The Warren (Bisbee) Mining District

Cochise County, Arizona

Ralph J. Stegen
Ernest Wright
Donald G. Bryant

Arizona Geological Society Spring Field Trip
April 30, 2005

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Dear Field Trip Participant,

Welcome to the Arizona Geological Society Spring 2005 field trip to Bisbee, Arizona. We are grateful to our Society President, Ralph Stegen (Vice President, Mine-Site Exploration, Phelps Dodge Exploration Corp.), for organizing and co-leading this trip with Ernest Wright (Phelps Dodge Mining Co., Copper Queen Branch) and Donald Bryant (Denver, Colorado), and to the management of Phelps Dodge Corp. for granting us access to the company property in Bisbee.

On this trip, we will visit one of Arizona's most famous mineral districts with a rich history that is well documented at the Bisbee Mining and Historical Museum (a must-see!). Our trip leaders will take us to outcrops of the Jurassic porphyry copper deposit and associated base- and precious-metal-bearing manto deposits and supergene-enriched copper deposits throughout the district (see maps on pages 3 and 22).

Safety is a primary concern for Phelps Dodge. Wear your personal protective equipment at all times. Look for comments regarding your safety in the guidebook at particular stops. And, please pay attention to your surroundings for your safety and the safety of your fellow participants.

Enjoy the trip!

Thank you,
David Maher
(VP Field Trips)

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Field Guide to the Warren (Bisbee) Mining District

Cochise County, Arizona

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Guidebook for the
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Introduction

The ore deposits at Bisbee were discovered in outcrop in 1876 by U.S. Calvary scouts searching for water. The first mining claim in the district was staked in 1878 on a cerussite and silver occurrence. In 1880, an outcropping mass of malachite and azurite with iron and manganese oxides was found along the northern slope of Queen Hill. The near-surface ores were produced until the 1890s when copper sulfide minerals were found within the deeper levels of the orebodies. Sulfide ores became predominant and were mined from Paleozoic sedimentary rocks until the mines were closed in 1975. Chalcopyrite and bornite fragments within breccia subsequently enriched by chalcocite and a chalcocite blanket were also mined from the Sacramento and Lavender pits.

Production: The district has produced copper from oxidized and sulfide manto ores and two periods of open pit mining. A summary of the production is below. The average district grade for the manto deposits is 6.0%, but in many of the oxidized orebodies grades of 12 to 23% was common. It also should be noted that the underground mining cutoff for the sulfide manto ores was around 3.5% copper. In addition to copper, the district has been a significant producer of gold (about 3 million ounces), zinc (355 million pounds), lead (324 million pounds), silver (102 million ounces) and manganese (28 million pounds).

Years	**Type**	**Ore Tons (000)**	**Leach Tons (000)**	**Grade (%Cu)**
1880-1975	Manto	53,000		6.00
1919-1929	Sacramento Pit Ore	9,000		2.00
1919-1929	Sacramento Pit Leach		12,000	0.72
1954-1974	Lavender Pit -Ore	92,674		0.81
1954-1974	Lavender Pit -Leach		109,515	0.35

Local Geology of Bisbee

Previous studies: The geology of the Warren Mining District has been very well described by governmental and mining company geologists. Two excellent comprehensive descriptive papers on the Bisbee geology and orebodies have been published (Ransome, 1904; Bonillas, 1916). Later published works provided district overviews and a synthesis of the geology of the orebodies (Tenney, 1932; Trischka, 1938; Wisser, 1927). Carpenter (1941) provided a concise description of the sulfide zoning and ore controls of the

EXPLANATION

QUATERNARY

Recent

Qal — Alluvium

Ql — Landslide deposit
Source rock indicated by color

Pleistocene

Qg — Pediment, terrace, and fan gravels

Pliocene(?) and Pleistocene

QTs — Valley fill

UNCONFORMITY

TERTIARY

Ti — Intrusive quartz latite porphyry
Includes gneissic granite in sec. 15, T. 23 S., R. 23 E.; hornblende diorite in sec. 25, T. 23 S., R. 24 E.; and altered diorite(?) in sec. 24, T. 23 S., R. 23 E. and in sec. 32, T. 23 S., R. 25 E.

CRETACEOUS

Lower Cretaceous — Bisbee Group

Kc — Cintura Formation
Grayish-red siltstone and mudstone, pale-red feldspathic sandstone, and minor greenish-gray calcareous claystone; a few thin beds of impure fossiliferous limestone in basal 100 feet. Maximum preserved thickness about 1,830 feet

Kmu, Kml — Mural Limestone
Kmu, *upper member, medium dark-gray limestone in relatively thick beds, subordinate sandstone in upper 50 feet. 220 to 275 feet thick.*
Kml, *lower member, interbedded light olive-gray-weathering calcareous sandstone and siltstone and impure fossiliferous limestone. 330 to 435 feet thick*

Km — Morita Formation
Grayish-red siltstone and mudstone, pinkish-gray to pale-red feldspathic sandstone, and minor greenish-gray calcareous claystone; a few thin beds of impure limestone in upper part and very subordinate pebble conglomerate in lower part. 2,600 feet thick

Kg — Glance Conglomerate
Locally derived boulder-to-pebble conglomerate with grayish-red matrix. 0 to more than 600 feet thick

UNCONFORMITY

JURASSIC **

Jj * — Juniper Flat Granite
Stock and associated dikes of porphyritic leucocratic alkali granite

PERMIAN

Lower Permian — Naco Group

Pc — Colina Limestone
Medium-gray thick-bedded limestone, slightly cherty in part. Maximum preserved thickness about 500 feet

Upper Pennsylvanian

PIPe — Earp Formation
Pale-red calcareous siltstone and mudstone with subordinate medium-gray thin-bedded limestone and marl. 350 to 540 feet thick

PENNSYLVANIAN (CARBONIFEROUS)

Middle and Upper Pennsylvanian

IPh (IPhu, IPhm, IPhl) — Horquilla Limestone
Medium light-gray medium-bedded limestone with subordinate pale-red calcareous siltstone and silty limestone.
IPhu, *upper member, about 440 feet thick.*
IPhm, *middle member, dominantly silty, about 180 feet thick.*
IPhl, *lower member, about 600 feet thick*

DISCONFORMITY

MISSISSIPPIAN (CARBONIFEROUS)

Lower and Upper(?) Mississippian

Me — Escabrosa Limestone
Medium- to light-gray thick-bedded to massive crinoidal limestone and medium- to dark-gray thin-bedded limestone. 665 to 735 feet thick

DISCONFORMITY

DEVONIAN

Upper Devonian

Dm — Martin Limestone
Medium- to dark-gray limestone, marl, dolomite and sandy dolomite, and calcareous siltstone. 290 to 475 feet thick

DISCONFORMITY

CAMBRIAN

Middle and Upper Cambrian

Ꞓa — Abrigo Limestone
Laminated hornfels with subordinate interlaminated limestone, silty and argillaceous limestone, and chert in basal 250 feet; next 200 feet is mostly interlaminated silty limestone and chert with limestone edgewise conglomerate common; next 180± feet is mostly glauconitic sandy dolomite and dolomitic sandstone with minor interbedded marl; top 40 to 100 feet is medium-gray laminated limestone that is locally dolomitized. Total thickness 700± feet

Middle Cambrian

Ꞓb — Bolsa Quartzite
Resistant yellowish- to reddish-brown-weathering siliceous sandstone. 300 to 450 feet thick

UNCONFORMITY

PRECAMBRIAN

Lower Precambrian

pꞒp — Pinal Schist
Dominantly drab muscovite, chlorite, and quartz schist

Contact
Dashed where approximately located

Fault
Dashed where approximately located; dotted where concealed; queried where doubtful. U, *upthrown side;* D, *downthrown side*

Reverse fault
Dotted where concealed; R, *upthrown side*

Thrust fault
Dashed where approximately located. Sawteeth on upper plate

Low-angle fault of uncertain displacement
Teeth on upper plate

Strike and dip of beds (24)

Strike of vertical beds

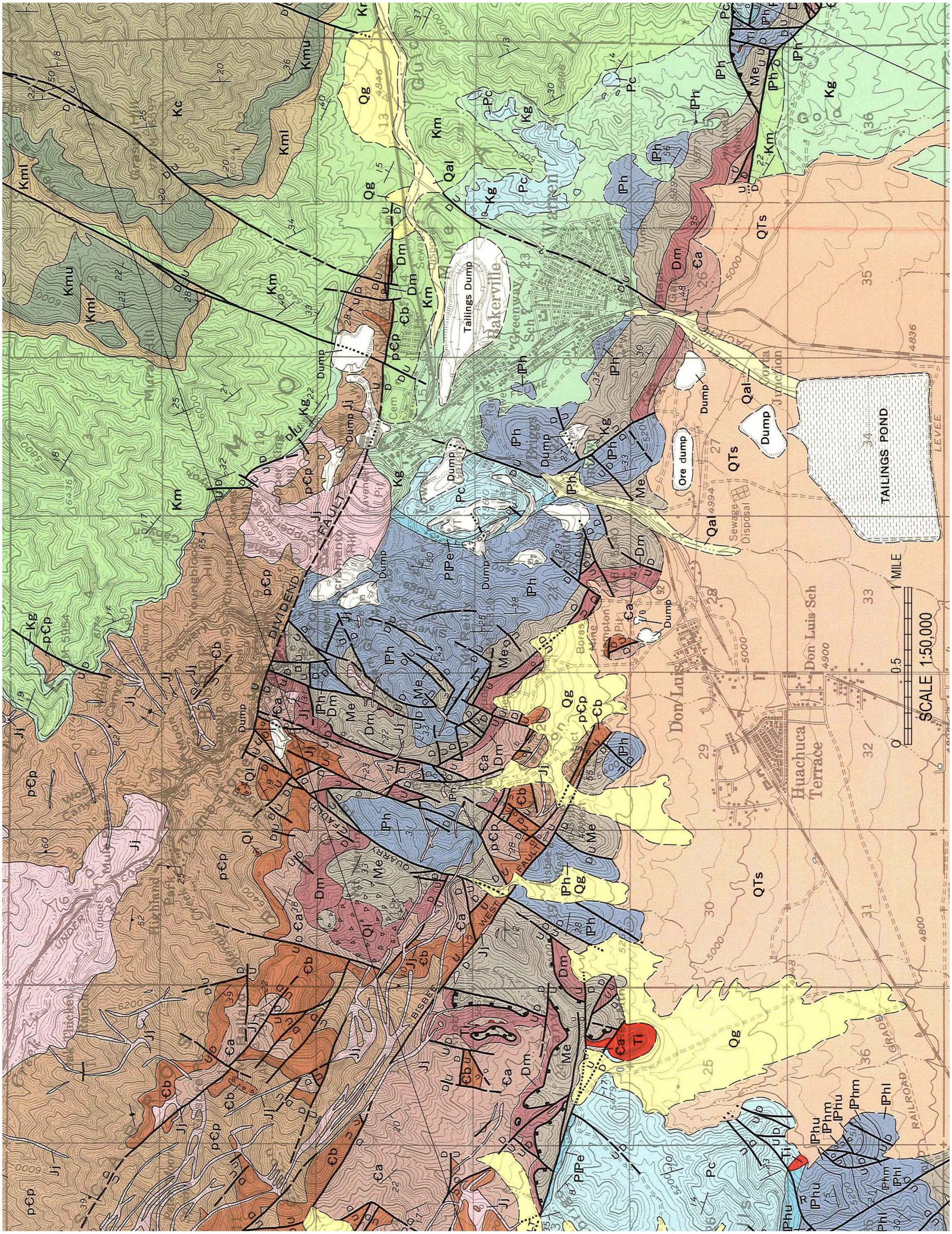
Strike and dip of overturned beds (83)

Strike and dip of foliation (45)

Strike of vertical foliation

[*Original figure contains handwritten annotation: "174 m.y."]

[**Original figure contains handwritten annotation:
"Sacramento Hill
Cochise Por
198-200 m.y."]


TAILINGS POND
LEVEE
Tailings Dump
Bakerville
Warren
Greenway Sch
Dump
Ore dump
Sewage Disposal
Don Luis
Don Luis Sch
Huachuca Terrace
DIVIDEND FAULT
SCALE 1:50,000
0
0.5
1 MILE

Campbell orebody while mining was active. Two important Ph.D. dissertations were generated in the 1960s. The first was by Bryant (1964) that discussed the nature of the intrusive hydrothermal breccias in the district. The second was by Nye (1968) who studied the relationship of structure and host rocks to the high-grade manto ores in the district.

The mining companies frequently hired consultants to work with the geology department to identify and generate exploration targets. The work by Blanchard (1926) and Boutwell (1910) are notable as they formulated guides to ore that were instrumental in the development of the district through the 1930s.

One of the relatively recent publications of the district was by Bryant and Metz (1966) in which the geology of the Lavender pit was presented with a clear focus on describing the Sacramento Hill intrusive rocks and breccias.

Stratigraphy

The stratigraphic framework of the district was described by Ransome (1904). Wisser (1926) added details from underground exposures not available to Ransome. A geologic map of the Bisbee district by Hayes and Landis (1964) is shown on page 3. Detailed rock descriptions can be found in the published references, and only general descriptions will be included here. The stratigraphy of the district includes a basement of Precambrian schist, which is overlain with 5,000 feet of Paleozoic sedimentary rocks. Cutting the Precambrian and Paleozoic rocks are Jurassic-aged stocks, dikes and breccia bodies. A thick sequence of Cretaceous conglomerate, sandstone, siltstone, and limestone crops out to the east and north of Bisbee.

Pinal Schist: The oldest rock in the district is the Precambrian Pinal Schist. Neither the top nor the bottom the Pinal Schist has been found. The schist is pale green to white on a fresh surface and may be pink when weathered. These rocks are quartz-muscovite and quartz-sericite schist and phyllite. The schist and phyllite typically contain 50% to 75% quartz, 25% to 50% muscovite or sericite and 1% accessory minerals including garnet, zircon, and magnetite. Thin and discontinuous quartzite beds occur within finer grained schist units. This rock is host to about 15% of the chalcocite mineralization at the Cochise deposit.

Bolsa Quartzite: The basal Cambrian unit is the Bolsa Quartzite and has been measured to be 430 feet thick by Ransome (1904). The base of the unit contains thin conglomerate beds and coarse quartzite beds for up to 50 feet, and followed by a uniform package of medium grained quartzite. Thin limestone beds occur at the top of the unit. The quartzite is a gray to white dense quartzite composed of 90% to 99% medium- to fine-grained quartz grains. The unit is locally arkosic with grains of plagioclase and microcline. The conglomerate unit near the base is matrix-supported with milky quartz pebbles in a quartz sand matrix. The quartzite beds are cross-bedding and graded. The unit can contain up to 1% pyrite which characteristically turns the surface of the rocks reddish when weathered. The Bolsa was mined as a silica source for smelter flux.

Abrigo Limestone: Conformable above the Bolsa Quartzite is the Abrigo Formation which was named and measured by Ransome (1904) to be 770 feet thick. This formation consists of thin to medium limestone beds, silty and limey shale beds, silty limestone beds, and locally thin quartzite beds. Regionally, the unit has been weakly metamorphosed to epidote in the bottom third of the formation (Bonillas et al, 1916). At the top of the Abrigo is a thin (0' to 12') coarse quartzite bed referred to as the capping quartzite by Boutwell (1910) and as the parting quartzite by Wisser (1926). The lower and upper sections of this unit are a significant host rock to the manto orebodies.

Martin Limestone: The Martin Limestone is the single representative of the Devonian system. This unit was measured by Ransome (1904) to be 340 feet thick and is conformable with the underlying Abrigo Limestone. The unit consists of medium-bedded, dark gray to brown fossil-bearing limestone with minor shale. The most common fossils are brachiopods, typically *Atrypa reticularis* and *Spirifer hungerfordi.* (Ransome, 1906). The shale in the unit is generally friable and has a pinkish hue. The entire section of Martin is a significant host to manto and chimney bodies at Bisbee.

Escabrosa Limestone: The Mississippian rocks in the district are represented by the thick-bedded Escabrosa Limestone. This unit is approximately 800 feet thick, although there is evidence for thicknesses of only 600 feet in some areas. The Escabrosa Limestone is a thick bedded (10' to 15') generally white to light grey limestone. The unit is generally fossiliferous with poorly preserved crinoid stems and less corals making up the bulk of the fossils. The most productive part of the Escabrosa as an ore host is the lower 300 feet of the unit.

Naco Group: The Pennsylvanian Naco Group is partially preserved in the district. The lower most exposed unit is the Horquilla Formation. Within the mining area the Earp and Colina Formations were exposed prior to being covered by stockpiles from the Lavender Pit in the 1960's and only the Horquilla will be described here. The Formation was named by Ransome (1904) and was measured to be 1,000 feet thick. The formation consists of thin-bedded (2" to 24 inches) to medium bedded (5 feet to 8 feet) blue-gray to gray limestone. These beds are typically thinned than the more massive beds of the similar Escabrosa Formation. Shale beds are common in the upper portions of the formation. Fossils consist of abundant crinoids and brachiopods, and the formation can be distinguished from the crinoidal Escabrosa Formation by the presence of fusulinids. Some minor orebodies were mined from the lower beds of the Horquilla.

Glance Conglomerate: The Glance conglomerate was named and measured by Ransome (1904). The Glance has a uniform thickness of 20 to 25 feet north of the Dividend fault, but south of the fault its thickness varies significantly (up to 1,000 feet). Bilodeau (1979) subdivided the Glance as based on the dominant lithology of the clast into an upper limestone-rich and a lower schist-rich. The Glance in the Lavender pit area is a purple brown colored conglomerate with clasts of Pinal Schist, Paleozoic limestones and the Sacramento Hill suite of igneous rocks and breccia. The limestone clasts are mineralized with gossan, copper oxide and carbonates, tourquoise, and iron and manganese oxides plus limestones that are not altered. The matrix is composed of the finer-grained lithologies observed in the clasts. Malachite, brochantite, tourquoise with iron and manganese oxides are found in the conglomerate matrix localized in channels along the base of the conglomerate.

Morita, Mural and Cintura Formations: Overlying the Glance is a thick sequence of sandsone, mudstone and limestone. Collectively these units are up to 4,000 feet thick. The Mural Limestone forms a distinctive cliff in the medial part of this sequence. No mineralization is known to occur in these Cretaceous rocks.

Igneous rocks

The intrusive rocks of the district have been the subject of detailed descriptions by Ransome (1904) and Bonillas (1916). A summary table of the characteristics of the district igneous rocks is shown on page 8. The relation of breccias to the igneous rocks were characterized and described by Bryant (1964; 1968), and Metz and Bryant (1966). Below is a discussion of the major phases of igneous rocks and the styles and types of breccia from the district.

Tuff: Occurring in a limited area below the Glance Conglomerate in the Lavender pit is a wedge-shaped outcrop of a Jurassic-aged (?) tuff. This unit is also exposed in the hanging wall of the Dividend fault on the south side of Highway 80, and as a small outcrop along the road to the Denn mine. This unit includes a basal breccia overlain by a coarse pumice tuff which is then overlain by a crystal-lithic tuff containing feldspar phenocrysts and small lithic fragments. The rock has not been dated, but its relationship to other geologic units is clear. The tuff rests atop Paleozoic limestone and is overlain by Glance Conglomerate. The tuff is cut by intrusive breccia, feldspar quartz porphyry and is mineralized by chalcopyrite, bornite and pyrite. The tuff is also strongly altered to a quartz-sericite assemblage.

Sacramento Hill Stock: The Sacramento Hill suite of intrusive rocks has received considerable attention by geologists in the district because of their spatial relationship to mineralization and the strong degree of sericite, quartz and pyrite alteration. Originally named the Sacramento stock by Ransome (1904) after its prominent exposure on Sacramento Hill, it was later divided by Bryant (1964) and Bryant and Metz (1966) into two intrusive phases and three breccia types: quartz porphyry, feldspar-quartz porphyry, contact intrusion or protoclastic breccia (cbi) of the Sacramento quartz porphyry, the Lavender Pit intrusive breccia (ib) and the widespread underground intrusive breccias (ib).

Additional data gathered from drilling and mapping programs in the late 1990s demonstrated the existence of at least three additional intrusive phases: 1) a stock-like mass beneath the Lavender pit (Warren porphyry), 2) another stock in the Cochise area (Cochise porphyry) with associated dikes, and 3) biotite quartz monzonite dike. The biotite-quartz monzonite dike strikes northeasterly within the footwall of the Dividend fault near the concentrator site and is thought to connect at depth with the Warren porphyry.

Quartz porphyry: The quartz porphyry has been strongly altered to a sericite, quartz and pyrite assemblage. In rocks that are less-altered, it consists of euhedral to subhedral quartz phenocrysts set in a groundmass of quartz and sericite. The quartz phenocrysts are dispersed throughout the rock and are typically embayed. The groundmass is composed of plagioclase and quartz. In a few specimens a modal analysis of the mineralogy determined the rock to be a quartz-monzonite porphyry. The quartz porphyry stock forms the current Sacramento Hill. This rock yielded a U-Pb age of 198.9 + 1.6 Ma (Lang, 2001).

Contact intrusive breccia: The open pit ore mined from the Sacramento pit in 1920's and 30's and later by a continuation of the Lavender Pit in 1970's was in the contact intrusion breccia (cib). The cib was a protoclastic breccia in the border of the Sacramento quartz porphyry. The protoclastic breccia concept was excellently described by Waters and Krauskopf (1941), in their paper on the Colville batholith in eastern Washington. The Sacramento quartz porphyry was intruded as a nearly crystalline diapir-like intrusive into predominately carbonate Paleozoic rocks with little or no associated hydrothermal solutions. These Paleozoic rocks were not at great depths or undergoing metamorphism. The intrusion of the porphyry produced an extensive zone of broken and sheared, even mylonitic, mixture of granulated rocks, limestones and the mantos of massive limestone replacements.

Igneous Rock Name	Rock Type	Phenocrysts	Groundmass	Accessories	Sulfide Mineralogy	Igneous Rock Alteration	Wall Rock Alteration	Wall Rock Mineralization	Age (Ma)
Lowell Volcanics	Pumice tuff, lithic tuff, crystal lithic tuff, crystal tuff	Plagioclase > quartz	Aphanitic, typically altered to sericite						
Quartz Porphyry	Quartz monzonite	Quartz - 5%	Aphanitic, generally completely altered to qsp		15% to 25% pyrite	Intense, pervasive quartz-sericite-pyrite	Calc-silicate	Chalcopyrite + pyrite	198.9 +/- 1.6 Ma
Feldspar Quartz Porphyry	Quartz monzonite	Qtz- 10%, plag- 40%, hb- 5%, bt-2.5%							199.9 +/- 0.8 Ma
Campbell Dike	Quartz monzonite	Quartz - 10%, palgioclase - 25% to 50%, hornblende - 5%, biotite - 5%	Aphanitic	Apatite, rutile, zircon	Chalcopyrite, pyrite	Quartz-sericite-pyrite	Calc-silicate	Chalcopyrite + bornite + pyrite	
Cochise Porphyry	Quartz monzonite	Quartz - 10%, Plagioclase - 40%	Quartz + orthoclase	Rutile, apatite, zircon	Pyrite - 10%	Strong quartz-sericite-pyrite + orthoclase	Quartz + orthoclase	Chalcopyrite + molybdenite	200 +/- 0.8 ma
Warren Porphyry	Quartz monzonite	Bt- 5%, qtz- 5%, palg- 25%	Qtz+ orthoclase		Py- 5%, cpy- 0.25%, Molybdenite- -0.1%	Weak sericite, orthoclase and biotite		Chalcopyrite + molybdenite	201.4 +/- 0.8 Ma
Andesite	Andesite	None	Chlorite, plagioclase						190.8 +/- 0.5 Ma
Rhyolite Porphyry	Rhyolite	Quartz - 25%, orthoclase - 25%, plagioclase - 10%	Quartz + orthoclase	Zircon	None	Trivial	Minor calc-silicate		174.6 +/- 0.5 Ma

Early descriptions of the Sacramento orebody cite irregular masses of high grade material separated by horses, or bodies of waste (Nelson, 1929). Unlike the known porphyry coppers, the ore mined, as shown in Plate 11 of Bonillas, et al, (1916), was un-oxidized, un-enriched and consisted of high grade massive sulphides including bornite and chalcocite with pyrite and minor chalcopyrite. This mineral assemblage is replicated in many parts of the Campbell orebody. The strong consistent trend of mantos with stratigraphic control extending northwesterly from the Campbell orebody through the Southeast Extension of the East Orebody and on to the Sacramento pit further supports this concept that the massive sulfide mantos were pre-quartz porphyry stock in age. The East orebody was mined by the main Lavender Pit and will be described in the section on Intrusive Breccias. The Southeast Extension of the East Orebody was mined by block caving methods from 1925 to 1933. Approximately 116 million ft^3 were mined but the grade is unavailable. The grade must have been moderately high to justify the use of block caving. This ore was surrounded by Lavender Pit intrusive breccia (Bryant, 1964, Plate 25) but whether it was originally enclosed by cib or was a manto engulfed by the ib is not known. But undoubtedly some the sulfide ore minerals making up the East or Lavender Pit orebody were transported by the intrusive breccia and derived from this body.

Feldspar quartz porphyry: A stock of feldspar quartz porphyry is situated to the south and east of the quartz porphyry intrusive. The feldspar quartz porphyry also occurs in the Paleozoic rocks as dikes and large sills. The rock is greenish-gray, strongly altered to a white clay and pyrite assemblage. The feldspar quartz porphyry is distinctive from the quartz porphyry by the absence of hydrothermal silica and lower pyrite content. The feldspar quartz porphyry exposed in the pit consists of quartz, feldspar and biotite phenocrysts in a groundmass of microcrystalline quartz and white mica. The feldspar phenocrysts are replaced by white mica and biotite is altered to chlorite. Quartz phenocrysts are embayed and comprise about 5% of the rock. Accessory minerals are zircon, apatite, and rutile. Pyrite constitutes less than one percent of the rock and is concentrated in the chloritic biotite phenocrysts. A U-Pb age of 199.9 + 0.8 was obtained from a feldspar quartz porphyry sample in the Lavender pit (Lang, 2001).

Campbell dikes: The underground feldspar quartz porphyry forms dikes in the Cole, Dallas and Campbell mines. Descriptions of samples from these dikes are similar to the feldspar quartz porphyry described above except hornblende was noted. The dikes generally trend northeast and dip moderately to steep angles northwest. Controlling the dikes are zones of fracture and small displacement faults (Nye, 1964). Contacts of the dikes with the wallrocks are marked by breccia or faults.

Intrusive breccia: An intrusive breccia is a heterogeneous mixture of angular to rounded, even spherical fragments which has been transported to its present position along preexisting structures. The intrusive breccia is in the form of dikes, sills and irregular masses varying in size from thin films to pipes several hundreds of feet in diameter. The contacts between intrusive breccias and the intruded rocks are sharp and smooth. At Bisbee, the fragments, derived from all the pre-Cretaceous rocks including the massive replacement or manto ores, range in size from minute particles to blocks over a hundred feet in diameter. The fragments have been transported upward for distances ranging from a few inches to several thousand feet. The matrix is composed of microscopic comminuted rock flour produced by attrition. Alteration effected during the mobilization of the breccias was weak to non-existent.

The intrusive breccias originated during the upward passage of hydrothermal fluids through fault or shatter zones. The fragments and fine-grained material of the broken zones were incorporated into the flowing stream, and transported upward by fluidization, saltation and suspension. During passage of the fragments, the channels were enlarged and smoothed as more and more debris was incorporated into the moving fluid. Deposition of the intrusive breccia occurred when the fluid pressure differential was insufficient to transport the fragments, or the channels became choked.

The intrusive breccias are a guide to ore because the presence of abundant ore fragments indicates that the source and/or an orebody may be nearby.

Lavender pit intrusive breccia: Unlike many of major copper deposits of the western U.S., the Lavender open pit mineralization is a fluidized (intrusive) breccia pipe, not associated with any obvious intrusive and is Mesozoic (?), not Laramide, in age. This intrusive breccia is composed of fragments and boulders of all the pre-Cretaceous rocks that have been transported in a fine-grained or rock-flour matrix of pulverized rock and sulfides (Bryant, 1974). The transporting media was a circulating hot water slurry flowing through pre-existing structures. The presence of pyrophyllite, dickite, halloysite and lack of kaolinite and sericite would seem to indicate that the temperature of this fluid was, at least, 270 degrees centigrade. Alunite is the only potassium containing mineral, but its origin may be related to the minor supergene activity. The sulfides are pyrite, chalcopyrite, bornite, chalcocite, sphalerite and galena which were often coated by an extremely thin film of chalcocite. The mineralization of porphyries was limited to silica and pyrite with a thin film of chalcocite and was below ore grade.

The general distribution of the different rock types exposed in the Lavender pit as of 1962 is shown in a figure by Bryant (1968, p. 3). One of the key items of this figure is the presence of intrusive breccia in the footwall (?) of the Dividend fault. The significance of this occurrence was not appreciated during Bryant's1958-1962 mapping program. Whether this occurrence is merely between separate fractures of the Dividend or truly post-major Dividend movement was not investigated. With major cultural activity and time, this question can probably not be resolved.

Underground intrusive breccias: Throughout the district cutting all the pre-Cretaceous rocks are dikes and sills of mineralized and barren intrusive breccia. Originally the mineralization within these breccias was assumed to be post or contemporaneous with breccias. One of the major reasons for this assumption was the presence of veinlets of sulfides extending from the breccia matrix into or along fractures into the fragments. In those breccias containing fragments of ore and massive sulfide matrix, the mineralization was attributed to preferential replacement in a very permeable media. The presence of unmineralized breccias was attributed to impermeability causing the ore bearing solutions to be diverted.

As a result of the discoveries in the Lavender pit regarding the age of mineralization, research using polished thin sections of existing samples of high-grade underground intrusive breccias is now being performed. Pyrophyllite has been discovered in these sections indicating high temperatures. In conjunction with the massive mixtures of copper sulfides, these high temperatures may have caused some annealing and recrystallization. To date some anomalous features have been observed but “no smoking gun” has been observed that definitely indicates that the fragments were mineralized before transportation.

A good example of the relationship between the massive sulfide mantos and intrusive breccias is illustrated below on page 12 as an isometric block diagram of a Cole Dallas orebody. Considering the extent of the mantos and the limited extent of the breccia, it seems unwarranted to attribute these orebodies to the efficacy of the intrusive breccia fluids.

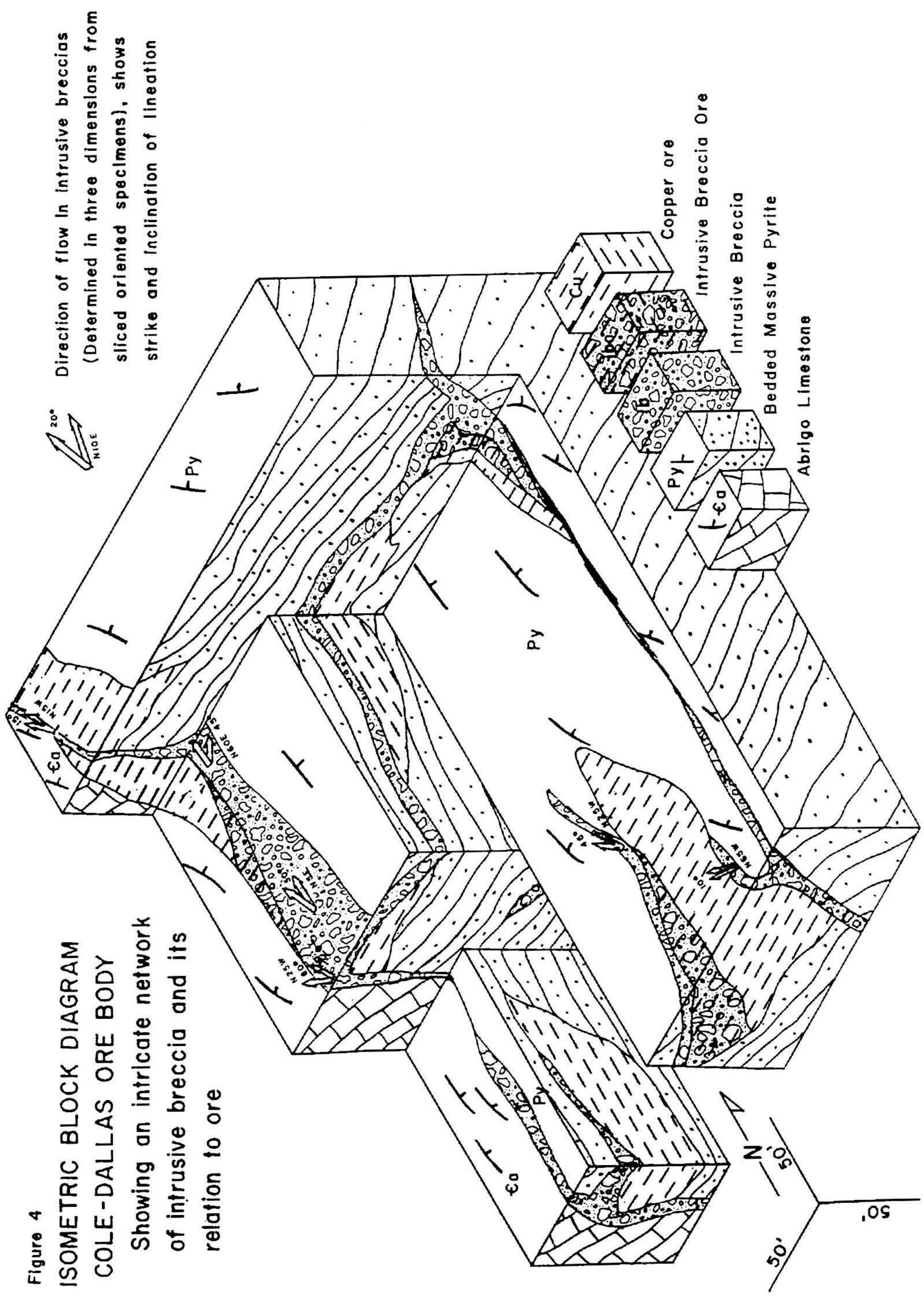


Figure 4
ISOMETRIC BLOCK DIAGRAM
COLE-DALLAS ORE BODY
Showing an intricate network
of intrusive breccia and its
relation to ore

Other porphyries: The Cochise porphyry is exposed in the northern side of the district as dikes and consists of coarse-grained biotite granodiorite with weakly disseminated pyrite and chalcopyrite. Recent mapping and drilling suggests that this dike connects at depth with a stock drilled in the Cochise area by Occidental Minerals in 1974. Lang (2001) reported a U-Pb date of 200 + 0.8 Ma for the Cochise porphyry. The Warren porphyry was intersected by a drill hole beneath the bottom of the Lavender pit. The Warren porphyry is a biotite-quartz monzonite porphyry with 50% plagioclase and 7.5% biotite phenocrysts in a groundmass of quartz and orthoclase. The rock contains disseminated chalcopyrite with less pyrite and minor molybdenite. A single sample from this rock has an U-Pb date of 201.4 + 0.8 Ma (Lang, 2001).

Several younger dikes are located in the outer areas of the district. These are typically equigranular, fine-grained to aphanitic and not altered. Lang (2001) dated an andesite dike that yielded a U-Pb date of 190.8 + 0.5 and a rhyolite with a U-Pb age of 174.6 + 0.5 Ma.

Structure

The structural geology of the Bisbee area has been discussed extensively by Nye (1968), Bryant (1964), Bonillas et al., (1916) and Ransome (1904). For this guidebook, we have chosen to discuss the major structural features because the district is in need of additional study. The principal structure in the district is the northwest-striking, south dipping Dividend fault. Another series of faults occur within the hangingwall of the Dividend fault and have northerly strikes and steep dips. These northeast-trending faults were an important control for some of the manto ore and dikes in the Cole, Dallas, Junction and Campbell mines. The Paleozoic sedimentary rocks in the Bisbee-Warren area have northerly strikes and dip easterly at moderate degrees.

Dividend fault: The Dividend fault strikes west to northwest with dips of 55 degrees to 85 degrees to the south. The fault displaced Precambrian, Paleozoic sedimentary, and Jurassic intrusive rocks; the Glance Conglomerate was deposited as the fault was active. Displacement measured across the fault is variable, but amounts of 5,000 feet are common. The fault to the east is covered by the Cretaceous Morita Formation. To the west the extent of the fault is not known because Pinal Schist comprises the footwall and hangingwall lithologies. The Cochise and Lavender are important parallel splays to the Dividend system because of their role in the localizing enrichment in the Cochise and Lavender areas.

Other faults: The Paleozoic rocks in the district are moderately to intensely broken by a system of discontinuous faults and fractures with principal orientations of north-northeast, northeast, and north. Dips are quite variable but range from 50 to 80 degrees. The individual faults have strike lengths measured in hundreds of feet with small displacements. Nye (1968) concluded that the faults formed prior to ore deposition as evidenced by pyrite occurring as fragments in fault breccia and as a replacement of the gouge. Chalcopyrite typically was found replacing the pyrite. The Dividend fault generally truncated these northerly-trending faults.

Orientation of Paleozoic rocks: The Dividend fault juxtaposed Paleozoic rocks against Pinal Schist in the Bisbee – Lowell area. The Paleozoic formations strike generally north to north-northeast and dip east from 25 to 35 degrees. The bedding of the strata is generally parallel with the northeast-trending faults. The dips of the bedding vary between mine levels reflecting numerous small amplitude folds.

Ore deposits

The Bisbee district mined four major types or ores: 1) carbonate-hosted copper-gold-zinc-lead-silver massive sulfide (and oxidized) bodies; 2) copper-rich fragments enriched with chalcocite in intrusive breccia; 3) supergene enriched blankets of chalcocite and covellite; and 4) manganese deposits in veins and replacement bodies.

Carbonate-hosted massive sulfide bodies: The principal source of the metals produced in the Bisbee district is from manto and chimney bodies in limestone. Structurally, the manto bodies are generally conformable to bedding and chimneys are not. The size of the individual orebodies was quite variable and ranged from a few thousand tons to rare cases of over a million. Metz (1956) estimated that one third of the production came from bodies less than 10,000 tons, another third from ore masses of 10,000 to 25,000 tons and the remainder with tonnages over 25,000 tons.

The ore bodies consist primarily of pyrite, chalcopyrite, and bornite with some sphalerite, galena and specularite. The primary sulfide mineralization in the manto deposits is generally fine-grained with individual sulfide grains averaging 0.1mm. Chalcopyrite and bornite occur as massive sulfides, disseminated within the pyrite, or disseminated in limestone units adjacent to the massive pyrite. Sphalerite and galena are common in generally small quantities, although in some peripheral deposits they occur in greater quantities than chalcopyrite. Specularite was an important constituent at the outer margins of the sphalerite and galena zone at the Campbell, Cole and Dallas mines.

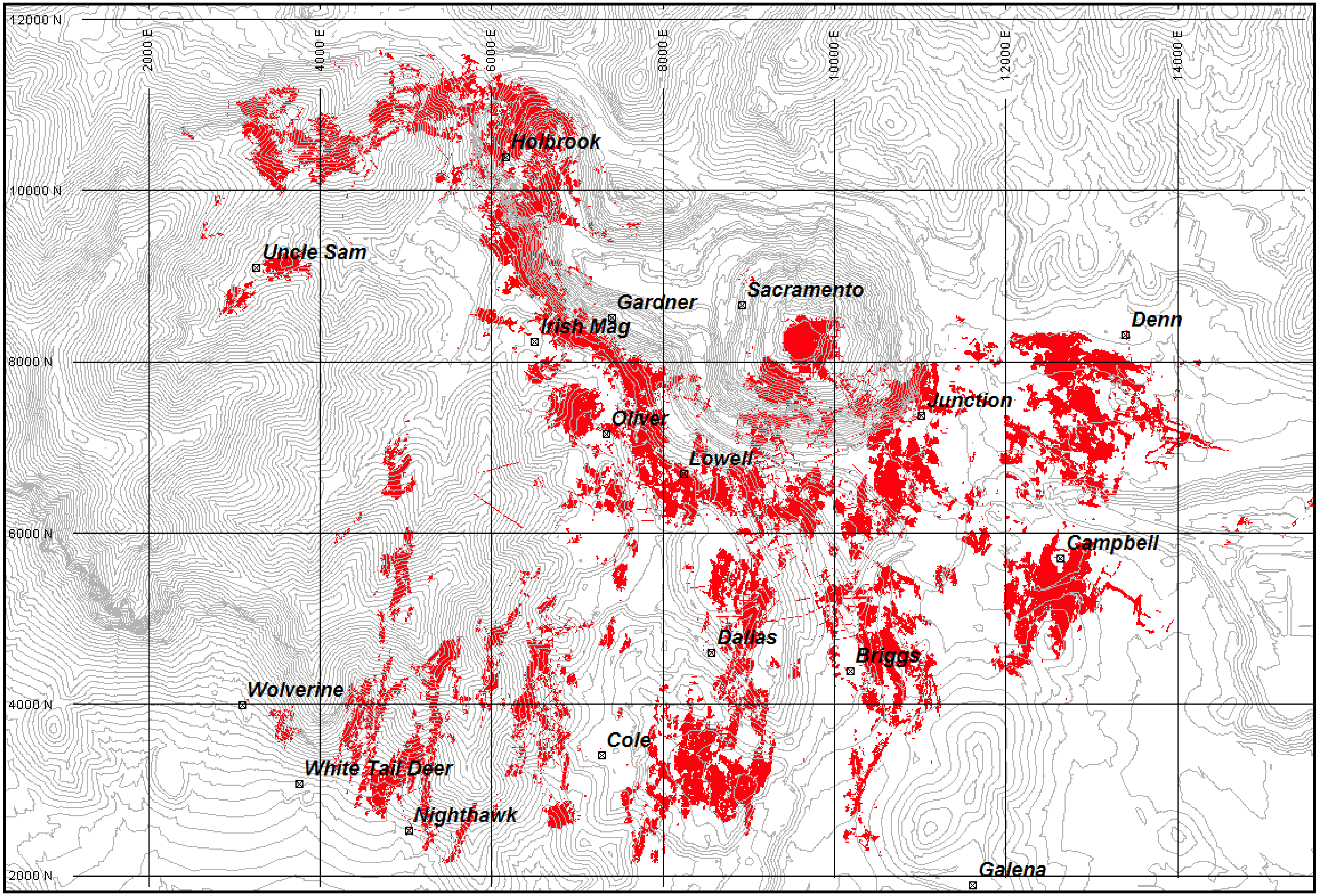
Nye (1968) documented the nature of the mineralization in the various sedimentary rock formations as shown by a table on page 16. A review of Nye's work shows approximately 12 types of structural control and 6 types of stratigraphic control. These controls focused principally on those which generated "ore grade" at the time (+3.5% TCu). The principal control in the

Escabrosa Limestone is the presence of strong fracturing. This fracturing is present where this formation is in contact with the Sacramento Stock near the Czar, Holbrook, and Hoatson shafts; and in the Campbell and Junction areas where strong fracturing is associated with major fault zones (a map of the orebodies mined by underground methods is on page 17). The significant controls in the Martin Limestone include local faulting and chemically reactive beds. The major controls in the Cambrian Abrigo Limestone are reactive beds, faults, and pyrite.

The controls on the mineralization at a +1.0% TCu cutoff are much broader in extent. At this lower cutoff, sulfide replacement zones are primarily massive to semi-massive pyrite with chalcopyrite found along the outer margin. The pyrite-rich masses are continuous for a distance of up to 2.5 miles (from the Higgins Mine south to the Campbell Mine). These mantos can be very strongly controlled by the stratigraphy. The upper and lower beds of the Abrigo Formation were preferentially replaced over the middle (shale-rich) portion of the formation. These manto orebodies are generally strata-bound and occur essentially continuously along strike and down-dip within the Abrigo Limestone. Along strike, pyrite-rich mantos occur on plan maps that are 500 feet to 4,000 long. Down dip these sulfide manto deposits are continuous for 500 feet to 1,500 feet and attain a chimney-like form.

The depth of oxidation is extremely irregular. Virtually all of the mining in the western part of the district was from oxide ores (Douglas, 1900). As deposits became deeper to the east, the amount of primary ore increased.

FORMATION	Escabrosa	Martin	Abrigo
Lithologic Character	Massive, pure limestone. Lower	Medium-bedded to massive. Part-	Thin- to medium-bedded.
	Chert beds	ly dolomitic. Part sandy, argillic.	Minor local dolomite. Sandy
			argillic, interbedded shale.
Response to Deformation			
Minor Folds	Broad, poorly developed	Moderately well-developed	Abundant, particularly from
			drag on faults.
Bedding Plane faults	Rare, beds poorly defined	Moderately abundant	Abundant.
Fracturing	Shattered to brecciated adjacent to	Shattered and brecciated to and	Limestone beds crackled be-
	and between faults.	between faults.	tween warped shale beds for
			some distance away from faults.
Form of Ore Bodies	Veins along steep fractures. Shatter-	Shatter-breccia zone replaced by	Partly crosscutting, generally
	breccia zones replaced by massive	massive sulfide. Some bedding	controlled by bedding. Assay
	sulfide. Sharp contacts with	control. Moderately sharp walls,	wall, disseminated pyrite forms
	wallrocks.	restricted disseminated pyrite halo.	broad halo around ore.
Extent and Type of Alteration	Restricted to immediate vicinity of	May extend a short distance from	Broad halo coextensive with diss-
	ore. Limestone recrystallized.	ore. Limestone recrystallized. Silica	eminated pyrite. Limestone re-
	Silica cap. Rare clay, sericite.	cap. Moderate clay, sericite, local	crystallized. Silicified beds.
		chlorite.	Abundant clay, sericite, chlorite-
			epidote zones.
Secondary Ore Bodies	Some clay. Much siliceous limonite.	Locally abundant clay, alternately	Clay abundant. Ravelly ground.
	Cavernous open spaces, collapse	with siliceous limonite. Some col-	Abundant limonite disseminated in
	breccia. Abundant oxide minerals.	lapse breccia. Both oxides and	rock and clay. Supergene sulfides
		supergene sulfides abundant	abundant, oxides sparse.


12000 N
10000 N
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10000 E
12000 E
14000 E
Holbrook
Uncle Sam
Sacramento
Gardner
Irish Mag
Denn
Junction
Oliver
Lowell
Campbell
Dallas
Briggs
Wolverine
Cole
White Tail Deer
Nighthawk
Galena

Sulfide fragments in intrusive breccia: As discussed above, fragments of copper and iron sulfides were abundant in the breccias associated with the quartz porphyry stock. This type of ore was mined underground in the elongated series of stopes (see page 17) that were located adjacent to the western and southwestern quartz porphyry stock contact. The prominent mines within this zone are the Holbrook, Irish Mag, Gardner, Oliver and Lowell mines. According to Bonillas (1916), the sulfides were not enriched or oxidized in this mined area of the breccia. Based on unpublished reports written during the time of development and mining of the Sacramento mine, the ore consisted of fragments and large masses of broken pyrite and bornite with very minor chalcopyrite in a breccia situated along the southeast margin of the quartz porphyry stock. Chalcocite enrichment of bornite was important in the upper part of the breccia that resulted in copper grades of 1.8 to 3.5 percent (Bonillas, 1916). This ore was probably derived from fragmentation and incorporation of a massive sulfide deposit not unlike the manto ores mined in Campbell orebody.

Supergene enriched deposits: Areas of sulfide enrichment contain chalcocite and covellite mineralization. This mineralization includes the replacement and/or coating of pyrite, chalcopyrite, and sphalerite, by the secondary minerals. Cross sections of the chalcocite blanket from Cochise and the Lavender pit areas are shown on pages 24 and 29.

The nature of the mineralogy has not been discussed in detail in any published works, however, unpublished work completed by Phelps Dodge (Khin, 1987) documented in detail the mineralogy and petrography of the mineralized zone north of the Dividend fault. The secondary minerals covellite and chalcocite replaced chalcopyrite and thinly coat pyrite. In some samples covellite and chalcocite are often intergrown and display mutual boundaries.

The copper sulfide enrichment and associated leached zone profile is complex in the district. The zone of leaching varies from 400 feet thick to less than 25 feet thick. The enrichment zone is very thin (<50 feet) along the topographically low areas, and as much as 400 feet thick in higher areas. However, structural control, two periods of enrichment, folding and rapid up-lift has left many numerous exceptions to these generalities.

A zone of chalcocite enrichment extends from Chihuahua Hill (east of the town of Bisbee) southeasterly to Copper King Hill and towards the Lavender Mill site. This zone dips gently to the southwest along the dip of the Dividend fault. The enriched blanket measures 6,000 by 4,500 feet. The deepest portions occur at the bottom of the Lavender Pit. Additional deep lenses of enrichment follow the dip of the older porphyry-breccia contact to the west.

Drilling in 1980 during the early stages of the Cochise area documented the presence of a chalcocite blanket with variable thickness. The mineralization was shown to mimic the topography. Geologic mapping in 1990-91 documented the existence of small fault splays from the Dividend fault which were associated with the highest-grade copper mineralization. Directed drilling during a 1996-1997 drill program documented that some of the high grade and deeper chalcocite mineralization is associated with these faults.

Bisbee district manganese deposits: At Bisbee in the limestones overlying the massive sulfide manto deposits, approximately 35,000 tons (Arizona Bureau of Mines, 1969 p. 216) of hand-sorted manganese ore averaging +/-40% has been mined, shipped via pack animals, trucks and train to Bessemer, Alabama. This ore was mined during World War I, World War II and the Strategic Mineral Procurement Program in the early 1950s. About 30,000 tons with a grade of <30% remain as a possible resource.

The ore, originally believed to be psilomelane (Jones and Ransome, 1920), is predominantly braunite (3MnMnO3.MnSiO2) as determined by Hewitt of the USGS and occurs as fissure fillings and limestone replacements with siliceous, hematitic and calcitic gangues with 0.25 to 2% Cu. The manganese ores are shallow deposits in fractures and replacements in Naco and Escabrosa limestone. The structural controlling features are all steep to vertical but not consistent in strike.

Except for the Mammoth deposit near the edge of the Lavender Pit, the manganese ores seem to be restricted to the periphery of the area of known mantos. Whether this apparent limitation is due to the restriction of fluids transporting the manganese, associated gangues and copper or a feature of erosion is a matter of conjecture.

The source of the manganese transported to the surface is unknown but two possible sources are suggestive. These are: (1) alabandite and rhodochrosite are known to be associated with the massive lead-zinc mantos in at least two mines. At the Higgins mine approximately 500 feet below the Twilight mine, Hewitt and Rove (1930) reported alabandite and rhodochrosite in Martin limestone associated with lead-zinc ore. The other occurrence was on the Junction 1900 with lead zinc but the deposit was not explored (Farnham, et al, 1961); and (2) manganese occurs in the calcium carbonate lattice(?) of Abrigo and Martin limestones adjacent to the massive copper sulfide mantos in the Cole, Dallas and Briggs mines; possibly, also in the other mines if checked. This zone, 2 to 3 feet thick, is generally dead-white in color and has been assayed in many stopes and contains 4 to 20 percent manganese by weight (Bryant, 1964 p.85). No observance of fracturing and leaching of this zone has been reported.

In 1928, Carl Trischa published a study of silica outcrops that although prominent and of interest and importance had had little attention. These vein-like outcrops are widely distributed throughout the district and have been the locus of mining activity but without production. The silica of these outcrops is dense, fine-grained and red, reddish or black in color due to contemporaneous iron or manganese. The outcrops are “hypergene” and might be considered guides to ore. Trischa classified the breccias into pre-Cretaceous and post-Cretaceous. Both are associated with zones of steep faulting or sheeting ranging from 30 to 100 feet wide. The pre-Cretaceous silica has not bee a good guide to ore (Trischa, 1928, p. 1048).

The post-Cretaceous silica or “boxwork” silica on vertical structures may contain some syngenetic pyrite and sparse galena, sphalerite or chalcopyrite (Trischa, 1938, p55) with variable amounts of manganese. These silica outcrops may be an indication of a major(?) fluid flow through the Bisbee rocks after Laramide(?) tilting of the Cretaceous rocks.

Considering the apparent vertical transport of the manganese and possible vertical transport of silica in the Bisbee district, the possibility that a major hot(?) fluid flow event occurred after tilting of Cretaceous rocks should be seriously considered. The event may have occurred either during the Laramide or the Basin and Range initiation!

Field Trip Stop Descriptions

Safety

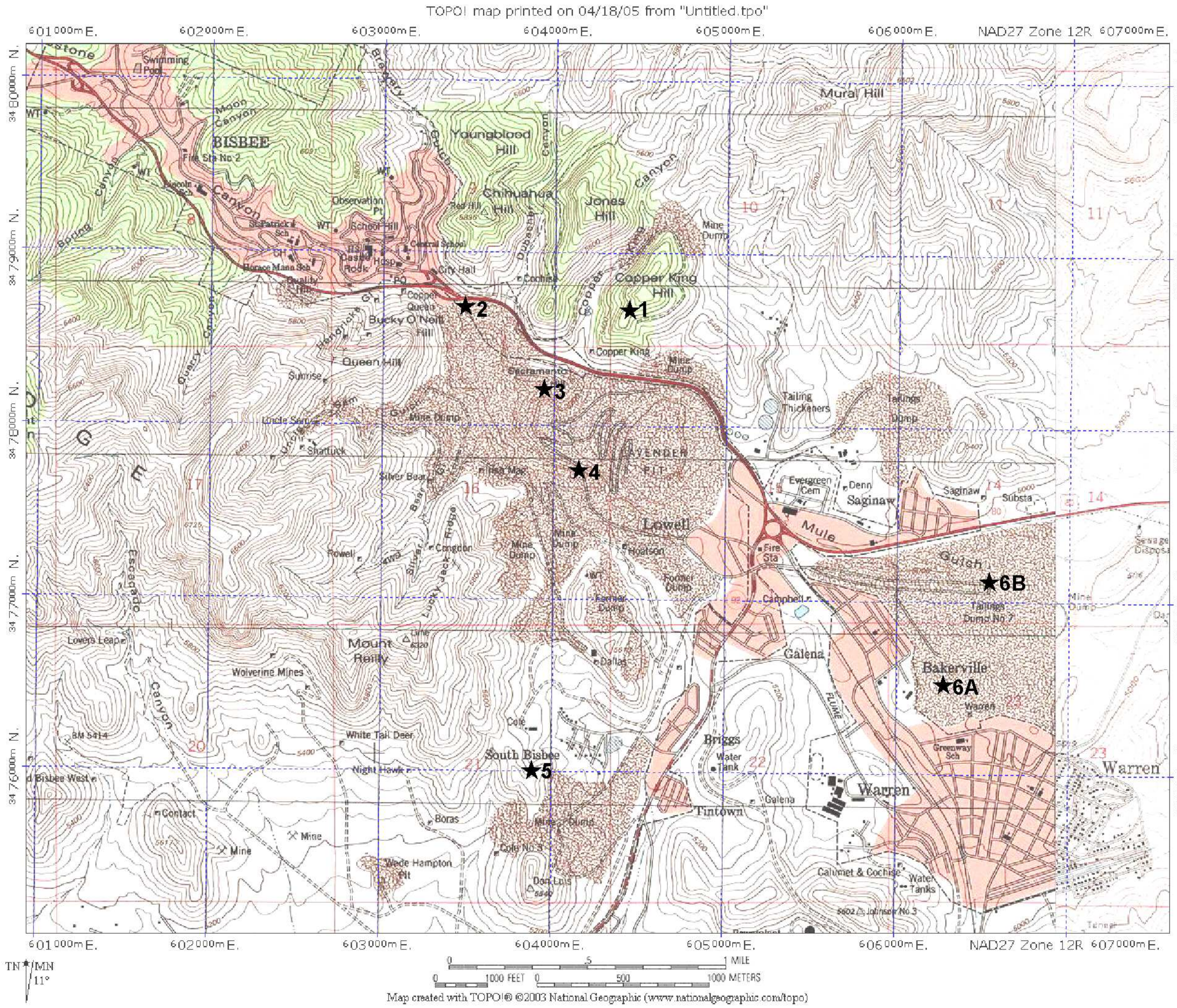
Will we be visiting sites to examine rocks along mine benches and open cuts. We ask that you not go directly to the bench or rock face to obtain samples as they are readily available from the talus piles directly below the bench face. It always is a good idea to check above you along the bench face for any loose or unstable material. A berm has been placed along the crest of the bench to protect people and equipment. Please do not walk up or along the berm. And finally, check around you for people close by before breaking rocks. Each of us is required to wear all personal protection equipment (hard hat, safety glasses and boots) for the full duration of the field trip on Phelps Dodge property.

Stop 1: Cochise area

A map displaying the field trip stops is on page 22. The first field trip stop will be to the Cochise area of the district where we will visit the southwest side of Copper King Hill. The stop will be at an open cut where a bulk sample of chalcocite was obtained for metallurgical test work. The elevation here is about 5600 feet.

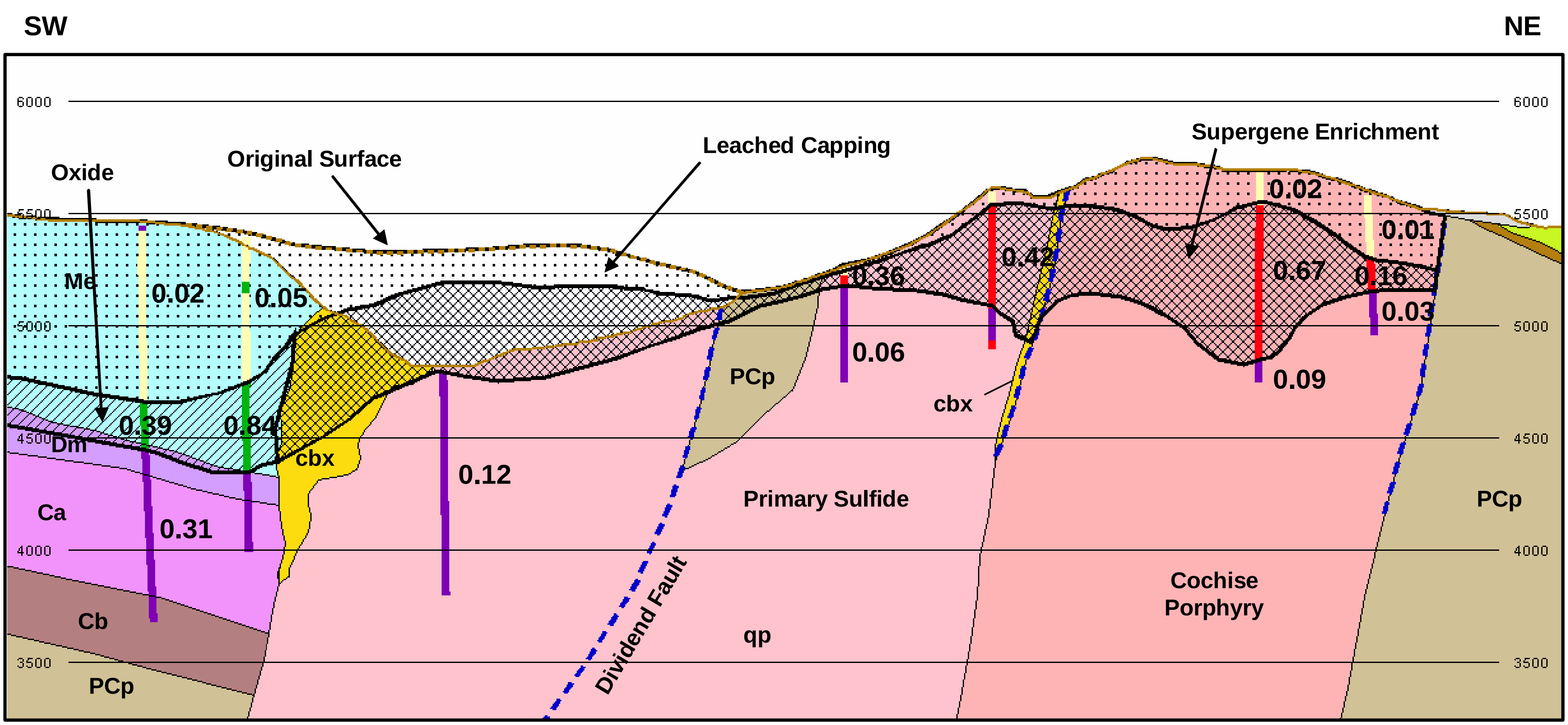
Field trip traverse: At this stop we will examine leached capping and chalcocite enrichment of pyrite and chalcopyrite within quartz porphyry and quartz monzonite porphyry. The large boulders to the right are from a quartz-pyrite breccia that separates the two rock types. This breccia extends within the trend of the slot that extends to the northwest. To the left or west is quartz porphyry and to the right or east is the Cochise porphyry. A small pendant of Precambrian schist within the Cochise porphyry crops out in the upper part of the east wall. Hematite-goethite leached cap is well exposed along the left face of the slot. Proceed through the slot and then to the right where chalcocite has enriched pyrite and chalcopyrite. Please continue along the road that passes to the higher areas of the cut and note the transition from chalcocite enrichment of hypogene sulfides to leached cap. Alunite occurs as veinlets along this road cut in the enriched zone. A sample of alunite from here yielded a K-Ar date of 9.08 + 0.22 Ma (Cook, 1994).

Exploration: Several phases of exploration drilling delineated a resource of chalcocite mineralized material of 276 million tons at an average grade of 0.47 percent copper (Phelps Dodge 2004 10-K Report). A cross section is included



(page 23) of the Cochise deposit that displays the character and distribution of the chalcocite blanket. Mineralization consists of chalcocite and covellite that replaced chalcopyrite and pyrite. Stockwork pyrite veinlets and disseminated pyrite average 7.5% by volume (range of 5 to 15 percent). Chalcopyrite is common as small inclusions within the pyrite. The hypogene copper grade as chalcopyrite averages 0.15 percent.

The chalcocite blanket in the Cochise area extends from Copper King northward to Jones Hill and southward to the ridge with the weather station. The blanket dips about 25 degrees southwest from here to the Dividend fault.


SW
NE
6000
5500
5000
4500
4000
3500
Oxide
Original Surface
Leached Capping
Supergene Enrichment
Me
Dm
Ca
Cb
PCp
cbx
0.02
0.05
0.39
0.84
0.31
0.12
PCp
Dividend Fault
Primary Sulfide
qp
0.36
0.06
0.42
cbx
0.02
0.67
0.09
0.01
0.16
0.03
Cochise
Porphyry
PCp

The drill holes in this immediate field stop area intersected 500 feet of chalcocite at grades of 0.2 to 1.0% that enriched a pyrite-chalcopyrite protore. The hypogene grades as chalcopyrite beneath the enrichment average 0.14% copper.

District overview: Several district geology and mining features are visible from the tour stop parking area. To the southwest, the prominent head frame near the pit limit is the Junction shaft. The purple-brown colored rock that comprises the shaft collar and upper half of the pit wall just below the head frame is the Glance Conglomerate. The Glance is a district-wide unit, but in this area the conglomerate has a wide range in unit thicknesses. An example of this can be seen in the pit wall where the Glance forms a u-shaped mass deposited on Horquilla limestone. This u-shaped mass is interpreted to have been a topographic low that was filled with the conglomerate. Drilling has confirmed the presence of this paleo-topographic feature with a trend that extends from the pit southeasterly towards the town of Warren.

The prominent rock stockpile to the southwest is the No. 7. This was leach-grade material mined from the Lavender pit and was leached with copper recovery by precipitation method and more recently by a bio-leach process. The latest published date for copper production from the No. 7 is 2002 when about 100,000 tons of copper were produced (Phelps Dodge 2004 10-K Report).

As we drive down the dirt road to the highway, the mountain to the north consists of Bisbee Group rocks. The prominent cliff-forming rock near the top of the mountain is the Mural Limestone. Some remnants of drill roads are visible in the lower part of the Bisbee Group. Holes were drilled to test for the presence of Paleozoic rocks north of the Dividend fault. The holes intersected Bisbee Group rocks resting on X feet of Glance Conglomerate then Pinal Schist.

Stop 2: Dividend fault and gossan in Escabrosa Limestone

The second stop will be in the extreme northern limit of the Holbrook pit. The drive to this site will take us through a gate at the base of Sacramento Hill, then westerly along the pit limit to the field stop. The elevation at the stop is about 5225 feet.

Stop orientation: At this location, we can observe across the cement ditch the Pinal Schist in fault contact with gossan hosted by Escabrosa Limestone. The Pinal Schist is very pyritic and constitutes the hangingwall of the Dividend fault. The Dividend fault here strikes N15W and dips 60 to 75 degrees south. The main trace of the fault can be seen in the northern wall of the Holbrook pit where pyritic schist is juxtaposed against the brown gossanous outcrops of the Martin and Escabrosa Limestones. The gossan exposed at our elevation extends five benches (each bench is 50 feet high) down into the pit. It was in this area that the very high-grade malachite, azurite, cuprite and native copper ores were mined from mantos in the Escabrosa Limestone via the Holbrook (mined-out in pit) and Czar (RV Park above) shafts of the Copper Queen mine. Historic geologic reports also mention some chalcocite enrichment of partly oxidized pyrite within the mantos along the Dividend fault. Stope timbers from underground mining activity are visible three to four benches down the pit wall just below where we are parked.

Mining history: We are located east of some important early mining history of the district that was concentrated in Queen Hill, the large hill just west of here. The prominent v-shaped cut directly above the RV Park is the original discovery location in the district. It was here that cerussite was found in 1877. Copper was discovered in 1880 along the north slope of Queen Hill as a mass of copper carbonates and iron oxides with an average grade of 23 percent copper (Douglas, 1900). The copper discovery site is still visible as an open stope just above the downtown area of Bisbee. The slag just west of here is from the smelter that processed the ore.

Holbrook pit overview: This stop also provides a good place to view the major geologic features of the Holbrook pit. A stock of quartz porphyry forms Sacramento Hill. Surrounding this stock to the west and south is the contact breccia, the feature that drove the open pit mining with its abundant fragments of bornite and chalcopyrite. Contact breccia is exposed in the bottom of the pit and can be traced north to about the location of the pit lake. The white-colored dike (kaolinite-altered) just west of the lake is within Martin Limestone. The Spray pit failure along the southwest side of the pit was the result of mining gossan in the Martin near the pit bottom. Drifts from the underground mines are visible in the southwest area of the pit just north of the pit failure. These drifts of the Copper Queen mine are in proximity to the strong iron and manganese oxides hosted by Escabrosa Limestone.

Stop 3: Sacramento 5250 bench

Traverse: At this stop, we will traverse the 5250 bench of the Sacramento pit to examine quartz porphyry that is strongly altered to a quartz-sericite-pyrite assemblage. In hand specimen, quartz phenocrysts are visible but the other primary minerals and texture of the rock was destroyed by the intensity of alteration. Sericite was identified at Sacramento Hill by Hutton (1958) as part of an orientation-level XRD study of alteration minerals in the Lavender pit area. According to Hutton, the distribution of sericite appears spatially associated to the quartz porphyry stock. Pyrophllite, dickite, diaspore and alunite as determined by Hutton were reported by Bryant (1964), but their distribution is restricted to the intrusive breccia now exposed only at the bottom of the Lavender pit. Pyrite along this bench occurs as fine-grained disseminations and in veinlets. The amount of pyrite is consistently between 15 and 25 percent by volume. There is virtually no chalcocite enrichment of the pyrite in this area of the pit. The oxidized pyrite and resultant leached cap is visible at the start of the bench traverse. Finally, alunite veinlets can be found in the pyritic areas of this bench.

It is notable from drill holes in this immediate are that the quartz porphyry has an average hypogene grade as chalcopyrite of 0.10 percent copper.

Sacramento area overview: Situated just southeast of here (mined-out by pit) were large stopes of the Sacramento mine that block caved bornite and some chalcopyrite fragments enriched by chalcocite within contact breccia. The orebody was found by sinking the shaft that intersected 300 feet of breccia grading 1.5% copper. An additional orebody was found east of here within the breccia. Total production from the two areas was about 2.3 million tons at a grade of 2.1% copper. Churn drill holes then delineated a reserve that was mined by open pit methods that started in 1917. Through 1931, the Sacramento pit produced about 10.4 million tons of ore grading 1.7% and 12.6 million tons of leach.

East district overview: Several features of the district geology are visible from here. Located to the east beneath the highway is a red, iron-rich ferricrete that was deposited within Mule Pass Gulch that originally separated Sacramento Hill from Copper King Hill. Also, the red-stained rocks near the base of Copper King Hill are in part colluvial deposits that also contain iron oxide. To the east, an outcrop of the Dividend fault is the vertical white-purple colored feature just north of the cement tailings thickeners. The Dividend fault here displaced Pinal Schist against Glance Conglomerate. The tan-colored buildings beyond the thickeners is the Denn mine yard where chalcopyrite-bornite ores were hoisted from mantos, breccias and fissures mined within the Escabrosa, Martin and Abrigo Limestones.

Stop 4: Lavender pit 5150 level

From Sacramento Hill we will drive along the northern limit of the Lavender pit, then through the town of Lowell and turn into the Copper Queen Branch mine yard. Mining in the Lavender pit commenced with stripping in 1951. From 1954 through 1974 the pit produced 95 million tons of ore at an average grade of 0.80% and 135 million tons of leach grading 0.35% copper. The Junction head frame is to the north. The Junction shaft is 2,727 feet deep and was used as a production shaft from 1903 through 1975 for the Escabrosa, Martin and Abrigo-hosted manto and breccia ores.

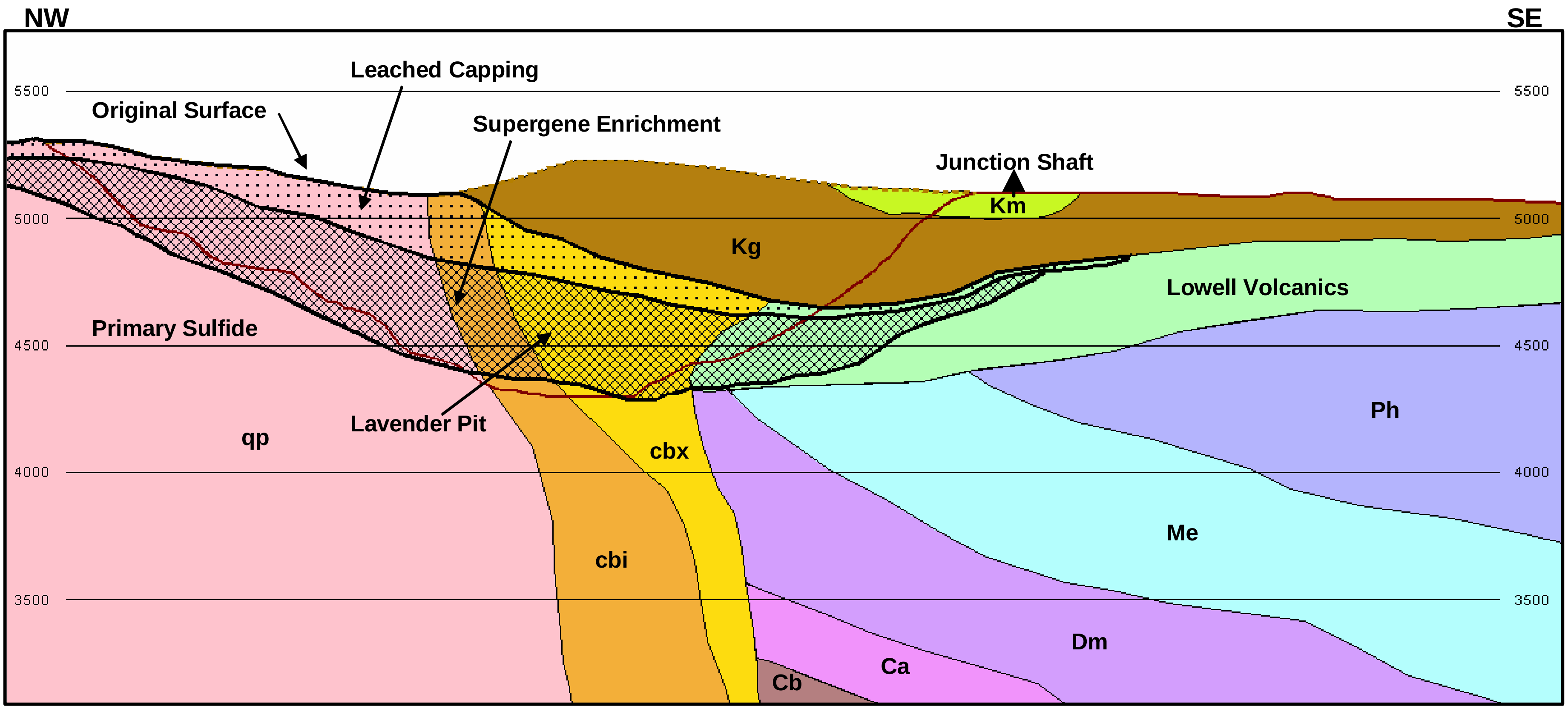
The field stop will be at the Lavender pit 5150 level. Horquilla and Escabrosa limestones dip 25 to 45 degrees east in benches along the haul road to the field stop. The Sacramento dike crops about 1,000 feet south of the power pole. This dike was mapped in underground workings from the Sacramento mine south about 5,000 feet to the Briggs mine (located south of Lowell).

Lavender and Holbrook pits overview: From the small in-pit dump, this is a good place to view the major geologic features of the Lavender and Holbrook pits. Directly north is Sacramento Hill, the site of our last stop. The Lavender is the large pit to the east and north; the Holbrook extension is to the northwest from here.

Drilling of the east Lavender pit area in the 1990s intersected a tuff that was deposited on top of the Horquilla and Escabrosa limestones. The tuff is 95 to 500 feet thick with pumice fragments up to 1 cm in size within a gray, fine-grained (< 2mm) matrix. The tuff has not been dated, but the geologic relationship to other rock types is well established. The tuff is cut by the Sacramento Hill stocks and intrusive breccia and is overlain by Glance Conglomerate. The tuff is host to chalcopyrite, bornite, pyrite and chalcocite as veinlets and disseminations with white mica, kaolinite and quartz. The tuff is poorly exposed in the bottom eight benches along the east side of the Lavender pit.

Contact breccia crops out in the lower benches and final levels of the Holbrook and west Lavender pits (pit area south of Sacramento Hill). The breccia along the south wall of the Holbrook pit is oxidized forming the yellow and red limonites that can be seen to transition into the pyritic benches below. From just north of us the pyritic breccia is found east then north around the quartz porphyry stock. It is quite apparent to see the impact of the contact breccia in the mining of the Holbrook and south Sacramento Hill areas. Intrusive breccia crops out along the deepest bench of the Lavender pit, just east of the pit lake. Unfortunately, we will not be able to visit this area of the pit, but will examine intrusive breccia at our last stop. The Pinal Schist, located in the footwall of the Dividend fault is the rock that forms the northern wall of the pit.

Supergene enrichment of chalcopyrite, bornite and pyrite by chalcocite resulted in formation of a blanket that was 50 feet thick at Sacramento Hill and increased to over 400 feet to the southeast in the Lavender pit (cross section on page 28). The chalcocite enrichment extended underground to the southeast and was mined in significant tonnages from the Junction and Campbell mines (Carpenter, 1941). The upper margin of the blanket was broadly concordant to the current or pre-mined topography and another blanket mimics the paleo-topographic surface that the Glance Conglomerate was deposited on.


NW
SE
5500
5000
4500
4000
3500
Leached Capping
Original Surface
Supergene Enrichment
Junction Shaft
Km
Kg
Lowell Volcanics
Primary Sulfide
Ph
Lavender Pit
qp
cbx
Me
cbi
Dm
Ca
Cb

The Glance Conglomerate in the Junction and Campbell mines contains clasts of Pinal Schist, Paleozoic limestones and the Sacramento Hill suite of igneous rocks and breccia. The limestone clasts are mineralized with gossan, copper oxide and carbonates, tourquoise, and iron and manganese oxides plus limestones that are not altered. Igneous rock and breccia clasts indicate hypogene and supergene processes (indigenous iron oxides in leached cap) occurred prior to erosion of these rocks and deposition to form the conglomerate. A drilling program to test the potential for an exotic deposit was completed in the 1980s. The drilling found that malachite, brochantite, tourquoise with iron and manganese oxides that replaced the conglomerate matrix are localized in channels along the base of the conglomerate.

The supergene story at Bisbee needs additional study, but it can be inferred that at least two separate cycles can be indicated by the geologic evidence: an older one that is post-Sacramento Hill intrusive and pre- or concurrent Glance age and another of Neogene or younger age. It is also apparent that the chalcocite blanket mined in the pit represents two enrichment cycles: an older one of Late Jurassic or Early Cretaceous age and another that is Neogene and younger.

Traverse: The field traverse will start in the bench face and drainage cut along haul road to observe contact breccia. Here the breccia consists of heterolithic fragments of quartz porphyry, limestone, silicified limestone and pyrite in a pyrite and chlorite-rich matrix. The fragments exhibit zoning across the breccia with quartz porphyry as the dominant lithology near the stock margin to limestone-rich near the Paleozoic rock contact. A critically important aspect to the economic significance of the contact breccia is the presence of bornite and chalcopyrite fragments. Descriptions of the Sacramento open pit mineralization by Bonillas, et al I1916) and DeKalb (1918) and the breccia discussion above prepared by Bryant (2005) indicate that the massive sulfide mantos were incorporated by contact breccia,

The traverse continues up the haul road to view the transition into the oxidized breccia. The breccia crops out to where it is truncated by the Bailey tunnel fault. Gossan can be seen within and along the fault. The rock exposed south of the fault is Horquilla Limestone that is recrystallized, plus containing chlorite and manganese alteration.

Field Stop 5: Atlas manganese mine

The drive to stop five will take us by the Copper Queen shops and offices. Glance Conglomerate crops out west of the truck shop forming the low outcrops covered by stockpile from the Lavender pit. As we pass north of the community of South Bisbee, the large head frame to the north is the Dallas and the one to the west is the Cole. These two mines are situated within an area where chalcopyrite and bornite mantos where mined extensively from the Martin and Abrigo Limestones. The stop will be at the Atlas mine to view the character of manganese mineralization within Horquilla Limestone.

Traverse: At this stop we will walk up the hill to the south and view manganese mineralization within several prospect pits and small adits. Several north-south trending faults have localized manganese in Horquilla Limestone. This mine produced about 800 tons with a grade of 45% manganese (Ransome, 1920).

West district manganese deposits: The Bisbee manganese deposits occur in a broad zone that is adjacent, peripheral to, and above the copper deposits. In the western part of the district, numerous manganese prospects and mines are found in two areas: west of the Cole-Dallas mines and another one about two miles northwest of here in a zone west of the Shattuck and Queen Hill mines. The largest single producer of manganese in the district was the Higgins mine, situated in the western area of Queen Hill where at least 42,000 tons of ore was produced (Wilson, 1930).

Cole-Dallas mine area overview: To the north of the Cole head frame is a moderate-sized dump located above the elevation of the Cole shaft collar. This dump is from the Cole adit, an exploration tunnel that was drove north through the ridge to the Powell mine. The tunnel did not intersect any significant mineralization. Up the hill a short distance from this dump is a line of manganese prospects along a northeast trending fault that produced 600 to 700 tons ranging from 38 to 49% manganese (Ransome, 1920). Another series of manganese prospects is visible about half-way up the hill to the west.

We are vertically above the southern extent of the significant underground mining in this area. To the west of here on the south side of Escabrosa Ridge, a group of mines produced oxide and sulfide copper ores from the Martin and Abrigo Limestones. The stope maps of these mines indicate an elongated zone of mantos with a northerly trend that extended 5,200 feet north to the Holbrook pit. Dumps of these mines are visible from the community of San Luis, located about one mile southwest of here.

Stop 6: Number 7 Stockpile

Our final stop will be the large Number 7 stockpile to examine manto and chimney ore from the Campbell mine and samples of igneous breccia. The drive to this stop will take us by South Bisbee, then north where the flat area to the east with old mine equipment is the dump of the Briggs mine, an important producer in this area. As we drive over the highway, the large head frame to the south is the Campbell mine. The sulfide ore at this next stop was mined from gold-rich (+0.5 gpt) manto and chimney bodies on the 1800 and 2000 levels.

We will make two stops at this stockpile. The first will be to observe intrusive breccia samples that were mined from the Lavender pit. At the second stop, large stockpiles of massive sulfide ore mined from the Campbell in the early 1980s.

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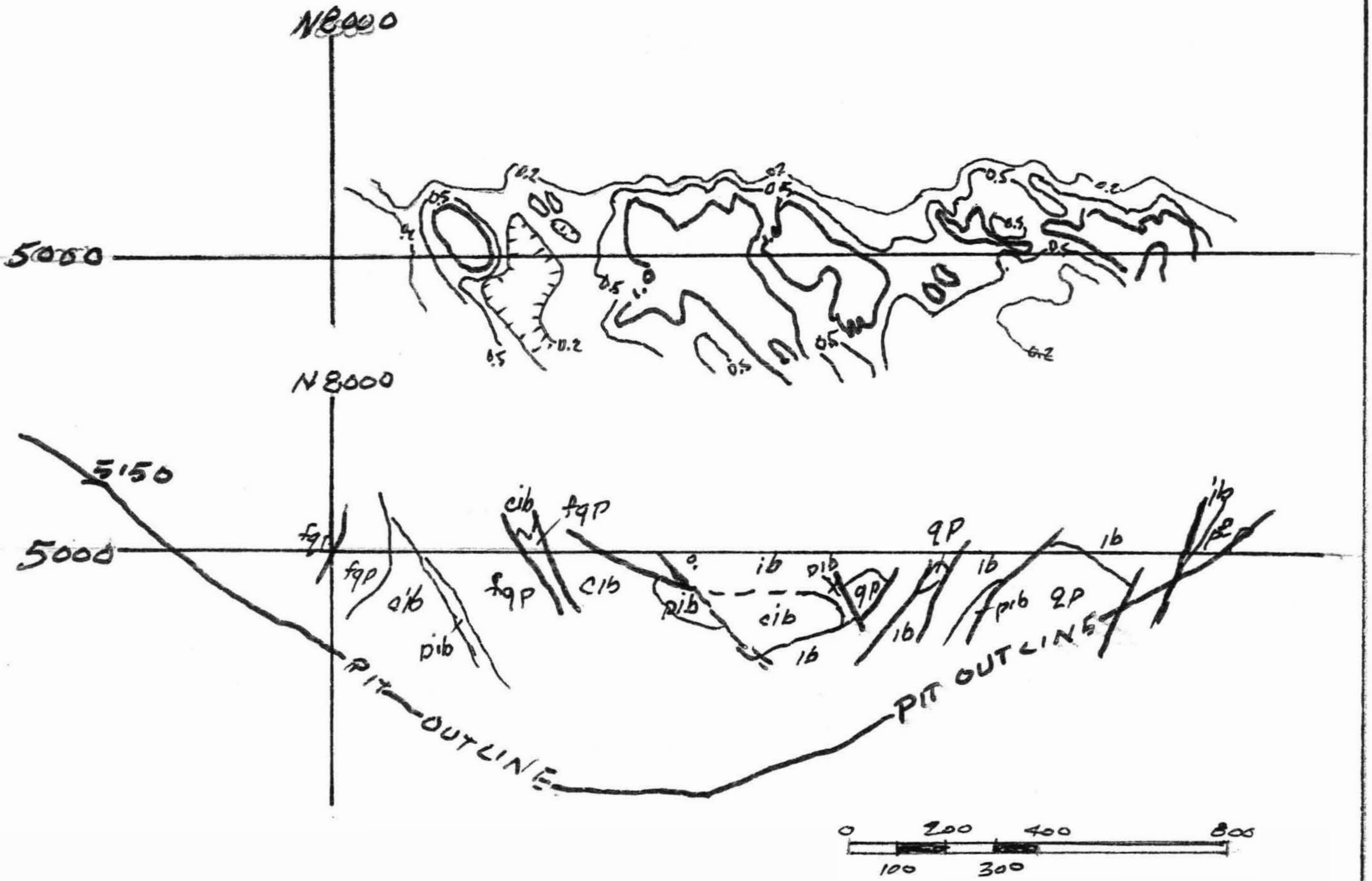


Cross Section - Lavender Pit Bisbee, Az

at Stop No 4

Bearing N14°E Looking N76W

for location see Guidebook

Upper Section - Ore distribution based on blast holes

Lower Section - Geol based on data 1962

ib/pib — intrusive breccia; pib - ib predom. qp fragments

fqp — feldspar quartz porphyry

qp/cib — Sacramento quartz porphyry; as - contact intrusion breccia

p€p — Pinal Schist

fault

contact

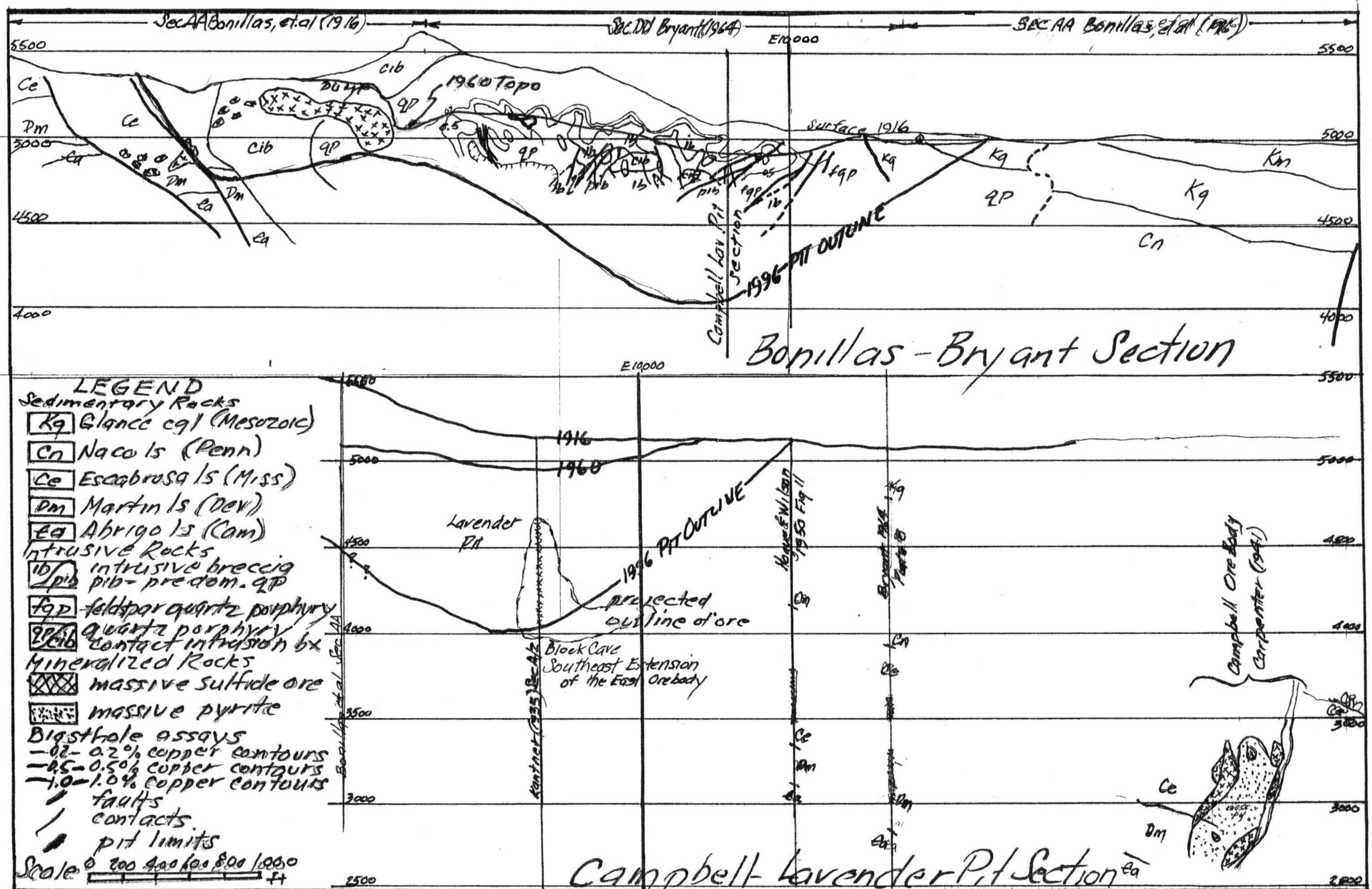
0.2 — 0.2% copper contour

0.5 — 0.5% copper contour

1.0 — 1.0% copper contour

pit outline 1969 aerial photos

D. Bryant 2005


Sec AA Bonillas, et.al (1916)
Sec DD Bryant (1964)
SEC AA Bonillas, et al (1916)
E10000
1960 Topo
Surface 1916
1996 PIT OUTLINE
Campbell Lav. Pit section
Bonillas - Bryant Section
E10000
1916
1960
Lavender Pit
1996 PIT OUTLINE
projected outline of ore
Block Cave Southeast Extension of the East Orebody
Campbell Ore Body Carpenter (1941)
Campbell-Lavender Pit Section
LEGEND
Sedimentary Rocks
Kg Glance cgl (Mesozoic)
Cn Naco ls (Penn)
Ce Escabrosa ls (Miss)
Dm Martin ls (Dev)
Ea Abrigo ls (Cam)
Intrusive Rocks
ib/pib intrusive breccia pib- predom. qp
fqp feldspar quartz porphyry
qp/cib quartz porphyry contact intrusion bx
Mineralized Rocks
massive sulfide ore
massive pyrite
Blasthole assays
-0.2- 0.2% copper contours
-0.5- 0.5% copper contours
-1.0- 1.0% copper contours
faults
contacts
pit limits
Scale 0 200 400 600 800 1000 ft