Trip 18 :

# Safford District (Sanchez) and Morenci – Metcalf

October, 1994

## Bootprints Along the Cordillera

Porphyry Copper Deposits from Alaska to Chile

Dear Field Trip Participants:

On behalf of the **Arizona Geological Society, Society for Mining, Metallurgy and Exploration Inc., and the U. S. Geological Survey**, we bid you welcome to the Bootprints Along the Cordillera field trip program. We have assembled a collection of field trips that portray the geologic and mineralogic diversity that exists along the cordillera of North and South America.

We wish to thank all of the field trip leaders who volunteered their time, effort, and expertise to organize their individual trips. We also want to thank collectively, all of the mining companies and staff who graciously allowed us to visit their properties. Without their cooperation, this program would not have occurred. A special thanks goes to Kathie Harrigan of Asarco for her help in the compilation of the field trip guides. We also want to thank Tucson Blueprint who underwrote the complete reproduction cost of the guides.

Mark Miller and Jim Briscoe
Field Trip Co-Chairmen
October 2, 1994

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**MORENCI DISTRICT AND SAFFORD DISTRICT(Sanchez) FIELD TRIP**
**October 8-9, 1994**

Welcome to the "Bootprints Along the Cordillera" post-meeting field trip to the Morenci and Safford mining districts. The trip will examine leached capping, hypogene and supergene sulfide mineralization, and copper oxide mineralization at Morenci on the first day of the trip. Day two will be spent at in the Safford area with an overview of the Safford volcanic field and with a more detailed look at the Sanchez copper-oxide deposit.

Most of the Morenci portion of the field trip will be in active mining areas. **PLEASE OBSERVE THE FOLLOWING SAFETY RULES:**

- A hard hat and safety glasses will be provided, and must be worn at all times while inside the mine gate.
- Please keep away from the bench faces. All geological features can be seen from the bench floor, and samples can be obtained from talus piles.
- Maintain your distance from bench crests.
- Please contain your enthusiasm when pounding on the rocks; flying chips can be created by attempting to break some of the harder rocks. Be considerate in a crowd by warning the bystanders of your intentions.

**SPECIAL SAFETY REQUIREMENT FOR STOP 1:**

- To view the geologic features described at this stop you will need to cross U.S. Highway 191. **PLEASE BE CAREFUL WHEN CROSSING THE HIGHWAY!!** Traffic will be moving at "highway" speeds, and motorists will not be looking for pedestrians.

**ACKNOWLEDGMENTS.** Parts of the descriptions used in this guide have been prepared by Morenci staff geologists for several trips and meetings that have taken place through the years. Contributors to these efforts include R.K. Preece, M.R. Pawlowski, R.M. North, J.B. Griffin, R.J. Stegen, M.A. Lowery, J.A. Ring, T.A. Weiskopf, and R.E. Lowery. Individual stops for the Morenci trip were prepared by M.W. Bartlett (Stop 1); R.M. North (Stop 2); E.G. Wright and R.K. Preece (Stop 3); R.L. Childers, and W.A. Schleiss (Stop 4); and J.A. Ring (Stop 5). E.J. Parr assisted with the figures for the guide. M.S. Enders, chief geologist, and R.K. Preece reviewed the general overview and stop descriptions. Permission to visit the Phelps Dodge Morenci, Inc. (PDMI) property was granted by Mr. J.L. Madson, vice president and general manager of Phelps Dodge Mining Company, and by Mr. T.R. Snider, PDMI general manager. The assistance of these people, and all others that have assisted in the understanding of the geology at Morenci are gratefully ackr owledged.

## MORENCI DISTRICT MINES AND SAFFORD DISTRICT (Sanchez) FIELD TRIP
## October 8-9, 1994

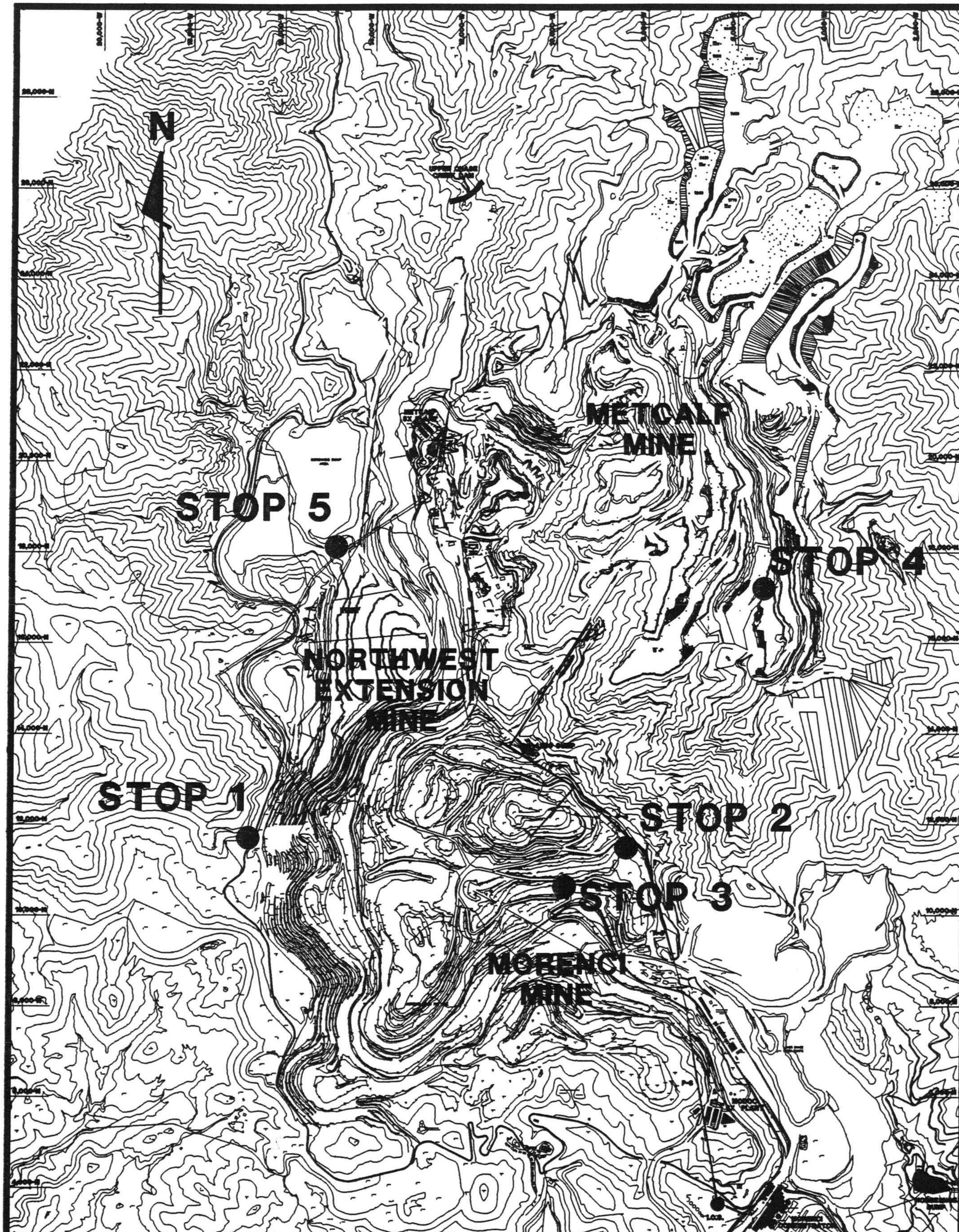
### Trip Itinerary

Saturday, October 8th, 1994

**6:45 a.m.** Assemble at the west side of the Holiday Inn City Center.
**7:00 a.m.** Depart Tucson
**10:30 a.m.** Arrive in Morenci. The tour will begin in the parking lot south of the PDMI employment office on the east side of U.S. Highway 191, across from the Morenci Fire Station. PDMI tour vans will be used for the mine tour.
**11:00 a.m.** **Stop 1: Morenci/Metcalf/Northwest Extension overview.** Mine overlook (off U.S. Highway 191 just south of mile marker 172) with an optional hike to observe leached capping on American Mountain. Lunch at mine overlook.
**12:15 p.m.** Leave mine overlook area for Morenci mine gate.
12:30 p.m. **Stop 2. Morenci Pit Overview.** From 4350 fuel dock overlook, west side of Chase Creek.
**1:00 p.m.** **Stop 3. Morenci Mine.** Medler Ridge area, near the interface between primary pyrite/chalcopyrite mineralization and supergene chalcocite enrichment.
**1:40 p.m.** Leave Morenci pit for stop at the Metcalf mine.
**2:00 p.m.** **Stop 4: Metcalf Mine.** Leached capping, partial leaching, and supergene sulfide mineralization.
**2:45 p.m.** Leave Metcalf mine for stop at Northwest Extension.
**3:00 p.m.** **Stop 5: Northwest Extension.** Oxide copper mineralization resulting from the in-situ oxidation of a chalcocite blanket.
**4:00 p.m.** Leave Northwest Extension.
**5:30 p.m.** Arrive Safford.

Sunday, October 9th, 1994

**9:00 a.m.** Assemble at the Best Western Desert Inn.
**9:45 a.m.** Overview of Gila Valley geology from Highway 70.
**10:30 a.m.** **Sanchez Mine site.**
**2:00 p.m.** Leave Sanchez site.
**5:00 p.m.** Arrive Tucson.




TOUR STOP LOCATION MAP

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## MORENCI DISTRICT OVERVIEW

The Morenci mining district, comprising the Morenci, Metcalf, and Northwest Extension deposits, is currently the largest copper-producing district in North America. The district is located in the Transition Zone between the Colorado Plateau and the Basin and Range physiographic provinces, at original elevations between about 4000 and 6200 feet. The geologic framework of the area is an intricately faulted plateau of Precambrian to Recent sedimentary, intrusive, and extrusive rocks exposed throughout the district.

Structural characteristics within the Morenci district reflect the various stress regimes that have affected southwestern North America through time. The Transition Zone is distinguished by: plateau-like uplifts; monoclines; basement-cored uplifts associated with the Laramide Orogeny; and major late Cenozoic (20 to 10 m.y.a.) normal faults similar to those found in the Basin and Range province. Generally, structural trends in the district reflect the influence of these two tectonic events. The area was periodically covered by Oligocene ignimbrite flows, with intervening periods of erosion and uplift along the Morenci-Reserve Fault Zone. This resulted in complex cycles of leaching and enrichment with subsequent preservation of the chalcocite-covellite blankets during periods of warm, semi-arid climate. The Miocene northeast- and northwest-tilted structural domains formed during Basin and Range extension and uplift of the Pineleno metamorphic core complex, and appears to control the latest stage of oxidation and enrichment.

Hydrothermal alteration and mineralization in the district is associated in time and space with an Early Tertiary intrusive complex composed of several distinct biotite granodiorite to granite porphyry stocks and dikes. Adjacent to the intrusives, Cu-Fe-Zn skarns occur in Paleozoic sedimentary rocks, while Precambrian granite and granodiorite as well as the Laramide calc-alkaline intrusive rocks host Cu-Mo stockwork mineralization. Although the geometry of known ore-grade mineralization in the Morenci district is demonstrably due to low-temperature copper redistribution during the Eocene to Miocene, the style and intensity of hydrothermal silicate and sulfide alteration assemblages had a major impact on the efficiency of supergene processes.
Because of the textural destruction attending pervasive hydrothermal phyllic and supergene argillic alteration, study of hydrothermal alteration is difficult, requiring detailed and time-consuming examination of outcrops and core. These studies have shown the general progression of hydrothermal alteration in the district to have been early potassic alteration (predominately K-spar alteration) followed by quartz-molybdenite veining, pervasive quartz-sericite-pyrite $\pm$ chalcopyrite alteration, and quartz-pyrite-chalcopyrite veining.

Supergene processes are responsible for the formation of most of the ore-grade mineralization at Morenci. Hypogene alteration resulted in a large volume of rock with 4 to 7 wt. % pyrite and 0.10 to 0.15% copper as chalcopyrite that attended pervasive sericitization. The most important supergene processes in rocks with high pyrite and sericite were the multiple cycles of leaching and sulfide enrichment. In areas of lower pyrite (1.5-2.5 wt. %) and sericite a single generation of leaching and sulfide enrichment was followed by essentially in-situ oxidation involving only minor transport of copper, as noted at Northwest Extension. Many factors have affected these supergene processes, including the composition of hypogene mineralization and their host rocks, climate, faults and fractures in the vadose zone causing solution channeling and some perched water tables, position and vertical migration of the 'permanent' water table through time, erosion rates, mid-Tertiary volcanic activity, and structural adjustments due to faulting.

## STOP 1. AMERICAN MOUNTAIN

M. W. Bartlett

Mineralization at American Mountain appears to be strongly controlled by the contact of quartz monzonite porphyry with Precambrian granite. Of lesser importance is the presence of the Producer fault/vein. This field trip stop will allow you to examine the leached capping and contact relationships for American Mountain.

### STATION 1

Quartz monzonite porphyry is well exposed along the southern end of the 4650 bench. It is highly altered to an assemblage of quartz + sericite and kaolinite, with a well developed quartz + sericite and limonite stockwork. In the outcrop, the monzonite is thoroughly leached with little relict pyrite. It does not appear to have contained much primary sulfide mineralization, based on the poorly developed leached capping signature. The exposed rock probably has a grade of about 0.15% Cu, probably contained in the iron oxides and copper wad. Low-grade chalcocite mineralization starts at 45 m below the bench and extends to a depth of 175 m. The Producer fault is not exposed in this bench, but it can be seen below (east) where it offsets Highway 191. The offset is the result of a wall failure in the pervasively sericitized monzonite porphyry during heavy rains in 1993.

### STATION 2

This steeply-dipping, northeast-striking fault is located about 3 m south of the main qmp/granite contact. Note the increase in hematite as the contact with the granite is approached. Primary sulfides were concentrated along the stock contact, and along the margins of monzonite dikes within the granite.

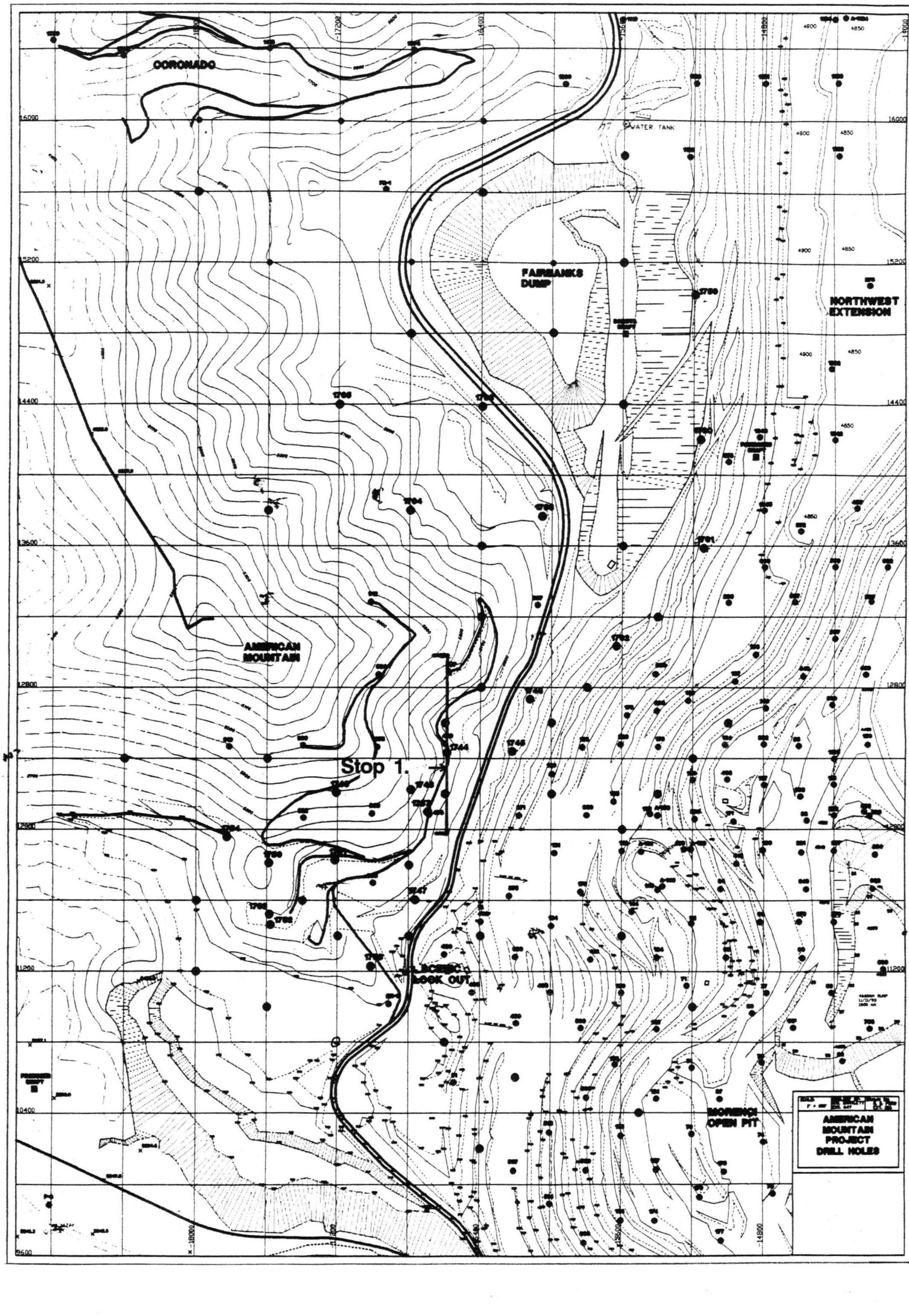
### STATION 3

The smooth hematitic surface above the stake is the contact between the monzonite and granite. There is some development of breccia and a narrow quartz-sulfide (now oxidized) vein formed along the contact. In this area, the contact strikes about N70-80E and dips about 80S. Based on recent drilling to the south, the contact becomes somewhat shallower at depth. Note the dramatic increase in the amount of hematite in the leached capping, which suggests a higher concentration of primary sulfides.

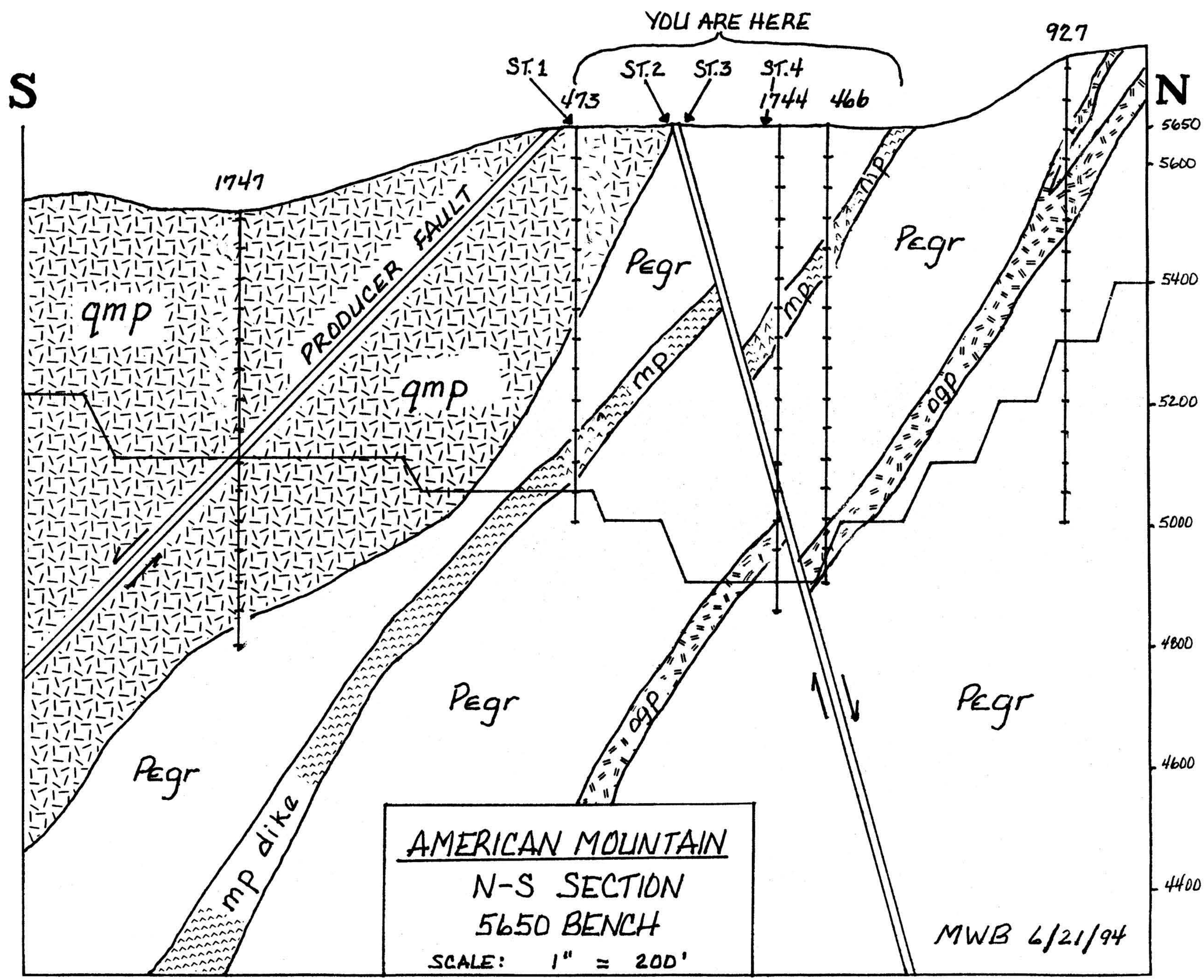
**AMERICAN MOUNTAN**
**FIELD TRIP STOP**
M. W. Bartlett

## STATION 4

This point marks a small monzonite porphyry dike which has intruded the granite. The dike exhibits increased quartz-sericite alteration. Just north of the dike, you will note the jarosite which indicates sulfides at the surface. There is abundant relict pyrite and a small amount of chalcocite preserved in the aplitic granite adjacent to the dike. From this point northward, the rocks are predominantly granite with occasional dikes of monzonite porphyry. The leached capping is better developed in the granite, perhaps in response to the amount of primary sulfides. The leached capping increases in thickness dramatically to the north, away from the monzonite stock. Mineralization in the granite to the north is characterized by minor copper oxides at the surface and extensive leached capping development. Supergene sulfides occur 180 to 240 m below the surface, although there are some minor "perched" zones of chalcocite in the leached capping.



CORONADO
WATER TANK
FAIRBANKS DUMP
NORTHWEST EXTENSION
AMERICAN MOUNTAIN
Stop 1.
SCENIC LOOK OUT
MORENCI OPEN PIT
AMERICAN MOUNTAIN PROJECT DRILL HOLES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AMERICAN MOUNTAIN
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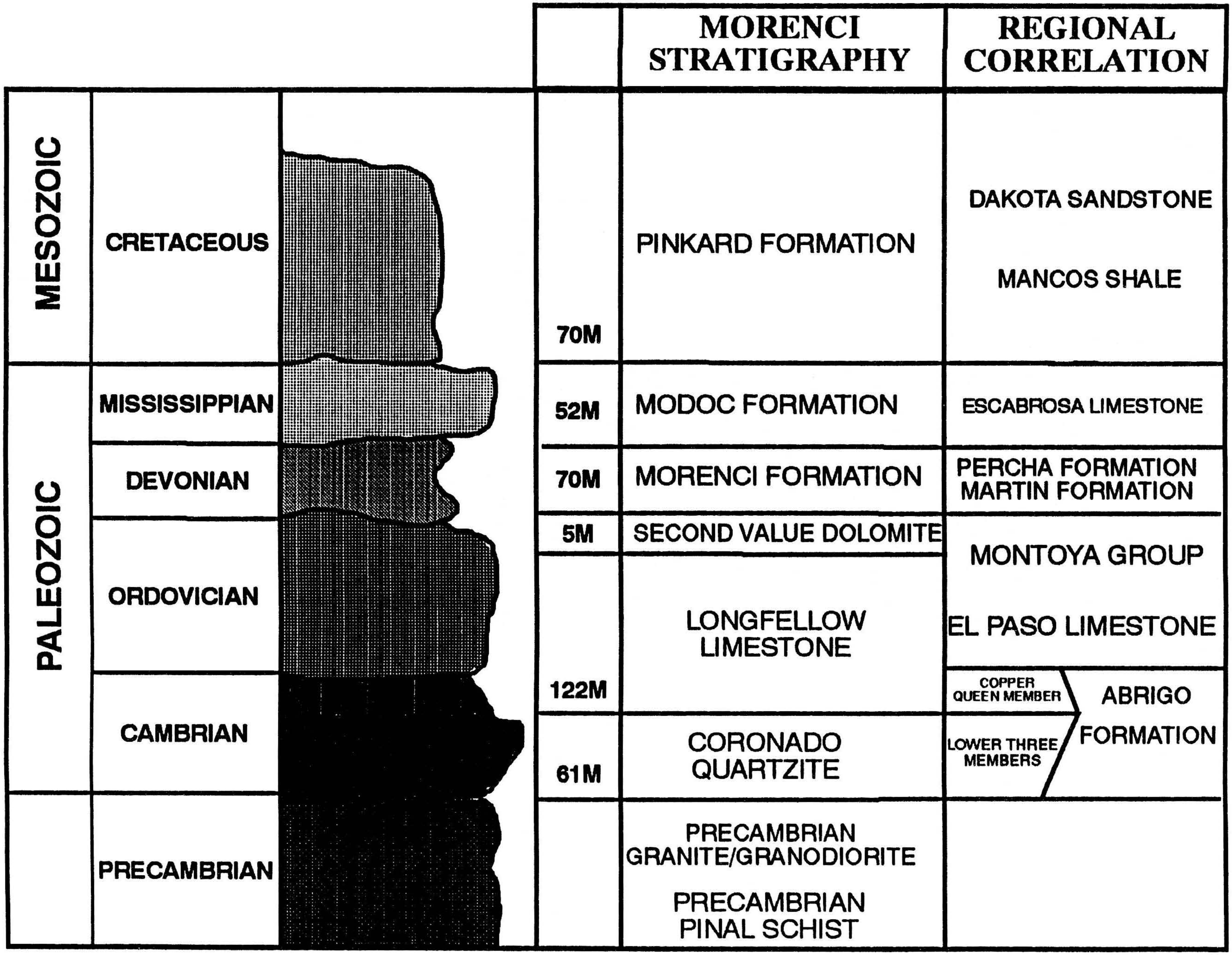
## STOP 2: 435O LEVEL, MORENCI MINE

R.M. North

Stop 2 overlooks the Medler area of the Morenci pit, and provides an overview of Morenci and Northwest Extension pits and the Western Copper prospect. The view is generally to the north-northwest. The current mining in the Morenci pit is exploiting the lower portions of chalcocite mineralization on the hanging wall of the Kingbolt fault. A slip surface of this structure is visible below the lookout point, and the fault can be observed in outcrop to the north across Chase Creek from our vantage point. The host rocks are Precambrian granite cut by dikes of Early Tertiary monzonite porphyry. The active benches to the northwest across the Morenci pit comprise the Northwest Extension pit. Production currently consists of chrysocolla, brochantite, malachite, and azurite hosted by Precambrian granite and Early Tertiary granite porphyry.

Paleozoic sedimentary rocks are exposed in the pit walls to the south and southwest, on the hanging wall of the south- dipping Quartzite fault. The Morenci stratigraphy and a regional correlation is shown in the stratigraphic column on the following page. The dark-colored rock exposed in the lower pit walls below the sedimentary sequence is is Early Tertiary diabase intruded along the Quartzite fault. Cu-Zn sulfide $\pm$ magnetite mineralization occurs in skarns formed from limestones and shales adjacent to the monzonite and granite porphyry stocks south of the Quartzite fault. Mineralization in the skarns is predominately vein-controlled, with only minor amounts of massive replacement bodies. Large volumes of ore-grade copper mineralization did not occur in the skarns, although early underground production was from high-grade supergene ore hosted by skarns.

The rugged mountain northeast of Chase Creek, on the footwall of the Kingbolt fault is the Western Copper prospect. Recent geologic and mine-planning work in this area has identified 530 million tons of additional sulfide ore with an average copper grade of 0.55%. This mineralization is hypogene chalcopyrite with chalcocite and covellite enrichment, hosted by Precambrian granite cut by monzonite and granite porphyry dikes.




**Morenici District Stratigraphy and Regional Correlation.**

## STOP 3. 3800 - 3850 MORENCI MINE

R. K. Preece

The Morenci mine has historically been composed of ores that averaged over 0.8% Cu, predominately as chalcocite-digenite. Mining is currently in the lower portions of the chalcocite enrichment blanket, where the copper grade distribution is a function of both the hypogene and supergene processes. Intensity of supergene chalcocite mineralization is generally a function of depth from the pre-mine topographic surface, although lateral variations are also present. The precursor hypogene sulfide mineralization also exhibits lateral and vertical variations in total sulfide content and the pyrite:chalcopyrite ratio. This stop is to examine pyrite+chalcopyrite ± bornite mineralization that has been partially replaced by chalcocite + covellite. Selection of the actual stop location will not be possible until a few days before the tour. Traverses that show the variations in either chalcocite enrichment or hypogene sulfide mineralization may be available.

As seen in the attached cross section, the chalcocite blanket in this part of the deposit was 80 to 350 m thick, although trace amounts of chalcocite may persist an additional 300 to 500 m in depth. A hematitic leached capping, 15 to 30 m thick, occurred over most of Morenci deposit, the remnants of which can be seen in the pit walls. Chrysocolla, malachite, and brochantite mineralization occurred in the zone of oxidation, in the northwestern portion of the Morenci deposit, parts of which are currently being mined in the Northwest Extension mine. The transition between the zones of enrichment and leaching/oxidation was relatively abrupt, with only minor amounts of partially leached sulfides. Near the top of the enrichment blanket, chalcocite completely replaced chalcopyrite, and partially replaced most pyrite grains. With depth, chalcocite replacement of pyrite gradually weakens to thin coats that occurs on a portion of the individual grains, while chalcopyrite continues to be completely to partially replaced. Near the bottom of significant secondary sulfides, covellite becomes important, pyrite is generally uncoated, and copper grades approach protore grades.

Hypogene mineralization within and underlying most of the Morenci deposit consists of a pyritic sulfide assemblage that is associated with quartz + sericite stockwork veining. Hypogene sulfide mineralization characterized by pyrite to chalcopyrite ratios of about 1:1 occurs in the northeastern portion of the the Morenci mine. Sulfides are veinlet and fracture-controlled, and are associated with a vein and alteration assemblage of quartz + sericite ± K-feldspar ± siderite. Specular hematite and magnetite are commonly present, usually as pre-sulfide phases. Deeper in the system, a low total sulfide assemblage consists predominately of chalcopyrite, occurring as isolated grains on microfractures. Quartz + K-feldspar + siderite and lesser amounts of biotite ± quartz veins are typically present.

This area of the Morenci mine is composed of a northeast-trending monzonite porphyry dike swarm within Precambrian granite to aplite. The dikes are peripheral to a monzonite porphyry stock that occurs west of the active mining area. The Kingbolt fault is exposed in the bench faces on the northern edge of the mining area, striking N30-45W, dipping 60-65SW. The Quartzite fault is south of the tour stop, strikes N85E, dips 70-80S, and controls the emplacement of a diabase dike swarm within monzonite porphyry and Precambrian intrusives.

## STOP 4: 5400 LEVEL METCALF MINE

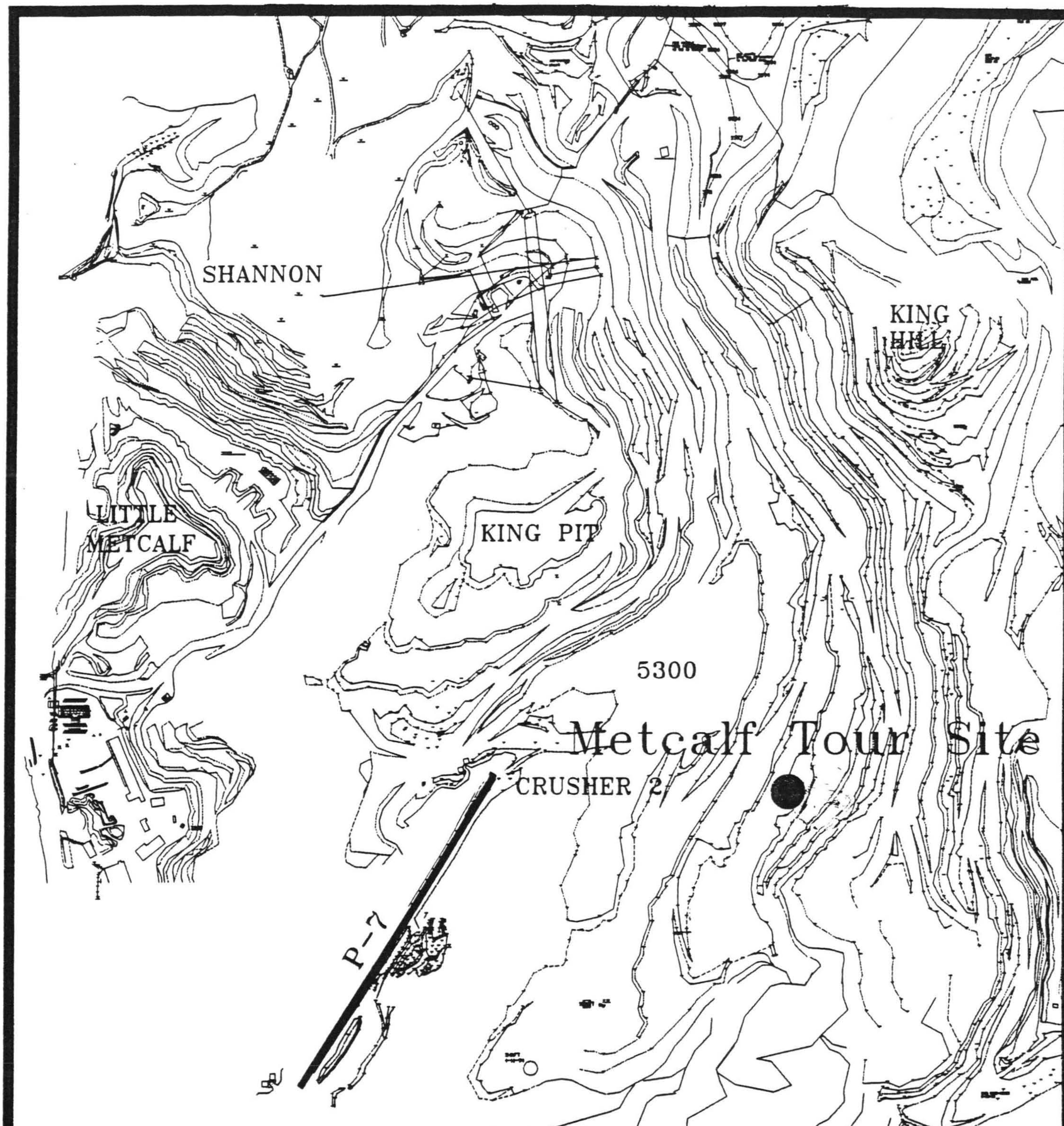
R.L. Childers and W.A. Schleiss

Tour stop 4 consists of a traverse that starts in chalcocite + pyrite ± chalcopyrite ± covellite ± molybdenite mineralization and ends in leached capping devoid of sulfides. Host rocks observed in this traverse consist of Laramide monzonite porphyry with scattered xenoliths of Precambrian granite.

The traverse starts approximately midway down the 5400 bench in Laramide monzonite porphyry which has intruded Precambrian granite. Sulfide mineralization consists of 4-5 to locally greater than 5 vol. % pyrite that occurs both as disseminations and associated with quartz ± sericitic stockwork veining. Chalcocite and minor amounts of covellite coat and replace pyrite and chalcopyrite. Strong pervasive quartz-sericite alteration is associated with the main stage of copper mineralization. The grade of the rock in this exposure ranges from 0.4% to +1.0% Cu. Quartz + molybdenite and alunite veins and veinlets occur as minor cross cutting vein sets. The continuous fault planes seen along the bench face strike N10E and dip 55-60 degrees west, and represent a portion of the War Eagle fault zone.

Approximately 100 m to the SSW the sulfide/oxide interface can be seen. The leached capping, although appearing steeply dipping in the bench face, dips approximately 50 degrees to the SSW. Limonites within this zone of partial leaching of the supergene enrichment are composed primarily of indigenous jarosite and hematite boxworks. The boxworks are located along fractures and are disseminated. Sulfides consisting of chalcocite + pyrite + molybdenite ± chalcopyrite/covellite are still prevalent. Copper grade within this zone of partial leaching are only slightly diminished by the leaching with grades ranging from 0.31 to +1.0% Cu.

Continuing to the SSW 90 m, the sulfide content steadily decreases and becomes absent within the leached capping. The rocks at this point, which consist of Precambrian granite and Laramide monzonite porphyry, still exhibit quartz + sericite stockwork veining. Transported limonites become more prevalent within the zone of leached capping. Total copper grades within the leached capping range from 0.03 to 0.10%.




Metcalf Mine
Morenci, Arizona

Drawing By:
G.A. Schern

Legend

1" = 1100 ft

Scale:

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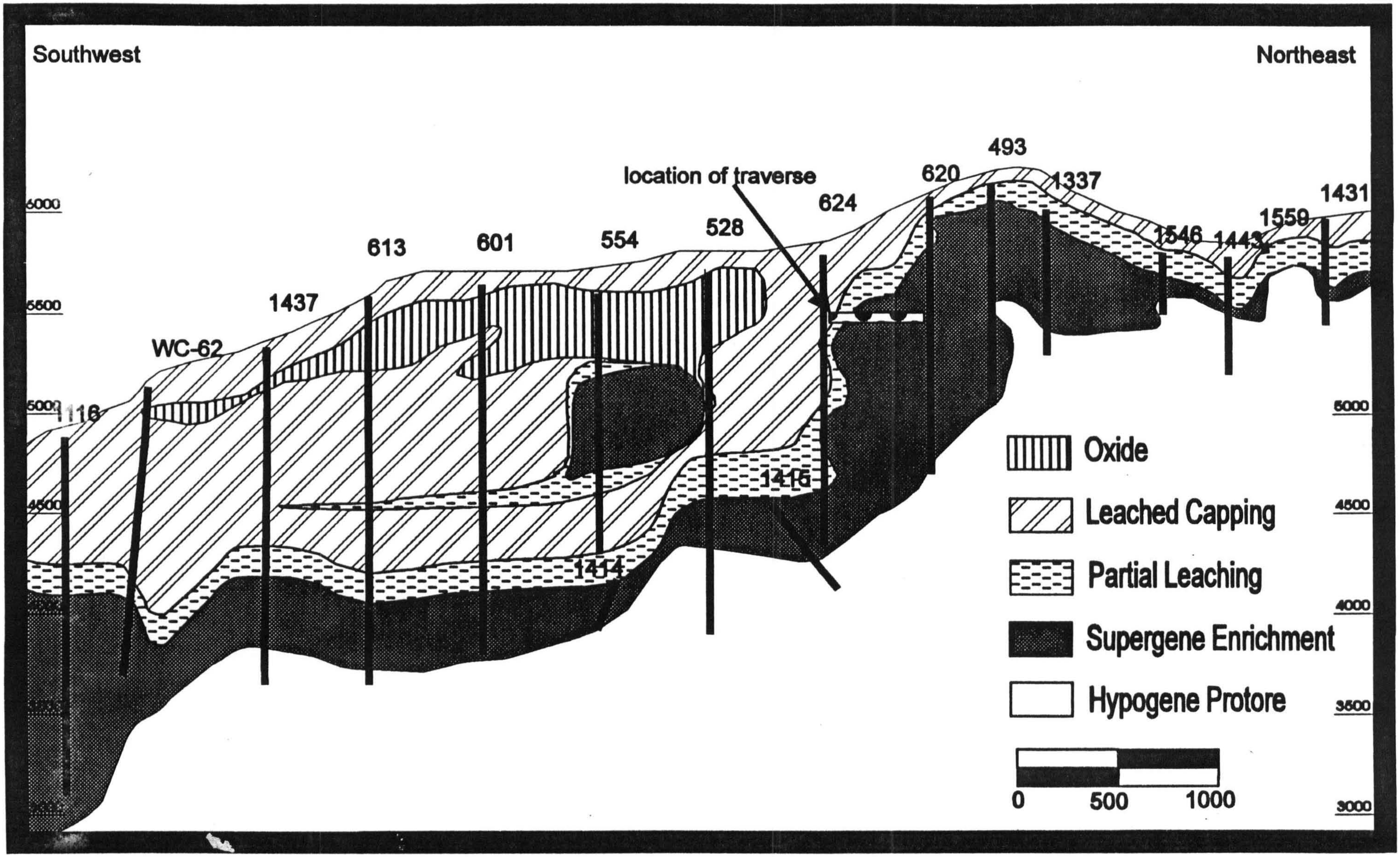
## Stop 4, Metcalf Mine Field Traverse




Section Through the Metcalf Mine Looking Northwest.

L.R.G. June 30, 1994

## STOP 5: 4900 LEVEL NORTHWEST EXTENSION MINE

J. A. Ring

The final stop of the day will be a traverse from hematitic leached capping through goethite + hematite iron oxides and into copper oxides including chrysocolla, brochantite, and malachite, with minor Mn-Cu oxides. Host rocks consist entirely of Early Tertiary granite porphyry.

### STATION 1

The traverse begins in a low total sulfide older granite porphyry were sulfide content is estimated from indigenous limonites to average 1-2 vol. %. Limonites consist of orange-red hematite + goethite that fill 0.5 to 1 mm boxworks and occurring along fractures. Copper values in this area range from 0.01 to 0.03% Cu.

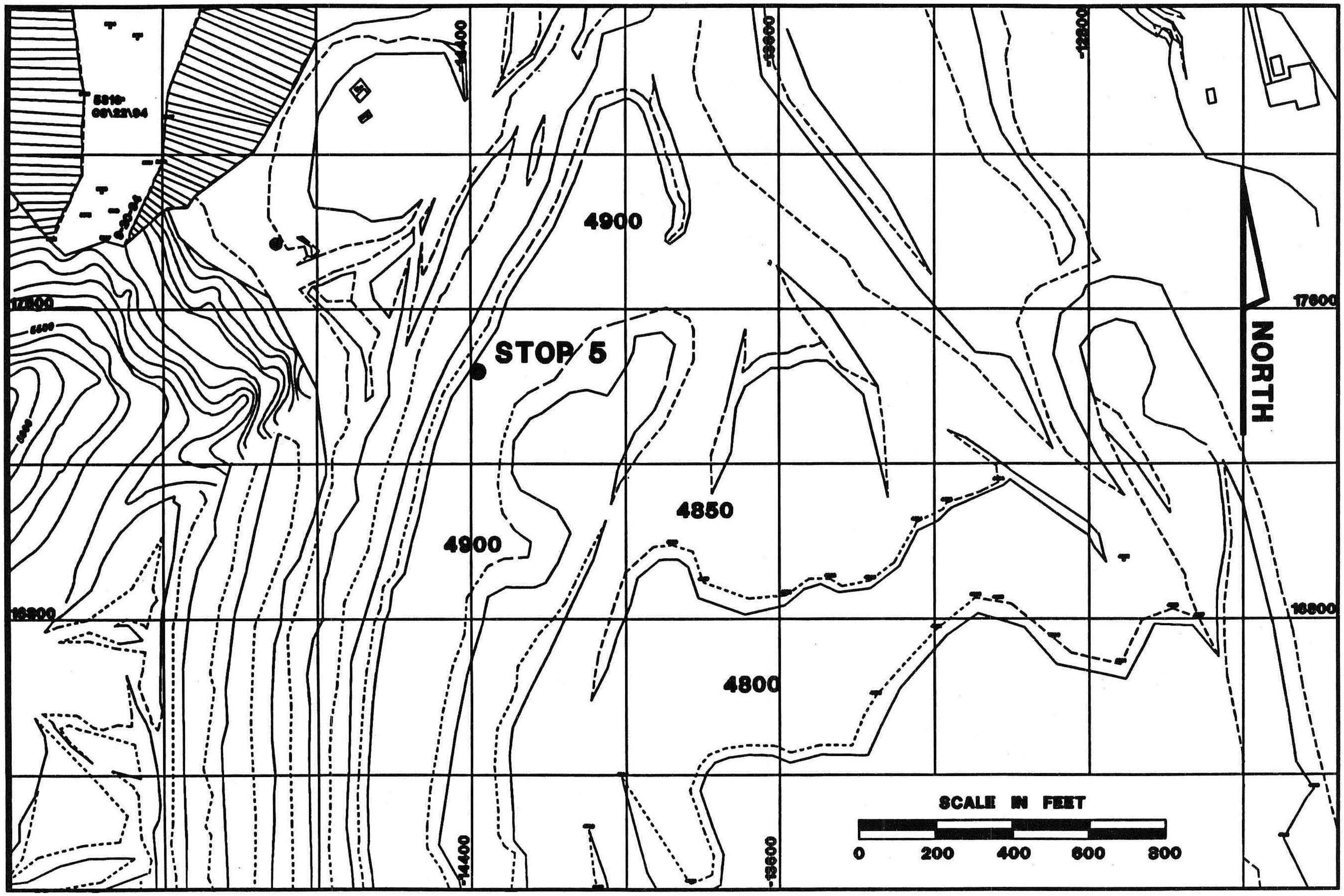
### STATION 2

Moving north along the bench face to station 2, a transition occurs from hematite-dominant capping into a goethite + hematite leached zone. Boxwork textures within this area are becoming more pronounced. Copper grades range within this area from 0.03 to 0.06% Cu.

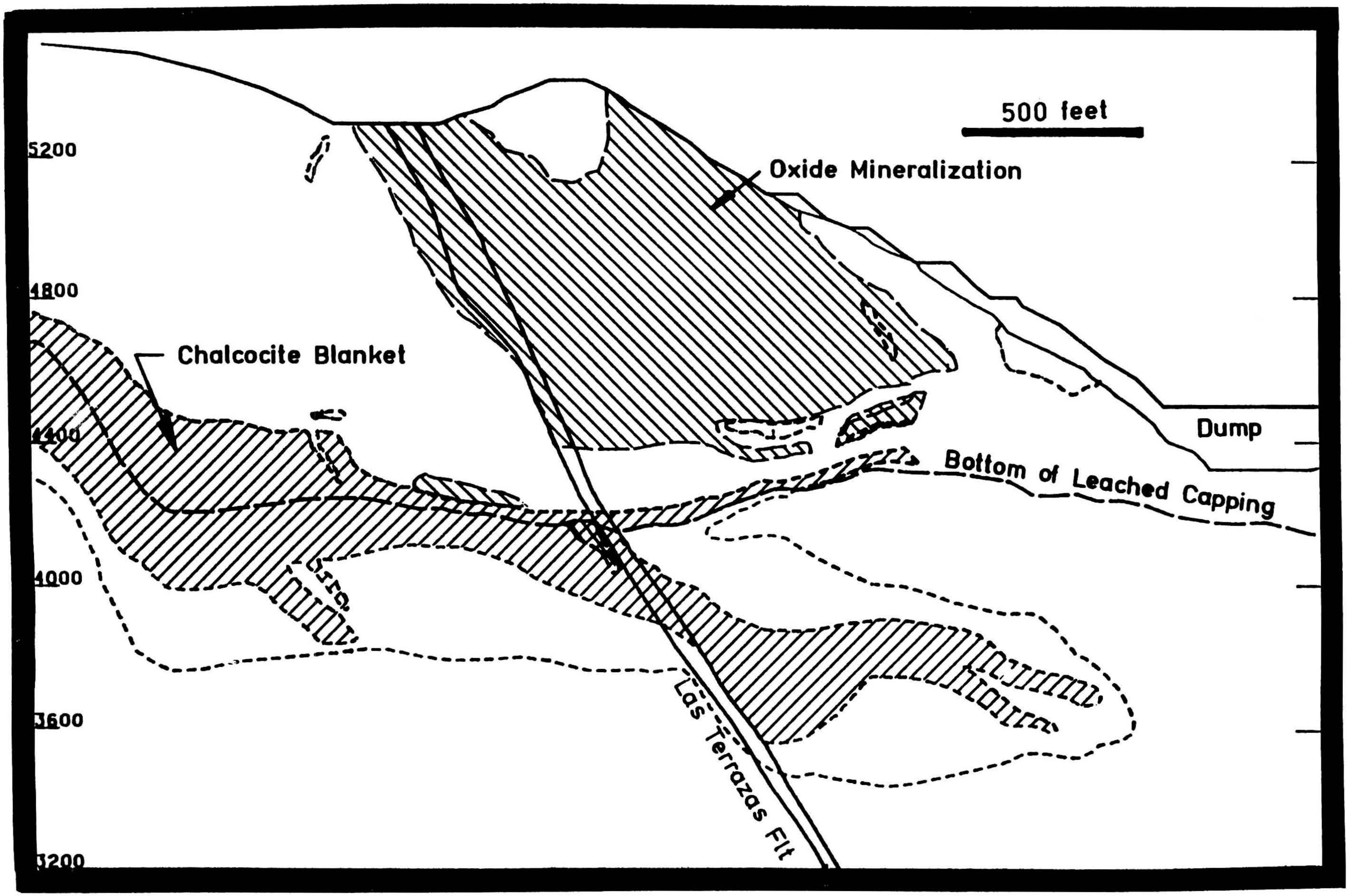
### STATION 3

A well-exposed contact between leached capping and copper oxide mineralization can be seen directly behind the sign for this station. Copper mineralization within this rock is composed of chrysocolla, brochantite, and malachite occurring as veinlets and fracture coatings. In addition, minor amounts of light-blue Cu-bearing clays replacefeldspars. Note that oxide copper minerals rarely occur in sites of precursor sulfides, indicating that copper transport did occur. The chemical evolution of supergene solutions can be observed by replacement textures that indicate a paragenesis of early brochantite, followed by malachite, and then chrysocolla. Copper values within this high grade zone range from 0.15 to 0.47% Cu.

# NORTHWEST EXTENSION 4900 BENCH



Stop 5, Northwest Extension




Section Through The Northwest Extension Mine Looking North

**Phelps Dodge MORENCI INC.**

# MORENCI FACT SHEET
(Revised January, 1994)

- The population of Morenci is about 4,700.

- There are 1,171 Company owned houses in Morenci, 1,121 are occupied.

- There are approximately 1,250 students in the Morenci Schools, 71 high school seniors (1993-1994 school year).

- 1991 Phelps Dodge Morenci received the National Safety Council's First Responder Award for having the top First Emergency Responder Team in the State and for their dedication to community emergency training in Greenlee and Graham County.

- The first mineral discoveries in Morenci were made in 1865 by volunteer Union soldiers from California.

- Between 1872 and 1882, ore mined by the Longfellow Copper Company was 20% copper. (We now mine ore that is less than 1% copper.)

- Phelps Dodge entered the Morenci mining picture in 1881 when it purchased an interest in the Detroit Mining Company.

- The first railroad in the District was built in 1879, it ran along Chase Creek from Clifton to the Longfellow incline in the area of the present open pit. Mules were used to pull the cars.

- The first locomotive was put into use in 1880.

- Phelps Dodge became the sole operator in the District in 1921.

- All mining, which was then by underground methods, stopped in 1932.

- Morenci has received the James Douglas Memorial Safety Trophy for the lowest lost-time accident frequency in Phelps Dodge Mining five (5) times in the last seven (7) years.

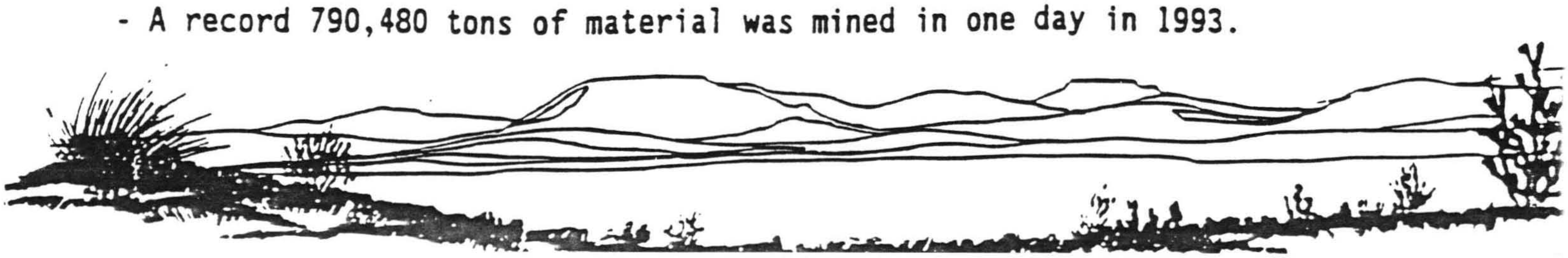
- Development of the open pit began in 1937.

- Since that time, 3 billion tons of ore and other rock material have been removed.

- In 1989 Phelps Dodge Morenci received the Chairman's Award for having the safest property in Phelps Dodge Corporation.

- Mining of copper ore for production in the open pit began in 1939.

- A record 790,480 tons of material was mined in one day in 1993.



**MORENCI FACT SHEET**
(Revised January, 1994)

- Morenci Mine has received the State Mine Inspector's Award for having the safest Mine in the State (498 mines total) in 1988, 1989, 1990, 1992 and is the leading contender for the award for 1993.

- The present smelter was built in 1942. It has been shut down since December 31, 1984.

- In 1989 the Mine Safety and Health Administration presented Morenci with an Outstanding Safety Award for working 1 million consecutive hours without a lost-time accident.

- Approximately 2,200 employees are employed in the Morenci operations (07/01/93).

- In 1990 Morenci employees received the Howard Pyle Safety Award presented by the National Safety Council for Arizona's Foremost Safety Example of all companies in Arizona.

- Phelps Dodge has approximately 50,000 acres in its Morenci (1 pit) operations. (81 square miles total mining operation - 3 pits.)

- The Morenci concentrator began producing copper concentrate in 1942, the Metcalf Concentrator in 1974.

- The two concentrators set a combined record of 148,139 tons of ore processed in one day (08/28/90).

- Together, the two concentrators produce about 450 million pounds of copper per year.

- The concentrators produce a concentrate that is about 30% copper from ore that was less than 1% copper.

- The Concentrator Division, both Morenci and Metcalf Concentrators, has received the State Mine Inspector Award for having the safest concentrators in the State in 1986, 1987, 1988, 1989, 1990, 1991 and 1992 and is the leading contender for the award for 1993.

- In 1994 the Concentrator Division completed over 3 million employee hours worked without experiencing a lost-time accident while producing 1.5 billion pounds of copper, a record that started in November of 1990.

- The SX/EW plant began operating in 1987 and was expanded in 1990 and 1992.

- The SX/EW plant presently produces 340 million pounds of copper per year.

**MORENCI FACT SHEET**
(Revised January, 1994)

- Since its start-up in 1987 the Morenci SX/EW has received the State Mine Inspector's Award for having the safest SX/EW in the State for the years 1987, 1988, 1989, 1990, 1991 and 1992 and is the leading contender for the award for 1993. In addition, they have worked over 1,200,000 employee hours and/or over five years without experiencing a lost-time accident while producing over 1.3 billion pounds of copper.

- The in-pit crushing and conveying system (IPCC) began delivering ore on February 20, 1989.

- It uses 60" and 72" wide conveyor belts.

- The system includes a total of six major conveyors, delivering ore from both the Morenci and Metcalf Mines.

- One belt is hung from the ceiling of the tunnel on rock bolts, providing easy access underneath for maintenance.

- The conveyors run at speeds of about 10 mph and a design rate of 9,000 tph.

- The mine has 14 drills, 18 shovels (three 15 yard, six 22 yard, seven 34 yard and two 40 yard), and 65 haulage trucks (seven 170 ton, fifty-one 190 ton and nine 240 ton).

- The Morenci Open Pit is 1.8 miles long, this is equivalent to 27 football fields placed end-to-end.

- Mine Safety and Health Administration presented a Outstanding Safety Award to Phelps Dodge Morenci for working 3.8 million consecutive employee hours without a lost-time accident.

- The average automobile contains 50 pounds of copper.

- 1991/1993 Morenci employees worked over 5.8 million consecutive employee hours without experiencing a lost-time accident.

- A 1,700 sq. ft. house contains approximately 400 pounds of copper.

- About 480 football fields could be placed on the West Tailing Pond, or about 5,930 basketball courts.

- For the last seven years Phelps Dodge employees have worked over a million employee hours each year without experiencing a lost-time accident.

# MORENCI FACT SHEET
(Revised January, 1994)

- The workers in the copper industry are the highest paid of any industry in the state. (Average $14.50/hr. without bonuses.)
- 35% of U.S. copper production is produced by Phelps Dodge Corporation, about 18% is produced at Morenci.
- In 1993 received the "SENTINELS OF SAFETY" Award for having the safest open pit mine in the U.S.A.

# GEOLOGY OF THE SANCHEZ PORPHYRY COPPER DEPOSIT

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## LOCATION

The Sanchez porphyry copper deposit is located about 10 miles northeast of the town of Safford and about 100 miles northeast of Tucson in T6S R27E, sections 25 and 26, Graham County, Arizona (fig. 1).

## REGIONAL GEOLOGY

### Introduction

The Sanchez porphyry copper deposit occurs within the Safford, or Lone Star mining district, a sub-province of the Southern Arizona-Sonora Porphyry Copper Province. The Safford district contains 4 well known porphyry copper deposits, Dos Pobres, Lone Star, Sanchez, and San Juan, and many prospects (fig. 2).

### Preliminary Mineral Rocks

The deposits occur within volcanic and related intrusive rocks of late Cretaceous to Eocene age. The volcanics total more than three thousand feet in thickness and appear to have been emplaced within an east-northeast-trending trough or graben that extended from the Safford area to Morenci (Robinson and Cook, 1966; Dunn, 1978). The volcanic rocks consist principally of hornblende-pyroxene andesite flows and breccias while the intrusives are mostly porphyritic diorites and monzonites. Based on limited isotopic dating, the volcanics are largely late Cretaceous to Paleocene in age while the intrusives and the hypogene mineralization were emplaced during the Eocene (Robinson and Cook, 1966; Langton and Williams, 1982).

The Safford volcanics form a continuous belt of outcrop extending along the southwest slope of the Gila mountains for about 15 miles, from the Sanchez deposit on the southeast to north of the Dos Pobres deposit on the northwest. At the crest of the range, the Safford volcanics are capped by post mineral volcanics of Oligocene to Miocene age. North of the range crest, the younger volcanic rocks extend over a very large area and the Safford volcanics are known only from a few scattered outcrops and the several tens of exploration drill holes that penetrate through the cap of younger volcanics.

The Safford volcanics and related intrusive rocks are widely altered to epidote, chlorite, albite, illite and calcite, especially along east-northeast trending fracture zones and where the volcanics consist of breccias and tuffs (Robinson and Cook, 1966; Langton and Williams, 1982). The propylitic assemblage alteration minerals are destructive of plagioclase, hornblende, pyroxene and glassy groundmass material. Within and adjacent to the porphyry copper deposits, however, the Safford volcanics and

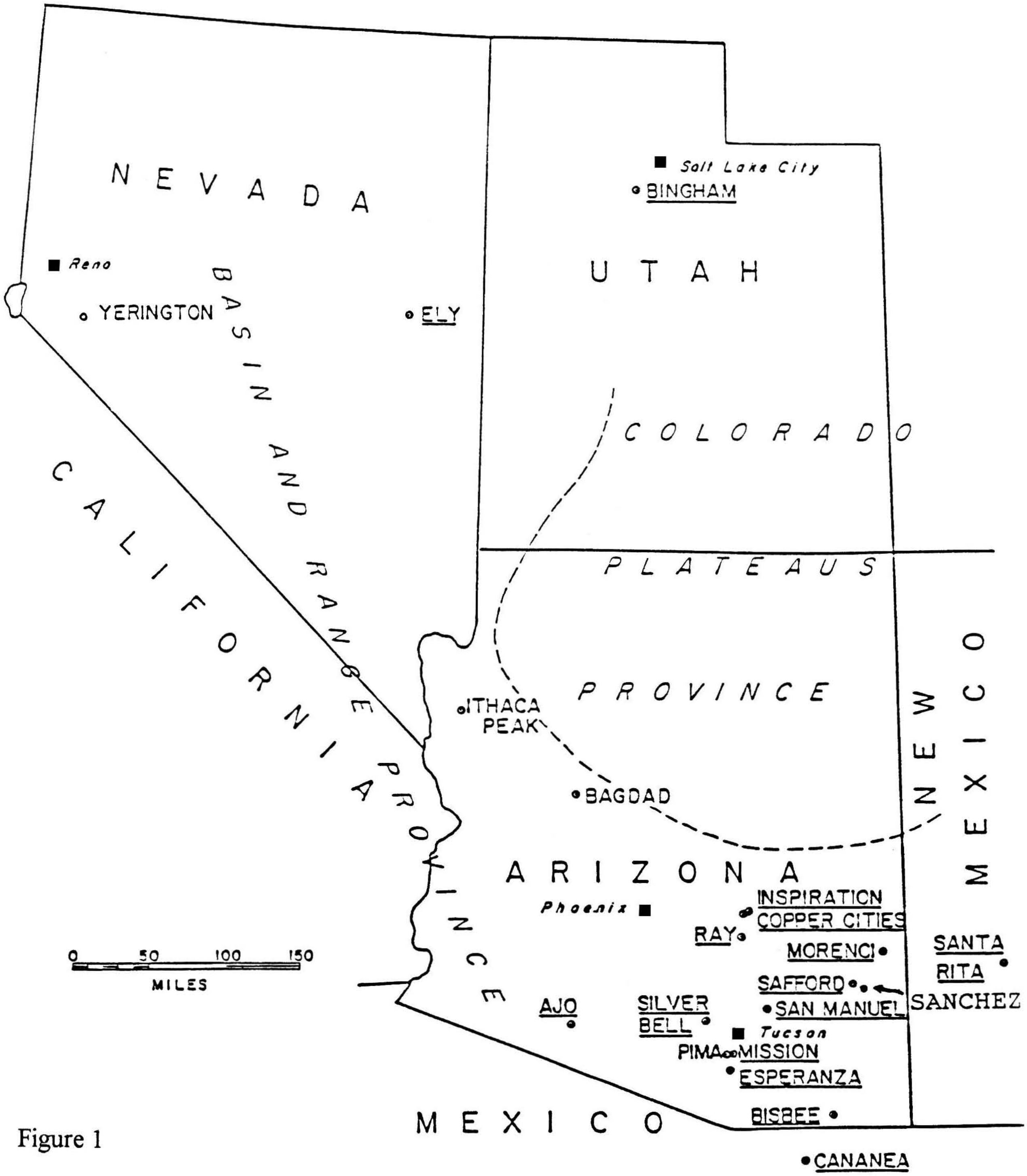


Figure 1

Map of the southwestern United States and adjoining regions of Mexico showing the principal physiographic subdivisions and the location of the porphyry copper deposits.

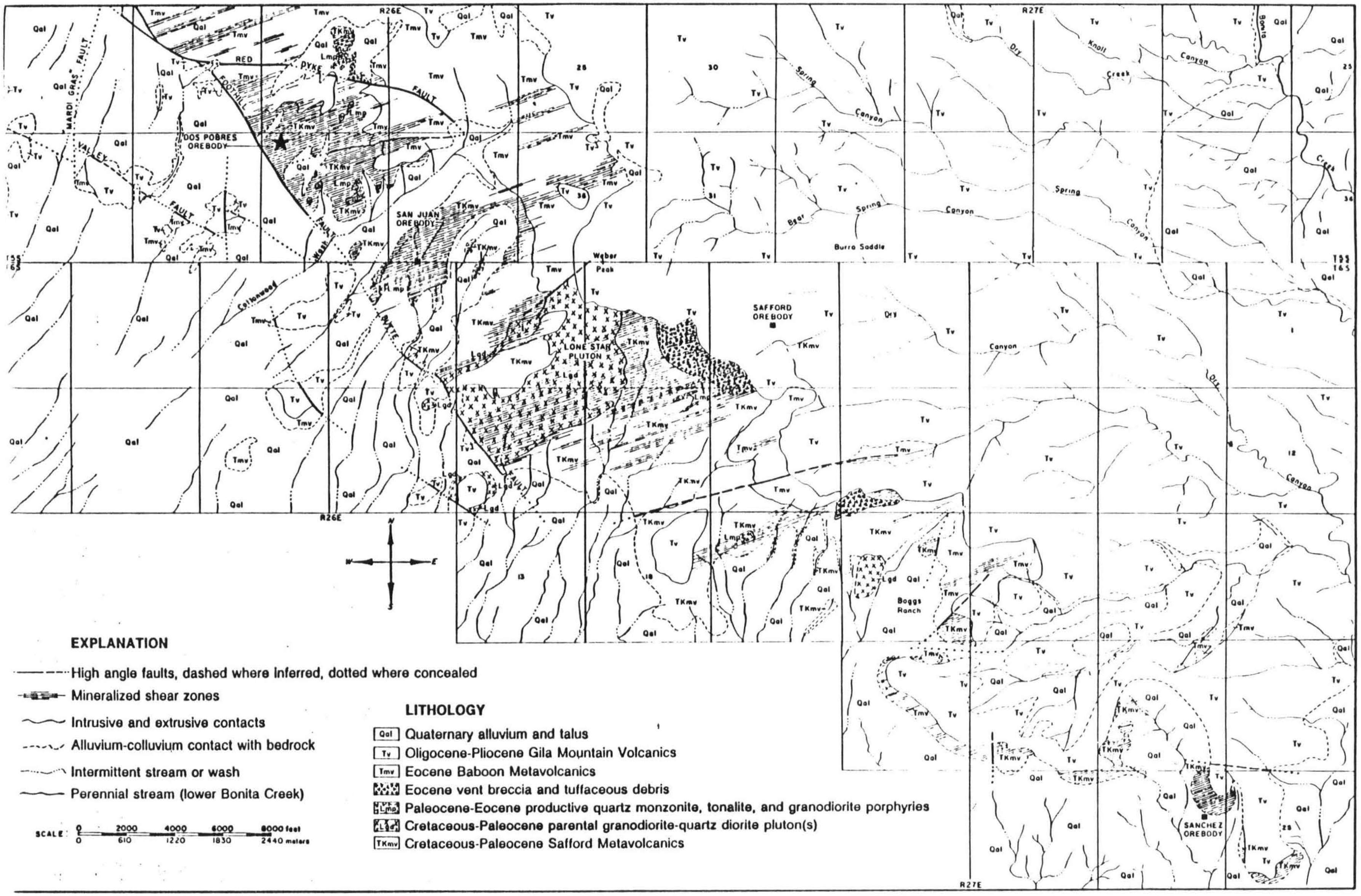


Figure 1 Geologic map of the Lone Star mining district.
Mapped and collated by R. Geer and others, Phelps Dodge Corp., 1972.

their intrusive counterparts are altered in varying degrees to k-feldspar, quartz, biotite, chlorite, magnetite and lesser amounts of sericite and quartz (Robinson and Cook, 1966; Dunn, 1978; Langton and Williams, 1982).

## Post Mineral Rocks

The Sanchez deposit is situated in a small, roughly circular, basin at the foot of the Gila mountains. The northern 20 percent or so of the deposit crops out on the southern nose of a ridge capped by about 100 feet of Miocene basalt flows that dip 10 degrees to the northeast (fig. 3).

The Gila mountains form the northern edge of the Safford Valley, a northwest elongate basin-like depression through which flows the modern Gila river. The basin was formed during the late Miocene or early Pliocene as a closed basin with internal drainage. The late Miocene-Pliocene sediments that filled the basin consist of an upper unit of tan and green clay and fine silt up to 800 feet thick and a lower unit of sands and conglomerates 100 to 200 feet thick. The clay and silt was deposited in evaporite lakes and playas while the sand and conglomerate was deposited in streams.

Between the Gila River and the Sanchez oxide copper deposit, the clay-silt unit is 100 to 200 feet thick while the underlying sand-gravel sequence is up to 100 feet thick. To the west, upper unit thickens to about 800 feet while the lower unit pinches out and then in the area of the leach pad site reappears and thickens to 200 feet or so. The Pliocene sediments rest on Safford volcanics.

During the Pleistocene, the Safford basin was breached by the Gila river which deposited well sorted gravel on progressively lower and narrower benches. At the leach pad site, the Pliocene gravels average 20 feet thick. Overlying the lake beds and Gila River gravels, and forming the surface upon which the leach pads will rest, are calcite cemented debris flow and alluvial fan deposits of coarse, angular rock fragments surrounded by clay and silt. The debris flow deposits attain a maximum thickness of about 100 feet adjacent to the Gila mountains and thin to a wedge edge 2 to 4 miles to the south.

# GEOLOGY OF THE SANCHEZ ORE DEPOSIT

## Introduction

The Sanchez porphyry copper deposit is located at the southeastern edge of the Safford Volcanics outcrop belt. The deposit is shaped like a vertical cylinder with a diameter of about 2500 feet and an axial length of more than 3500 feet. The deposit is centered on a monzonite porphyry stock and adjacent breccia pipe but is hosted mostly by andesite flows of the Safford Volcanics (figs. 3 and 4) .

## Safford Volcanics

In and around the Sanchez deposit, the Safford Volcanics are more than 3500 feet thick and consist of porphyritic andesite lava flows and possibly vent related subvolcanic intrusives (?). The volcanics are purple to dark gray or green and are distinguished

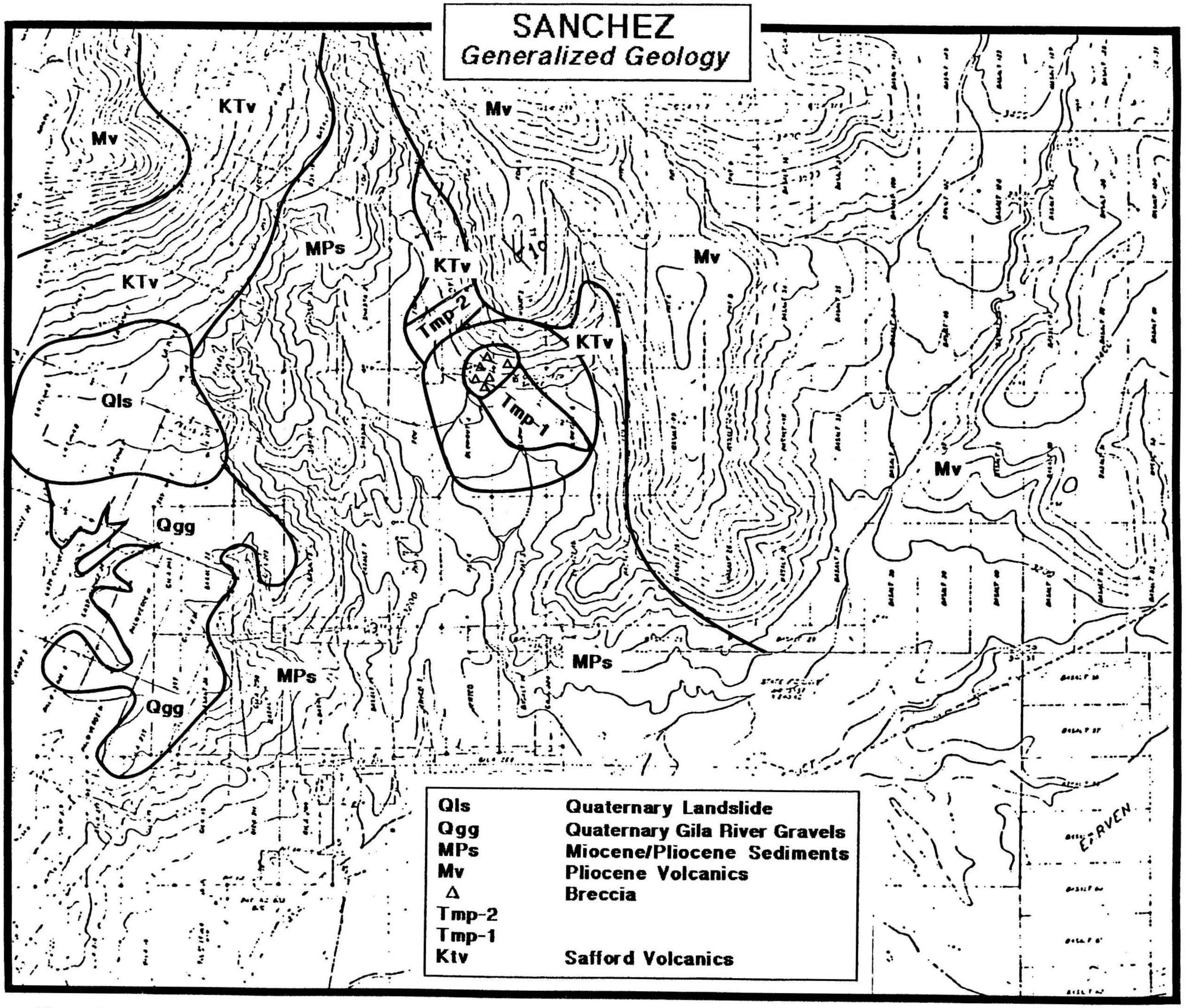
SANCHEZ
Generalized Geology
Mv
KTv
Mv
MPs
KTv
KTv
Mv
Tmp-2
KTv
Qls
Tmp-1
Mv
Qgg
MPs
MPs
Qgg
Qls Quaternary Landslide
Qgg Quaternary Gila River Gravels
MPs Miocene/Pliocene Sediments
Mv Pliocene Volcanics
Δ Breccia
Tmp-2
Tmp-1
Ktv Safford Volcanics

Figure 3

# SANCHEZ MINE
## Section 15 500 North
*Looking North*

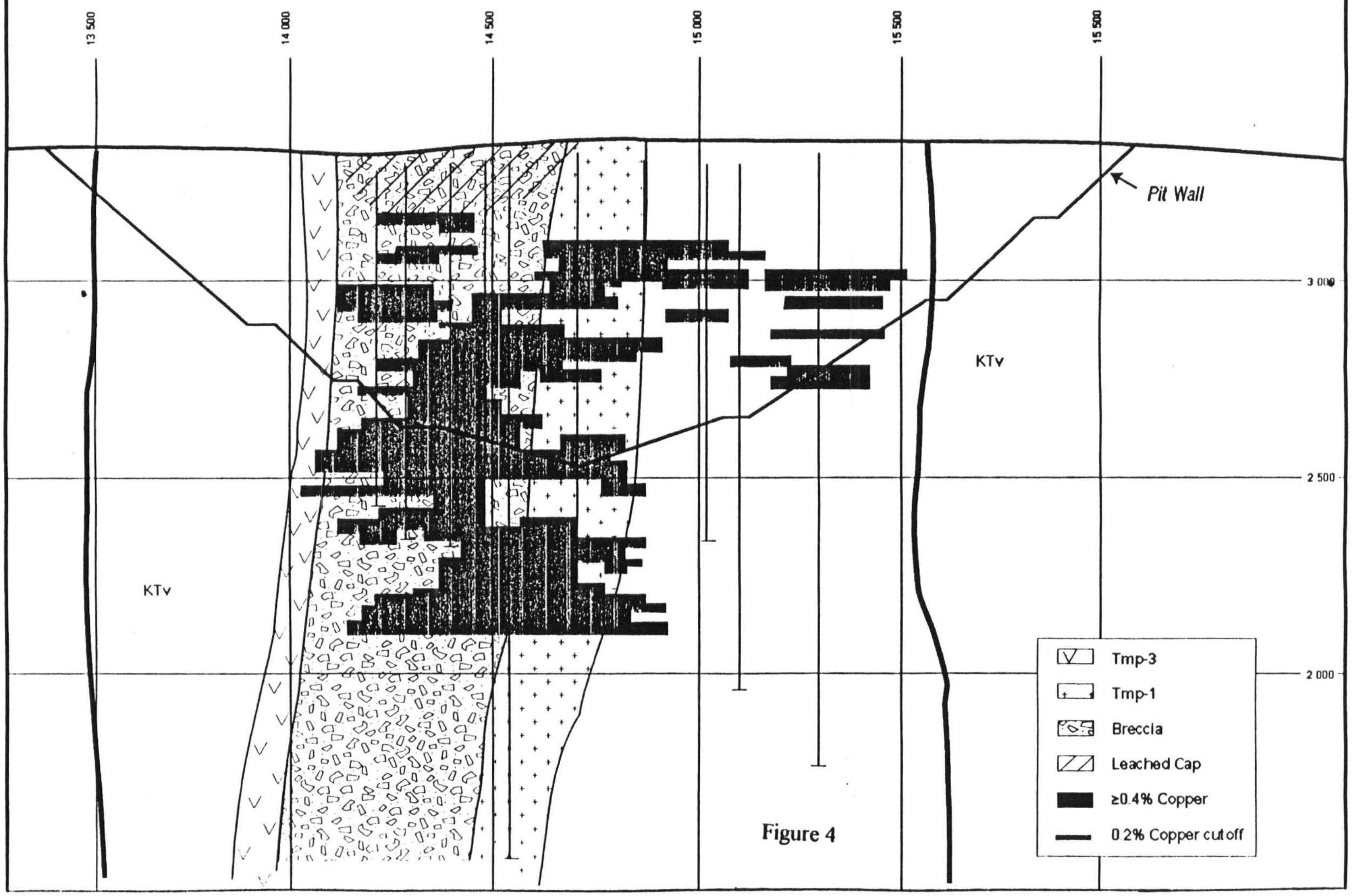


Figure 4

by elongate plagioclase phenocrysts. Peripheral to the deposit, the volcanics are dominated by breccias (probably lahars).

In thin section, the flows are made up of phenocrysts. of lath-like plagioclase (andesine) and lesser hornblende, now altered to chlorite, magnetite and biotite. The phenocrysts. are surrounded by a fine-grained matrix of alkali feldspar, plagioclase, biotite, and minor magnetite and quartz.

Intrusives

In and around the the Sanchez deposit, the Safford volcanics are intruded by monzonite porphyry stocks, dikes, and irregular apophyses named from oldest to youngest: Tmp-1, Tmp-2, Tmp-3 and Tmp-4 on the basis of cross cutting relationships, texture, and the presence of various alteration-mineralization facies.

TMP-1, the oldest monzonite porphyry, forms a cylindrical stock about 800 feet in diameter located at the approximate center of the Sanchez ore body.  Tmp-1 is generally pink or tan. It is composed of abundant, blocky plagioclase phenocrysts, shiny black biotite books, and minor quartz phenocrysts in an aphanitic, gray to pink matrix of fine-grained plagioclase, biotite, K-feldspar, and quartz. Tmp-1 is widely and pervasively affected by potassic alteration.

In thin section, Tmp-1 is constituted as follows:

Phenocrysts;

Plagioclase: estimated 20% to 25% percent of the rock, intermediate in composition (andesine), average about 3mm in length but up to 8 mm. They are blocky to rectangular and some are zoned with more calcic cores. Some phenocrysts are embayed or resorbed by matrix material. Most are partly replaced by sericite but some also contain epidote, K-feldspar, biotite and a few have trace amounts of calcite. In areas of high-grade copper mineralization, the centers of many grains host chrysocolla.

Biotite: estimated 2% to 5% of the rock as black, shiny books 1mm to 3mm in diameter, generally unaltered.

Hornblende: estimated 2% of the rock, entirely altered to chlorite, biotite and magnetite.

Quartz: rare, equant grains.

Groundmass:

Plagioclase, K-feldspar, albite, biotite and quartz.

Chemical composition (average of 2 bulk metallurgical samples):

| | TMP-1 | ANDESITE | BRECCIA |
|---|---|---|---|
| Al2O3 | 14.26 | 16.98 | 15.53 |
| CaO | 1.36 | 2.69 | 0.62 |
| Fe (as Fe2O3) | 6.66 | 6.16 | 6.79 |
| K2O | 3.17 | 2.42 | 2.66 |
| Mg | 1.69 | 2.40 | 2.13 |
| MnO | 0.04 | 0.05 | 0.02 |
| Na2O | 3.38 | 4.53 | 3.66 |

| | | | |
|---|---|---|---|
| $P_2O_5$ | 0.14 | 0.23 | 0.17 |
| $SiO_2$ | 65.53 | 61.09 | 64.74 |
| $TiO_2$ | 0.44 | 0.59 | 0.61 |

As a result of potassic alteration and post mineral oxidation, the TMP-1 analysis may not accurately reflect its premineral composition.

Tmp-2 occurs as a partly exposed, and apparently E-W elongate, stock at the north and northwest margin of the ore body. Tmp-2 is petrographically and megascopically indistinguishable from Tmp-1 except for the absence of potassic alteration and its accompanying sulfide mineralization. However, Tmp-2 is cut by numerous northwest trending quartz-sericite structures which impart to it a copper grade of 0.05% to 0.15%. The absence of potassic alteration in this rock and its presence in adjacent TMP-1 and andesite suggests that Tmp-2 was emplaced after the termination of potassic alteration. The presence of fracture-controlled quartz-sericite-pyrite alteration requires that TMP-2 was emplaced prior to late fracturing and quartz-sericite alteration.

Tmp-3 is similar in composition and texture to Tmp-1 and 2 but is darker in color. At the surface, Tmp-3 occurs as a circular body about 50 feet in diameter located at about 15,700N, 14,200E and as a body about 150 feet in diameter located at about 17,500 N, 14000E. TMP-3 was also penetrated by holes 113, 414 and 448. Tmp-3 appears to occur as small, pipe-like bodies situated around the margin of the breccia pipe. Tmp-3 is a gray, porphyritic rock distinguished from Tmp-1 and 2 by its darker matrix, the presence of fresh hornblende, and the absence of hydrothermal alteration and mineralization. Tmp-3 clearly postdates Tmp-1, Tmp-2, mineralization and alteration, and the breccia pipe.

Tmp-4, formerly called porphyritic andesite, is distinguished from the volcanics and the other intrusives by sparse, blocky, plagioclase phenocrysts and a dark-gray matrix. Tmp-4 occurs as a northwest trending dike 5 to 10 meters wide extending from about 15,000N, 15,000E to 16,200N, 14,250E where it cuts across Tmp-2. Tmp-4 is petrographically similar to Tmp-1, Tmp-2 and Tmp-3. Tmp-4 is unaltered and lacks primary mineralization but contains local high-grade concentrations of exotic chrysocolla. While Tmp-4 is classified as the youngest intrusive it is not in contact with Tmp-3 so it may well turn out that Tmp-4 is older than Tmp-3.

Breccia; Between the northwestern edge of Tmp-1 and the Safford volcanics is a tubular body of breccia about 500 feet in diameter (figs. 3 and 4). The northeast half of the breccia pipe is well exposed at the surface while the southwest half is covered by alluvium. The breccia was penetrated by DDH's 104, 115, 203, 301, 401, 403, 407, 410, 442, 443, 450, 601, 802, 901, 902, 903, of which only the core from 410 and 802 still exists. According to geologic maps compiled by Inspiration, a former property holder, breccia occurs throughout the western half of the underground workings.

The breccia consists of angular to rounded andesite and Tmp-1 fragments surrounded by rock flour or, locally, by amethyst quartz-filled vugs. In general, rock fragments make up 40% to 70% of the breccia while the remainder consists of rock flour, quartz and the leached remnants of sulfide minerals. As shown in table 1, the chemical composition of the breccia is intermediate between that of Tmp-1 and andesite. In the center of the pipe, sulfides constituted 4% to 5% by volume of the rock but towards the edges they diminish to 1% to 2%. As a result, oxidation of the center of the pipe resulted in a leached capping where 90 % of the copper values were removed (copper grades here range from 200 to 500 ppm), while toward the edges, only about 20% of the original copper values were removed. Copper leached from the upper parts of the pipe was deposited at depth and adjacent to the pipe as a chalcocite enrichment blanket.

The relative timing of breccia emplacement can be determined to have occurred in the interval between potassic alteration and quartz-sericite-pyrite alteration and thus, after emplacement of Tmp-1 and Tmp-2 but before emplacement of Tmp-3 and Tmp-4, by the following observations: 1) breccia fragments contain rotated quartz-biotite-K-feldspar veinlets which are absent from the matrix and, 2) quartz-sericite-pyrite veins cut fragments and matrix.

## WALL ROCK ALTERATION

The Safford Volcanics in the Sanchez deposit and its immediate surroundings are affected by three general alteration types; potassic, quartz sericite, and propylitic.

### Potassic Alteration

Potassic alteration extends beyond the limits of the ore body but is most intense in andesite within 100 to 200 feet of the Tmp-1 contact. Much of the potassic alteration is vein controlled and is intimately associated with magnetite, chalcopyrite, bornite, molybdenite and minor pyrite.

Within Tmp-1, potassic alteration minerals make up 10 to 20 percent of the rock and consist dominantly of K-feldspar and quartz and lesser amounts of biotite and magnetite. In detail, potassic alteration consists of several sub-types as follows:

1) Quartz-magnetite-biotite biotite veinlets containing bornite and chalcopyrite.

2) Stockwork type quartz veins or veinlets rimmed by biotite alone, or biotite plus K-feldspar. Locally, the biotite may depart from the quartz and form monomineralic veinlets. These veinlets also contain chalcopyrite and bornite.

3) Pervasive, or disseminated quartz-K-feldspar alteration adjacent to quartz veins. The veins and veinlets appear to fill through-going fractures and to cut, and destructive of, biotite-magnetite alteration. These quartz veins contain copper sulfides.

Throughout Tmp-1, chlorite locally occurs in hornblende and magmatic sites while epidote is occasionally present in the cores of plagioclase phenocrysts. Whether these minerals formed prior to, during, or after potassic alteration has not yet been determined.

The most intense form of potassic alteration occurs in the volcanics within 100 to 200 feet of the Tmp-1 contact where the volcanics consist of hornfels composed of fine-grained secondary biotite, K-feldspar, plagioclase, magnetite, and minor quartz. Also present is a dense network of biotite-magnetite-K-feldspar-(plagioclase?) veinlets. Proceeding away from the zone of intense potassic alteration, the percentage of biotite, K-feldspar, and magnetite declines while chlorite becomes more abundant.

Copper mineralization in the potassically altered andesite originally occurred in fine chalcopyrite-bornite stockwork veinlets and in northeast trending, through-going quartz veins and veinlets.

Quartz-Sericite Alteration

Quartz-sericite-pyrite alteration occurs throughout the ore body in northwest trending fracture zones. Within the breccia pipe, and especially in its center, quartz sericite alteration is pervasive resulting in the total destruction of plagioclase and the partial destruction of ferromagnesian minerals. Quartz sericite alteration is clearly later than potassic alteration. Prior to oxidation, the quartz sericite zones also hosted pyrite and chalcopyrite.

Propylitic Alteration

Beyond the limits of the ore body, the volcanics are altered to epidote, chlorite, albite, calcite, pyrite, and zeolites. The intensity of propylitic alteration varies with rock type and fracture density; it is most complete in breccias and fracture zones and weakest in unfractured flows.

Propylitic minerals also occur within the potassic alteration zone as follows: 1) epidote is present in minor amounts in plagioclase phenocrysts, 2) chlorite is present in hornblende and plagioclase sites, and 3) towards the edges of the ore body, chlorite and epidote appear as fracture coatings.

STRUCTURE

At this point in the study of the Sanchez deposit, it appears that the ore body and its surroundings occur in a geological setting remarkably free of major and even minor structures. While previous workers have mapped and otherwise described or inferred the presence of one or more west trending major faults cutting the ore body, none were found in the present study of surface outcrops and drill core. Mapping during 1992 discredited the west trending faults shown on the Inspiration surface geological map but defined a previously unmapped northeast trending quartz-sericite-pyrite vein.

While faulting is absent or of minor importance within the outcropping part of the ore body, post mineral faults offset the post mineral volcanics to the north and south of the deposit. These faults have normal displacements of 50 to 100 feet and rotate the volcanics about 10 degrees to the northeast.

MINERALIZATION

The Sanchez copper deposit is made up of 3 mineralogical zones, an upper, oxide copper zone extending from the surface (average elevation about 3200 feet) down to 2150 feet, a mixed oxide and native copper zone between about 2150 and about 2000 feet, and a sulfide zone below about 2000 feet elevation.

Oxide zone

Extensive radiometric dating and geological studies show that the principal period of porphyry copper oxidation and enrichment in southern Arizona occurred between 50 and 25 mya during a time of tectonic and volcanic quiescence. The evidence for ancient oxidation of the Sanchez ore body consists of the following: 1) the oxide zone extends more than 900 feet below the present water table, more than 1300 feet below the Pliocene playa lake bottom, and at least 1400 feet below the Quaternary Gila River channel, 2) the oxide-sulfide interface is parallel to the base of the Miocene volcanics (tilted about 10 degrees to the northeast), and 3) the oxide deposit is capped by Miocene volcanic rocks.

The principal copper mineral within the oxide zone is chrysocolla, followed in abundance by neotocite, a manganese bearing copper silicate, tenorite, minor native copper, and traces of atacamite. These minerals occur for the most part as highly visible coatings on fractures, or, in the case of chrysocolla, as disseminations within plagioclase phenocrysts in Tmp-1. Locally, however, the oxide copper minerals are hidden from view as very fine-grained inclusions within limonite accumulations. Previously reported malachite and cuprite were not found in this study and are believed to be absent from the deposit. Calcite, a mineral of some concern to a leaching operation is mostly absent from the deposit but locally constitutes 0.1 to 0.2 percent of the rock. Evidently, the minor amounts of calcite originally present in the sulfide deposit were largely destroyed by sulfuric acid generated in the oxidation of pyrite, chalcopyrite and bornite.

The oxide copper minerals are accompanied by goethite, minor hematite, and rare jarosite which is present along quartz-sericite zones and within the breccia pipe.

Prior to mining, most of the great porphyry copper deposits in southern Arizona consisted of an upper, leached capping underlain by a chalcocite enrichment blanket. The absence of these features at Sanchez (except in the breccia pipe) and, indeed, the very existence of the outcropping Sanchez oxide copper deposit results from two factors: 1) the average total sulfide content of the Sanchez sulfide deposit is low (about 1.5% by volume) and is made up largely of chalcopyrite and bornite. As discussed by Anderson, 1982, oxidation of this type of sulfide deposit will not generate enough sulfuric acid to leach copper from the oxidized zone, and 2) the principal silicate minerals at Sanchez are feldspars, biotite, chlorite, magnetite and epidote which are more reactive to acid solutions than the quartz-sericite assemblage that hosts deposits with leached cappings and important enrichment blankets. Thus, at Sanchez, the small amount of acid generated by sulfide breakdown during oxidation was neutralized by reaction with the wall rocks.

Within the breccia pipe, where the sulfide content was high, and quartz-sericite alteration was more intense, oxidation of sulfides produced enough acid to leach most of the copper. Copper leached from the upper part of the pipe was reprecipitated at depth as a chalcocite blanket. Later lowering of the water table resulted in oxidation of the enriched blanket. Based on the presence of several oxidized, high-grade layers at depth within the breccia pipe, the process of leaching and enrichment was repeated on a number of occasions.

A third factor responsible for the creation of the Sanchez oxide deposit is that oxidation took place during a long period of peneplanation and desertification when chemical weathering was more rapid than erosion and when the water table was and deep.

Mixed Oxide Sulfide Zone

The mixed zone, which averages about 150 feet in thickness, occurs at the base of the oxide deposit and above the unoxidized sulfides. Copper minerals of the mixed zone consist of chrysocolla, neotocite, native copper, delafossite, possible cuprite, chalcocite and minor amounts of chalcopyrite and bornite. Overall, the copper grade of the mixed zone is about 10% higher than the oxide zone due to overall minor copper leaching from the oxide zone.

Sulfide Deposit

Primary sulfide mineralization (and wall rock alteration) at Sanchez is similar in most regards to that described in the other deposits of the Safford district. Overall, the Sanchez deposit is typified by a relatively low total sulfide content, the absence of a pyrite-sericite halo, a high chalcopyrite/pyrite ratio and (at least locally) a relatively high gold content. As deduced by study of core from the lower, unoxidized part of the deposit, the original sulfide content of the deposit averaged about 1.5% by volume, with chalcopyrite and bornite more abundant than pyrite. As stated in the discussion of alteration, chalcopyrite and bornite with minor pyrite occur in stockwork type veinlets together with quartz, K-feldspar, biotite, and magnetite. Chalcopyrite also occurs in later quartz-pyrite-sericite veinlets. Overall, sulfide copper mineralization is strongest in the central part of the deposit and gradually diminishes outwards. The principal exception is the pyrite dominant central part of the breccia pipe where the total sulfide content is up to 5 percent by volume. Molybdenite in minor amounts is present throughout the sulfide deposit and gold locally exceeds 0.01 opt.

Quartz-sericite-pyrite-chalcopyrite mineralization occurs in northwest trending fractures cross cutting potassic alteration and chalcopyrite-bornite mineralization.

SUMMARY

Sanchez is an oxidized, low-total sulfide porphyry copper deposit localized in volcanic and intrusive rocks of intermediate composition. Copper grades are highest at the center of the deposit and gradually diminish outward. Copper minerals in the oxide deposit consist of dominant chrysocolla, neotocite and tenorite, minor native copper, and trace atacamite.

Alteration is dominantly potassic and the deposits lacks a pyrite-sericite halo: however, pyrite and sericite are present in late west trending fracture zones and in a centrally located breccia pipe.

The deposit is located within an intrusive center of intermediate composition stocks, plugs and dikes that were sequentially emplaced during the mineralizing event. The presence of a large breccia pipe within the deposit suggests a high level of exposure of the porphyry copper system.

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