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ASARCO

Southwestern Exploration Division

JDS

October 24, 1988

SWED Staff

AGS Fall Field Trip, 1988
Tombstone-Bisbee-Commonwealth

The Guidebook for the 1988 Fall Field Trip of the Arizona Geological Society (149 pages, spiral bound) of October 22-23 has been placed in the Asarco Library.

The trip covers the Tombstone-Bisbee-Commonwealth areas of Cochise County.

Santa Fe Minerals has now tied up much of the patented and unpatented claims in the main Tombstone area and has three rigs busy. They are testing, by 3000 foot drill holes, for replacement deposits in the Abrigo and Martin limestones; Peter Megaw, project geologist.

At Bisbee, the PD group has five geologists working on the drilling, interpretation, and engineering studies coupled with the economic analysis. Reserves have been announced in the range of 170 million tons at 0.45% copper in this Cochise deposit (north of the Dividend Fault). They have announced that all the copper will be recovered in a Solvent Extraction plant.

In the Gleeson area, Santa Fe has several core rigs busy. One "wag" said he wouldn't touch that area with a ten-foot pole and was glad his name would not be attached to the project. Apparently Jim Loghry is one of four consultants to the Santa Fe Gleeson project (he was not on the trip).

The Commonwealth Mine at Pearce is now being prepared for drilling (and fund-raising) by Westland Minerals Corporation. The cyanide tailings (±½ million tons at 2 oz./ton silver and 0.01 oz./ton gold, very high silica) are presently being shipped to the PD Hidalgo smelter.

H. Drewes, R. Newell, S. Eade, and J. Guilbert all combined to expound on the geology, mineralization, and on their thoughts to the group during the excellent days for an outing.

James D. Sell

JDS:mek

James D. Sell

cc: W.L. Kurtz

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

March 18, 1970

MEMORANDUM FOR: W. E. Saegart

Bisbee District
Cochise County, Arizona

On March 17, 1970, upon returning from Agua Prieta, Sonora, I noticed a new drill road and tripod rig east of Bisbee. As near as I can place it, as I did not have a topo sheet with me, the rig was high up on the north side of Black Knob and in the NW quarter of Section 28, T23S, R25E.

No additional investigation was undertaken.

James D. Sell

James D. Sell

JDS/kvs

cc: BEKilpatrick

1969 Annual Summer Meeting

of the

Mining Geology Division

Arizona Section

AMERICAN INSTITUTE OF MINING, METALLURGICAL

AND PETROLEUM ENGINEERS

* * *

PROGRAM

* * *

Presented by

PHELPS DODGE CORPORATION

Copper Queen Branch

Bisbee, Arizona

June 28, 1969

SCHEDULE

Friday, June 27, 1969

4:00PM - 8:00PM	Registration	Copper Queen Hotel

Saturday, June 28, 1969

7:00AM - 12 Noon	Registration	Copper Queen Hotel
7:30 AM	Underground Tour	Cole Shaft
8:30 AM	Open Pit Tour	Main Gate
12 Noon	Luncheon	Copper Queen Hotel
2:00 PM	Technical Session	Greenway School
6:00 PM	Cocktail Hour	Copper Queen Hotel
7:00 PM	Banquet	Copper Queen Hotel

TECHNICAL SESSION

Greenway School Auditorium

Cole Avenue, Warren

A Welcome to the Mining Geology Division Members	Mr. Henry Clark
Geology of the Bisbee Area	Mr. Richard Leisure
Structural Control of the Sulfide Replacement Deposits	Mr. Keith Coke
Underground Gravity Surveys at Bisbee	Mr. Robert Schnepfe

~~1D5~~

GEOLOGY OF THE BISBEE AREA

Abstract

The geologic formations outcropping in the Mule Mountains in the Bisbee area consist of the Precambrian Pinal schist basement overlain by 1,200 feet of Cambrian Bolsa quartzite and Abrigo limestone, 300 feet to 375 feet of Devonian Martin limestone, 600 feet to 800 feet of Mississippian Escabrosa limestone, and 3,000 feet of Pennsylvanian-Permian Naco group. During late Triassic or early Jurassic time, the Juniper Flat granite with associated dikes and the Sacramento Stock were intruded into these formations, accompanied by complex faulting and brecciation. Peneplanation north of the Dividend fault was followed by the deposition of 5,000 feet of the lower Cretaceous Bisbee group. Post-Cretaceous tilting, faulting and erosion gave rise to the present surface.

STRUCTURAL CONTROL OF THE SULFIDE REPLACEMENT DEPOSITS AT BISBEE

Abstract

Orebodies around and adjacent to the Sacramento stock south of the Dividend fault were probably of a pyrometasomatic origin. Their configuration was influenced largely by the bedding of the limestone host and to some extent by fracturing. Orebodies lying away from the stock tend to occur in groups or clusters. The placement of these clusters was influenced largely by steeply-dipping north-south trending fracture zones which occur between branches of northeast-southwest trending faults. A prerequisite of the host rock was its ability to fracture under stress. This prerequisite is met in the thinly-bedded Abrigo formation, the Parting quartzite overlying the Abrigo, the impure and brittle Martin limestone, and the chert zones in the lower portion of the Escabrosa limestone. Post-Cretaceous movements along many of these northeast-southwest faults have displaced the ore-bearing fracture zones along with the Cretaceous sediments, and further displaced the Paleozoic formations.

UNDERGROUND GRAVITY SURVEYS AT BISBEE, ARIZONA

BY ROBERT N. SCHNEPFE

Abstract

Twelve thousand gravity stations have been occupied in 160 miles of crosscut underground at Bisbee. All of these values are referenced to a base network, permitting direct comparison of the data. Latitude, free air, Bouguer, terrain, and regional corrections are made to the raw data. The resulting residual gravity data presented in the form of contour maps.

The density of the country rock is remarkably uniform and averages 2.70 g/cc. A density contrast of 1.00 g/cc between the massive sulfide mineralization and the country rock is generally assumed in making theoretical calculations.

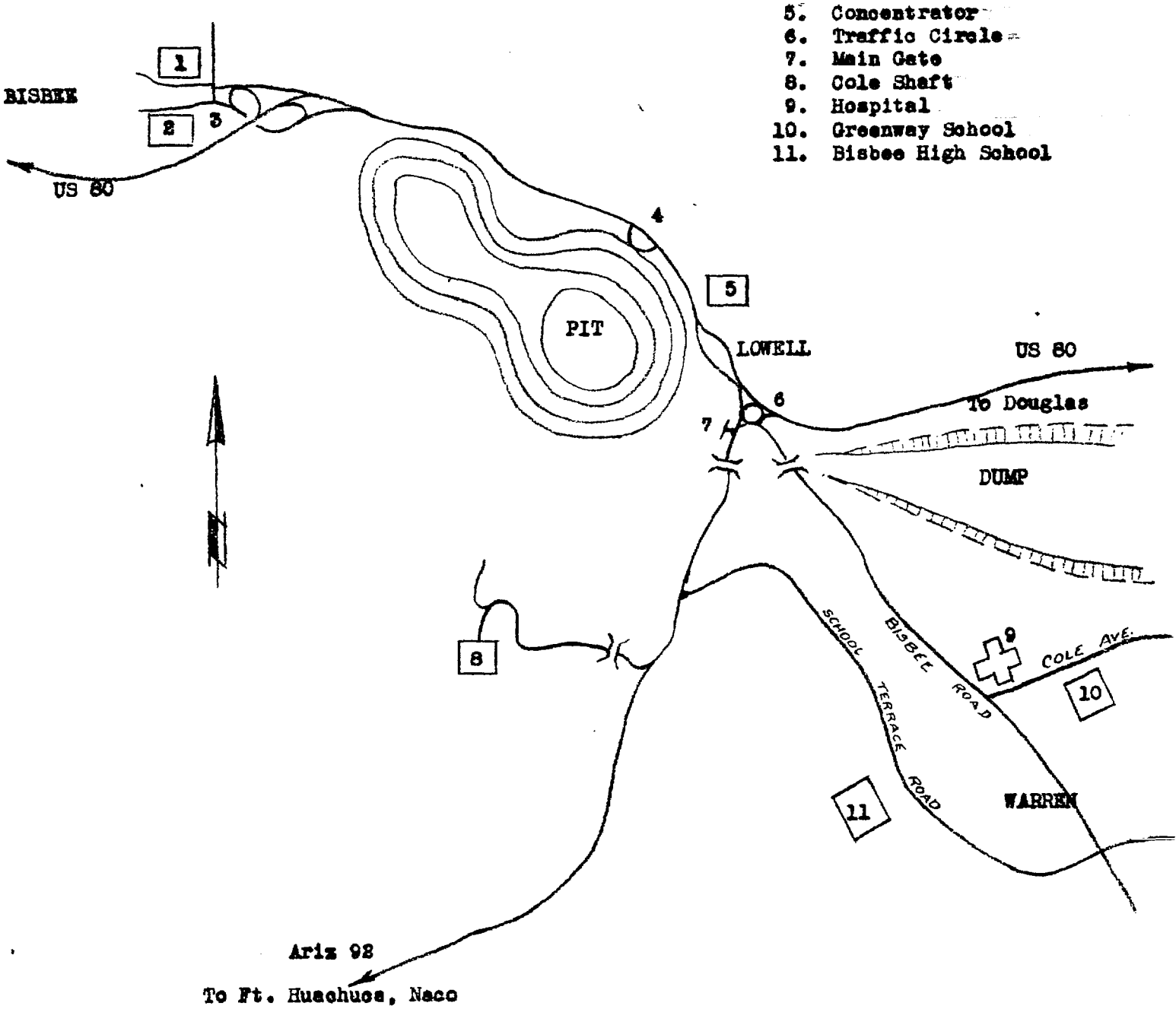
Limited station distribution precludes the use of mathematical interpretational aids. Non-sulfide disturbing influences are solution caverns, mine workings, epidote skarn, dolomitic limestone, gossan, and some copper oxide mineralization.

Five examples of gravity anomalies in various portions of the mine are shown. These illustrate a number of the problems encountered in the interpretation of the results, as well as the size and magnitude of the anomalies to be expected. One example of a vertical section showing the relation of the apparent density to the gravity contours is given.

Eighty percent of the recommended holes that have been drilled have cut sufficient sulfide mineralization to account for the anomaly they were investigating. The gravity data is also used in planning exploration crosscuts.

MAP OF BISBEE AREA

1. Copper Queen Hotel
2. P.D. Mercantile
3. Parking Lot
4. Lavender Pit Lookout
5. Concentrator
6. Traffic Circle
7. Main Gate
8. Cole Shaft
9. Hospital
10. Greenway School
11. Bisbee High School



1 Mile

[illegible] and inter-actions and

REX IRON WORKS CO.

Phelps Dodge

ECONOMIC GEOLOGY

AND THE

BULLETIN OF THE SOCIETY OF ECONOMIC GEOLOGISTS

VOL. 63 JANUARY–FEBRUARY, 1968 No. 1

Intrusive Breccias Associated with Ore, Warren (Bisbee) Mining District, Arizona

DONALD G. BRYANT

[redacted]

Tucson Citizen 11/17/95

11/95

ENVIRONMENT WATCH: LATIN AMERICA

9

e.

ch-

na

1.

File Bisbee District

30 So. Main St.
P. O. Box 1889

DUPLICATE

Jacobs Assay Office

Registered Assayers

PHONE Main 2-0813

Certificate No. [illegible]

Tucson, Arizona, [illegible] 196[illegible]

Sample Submitted by Mr. [illegible]

SAMPLE MARKED	GOLD Ozs. per ton ore	GOLD Value per ton ore *	SILVER Ozs. per ton ore	COPPER Per cent Wet Assay	LEAD Per cent Wet Assay	Per cent Wet Assay	Per cent Wet Assay
		$					
[illegible]				[illegible]			

Pyrite exposed in Road Cut on highway north of Lavender pit

Bisbee east of Dividend fault sulphides

* Gold Figured $35.00 per oz. Troy

Charges $ 1.50
[illegible]
1.75

Very respectfully,

[illegible]

August 17, 1960

NOTES ON GLANCE CONGLOMERATE IN BISBEE DISTRICT

(1) 8 miles NW of Bisbee: Congl dips at very low angle under Morita -- congl. composed mainly of angular to sub-rounded schist fragments. Occasional felsite por pebble. Numerous thin beds of red, sandy mudstone. Cg passes upward into ± 30' of red mudstone which is overlain by arkosic ss (gray, thick bedded) of Morita. Gl. congl. overlies Pre€ schist; thickness varies from a few feet to several hundred.

---

5 miles SE of Bisbee, 1/2 mile WSW of Gold Hill

Congl of same character as at No. 1 loc. Dips northerly under red sandy siltstones which contain thin congl beds with some well rounded schist fragments. This (red siltstone) presumably is basal unit of Morita F. Congl. contains numerous vein quartz boulders as well as boulders of mineralized limestone and porphyry.

3/4 mile SE of Gold Hill

Ls congl with red mud matrix dips north to northwest. Appears to overly schist congl with a few ls boulders which outcrops in railroad cut 1/2 mile to south. Congl. contains many mineralized boulders.

Glance Mine Area

Hill on which Glance shaft is located is composed of east dipping conglomerate beds. Boulders are schist and quartzite (angular to subrounded) with some ls. fragments. Ls congl with occ. red brown sandstone and siltstone (Morita?) boulders occurs on E, W and S side of hill, and thus, in this area the ls congl appears to underlie the schist bearing congl. Passing westward from the Glance Hill, the ls congl appears to gradually change to a mixture of ls, schist, ss and quartzite.

GENERAL

The arkosic ss and red mudstone fragments in the ls congl. suggests a possible post-cretac. age, but no field relations were found to support this. Ransome (PP. 21, 1904) considers Glance cg. to have a maximum thickness of about 600 ft. in Bisbee district.

J. H. COURTRIGHT

46 mil. tour pre-mine strip

KR

INTRUSIVE BRECCIAS AT BISBEE

At Bisbee there are a great number of unusual breccias whose existence is not generally known to outside geologists. They are called intrusive breccias and, as the term implies, the breccia fragments were intruded into the formations where they are now found.

The Bisbee intrusive breccias are a hetergeneous agglomeration of rock fragments comprising rocks from underlying formations. By some mechanism, not clearly understood, the component fragments have been forced through the overlying rocks for great distances following whatever path offered the least resistance to their passage. The fragments may have migrated a short distance only and be similar to the wall rock enclosing the breccia or they may comprise all lower formations including the Bolsa Quartzite and Pinal Schist as well as porphyry.

Fragments of nearly any size are locked in a matrix of cementing material. Thin section examination of the matrix reveals that it is composed of smaller fragments of the same rocks that make up the breccia; the matrix is often cemented by calcite and silica introduced after the breccia was intruded.

In form, the breccias are extremely irregular. A few are dike-like but characteristically they may follow a joint for a short distance, then switch abruptly to a bedding place or an intersetting fracture. Sometimes they are tabular but often they swell out to occupy irregular volumes in the limestones.

The breccias may be very small masses of perhaps pencil width occupying joints or fissures or they may be masses of considerable size with dimensions on a single level of several hundred feet.

Component fragments also vary in size as is evidenced by the specimens on display. The biggest specimen observed by the writers was a perfectly rounded boulder perhaps three feet in diameter in a bench of the Lavender Pit. It was not accessible so its composition could not be determined.

The relative age of the intrusive breccias seems to be clearly established. They frequently contain rounded boulders of porphyry and are, therefore, post porphyry.

They also often contain rounded pebbles of barren pyrite showing that a period of intense pyritization had occurred prior to instrusion of the breccias. The breccias themselves are sometimes more or less completely replaced by ore minerals.

Assuming a genetic relationship between the porphyry and the pyritic mineralization the sequence of events would then be:

1. Intrusion of the quartz monzonite porphyry into the Paleozoic limestones;

2. A period of pyritic mineralization in which the porphyry was sparsely pyritized and portions of the surrounding Paleozoic limestones suffered massive replacement by pyrite;

3. Intrusion of "pebble dikes" or intrusive breccias into the Paleozoic limestones, the porphyry stock and into the schist;

4. The period of ore mineralization which resulted in the "halo" of limestone replacement ores as well as the disseminated protore of the Sacramento Stock.

An interesting feature of the breccias is that the degree of rounding of the fragments appears to be a function of the distance traveled. A breccia whose component fragments are predominately limestone may be made up of angular boulders; the quartzite and schist boulders observed in the breccias are usually rounded and resemble stream worn boulders.

In a number of places it has been possible to observe the mechanics of assimilation of wall rock fragments into the clastic stream of intrusive breccia fragments. Intrusive breccia material occupying irregular channels isolates and engulfs projecting blocks of the host rock or surrounds big blocks of rock cut on all sides by fractures. The next stage is a breccia whose angular fragments would all obviously fit together like pieces of a jigsaw puzzle but are held apart by the matrix material. The final stage is a breccia of rounded boulders which have been moved thousands of feet from their source.

The intrusives are found throughout the productive area and are seemingly most abundant in the immediate ore area. They are particularly abundant in the main Sacramento Stock. They have also been observed in the limestones outside of the known productive area and in the schist above Brewery Gulch north of the Dividend Fault. They occur in every formation up to and including the Naco Limestone. The intrusive breccias form a "halo" around the Sacramento Stock area just as the limestone replacement ores do but of greater radius; some are well over a mile horizontally from the closest porphyry of the Sacramento Stock.

Increasing familiarity with intrusive breccias disclosed they they are closely associated with ore deposits in a great many cases. Mineralizing solutions frequently tended to follow the same paths followed by the breccias and in many cases the breccia was replaced more or less completely by ore. Schist and quartzite fragments were more resistant to replacement than were the limestone fragments. In many of our ore deposits the intensity of replacement actions has nearly obliterated the breccia structure but often a careful examination will reveal ghosts of the old rounded or subangular fragments.

It is probable that over 90 percent of Bisbee ore bodies are directly associated with intrusive breccias; if it were possible to study every stope round by round as mining progressed it might develop that the percentage is even higher.

If it is borne in mind that the ore in Bisbee occurs not in an ore body but in literally hundreds of isolated, separate and discreet ore deposits, this association of intrusive breccias and ore becomes truly remarkable.

ORIGIN OF BRECCIAS

A great many theories have been offered by various geologists as to the origin of the Bisbee breccias. Many of them are subject to some serious objection. For purposes of discussion, a few of the most commonly held theories are summarized.

1. The fragments were "floated" through the rock under very high pressure. The matrix probably contained a high percentage of sulphide and thus formed a high density slurry to float the rock fragments.

Objection: While some of the breccias have a sulphide matrix this is undoubtedly due to subsequent replacement. Thin section examination shows the average matrix to be identical in composition to the larger fragments which can be identified megascopically.

2. The dikes were plugs of solid material driven ahead of an advancing magmatic intrusion.

Objection: The dikes are post Sacramento Stock porphyry. No evidence of another intrusion has been found.

3. The "contact breccia" represents explosion material which has blown high in the air and tumbled back into the void of what is now the Sacramento Hill Stock. The porphyry was intruded later and engulfed most of the explosion breccia leaving only patches around the stock. This theory has enjoyed considerable popularity and has been expressed in a number of publications.

Objection: The breccia dikes are definitely post porphyry. The theory entirely ignores the dikes which extend for a mile or more out into the surrounding rocks. The writers know of no evidence whatever that the breccias were formed by this means.

4. The entire area was under extreme pressure. There was a sudden release of pressure caused by an eruption of molten material or gas through to the surface. This sudden release of pressure caused a violent migration of material toward the point of release.

Objection: The spider web of dikes out from the Sacramento Hill Stock shows that material was forced up or out by a deeper seated pressure rather than inward toward a point of sudden release.

5. The magma of Sacramento Stock was intruded into the limestones but was not extruded onto the surface. Cooling and crystallization started with a consequent rise in pressure of the remaining magmatic solution. This resulted first in the release of hydrothermal solutions which pyritized the surrounding rocks. Later

as crystallization progressed and solution pressures rose sufficiently, an escape of gases or liquids along all available paths occurred. The gases, having velocity, were then able to force along their myriad channels fragments of the outer solidified shell of porphyry together with fragments of all rocks traversed. Fragments of this clastic stream helped abrade the walls of the channel and enlarge it; gas pressure ahead of the intrusive pressure helped open channels for the fragmental material. Later, ore solutions followed these breccia dikes replacing susceptible portions of the dikes on the adjacent limestones.

This last explanation is favored by the writers. While it is hardly susceptible of proof, it does answer most of the problems posed by the Bisbee breccia dikes.

The same idea of rising pressure due to crystallization of a silicate system has been used by others to account for intrusive breccias--notably by W. H. Emmons and F. M. Chase.

Not for Publication

W. G. Hogue & H. E. Metz
Bisbee, Arizona
May, 1956

mbb

INTRUSIVE BRECCIA SPECIMEN INDEX

Lavender Pit Specimen No. 1 to No. 5 inclusive.

All show intense hydrothermal alteration.

No. 1 - Fragments of Pinal schist and Bolsa quartzite. Cluster of pyrite blebs near top of specimen believed to be intrusive.

No. 2 - Rounded porphyry fragment at the top left. Other fragments too altered to identify.

No. 3 - Note the rounded pebble of sulphide near the bottom of the specimen. Other fragments of porphyry and Bolsa quartzite.

No. 4 - Fragments of Pinal schist and porphyry.

No. 5 - Rounded boulder - probably Pinal schist.

Breccia specimens from the Abrigo Limestone No. 6 to No. 12 inclusive.

Minimum distance of travel normal to the bedding: Pinal schist - 1000 feet
Bolsa quartzite - 600 feet

No. 6 - Sawed face shows fragments of porphyry and pyritic limestone. Schist fragments are identifiable on the rough sides.

No. 7 - Small dike consisting of fragments of Pinal schist, limestone and pyrite. Massive pyrite on the walls probably pre-dike. Note the bornite stringers cutting pyrite and dike material on the rough face.

No. 8 - Fragments of Schist, Bolsa quartzite and porphyry. Nearest known porphyry instrusive is 400 feet.

No. 9 - Rounded fragments of Pinal schist, Bolsa quartzite and pyrite.

No. 10 - Specimen from an ore body showing incomplete replacement by ore minerals. The unreplaced fragments are Bolsa quartzite and Pinal schist.

No. 11 - Specimen from an ore body, like No. 10 shows incomplete replacement by ore minerals.

No. 12 - Pebble of Bolsa quartzite from the same breccia as No. 10.

No. 13 to No. 17 inclusive - Breccia specimen from the Campbell pipe showing dissimilar limestone and various degrees of replacement.

No. 19 - Quartzite boulder.

No. 20 - Limestone boulder.

No. 21 - Quartzite boulder.

J.H. Courtright

Sac pit - develop - started in 1909
- 7 mil tons 1.10 cu - to 1927
total block cave - 10 mil

Phelps Dodge Corporation
Copper Queen Branch

ORE DEPOSITS OF BISBEE DISTRICT

75 sq miles in mining dist.

by

Harry E. Metz

Lavender pre mine strip 46 mil
12000 ton/day -
Conc 12% cu -

A great deal has been written on the ore deposits of the Bisbee District. Much of this paper is simply a summary of earlier literature. In some cases it has been necessary to modify the older ideas as well as develop new ones to explain some of the more recent discoveries.

ROCKS

The oldest rock of the district is pre-Cambrian Pinal schist. Resting unconformably on the schist is over 4,000 feet of Paleozoic sediments. The base of the Paleozoics is represented by 400 feet of Cambrian Bolsa quartzite. This is followed by 770 feet of sandy, thin bedded Abrigo limestone of late Cambrian age. Ordovician and Silurian sediments are missing. Following the Abrigo limestone is 350 feet of Devonian Martin limestone which, in turn, is followed by the Carboniferous limestone, consisting of 700 feet of Escabrosa limestone of Mississippian age and over 2,000 feet of Naco limestone which is Pennsylvanian.

Resting on a very irregular erosion surface of pre-Cambrian schist and Paleozoic sediments with their intruded rocks are about 5,000 feet of early Cretaceous sediments. The lower member of this series is the Glance conglomerate, from 20 to over 500 feet thick; followed by 1,800 feet of shales and sandstones, the Morita formation; 650 feet of fossiferous Mural limestone which has formed the conspicuous cliffs to the northeast; and this, in turn, by at least 1,800 feet of shales and sandstone - the Cintura formation.

Cutting the schist and Paleozoic sediments is a large stock of granite, the main exposure of which is in the northwestern part of the district and forms the very rough terrain north of the road on the west side of the Divide. Branching out from the granite stock are numerous sills and dikes of granite and rhyolite

porphyry, which are scattered throughout the western part of the district. They are relatively unaltered and have a composition like that of the granite and are believed to be part of the same intrusion.

The most important igneous rock of the district, because of its relationship with the ore deposits, is a stock-like mass of highly altered quartz monsonite porphyry. It is about a mile in diameter. A major fault, the Dividend, splits it into two different geologic settings. On the north, or footwall exposure, it intrudes the Pinal schist. The porphyry, and schist surrounding the porphyry, are highly altered and silicified. On the west side of the stock is a considerable zone of bleaching in the schist. On the south, or down thrown side of the fault, the porphyry has intruded the Paleozoic sediments. Branching dikes and sills spread out from the stock in much more profusion in the limestone than in the schist. This is more evident in the underground sections than is indicated on the surface where a good part of the stock is hidden by cover. Alteration due to intense mineralization has practically made the original composition indeterminate; however, recent thin section studies have indicated that it was probably quartz monzonite porphyry. The usual contact metamorphic minerals are conspicuously absent in the limestone surrounding the stock. There is a highly silicified, iron-soaked zone of limestone adjacent to the stock which may have been caused by contact metamorphism but which was more probably the result of mineralization.

Seemingly quite closely associated with the porphyry are dikes and sills of breccia consisting of rounded pebbles and cobbles of the formation through which they passed. It is not unusual to find rounded schist fragments in dikes cutting the Naco limestone and in nearly all are pebbles or fragments of Bolsa quartzite. This type of breccia is designated as intrusive breccia and will be more fully described in the next paper.

FAULTING

The producing area of the district is terminated abruptly on the north by the Dividend fault, which was mentioned earlier. It has split the porphyry stock and dropped the Paleozoics on the south against the pre-Cambrian schist to the north. The general strike of the fault is about N 70° W with a southerly dip of from 65° to 80°. Remnants of Bolsa quartzite on the north, coupled with the Paleozoics to the south, give a fairly accurate record of the vertical displacement which, in the vicinity of the Saginaw shaft to the east, is over 5,000 feet and, at the Copper Queen Glory Hole in Bisbee, 2,000 feet. A short distance east of the Saginaw shaft, the fault is lost under the surface gravels, while to the west it passes into the schist above Bisbee and is lost in the complex south of the Juniper Flat granite.

The Paleozoics in the productive area are cut by a series of northeast fractures which have been segregated into a number of fault zones. They have a strike which is complementary to the Dividend fault, roughly N 20° E, and dip steeply to the west. Individually, the fractures seem insignificant and little more than a joint, but collectively over a wide zone may account for considerable displacement. Ore occurrence is intimately associated with these northeast fractures. The major fracture zone in the Junction area is the Mexican Canyon. It is a zone possibly 1,000 feet wide which has an overall displacement of from 400 to 500 feet. Ore has been found intermittently in this zone for a vertical extent of over 2,000 feet. Another important zone, which is a major producer today, is the Dallas fault zone. In all, over twenty fault zones have been segregated.

Complementary to the northeasters are the northwesters. They are a series of fractures with a northwest strike and in all respects are similar to the northeasters, but do not have their persistency. These, too, are important ore producers, particularly where they join with the northeast system.

Cutting diagonally to the southeast across the productive area is the Oliver fault. It has a dip of about 45° to the southwest, and has a normal displacement which is confined to a fairly definite plane rather than a zone, of about 500 feet. The northeast fault zones cut the Oliver fault. Areas where these zones cross the Oliver have been particularly fruitful in regard to ore. The large Cole-Dallas ore bodies of today are the result of the juncture of the Oliver, the Dallas and the Mexican Canyon.

Age of the initial movement on these faults can only be placed as post-Paleozoic and pre-Cretaceous. Many show post-Cretaceous movement also, which has led to considerable controversy in regard to the age of the ore. The post-Cretaceous movement is due to reopening of the earlier fractures in post-Cretaceous time.

GEOLOGIC HISTORY

The very early historical events of pre-Paleozoic time are omitted here and only those that are more closely associated with the ore occurrence are related.

In post-Paleozoic and pre-Cretaceous time, probably Triassic or Jurassic, there was initial movement on the Dividend, Mexican Canyon, Campbell faults and many others. These provided channels for the intruding porphyry. The main stock was formed along the Dividend fault, and the dikes and sills along the others. The intrusion, which must have engulfed large portions of the limestone, displaced portions of it also, causing new faults and fractures as well as intensifying old ones.

Following the porphyry intrusions there was a period of intense mineralization, principally of pyrite and silica, which resulted in heavy replacement throughout the porphyry stock and the surrounding schist and limestone.

The pyrite mineralization in the porphyry and schist was more of the disseminated type, while in the limestone it formed large irregular lenses of massive pyrite. A period of fracturing followed the initial pyritization more or less along

the older fractures, and brecciated the sulphide bodies along or adjacent to them. Intrusive breccia then invaded the area along the existing fracture channels, picking up fragments of low grade pyrite as well as fragments of the other formations along its course. The next mineralizing stage was copper bearing, apparently following the same channels as the earlier porphyry, pyrite, and intrusive breccia. Fractures in the brecciated pyrite were filled with copper sulphide along with slight replacement of the pyrite itself. The reaction on those pyrite masses which were not brecciated was confined principally to the pyrite-limestone contact resulting in lenses of copper ore around low grade pyrite. Fractures were not present to permit penetration of the copper mineralizers to the interior of these masses in any appreciable amount. Where fractures did exist, lenses of ore resulted in the low grade core. The main activity of the copper mineralizers was in the limestone, but there was some introduction of copper in the main porphyry stock. Lead-zinc mineralizers followed the copper, replacing the limestone in the extremities of the pyrite-copper bodies.

Next was a period of erosion which cut down the upper Paleozoic into a very rough irregular surface. The upper portion of the porphyry stock was leached and the copper redeposited at the water table as a chalcocite blanket. Displacement on the Dividend fault then dropped the southerly side into a protected basin under a shallow sea, and the northerly side was elevated into a range of mountains which was subjected to intense erosion. Rapid erosion not only stripped the Paleozoics from the north side but the chalcocite blanket of the porphyry stock as well, and finally resulted in a peneplane at sea level. The basin to the south was, in the meantime, filled with detrital material. Finally the entire area was dropped below sea level and a thin blanket of detrital material was deposited on the north as well. This detritus became the basal conglomerate of the Cretaceous. The remaining Cretaceous sediments were then deposited in shallow seas. The entire area was elevated;

there was additional displacement on the Dividend fault; regional tilting to the east; and erosion which stripped off the Cretaceous cover over the porphyry stock and surrounding limestone.

AGE OF MINERALIZATION

The age of the mineralization in the Bisbee district has long been controversial. It is believed that evidence uncovered in recent Pit operations has settled the question beyond reasonable doubt. This evidence places it as post-Paleozoic and Pre-Cretaceous and is as follows:

1. Pebbles of altered porphyry in the Glance conglomerate, which even microscopically are indistinguishable from that in the main porphyry stock. Alteration of the porphyry was an effect of the mineralization. It is evident that the porphyry pebbles were altered prior to their deposition in the Glance. The abundance of the porphyry pebbles in the conglomerate increases as the porphyry contact is approached, indicating that the pebbles were derived from this stock, and not from some other remote source of supply.

2. Pebbles of ferruginous silica in the Glance conglomerate which were obviously derived from the oxide zone of the porphyry stock.

3. Pebbles of silicified limestone in the conglomerate in all respects similar to silicification accompanying the mineralization of the limestone.

4. Complete lack of alteration of the Glance conglomerate where it is in contact with the porphyry. The porphyry is altered yet the Glance conglomerate is unaffected. Small veinlets of quartz cutting the Glance show a zone of bleaching for a few inches on either side and a similar condition should have occurred along the porphyry contact if the mineralization had been later.

5. The porphyry blanket of chalcocite and its capping more or less conforms to the pre-Cretaceous surface under the Glance conglomerate. This indicates that

the enrichment is related to that early erosion period and not the one going on today.

6. No ore has ever been found in the Glance conglomerate or above it.

Against such overwhelming evidence, the following arguments may be presented:

1. Fracture zones which cut the Cretaceous sediments are also important ore zones in the Paleozoics. This is true, but is due to reopening of older fractures after deposition of the ore.

2. Veinlets of quartz cutting the Cretaceous contain copper mineralization. This post-Cretaceous mineralization is entirely different from that which resulted in the important ore deposits. The post-Cretaceous type is fissure filling, while the pre-Cretaceous type is strictly replacement.

ORE BODIES

Ore has been found in all the Paleozoic limestones; however, the most productive horizons have been the upper 300 feet of the Abrigo limestone, all the Martin and the lower 300 feet of the Escabrosa, a total of about 1,000 feet. Most of the production has been from these horizons. The reason for these productive horizons is due to the physical property of the lime beds in that they are very brittle and any slight movement would tend to shatter them, which permitted penetration of the ore solutions. The beds above and below these horizons are elastic and tend to either bend or break along one main fracture. The Paleozoic beds have an average dip to the northeast of from 20° to 25° and the productive horizon conforms to this average dip, ever becoming deeper to the east.

A horizontal projection of the ore bodies shows a semicircular arrangement around the main porphyry stock with offshoots resembling the spokes of a wheel. This arrangement is the result of replacement in the fracture and fault zones

mentioned earlier. The semicircular pattern is due to replacement in the intense fractures caused by the porphyry displacing the limestone. The radiating spokes are along the northeast zones.

Ordinarily, the copper ore bodies occur in close association with larger bodies of massive pyrite. Commonly, copper ore lenses are found peripheral to a larger pyrite lens on the limestone contact. Another type of occurrence is as filling and partial replacement of the earlier brecciated pyrite. Lead-zinc mineralization occurs in the outer fringes of the pyrite and copper mineralization, sometimes on the contact and sometimes as outliers. At times, in the thin bedded Abrigo deposits, there will be a bed of copper ore sandwiched between two beds of lead-zinc.

Much of the ore, particularly in the Briggs, Junction and Campbell areas, is closely associated with porphyry dikes and sills. Ore may occur along the porphyry in contact with it, particularly where there is an irregularity or, more favorably, an embayment in the porphyry contact. This association is due to structural relationships. Fractures which formed the channels for the intrusion of the porphyry likewise were channels for the mineralizers. In addition, fracturing adjacent to the porphyry was intensified, due to the actual displacement of the limestone, making an ideal host rock. With the exception of the main stock, replacement of the porphyry by copper minerals in sufficient amount to make ore is rare. In the main stock there were important ore bodies of this type but in the outlying limestone, apparently the affinity for the limestone and pyrite was too great for this to occur.

The shape of the ore bodies is nearly always influenced by the bedding of the limestone which it replaces. Some limestones influence it more than others. Deposits in the thin, shaley beds of the Abrigo are practically always tabular, in conformance with the limestone beds. Unreplaced shale and different textures of the

sulphides in the ore body clearly show the original bedding of the limestones. Likewise in the Martin, with its dirty but more massive beds, the deposits are usually bedded but have greater relative thickness than the Abrigo type. Deposits in the clean Escabrosa limestone are usually thick and massive, with a tendency for the vertical dimension to be greater than the horizontal, but even they plunge with the bedding, but normally at a greater angle. The bedded type of deposits in the Abrigo and Martin occur at the intersection of a fracture and a favorable bed, resulting in a deposit with elongation along the break, and a rake corresponding to the trace of the bed and fracture intersection.

The type of limestone in which the deposits occur also influences the ground conditions for mining purposes. Deposits occurring in the Abrigo and Martin limestones usually require some timber method of mining because of the poor bond between the beds due to the shaley partings. The thick, massive ore bodies of the Escabrosa usually stand better, permitting some open type of mining method.

Size of individual ore bodies is quite variable, from a few thousand tons to--in exceptional cases--over a million. Possibly a third of the production today is from ore bodies of less than 10,000 tons, a third from ore bodies of 10,000 to 25,000 tons, and the remainder from ore bodies of over 25,000 tons.

In the ore zones, intermittent lenses of ore may be found over quite a long range, both vertically and horizontally. The Denn Side Line ore zone has been productive for over 2,000 feet vertically in an area about 2,000 by 500 feet horizontally more or less parallel to the Dividend fault. The Baras-Home-Reindeer ore zone has a vertical extent of over 1,000 feet and a horizontal of about 300 feet by 1,200 feet.

The depth of oxidation is extremely irregular. Practically all the mining in the western part of the district was from oxide ores. In fact, Dr. Ransome held

little hope for the primary zone when he first examined the district. As the deposits became deeper to the east, the proportion of primary ore increased. Certain zones of oxidation are very persistent and extend to a considerable depth. A small oxide ore body of native copper and cuprite was recently mined on the 2433 level of the Campbell mine, and another oxide zone was cut on the 2700 level of the Junction. This deep oxidation is due to downward flowing ground water in the ore zone fractures.

PORPHYRY ORE

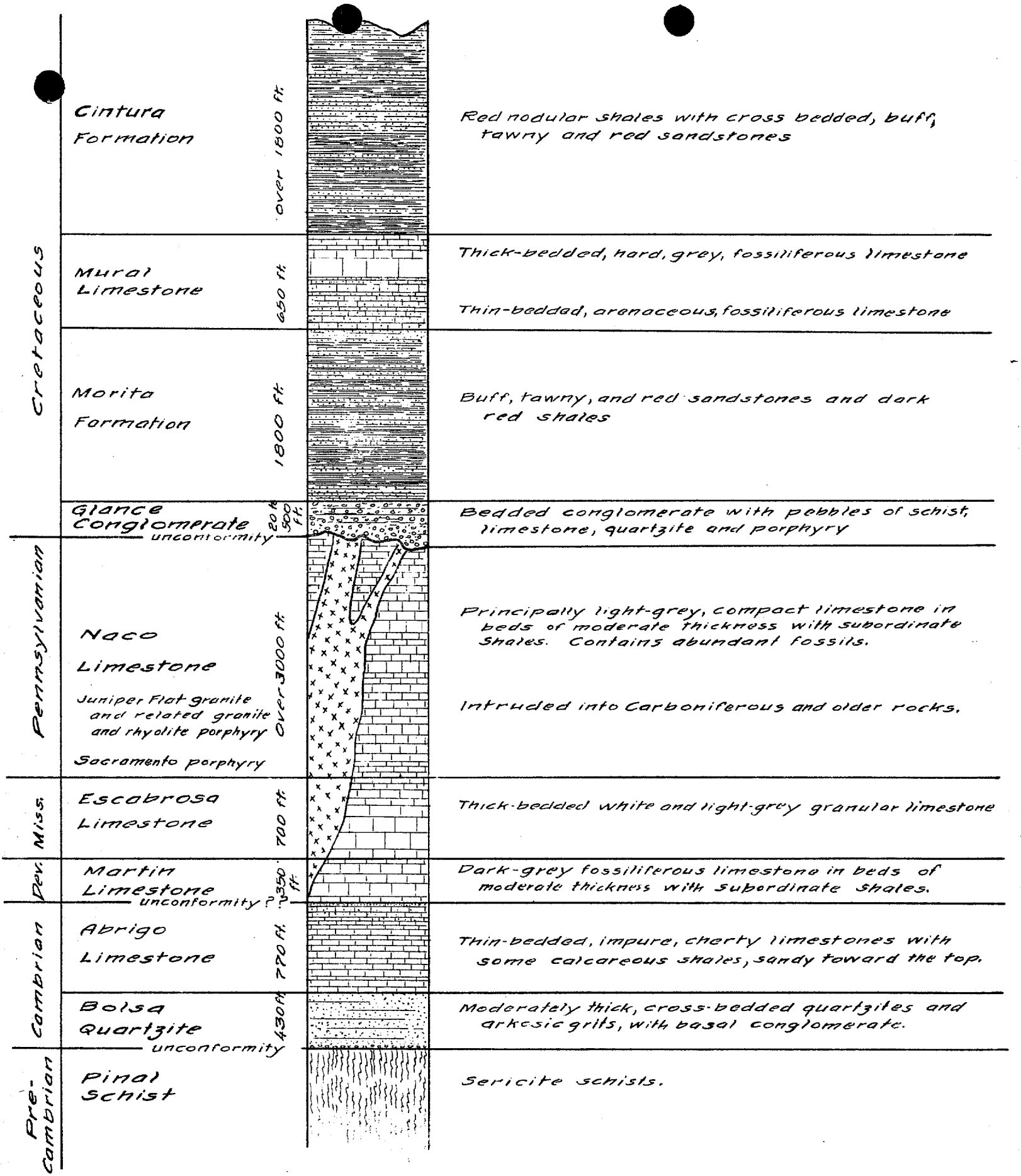
Leaching and redeposition of the copper in the main porphyry stock south of the Dividend fault has produced a chalcocite blanket of copper ore. Fracturing of the stock influenced the enrichment process by permitting thorough leaching, channelling of the percolating waters, and by permitting intimate contact with pyrite grains for precipitation. The transition from the oxide capping to the sulphide zone, although abrupt, is very irregular. Pendants of oxide extend to considerable depths along fractures in the sulphide zone and, likewise, sulphide of the undisturbed porphyry into the oxide zone. Leaching of the capping is thorough. It contains, in general, only traces of copper. There is no mixed oxide-sulphide ore such as is common in this type of deposit. Sulphide content of the ore is from 15% to 18%, practically all pyrite. The pyrite has been fractured and a thin film of chalcocite has been deposited on its many surfaces. This intimate filming of chalcocite on the pyrite adds to the metallurgical complication.

The chalcocite blanket dips to the east in conformance with the bottom of the Glance conglomerate which covered a considerable portion of it. The ore is from 50 feet to as much as 400 feet thick, the thinner portion being to the west at Sacramento Hill where the porphyry is very siliceous and compact. The oxide capping,

too, is thinnest at Sacramento Hill where the leaching process was slow, and also where it was exposed to erosion.

NOT FOR PUBLICATION

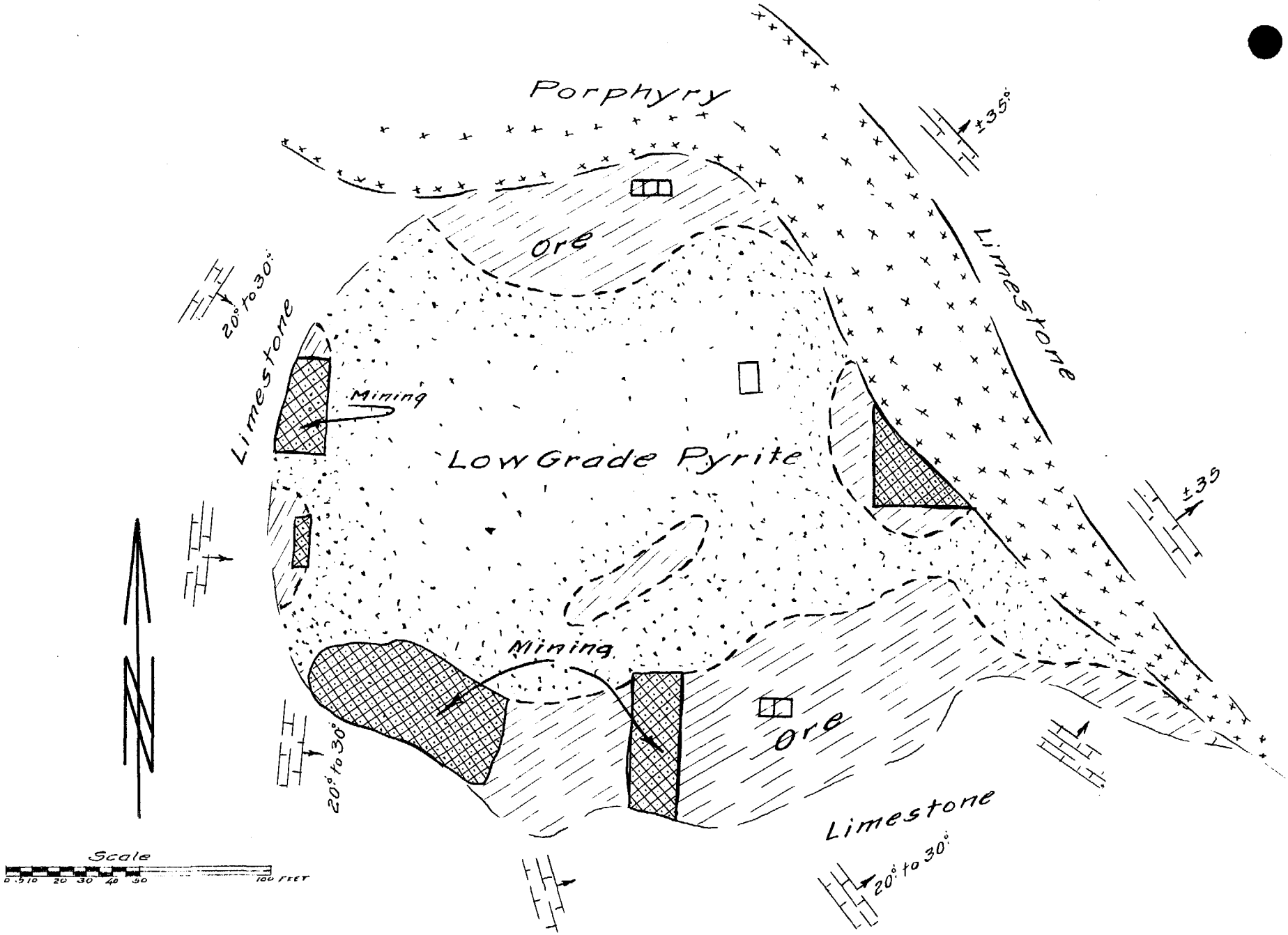
A. I. M. E.
Geology Subsection
Bisbee, Arizona
May 26, 1956
HEM:c



COLUMNAR SECTION
SEDIMENTARY ROCKS BISBEE, ARIZ.

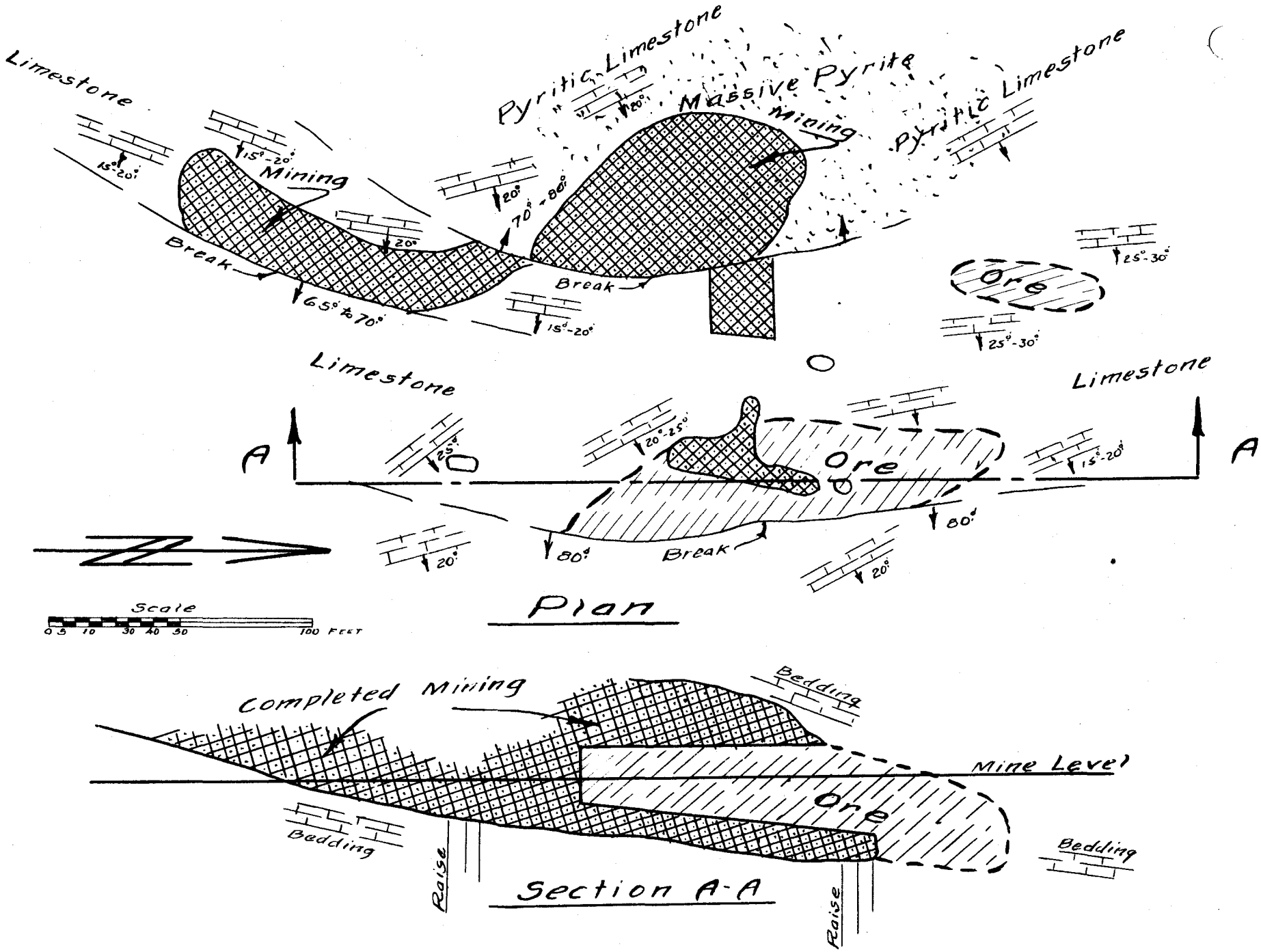
BISBEE, ARIZ.

From F. L. Ransome



PYRITE PERIPHERY-PORPHYRY CONTACT DEPOSIT

BISBEE, ARIZ.
4-20-56



TYPICAL ABRIGO TYPE ORE DEPOSIT

BISBEE, ARIZ.
4-20-56

Milling Practice at the Lavender Pit Concentrator

by H. K. Martin

no cpy !

≠ 83% recov. of total Cu

AMERICAN SMELTING AND REFINING COMPANY
San Francisco California

July 22, 1952

Mr. R. L. Lacey
American Smelting and Refining Co.
600 Pacific National Life Bldg.
Salt Lake City 1, Utah

Dear Sir:

BISBEE, ARIZONA
GEOPHYSICAL PROSPECTING

Yesterday Mr. John Hope, exploration geologist with Phelps-Dodge, told me of a geophysical method which is being used successfully to find sulphide replacement ore bodies in the Bisbee District. Though you probably are aware of the method, it was news to me and I am passing it along to you as being of possible general interest because ore is being found. Mr. Hope's knowledge of geophysics is only general as is mine, so in the following description no pretention is made of understanding technical details.

A gravimeter called the Frostmeter($10,000) is used underground, not on the surface. Readings are taken in various parts of the several hundred miles of underground workings in the district. This work is under the direction of a Mr. Milo; it has been going on for a couple of years; and considerable work remains to be done. Apparently the idea for this use of the gravimeter did not originate with Milo but he has had a lot to do with developing the technique. The method was first tried out on the known Campbell ore body, a large, massive sulphide replacement with absolutely no alteration halo. Their anomalies defined the shape and position of the ore body very accurately. Since then, they have found a number of other anomalies of smaller dimensions and drilling of these has found ore in every case. Though these ore bodies have all been comparatively small, the success of the method has been amply demonstrated.

The underground station readings are corrected for surface topography fo for an area above the station with a radius of about one-quarter mile. This correction is very intricate. A circular grid containing concentric rings divided into mathemat'cally precise segments of different sizes, is centered on the surface contour map over the station. Depending on intersections with this grid, elevations are laboriously plotted on cards. These cards are then put through an IBM machine at a cost of $25.00 per station. As I understand it, a couple of these stations with their corrections are established several hundred feet apart underground. Then intervening readings are taken and the two corrections somehow are adjusted to apply to these intervening stations.

I apologize for the crude nature of this description but would be interested in having your comments about the method.

Yours very truly,

Kenyon Richard

KR:MB
cc:MHlandwehr bcc:ALPayne
FWRichard JHCourtright
LKWilson