, malachite and azurite, 0.06 oz/t Au and 3.5 oz/t Ag from lens-shaped breccia zones which averaged 55% silica, were very iron oxide rich and appear to be silicified volcanic rocks off the margin of the main chalcocite orebody. iii) 35,000 tons of fine grained, brecciated and iron-oxide bearing material which averaged 90% silica, 0.40 oz/t Au and 2.0 oz/t Ag. This material is also peripheral to the main orebody and adjacent to top and bottom margins of a diorite sill which intrudes the volcaniclastic succession overlying and flanking the chalcocite body. The diorite has a core of chlorite, epidote and calcite pseudomorphing primary minerals, a middle zone which is essentially an argillic assemblage and an edge that is extremely siliceous and which fades into a siliceous hornfelsic-textured equivalent of the hosting volcaniclastic rocks.

The interpretation is that the chalcocite body is a supergene enriched pyritic lense of syngenetic origin above a focused discharge site for hydrothermal fluids, probably sea water convected by the heat of a rhyolite dome. The siliceous gold ore lenses at the margin of the diorite sill are viewed as primary gold concentration in chert off the edge of the rhyolite dome, locally reworked, silicified, and reconstituted into higher grade pods by alteration of the diorite sill at its time of emplacement. This alteration was essentially an exchange of water into the sill and silica into the possibly still wet volcaniclastic rocks. A third reconstitution and upgrading took place after lithification, uplift, fracturing along linear faults and downward percolation of ground water, which redistributed silica, copper, iron, and precious metals into the now most auriferous zones adjacent to the diorite sill but notably within 300 feet of the Precambrian-Paleozoic unconformity. The silica-copper ore bodies are interpreted as mainly supergene concentrations of quartz and secondary copper minerals in broken volcanic rocks adjacent to the steep regional Verde Fault. This copper and appreciable precious metal was carried downhill from the major United Verde orebody which is uphill and across the regional fault from the United Verde Extension. The supergene process is still active and can be observed in the stream course which bisects both deposits and the fault.

INTRODUCTION

Copper was the principal product through the first half of this century at Jerome in Yavapai County, central Arizona. This came from two large and several small massive sulfide bodies stratabound within steeply dipping Proterozoic volcanic rocks successively overlain by flat lying Paleozoic sandstone and limestone and Tertiary conglomerate and basalt (Anderson and Creasy, 1958). The first found, and largest of these deposits was the United Verde which outcropped and produced 33 million short tons at 4.8% Cu, .043 oz/t Au and 1.5 oz/t Ag from massive and stringer chalcopyrite in the footwall of a pyritic lense perched upon a chlorite pipe penetrating a rhyolite footwall and overlain by chert, tuffs, and basalt (figure 1 and table 1). The second largest orebody was the United Verde Extension (UVX) which did not outcrop but was found by underground exploration on the downthrown side of the Verde Fault which bisects the area. The United Verde Extension produced 3.9 million short tons averaging 10.2% Cu, 0.039 oz/t Au, and 1.7 oz/t Ag, mostly from a lense of chalcocite above a chalcopyrite stringer zone within rhyolite and overlain by chert and tuff. Initially these massive sulfide bodies were interpreted as sulfide replacement of schistose rock and the United Verde Extension was believe to be the downfaulted, supergene enriched, top of the United Verde. Subsequently Paul Handverger's and Paul Lindberg's (1974) mapping convinced most that the two ore bodies are independent, each above their own hydrothermal roots which flair out upon a common exhalative stratigraphic horizon now folded into the Jerome Anticline and separated by over 2,000 feet of normal displacement on the Verde Fault (figure 2).

In 1980, Paul Handeverger, vice-president of Verde Exploration, Ltd., had the presence of mind to assay for gold in ferruginous cherty specimens from the company's classic rock collection taken from mine workings inaccessible since the 1930's. These rocks were originally mapped as gossan above the supergene copper deposit (figure 2). It was Handverger's contention that this might be auriferous chert peripheral to a volcanogenic base metal massive sulfide deposit and an attractive target of gold-bearing silica flux rock much in demand by Arizona's copper smelters. A. F. Budge (Mining) Limited has drilled this target from rehabilitated mine workings (figure 3) concurrently with compilation of past production records. This work has defined three ore types on the basis of metals, gangue minerals, and location, and supports a reinterpretation of distribution of precious metals at the United Verde Extension.

CHALCOCITE-CUPRITE ORE

The main ore body which sustained production at the UVX was an equi-dimensional lense of massive chalcocite and cuprite of approximately 3 million tons at 12% Cu, 0.03 oz/t Au and 1.2 oz/t Ag, which extended from 400 to 800 feet below the Precambrian-Paleozoic unconformity to diminishing amount of chalcopyrite and pyrite in stringers within chloritic schist persisting downward an additional 250 feet. It has a footwall of rhyolite against the Verde Fault and a hanging wall of chert and tuffs.

COPPER-SILICA ORE

Copper-silica ore was mined from more than 20 separate bodies aggregating about 850,000 tons of 6% Cu, 0.06 oz/t Au, 3.5 oz/t Ag, plus 55% SiO_2 and 12% Fe. Gold abundance was extremely variable from stope to stope and body to body over a range of 0.02 oz/t to 1 oz/t (tables 2 and 3). These ore bodies are between 100 and 400 feet below the Precambrian-Paloezoic unconformity in immediate hanging wall strands of the Verde Fault (figure 4). Malachite, azurite, chalcocite, and minor cuprite and native copper occur with up to 25% hematite and goethite along fractures in shattered, massive, fine grained quartz. The hematite varies from blood red to brown in color and earthy and porous to massive and flinty. Some hematite is specular.

GOLD-ONLY ORE

Gold-only ore was discovered in the 1920's when an exploration cross-cut intersected a fine grained, gritty quartz interval which "flowed like sand" and contained more than 1 oz/t Au. This material was more than 90% SiO_2 and virtually devoid of alumina and alkalis. It was mined for flux and shipped direct to the smelter at the rate of one car of gold-only ore to three cars of massive chalcocite. Most of the gold-only ore came from one stope, the Gold Stope (figures 3, 4, and 5) of 35,000 tons averaging 0.4 oz/t Au and 2.0 oz/t Ag with less than 1000 ppm combined base metals but with appreciable As, Bi, Hg, Mo, Sb, Se, Sn, and Te. Except for Sn as cassiterite, none of these trace metals has been identified in mineral species. Gold occurs in micron-size grains of native metal and electrum.

The Gold Stope, and additional gold-only ore bodies found by recent exploration, are farther into the siliceous hanging wall of the Verde Fault and stratigraphically above copper-silica ore. They are in the first 300 vertical feet below the Precambrian-Paleozoic unconformity, and within wrinkles on foot and hanging wall of a diorite sill which is roughly conformable to the Verde Fault and to hanging wall tuffs and cherts. The ore bodies are shattered lenses with several generations of hairline to millimeter thick fractures healed by quartz and yellow to brown geothite and hematite which contain in some instances discordant pipe-like zones of matrix-supported breccia in which clasts are inches to several feet in diameter of finely fractured, equigranular, fine grained quartz. Clasts are angular to round and both clasts and matrix are traversed by nearly horizontal liesegang bands of variously colored iron oxides. Fractures and bands fade outward from the hanging wall of the Gold Stope into doubly graded chert breccias. The footwall of the Gold Stope grades into a massive siliceous hematite-rich rock and progressively into a beige delicately banded to massive and siliceous margin to the diorite sill. This so-called beige-banded silica is the hornfelsed margin which occurs everywhere concentric to the diorite sill.

THE DIORITE SILL

The diorite sill has an average thickness of 250 feet and extends from above the massive chalcocite-cuprite body for 2,000 feet to the northwest beneath the Precambrian-Paleozoic unconformity (figure 3). It has a core with a sub-ophitic texture of chlorite, epidote, and calcite pseudomorphing plagioclase and hornblende. This propylitic assemblage at the core of the sill grades outward to both hanging and footwall zones dominated by clay minerals. There is abundant hematite and occasional native copper along fractures. The argillic zone grades outward to an intensely silicified and kaolinized margin. Beyond are the earlier volcanics, generally cherts, which are hornfelsed for several feet adjacent to the diorite.

INTERPRETATION

In brief, the United Verde Extension ore body is steeply inclined and from bottom up is veinlets of chalcopyrite and pyrite in black chlorite overlain by a lense of massive chalcocite after pyrite and succeeded upward by extremely siliceous, iron-rich, broken rocks adjacent to the Verde Fault and in hanging and footwall of a diorite sill. This siliceous, iron-rich rock contains copper-silica bodies with 0.06 oz/t Au and 3.5 oz/t Ag and gold-only bodies with an average of 0.17 oz/t Au and 3.8 oz/t Ag which are close to the diorite sill and the unconformity between Precambrian and Paleozoic.

Lindberg's (1974) interpretation of base metal massive sulfide distribution does not consider gold except as a primary trace metal of volcanogenic base metal massive sulfide deposits with some supergene enrichment in the UVX. In his interpretation the siliceous, iron-rich zone is an in situ gossan immediately below the unconformity and immediately above the supergene massive chalcocite-cuprite body.

However, it is our contention that the hypogene and supergene processes must be somewhat more complex to explain the total metal content and its distribution relative to the diorite sill. We interpret the following events: 1) the diorite sill intruded into still hydrous exhalative cherts and cherty tuffs overlying and flanking the primary sulfide deposit of the UVX.

2) during emplacement and cooling the diorite was hydrated by water from the cherts and tuffs to propylitic and argillic mineral assemblages by an exchange of water for silica. The bulk of expelled silica is now the beige-banded siliceous halo to the diorite, and the siliceous, repeatedly fractured cherts and tuffs marginal to the sill.

3) intake of cold water into the sill was diffuse but discharge of warm water bearing iron, gold, and other metallic elements was focused at step-like wrinkles in the sill margins and into coincident disrupted zones within flanking cherts and tuffs. This fluid flow affected the first upgrading of iron and precious metals and other attendant trace elements at epithermal-like sites.

4) with erosion following Tertiary normal movement on the Verde Fault, the United Verde massive sulfide deposit was exposed. Meteoric water running down the fault scarp and into the fault zone progressively enriched the copper deposit of the UVX in place but also selectively leached precious metals, copper, silica, and iron from the United Verde and redeposited them in the Verde Fault zone in the first few hundred feet below the unconformity.

There is no convincing pseudomorphous evidence that the siliceous and iron-rich area was ever sulfide-bearing or particularly metalliferous. In addition, the present course of Bitter Creek is through the United Verde to the UVX and during the rainy season has running water which is milky with silica gel and assayable iron, copper, and gold. This is depositing as ferricrete just down stream from the UVX and as copper oxides on fractures in Tertiary basalt.

CONCLUSIONS

The primary gold content of the base metal massive sulfide deposits at the United Verde and UVX is average for this type of deposit. The elevated gold content at the UVX is by secondary hypogene concentration in peripheral cherts during early mafic sill emplacement in the Precambrian and, by transported supergene enrichment from Tertiary to present.

ACKNOWLEDGEMENTS

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Two excellent theses at the University of Western Ontario have advanced understanding of the effects of the diorite and the petrology of the silica body. They were done by Steve Harding (1986) and Iain Sloan (1987) respectively.

Other laboratory support is much appreciated from Tom Nash (petrographic study - USGS, Denver), Holly Huyck and Tiebing Lieu (XRD and SEM work, University of Cincinnati, Ohio) and Peter McLean (petrographic study of the gold-only ores, University of Western Ontario, London, Ontario).

	U.V.	U.V.X.
Production (millions short tons)	33.0	3.9
%Cu	4.8	10.2
oz/t Au	0.043	0.039
oz/t Ag	1.6	1.7

Table 1: Production from the United Verde and United Verde Extension Mines

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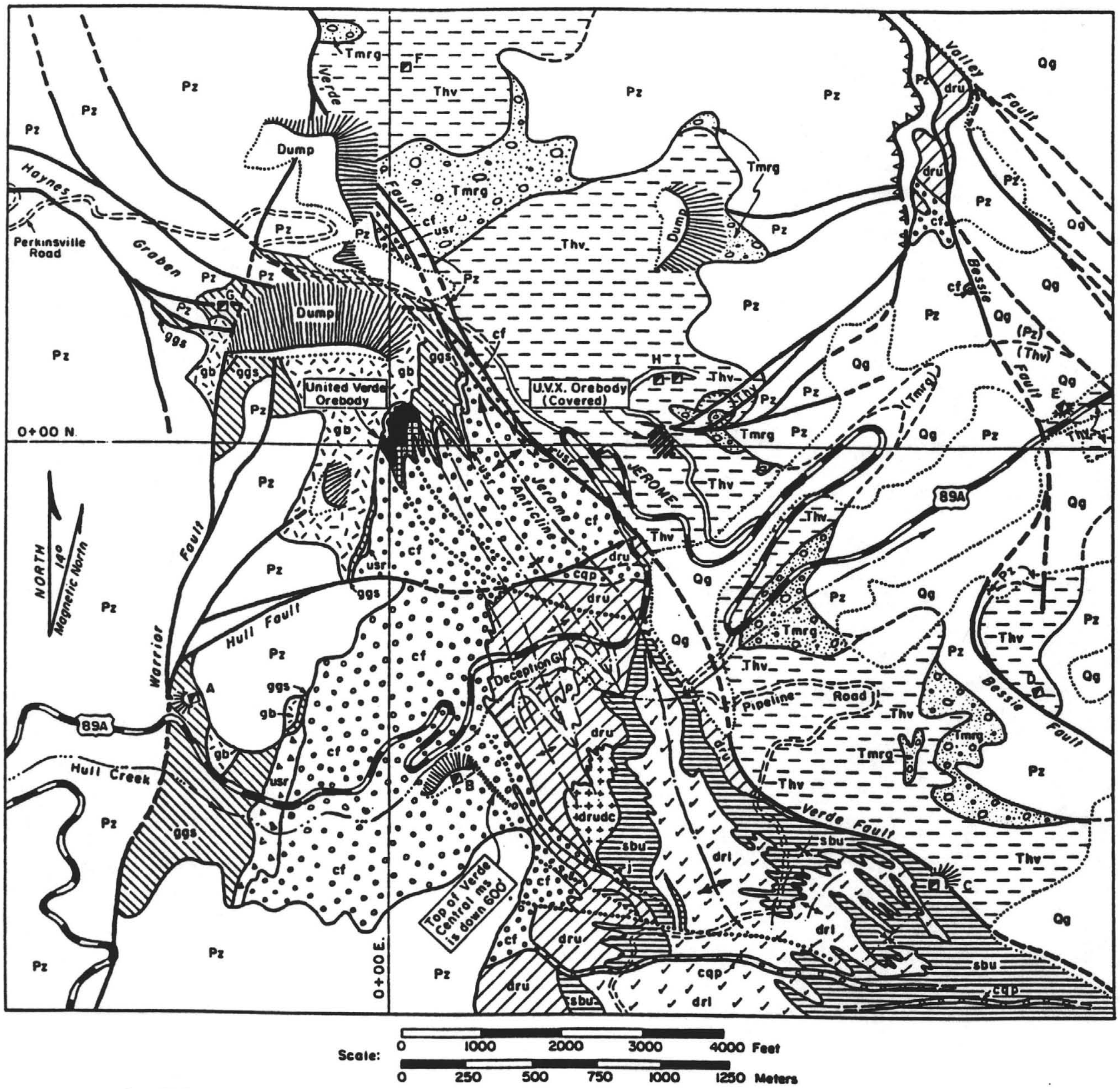


Simplified geologic map of the Jerome area, Verde district, Yavapai County, Arizona (modified from Lindberg, 1986). Post-1971 detailed contact mapping modifies the interpretations and nomenclature of Anderson and Creasey (1958) and Anderson and Nash (1972). Current informal district usage is given below.

MAP SYMBOLS:

- Shafts: A=Jerome Grande, B=Verde Central, C=Verde Combination, D=Gadsden, E=Texas, F=A&A, G=Haynes, H=Edith & I=Audrey
- F_1 Folds (NNW) & F_2 "Cross Folds"
- Proterozoic Cauldron Faults
- Tertiary Faults; Laramide/Miocene

PHANEROZOIC ROCKS:

- Qg Quaternary Alluvium
- Thv Miocene Hickey Basalt
- Tmrg Pre-Miocene Conglomerates
- Pz Paleozoic Sediments; Undiff.

PROTEROZOIC ROCKS:

- gb Synvolcanic Intrusive Gabbro Sill
- ggs Grapevine Gulch Fm; Volcaniclastic Sediments, Tuffs
- usr Upper Succession Rhyolite/Dacite Domes & Breccias
- ms United Verde & U.V.X. (Concealed) Massive Sulfides
- bs Mg-Chlorite Alteration Zone ("Black Schist")
- cf Cleopatra Formation; Undiff. Rhyodacitic Extrusive
- cqp Cleopatra Quartz Porphyry Dikes
- ms Verde Central Massive Sulfide Horizon
- dru "Upper Deception Rhyolite" with Polygonal Flow (p)
- drudc Dacitic Dome within "Upper Deception Rhyolite"
- sbu "Upper Shea Basalt"; Includes Minor Rhyolitic Strata
- drl "Lower Deception Rhyolite" Flows & Breccias

FIGURE 1 - JEROME AREA GEOLOGY; from Lindberg and Gustin, 1987.

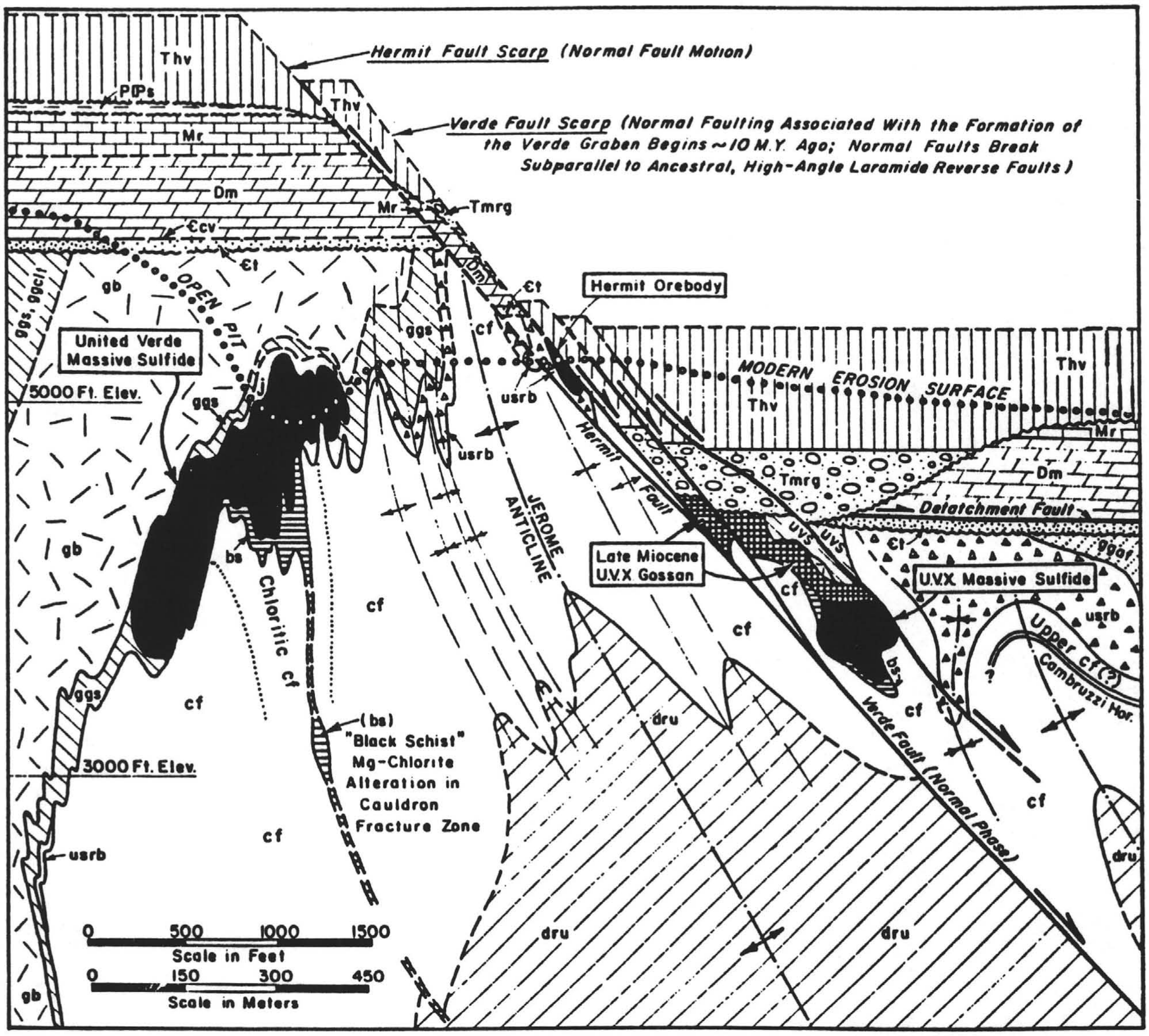


FIGURE 2 - EAST-WEST CROSS SECTION, LOOKING NORTH, THROUGH THE JEROME ANTICLINORIUM; from Lindberg and Gustin, 1987. Geologic notations are given in figure 1. The time is about 10 Ma when normal Verde graben faulting began. Note the UVX "Gossan" which is reinterpreted herein as primary chert, metasomatic silica, and supergene silica. It hosts the "copper-silica" and "gold-only" ores. The "uvs" unit adjacent to the gossan is actually the argillic-altered diorite sill.

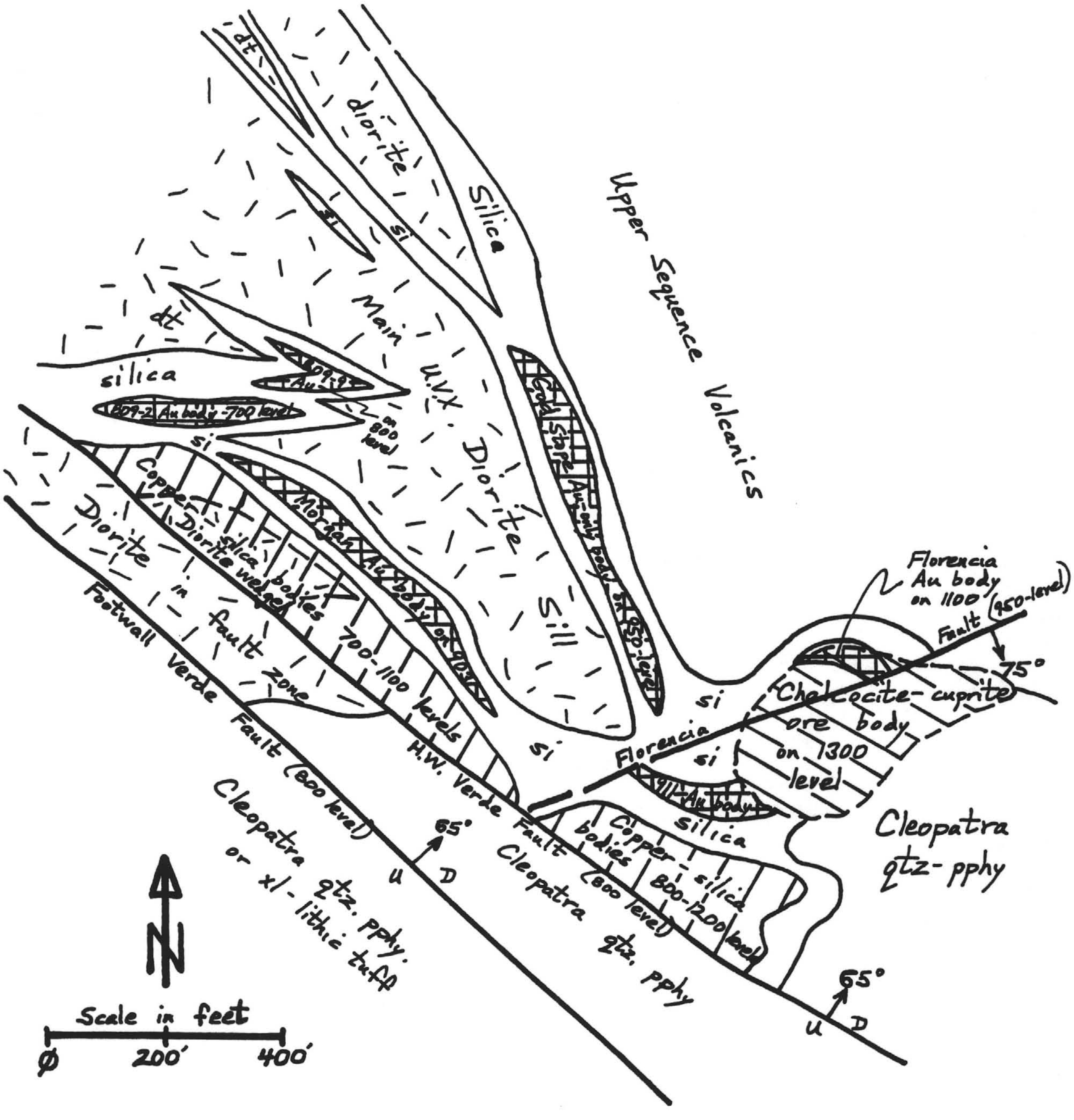


Figure 3 - U.V.X. Composit Plan

Showing three main ore types (chalcocite-cuprite, copper-silica, and gold-only) with respect to major structures, silica, and the diorite sill.

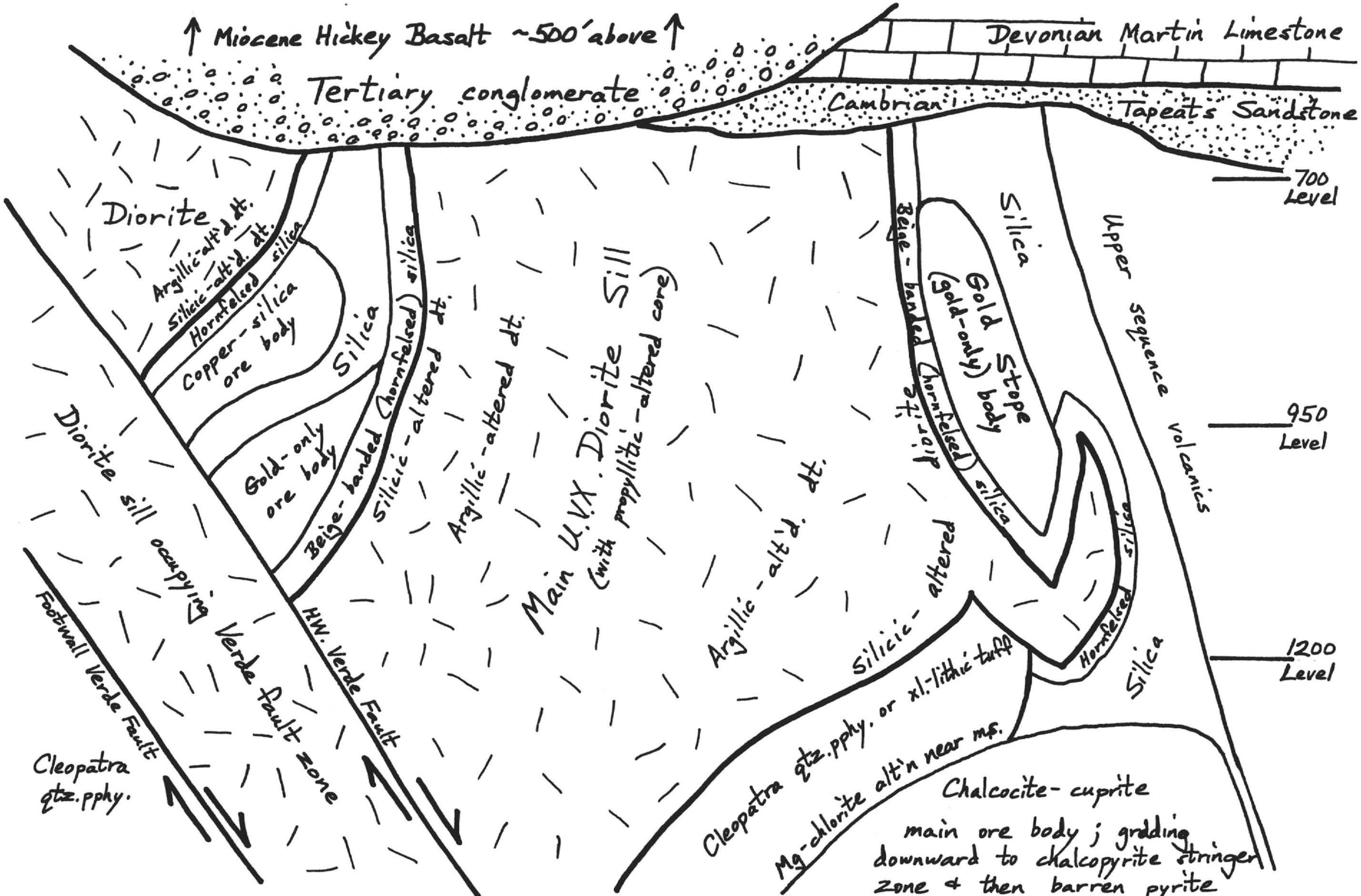


Figure 4 - U.V.X. Schematic X-Sec., looking NW

Showing three ore types with respect to Verde fault, silica bodies, diorite sill, and Precambrian-Paleozoic/Tertiary unconformity.

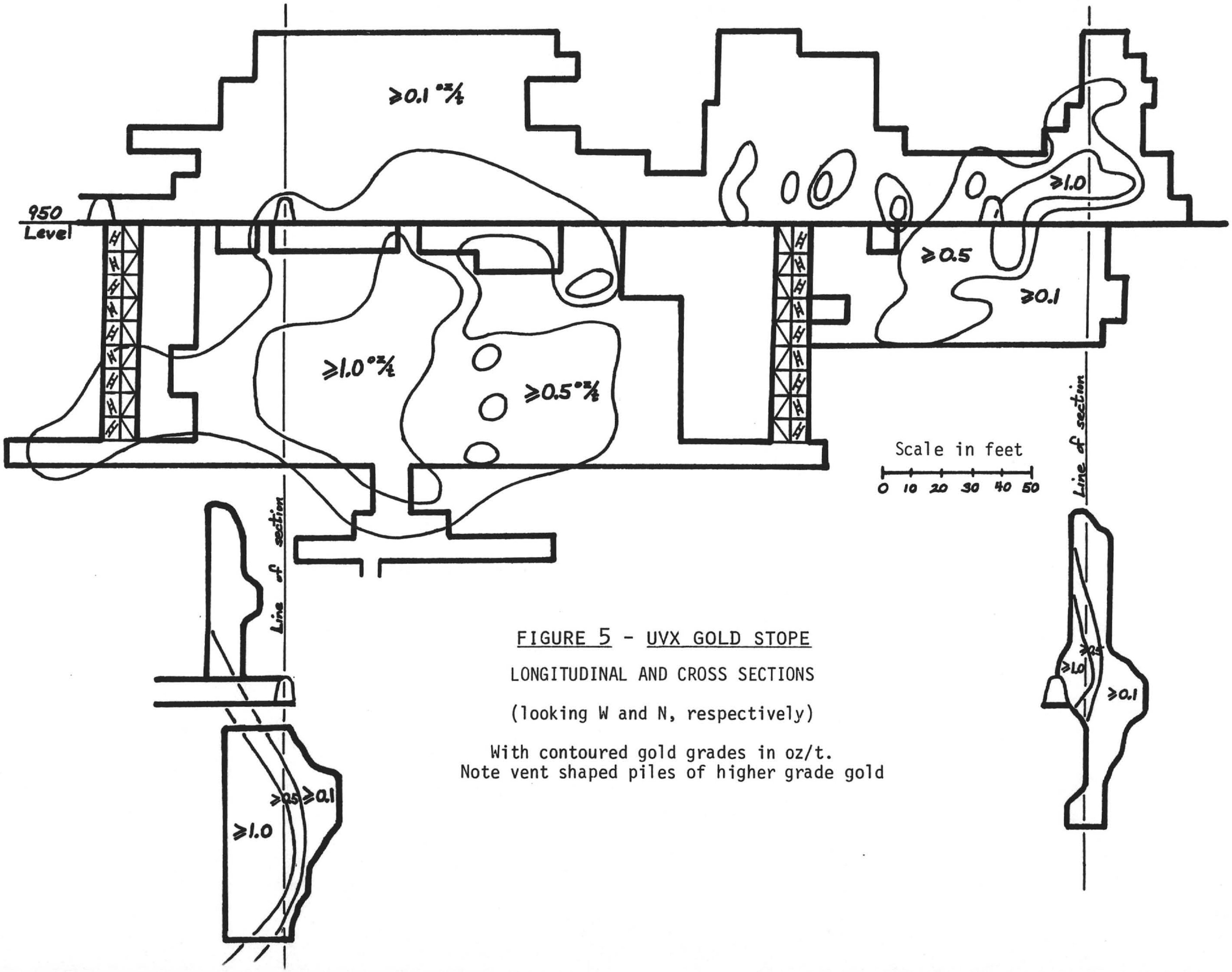


FIGURE 5 - UVX GOLD STOPE

LONGITUDINAL AND CROSS SECTIONS

(looking W and N, respectively)

With contoured gold grades in oz/t.
Note vent shaped piles of higher grade gold

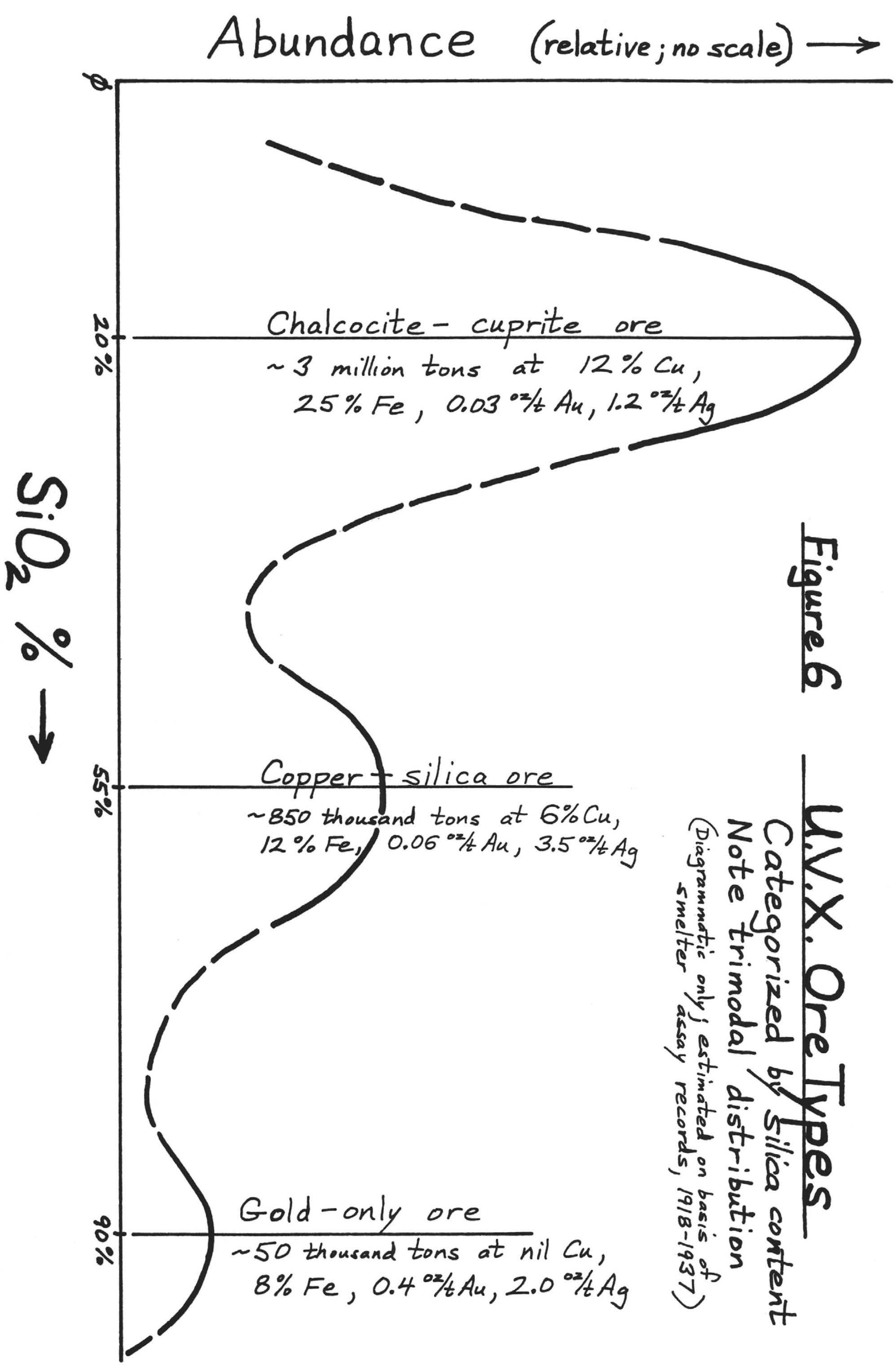
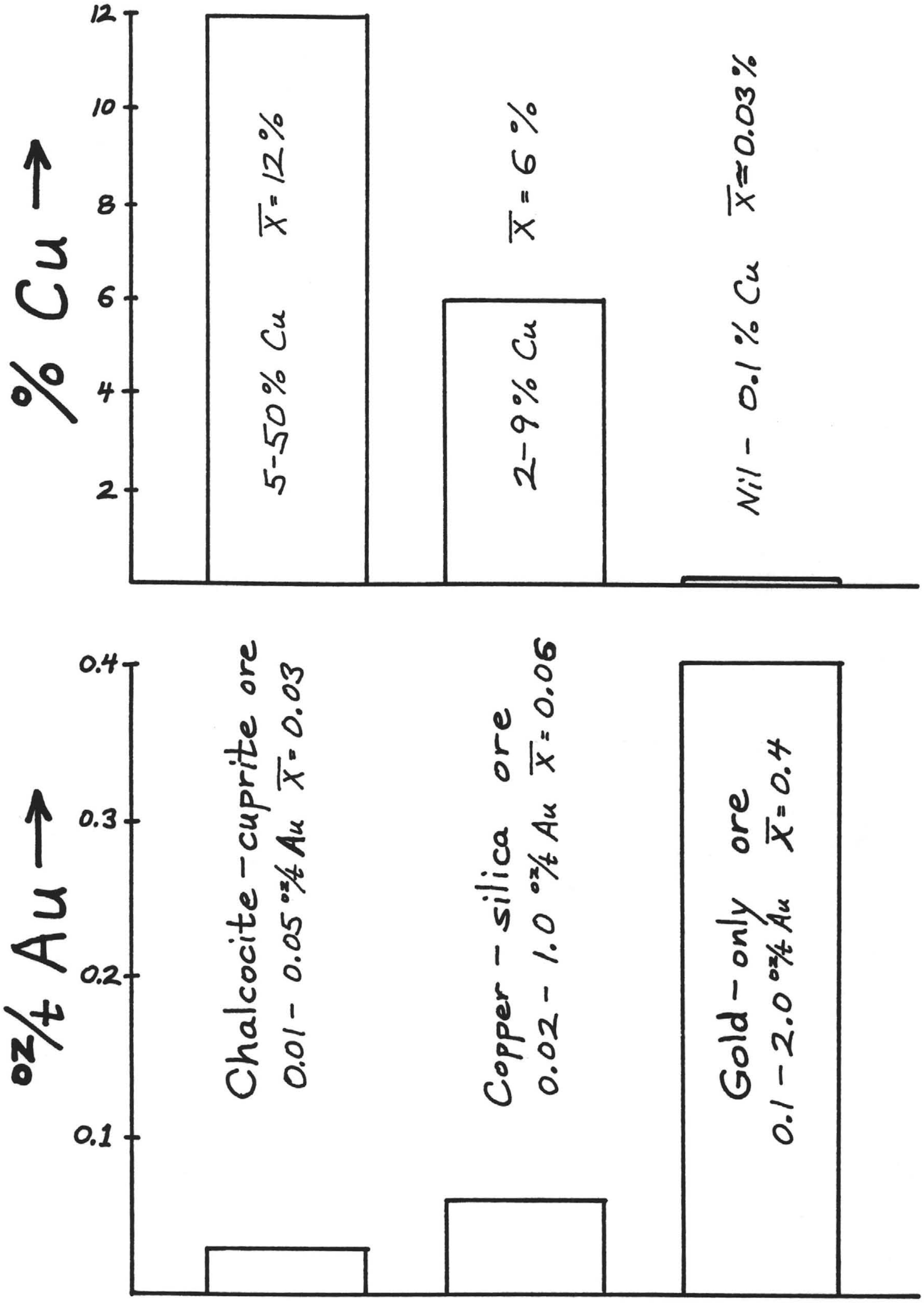


Figure 6 — U.V.X. Ore Types

Categorized by silica content

Note trimodal distribution

(Diagrammatic only; estimated on basis of smelter assay records, 1918-1937)



Figures 7+8 - Histograms of average copper + gold by ore type for all U.V.X. production.

TABLE 2 - ANALYSES OF UNITED VERDE EXTENSION ORE TYPES PRODUCED*

	CHALCOCITE-CUPRITE			COPPER-SILICA			GOLD-ONLY			TOTAL
Tonnage* (short tons)	3,000,000			850,000			50,000			3,900,000
Grades	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	
%Cu	5	50	12	2	9	6	Nil	0.1	Nil	10.2
%SiO_2	10	30	20	45	65	55	80	99	90	30
%Fe	20	30	25	4	20	12	1	17	8	22
oz/t Au	.01	.05	.03	.02	1.0	.06	0.1	2.0	0.4	0.04
oz/t Ag	0.5	100.	1.2	2.0	50.	3.5	0.5	10.	2.0	1.7

*Approximate figures, based upon smelter assay data, annual reports, and production records, 1915-1938; new gold reserves not included in chart.

TABLE 3 - CHARACTERISTICS OF UVX METAL CONCENTRATION TYPES

Metal conc. type	CHALCOCITE-CUPRITE	COPPER-SILICA	GOLD-ONLY
Old ore term	Main orebody/1st Class	Silica ore/2nd Class	Gold ore/silica flux
Vertical position	400'-800' beneath Palezoic unconformity	Top 400' of p€	Top 300' of p€
Horizontal position	Nearly equidimensional lobe at top of massive sulfide pipe	N.W. of main orebody and adjacent to (H.W. of) Verde Fault	N and NW of main orebody on stratigraphic top of and parallel to Cu-silica ore. Spatially related to diorite sill.
Ore minerals	Chalcocite, cuprite, native copper, chalcopyrite	Chalcocite, malachite, azurite	Native gold, electrum
Gangue minerals	Pyrite, hematite, silica	Silica, hematite	Silica, hematite, geothite
Footwall rock/ structure	Cleopatra "qtz pphy" or qtz. crystal tuff	Verde Fault	Copper-silica ore or iron rich silica or intrusive (diorite)
Hanging wall rock	Exhalative chert, upper sequence flows, volcani-clastics	Ferruginous silica, "gold-only" silica ore	Intrusive (diorite) and upper sequence flows/ volcaniclastics
Footwall alteration	Chloritization, silicification	Silicification	Silicification
Genetic interpretation	Supergene enrichment of chalcopyrite - pyrite volcanogenic massive sulfide deposit. Possibly some primary chalcocite in a fairly oxygenated environ-ment.	Supergene copper from United Verde, deposited in H.W. breccia along the Verde Fault, with some possible precursor Cu-Au-silica exhalite.	Supergene Au & Ag, Fe & SiO_2 from the U.V., deposited in more distal HW breccias where exhala-tive Au-silica and silica-Fe fm. had already been locally upgraded by contact metamorphism from the diorite sill.