ALTERATION AND MINERALIZATION OF THE CYPRUS JOHNSON DEPOSIT, COCHISE COUNTY, ARIZONA

by

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Abstract

The Johnson mineralized area is on the northeast side of the Little Dragoon Mountains in southeast Arizona. Initial mining by Cyprus Mines Corporation (1942-1957) centered on metasomatic massive sulfide deposits largely confined to the middle member of the Cambrian Abrigo Formation. Currently a stratigraphically controlled secondary copper oxide deposit in the lower member of this formation is being mined by open-pit methods.

Rocks of the area are of Precambrian to Holocene age, but the bulk of the economic minerals occurs as skarn deposits in Paleozoic rocks, which lie in a slightly undulating monocline striking northwest and dipping 40° NE. The Paleozoic sedimentary rocks were metasomatically altered by intrusion of the 53-m.y. Texas Canyon quartz monzonite, a barren stock characterized by K-feldspar phenocrysts. Wherever the east side of this stock protrudes into the sedimentary rocks, a mineral deposit has been found adjacent to or in line with the protrusion (Johnson, I-10, Strong & Harris, and Dragoon deposits).

Two phases of a single alteration process are evident: metamorphism of impure carbonate rocks to silicate rocks and metasomatism in which potassium, base metals, sulfur, etc. were added by way of quartz veins. The lower Abrigo hornfels has been pervasively invaded by mineralized quartz veins. About 30 percent enrichment has resulted from supergene processes; oxidation of secondary chalcocite and primary chalcopyrite produced an economic mining grade. The impervious underlying Bolsa Quartzite confined the secondary solutions to the hornfels. The principal ore minerals are chrysocolla, malachite, azurite, and tenorite(?).

Conjugate fault systems and intrusion of the stock resulted in massive fracture of the lower Abrigo hornfels at Johnson, creating a particularly amenable host for quartz veining and secondary leaching processes.

Introduction

The Johnson district is in the Dragoon quadrangle in northwestern Cochise County, Arizona, 60 miles east of Tucson via Interstate 10 (Fig. 1). Initial mining (1942-1957) by Cyprus Mines Corporation was centered around metasomatic massive sulfide (chalcopyrite, sphalerite, and pyrite) replacement deposits largely confined to the middle member of the Cambrian Abrigo formation. Currently, a stratigraphically controlled secondary copper oxide deposit in the lower member of the Abrigo Formation is being mined by open-pit methods. The present phase of mining is designed to process 22 million tons of oxide ore having a grade of 0.85% total copper.

The rock formations of the area include early Precambrian, late Precambrian, Paleozoic, Mesozoic, Tertiary, and Quaternary units. Table 1 is a generalized stratigraphic section at Johnson (Cooper and Silver, 1964).

The bulk of the economic minerals occurs in skarn within the Paleozoic sedimentary rocks. These rocks lie in a slightly undulating monocline striking northwest and dipping 30°-40° NE. (Fig. 2). They have been altered by the metamorphism and metasomatism associated with the intrusion of the Texas Canyon quartz monzonite stock.

The Texas Canyon Quartz Monzonite Stock

The stock is a biotite quartz monzonite displaying potassic feldspar phenocrysts 2-5 cm long. An alteration phase, largely confined

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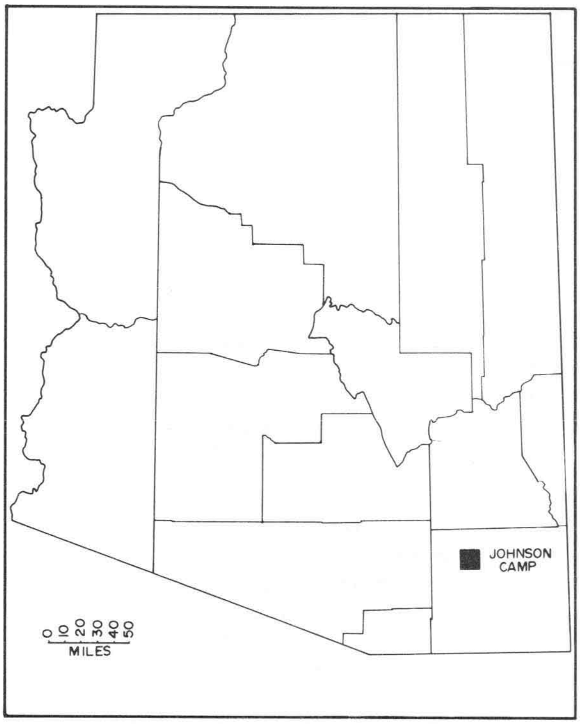

Fig. 1. Index map of Arizona

to the northeast periphery of the stock, is characterized by multiple quartz veining, which is sometimes tungsten bearing. Surrounding the quartz veins are two zones of alteration: (1) a hard inner zone, usually only a few centimeters wide, containing varying amounts of muscovite, silica, and pyrite, and (2) a wider outer zone displaying only weak argillic alteration (Cooper and Silver, 1964). The stock is early Tertiary in age, 53 m.y. (Livingston and others, 1967), elongate to the northeast, and occupies an area of roughly 4 x 7 miles.

The stock is generally concordant with the steeply dipping Pinal Schist and discordant with the post-Pinal rocks. The most prominent joint attitude measured by Cooper and Silver (1964) is N. 45° E., dipping 86° SE., with less well defined attitudes of N. 5° W., dipping 65° W., and N. 75° W., dipping 85° S. They suggest that the stock has a gently arched roof, the northeast extension of which lies under Johnson at moderate depth. Evidence for this conclusion is:

1. The intense igneous metamorphism near the Johnson deposit as much as 1.5 miles from the exposed contact.

2. The occurrence of tremolite in the Glance Conglomerate at the north end of the Gunnison Hills, as much as 3 miles from the exposed stock.

Kantor (1975) offers an interesting variation to the eastward extension of the stock. He theorizes that a portion of the stock intruded above the altered and mineralized zones at the Johnson deposit for a distance of at least 2 miles. Hence, mineralization and alteration were downdip rather updip phenomena. His arguments for this reasoning are:

1. The great horizontal extent of the copper-zinc mineralization and calc-silicate tactitization relative to the short vertical or downdip extent.

2. The relatively uniform dip to the base of the alteration and mineralization.

3. The fact that no drill holes or mine workings in the district ever penetrated the stock below the Paleozoic rocks.

It is interesting to note that on the northeast side of the stock, its protrusive character is a harbinger or indicator of mineralization. The Johnson, I-10, and Dragoon deposits are all closely associated with discordance of the stock with the post-Pinal sedimentary rocks.

Metamorphism

The Johnson deposit falls within Cooper's alteration zone 4 (Cooper, 1957), which is characterized by marbleization of the pure dolomites and limestones. The impure dolomites have been altered to forsterite, diopside, tremolite with or without calcite, while the impure limestones were altered to garnet, diopside, epidote, wollastonite, and idocrase. The shale of the lower Abrigo has been altered to a biotite hornfels.

The following is a brief comparison of the altered Paleozoic sedimentary rocks in the immediate vicinity of the Johnson deposit with their unaltered equivalents in the Dragoon Mountains as described by Cooper and Silver (1964).

Martin Formation

The Martin Formation has an upper 30-foot unit of dolomitic shale and siltstone overlying 1 to 3-foot beds of dolomite and sandy or silty dolomite. The top shale unit has been altered to a hornstone, which consists of diopside-hedenbergite and lesser tremolite with interstitial K-feldspar and quartz. The clean dolomites have been dedolomitized to diopside-tremolite-calcite rock and locally to tremolite-forsterite-calcite rock in a groundmass of variable quartz and K-feldspar. In the field, these rocks are called tactites.

Table 1. Generalized section at Johnson

Age	Group, Formation, or Member	Thickness, ft
Tertiary and Quaternary		0-1500+
	Unconformity	
Tertiary	Texas Canyon Quartz Monzonite	
	Unconformity	
Pennsylvanian	Horquilla Limestone	1600
Pennsylvanian or Mississippian	Black Prince Limestone	125
Mississippian	Escabrosa Limestone	650
Devonian	Martin Formation	200
Cambrian	Abrigo Formation	
	Upper Abrigo dolomite	100-120
	Middle Abrigo limestone	150-200
	Lower Abrigo limestone	250-300
	Bolsa Quartzite	50-100
	Unconformity	
Upper Precambrian	Apache Group	
	Diabase	
	Dripping Spring Quartzite	100-150
	Barnes Conglomerate	5
	Pioneer Shale	300
	Scanlan Conglomerate	2
	Unconformity	
Lower Precambrian	Pinal Schist	5000+

Abrigo Formation

Upper Abrigo. The upper Abrigo has a quartzite upper bed followed by 6 to 12 inches of interbedded dolomitic sandstone and sandy dolomite. These dirty dolomites alter to a diopside-tremolite-calcite rock with a groundmass of variable quartz and K-feldspar. Again, in the field these rocks are frequently referred to as tactites or white tactites.

Middle Abrigo. The middle Abrigo is a crenulated limestone with intercalated limy sand and shale partings 0.3-2.5 cm thick. These partings increase in frequency with depth thereby forming a gradational contact with the lower Abrigo shale. Under metamorphic conditions, the limestones alter to predominantly garnet with lesser diopside, quartz, and calcite. The intercalated shale partings alter to a hornfels consisting of biotite and feldspar with small amounts of quartz, sphene, epidote, and apatite. In places, both the limestone and shale units have been garnetized. Unit 5 at the top of this member of the Abrigo Formation has been strongly garnetized, frequently in well-defined shoots at fold crests, and has accounted for 95 percent of the pyrometasomatic copper-zinc replacement deposits in the district.

Lower Abrigo. The lower Abrigo is a gray fissile shale with intercalated carbonate and quartzite beds. The carbonates are dolomite near the base and limestone near the top.

The shale has been altered to a biotite hornfels that consists of biotite with variable K-feldspar and lesser quartz, epidote, sphene, and chlorite. The minor carbonate interbeds have been altered to bands of epidote, diopside, tremolite, and calcite. The quartzite

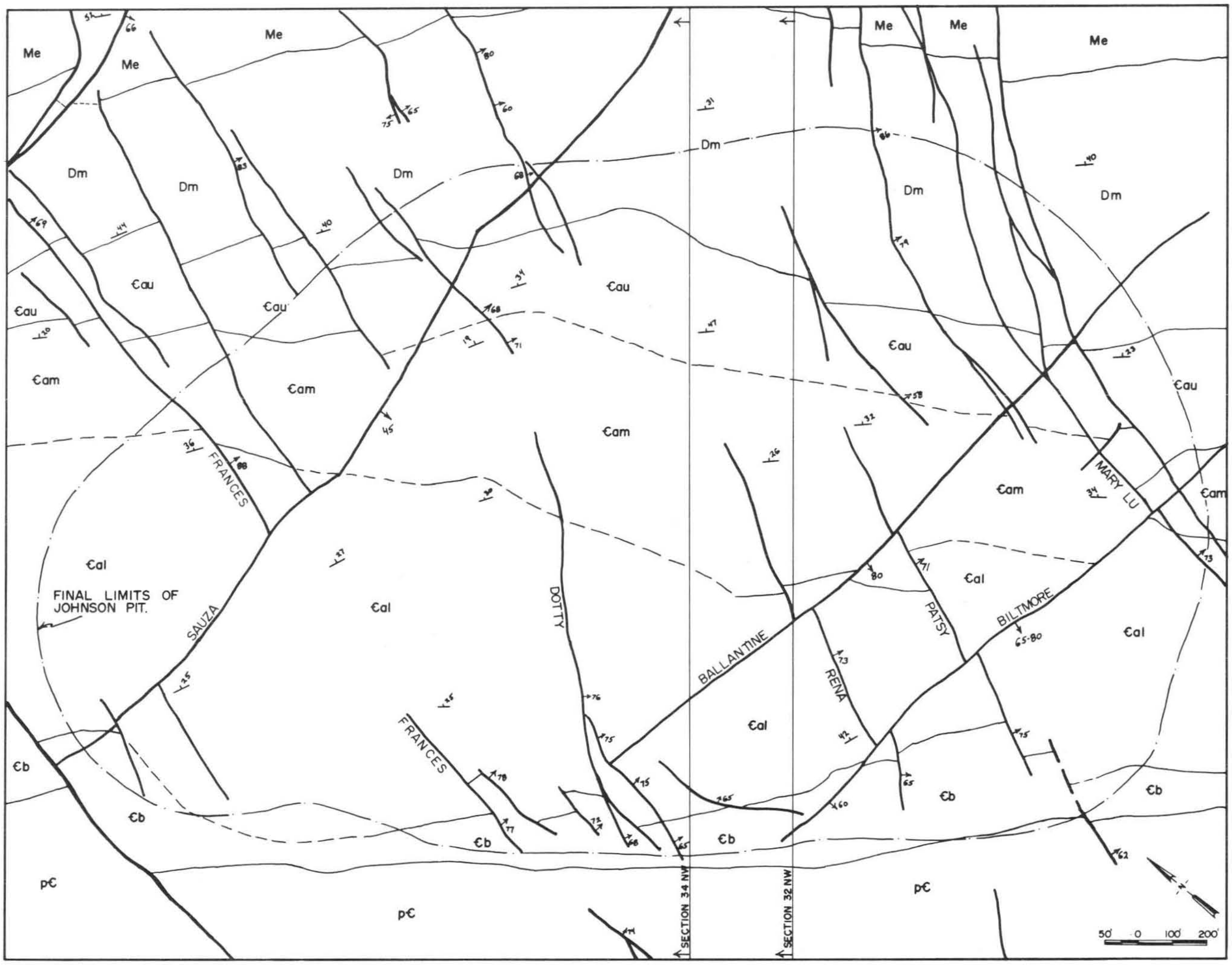

Fig. 2. Surface geology at the Johnson pit. Me = Escabrosa, Dm = Martin, Ꞓam = middle Abrigo, Ꞓal = lower Abrigo, Ꞓb = Bolsa, pꞒ = Apache.

bands, usually rich in K-feldspar, may be partially altered to garnet-diopside or epidote-diopside assemblages.

This member of the Abrigo formation is currently being mined for its copper oxide content.

Bolsa Quartzite

The Bolsa Quartzite has not been appreciably affected by the metamorphism. Studies made by Cooper (1957) and Baker (1952) suggest that most of the above-described metamorphism involved reactions between the original constituents of the beds. Migration was probably limited to adjacent beds in a medium of liberated carbon dioxide. Little, if any, material, except possibly water, was added to the system.

Metasomatism

Most metasomatic alteration took place later and at lower temperature than the metamorphism of the host rocks (Baker, 1952). The most striking effect of the metasomatism was, of course, the copper-zinc mineralization associated with the replacement deposits of the middle Abrigo and the mineralization presently being mined in the lower Abrigo. Late manganiferous garnet rims indicate some manganese metasomatism (Baker, 1952).

Cooper (1957) found that the unmetamorphosed Abrigo Formation contains 20-25 percent and, in some cases, 50 percent detrital and authigenic K-feldspar in all parts of the Little Dragoon Mountains. He therefore believes that potassium metasomatism was relatively minor and was confined to the transfer of potassium between beds through defeldspathization.

However, the appreciable K-feldspar in the quartz veins and the alteration of the diabase, which underlies the Dripping Spring Quartzite, to a magnetite-biotite-orthoclase hornfels containing 50%-60% K-feldspar, 25%-30% biotite, and 5%-10% magnetite suggest fairly widespread potassium metasomatism.

Other common late alteration products frequently associated with small amounts of sulfides are calcite, quartz, ferrotremolite, chlorite, and fluorite.

Structure

Baker (1952) recognized three sets of faults during his underground studies of the copper-zinc replacement deposits: Northeasters, Easters, and Northwesters. This fault system has been further defined in the pit area by diamond drilling and pit mapping (Figs. 2 and 3).

The Northeasters are the most numerous and best developed set. They strike N. 10°-30° E. and dip 70°-75° SE. They are normal faults with apparent right-lateral displacement of the beds. The faults are commonly quartz-filled veins that contain K-feldspar, fluorite, calcite, and sulfides. The Northeasters are usually offset by other faults but the reverse relationship is also true. The Northeasters, serving as channelways, were instrumental in the formation of the replacement orebodies of the middle Abrigo (Baker, 1952).

The Easters range in strike from N. 60° E. to S. 60° E. They consist of a low-angle set of normal faults, which dip 30°-50° S. and a high-angle set of reverse faults, which dip 75° S. The Republic and Sauza are the two most prominent low-angle Easters in the pit area, while the Ballantine and Biltmore are the prominent high-angle reverse Easters (Fig. 3).

The Northwesters are relatively rarer than Northeasters and Easters. They strike N. 15° W. and dip steeply either east or west.

Structural analysis by stereographic projection indicates that initial faulting began while the beds were still horizontal prior to Late Cretaceous tilting to the northeast and intrusion of the Texas Canyon stock. This early conjugate fault system consisted of east-dipping Northwesters, Northeasters, and steeply dipping Easters, which were then normal faults dipping north. During or after tilting, another conjugate system developed consisting of west-dipping Northwesters, Northeasters, and low-angle Easters. Later movement of the entire system probably occurred during intrusion of the Texas Canyon stock.

Mineralization

Primary Mineralization of the Lower Abrigo

The lower member of the Abrigo Formation has been massively fractured by the above-described fault system. These faults and fractures are the sites for the late mineralized quartz veins that pervade the hornfels.

Cooper and Silver (1964) and Baker (1952) limit these metasomatically introduced quartz veins to the Northeast fault system. Pit studies, however, indicate that the vein fillings are polydirectional, but the bedding-plane orientation is predominant. The veins are commonly less than 3 cm but are rarely as much as 60 cm wide.

Quartz, feldspar, and occasionally calcite constitute the chief vein material. Of the primary sulfide mineralization, pyrite is the most abundant and widespread, with much less chalcopyrite. Galena, molybdenite, bornite, and tetrahedrite have also been rarely noted. Commonly, the sulfides occur as open-space fillings. Other primary minerals found in the quartz veins are magnetite, hematite, fluorite, scheelite, and wolframite.

In addition to the mineralized quartz veins, there is disseminated pyrite and lesser chalcopyrite. However, the bulk of the mineralization is quartz vein dependent; even the disseminated sulfides increase with the intensity of the quartz veining.

Secondary Mineralization

Oxidation has been stratigraphically controlled by the channeling of the secondary solutions downdip through the massively fractured lower Abrigo. This channeling was controlled by the overlying tactite beds and more importantly by the impermeable underlying Bolsa Quartzite, which guided the secondary solutions downdip, and the Bolsa is now the footwall of the orebody and the contact is a horizon of high copper values (Fig. 4). Structurally high Bolsa Quartzite at the northwest and southeast ends of the pit has formed a trough of quartzite that contains the bulk of the deposit.

The downdip limit of the oxide portion of the deposit is the Sauza fault, which has apparently produced an impervious barrier for the secondary solutions (Fig. 4).

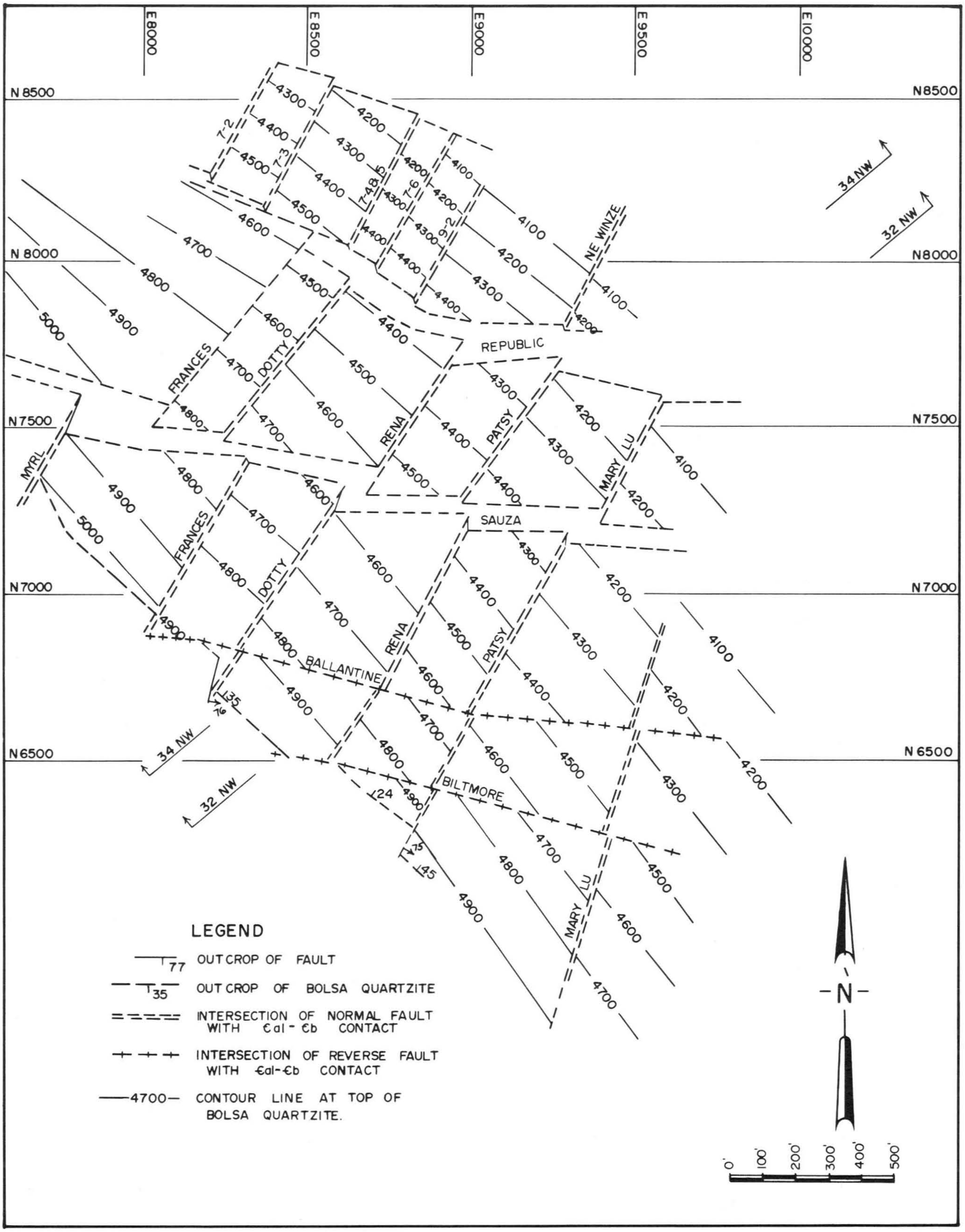

Fig. 3. Structural contour map of the lower Abrigo—Bolsa contact

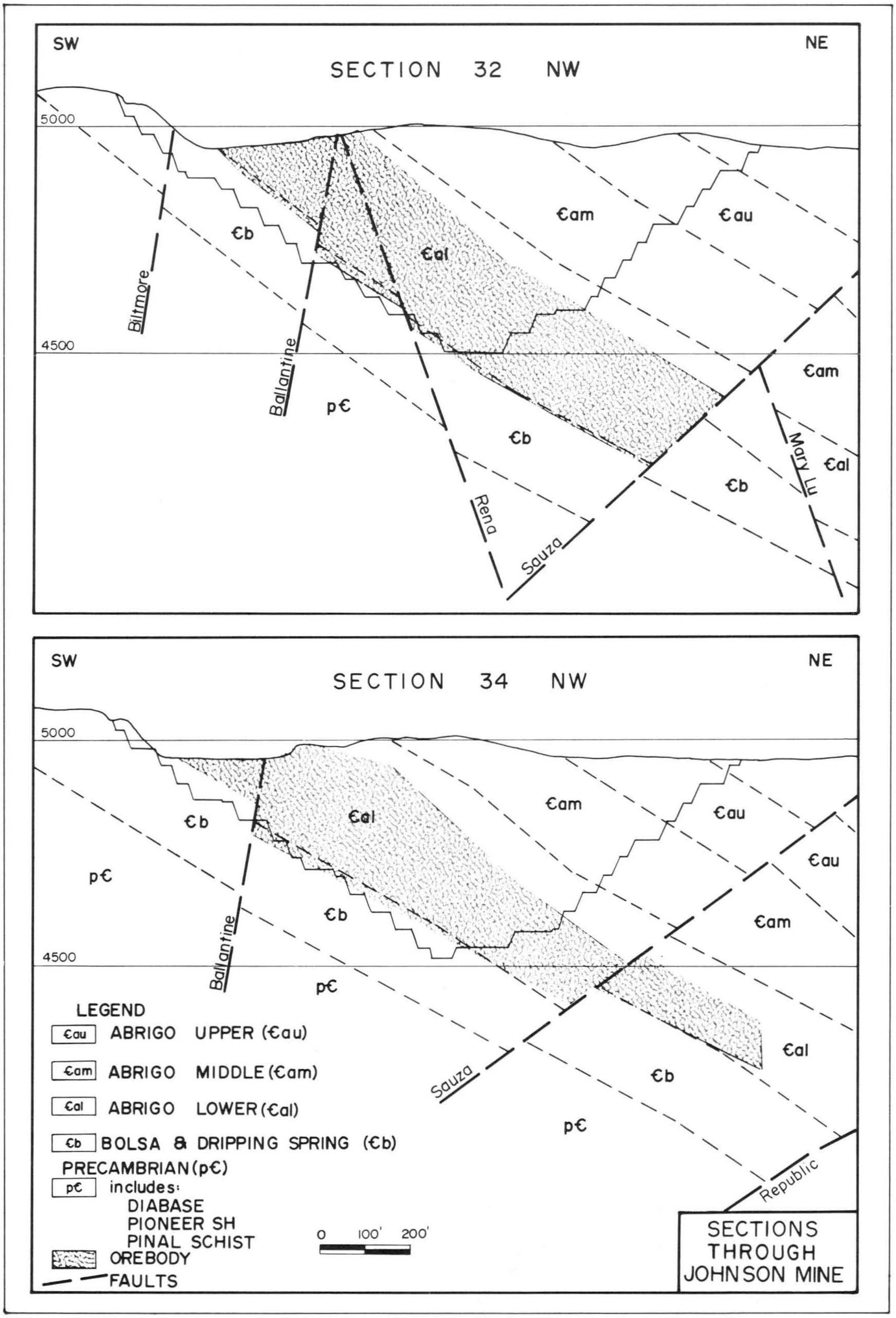

Fig. 4. Sections through Johnson mine, looking northwest

The principal secondary copper oxide is chrysocolla, but other common oxides are tenorite(?), malachite, and azurite. Rarer oxides include aurichalcite, chalcotrichite, and unidentified copper oxides. Most copper oxides occur in fractures.

Abundant montmorillonite and lesser kaolinite are the chief secondary argillaceous products of the oxide zone. Indigenous limonite-goethite, hematite, and jarosite are characteristic of all quartz veins and are frequently associated with casts and boxworks. Pyrolusite and psilomelane occur in some fractures of the host.

Secondary Enriched Zone

There was appreciable interpenetration between the oxide zone and the secondary enriched zone, but some chalcocite commonly appears at about 500 feet. The enrichment is quite weak and frequently nothing more than paint on the primary sulfides. The average enrichment appears to be about 30 percent.

The values gradually decrease downdip to 0.1-0.4% copper. The deepest hole intersected the lower Abrigo 1,700 feet downdip and these values were still holding. However, the presence of chalcocite indicates that the true primary values have not been intersected.

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