CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

W~~X~~K — ~~F+G~~

San Manuel

1970 — mill records

heads .0226 MoS_2 (.0136 mo)

tail .002 MoS_2

Recov. 82.7 %

[illegible]

± 6~~X~~¢/ton @ $6.00 mo

± $1.20

Sierrita

San Manuel

54,700 tpd   1978 - .64% cu

1978 - 19,600,000 tons ore

1.8 lbs Mo   2,955   " MoS_2

12.0 lbs cu   117,390   cu

.04 $.30   525,406   ag

.002 $.50   24,956   Au

cu 8.00
mo 3.00
$11.70 = 4.00/ton profit on $86M/yr

Cost ~~70¢/lb = 8.40~~
65/lb $7.80

Similkameen

22 000 tpd   .41 % cu

7.5 m   - 37.000 Au
140 000 Ag

San Manuel 5-22-79

10-K Report

est $4^{\underline{00}}$/ton profit

80 m/yr less 30 m tax

= 50 mill/yr

or ± $2^{\underline{00}}$ per share

JDS home # 883-4682

info from JDS

from handbook (San Manuel, 1978)

1475' 1st level mined to completion early in 1965.

2075' 2nd level, along with the 2375' or intermediate level is now being mined.

2675' level under development.

- driving 2900 production at level in Kalamazoo.

- (from AGI list #41) copper - 20 ppm (abundance in soil)

- (from "Geochem by Goldschmidt") 1954 average American ~~magnetic~~ magmatic rocks - 70 ppm copper.

- (from "Geochem of Hydrothermal Ore Deposits):

ultramafic - 10-20
mafic - 87-100
intermediate - 30-35.
granitic - 10-20
syenitic - 5

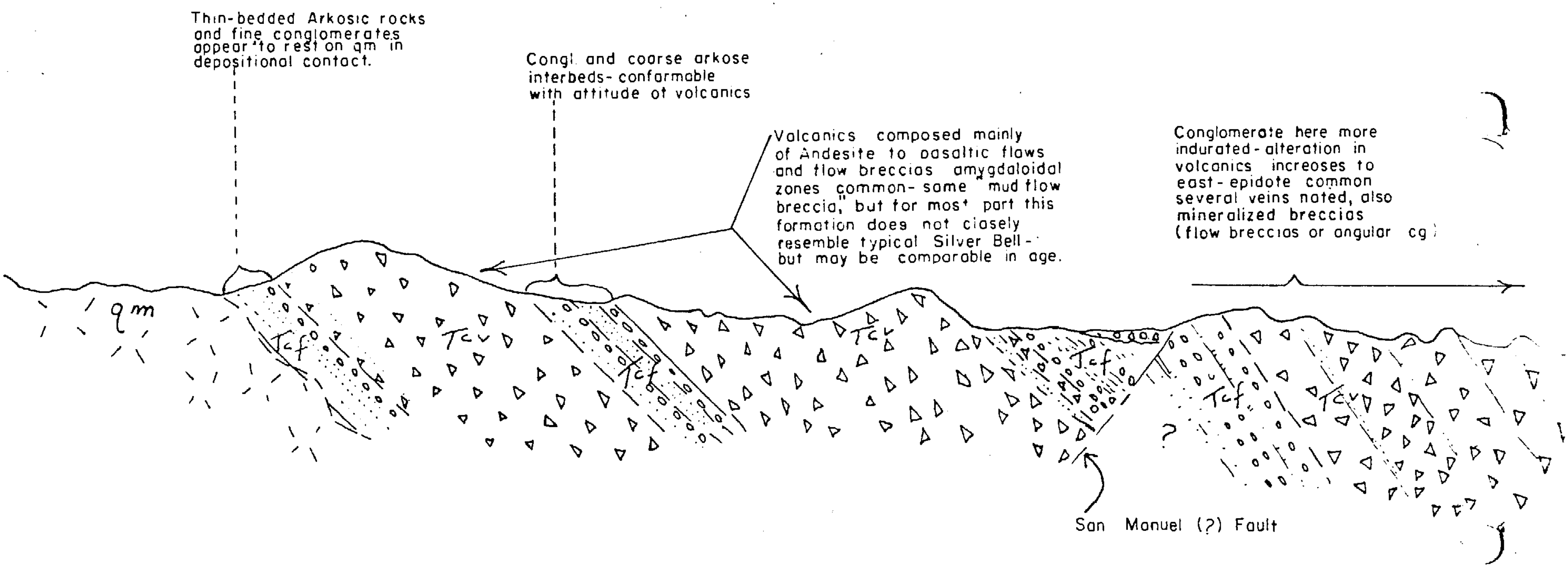
USGS PP 440-D 1964 62 + 58

Copper crust 47 - 45

continental crust 55

No San Manuel porphyry noted in cloudburst JHC

Alteration - mineralization indicate Cloudburst is pre - porphyry. JHC



Tc	Cloudburst Formation
Tcf	Cloudburst fanglomerate (composed mainly of qm and volcanic rocks boulders ang to sub rounded
Tcv	Volcanics in Cloudburst
Qm	Pre Cambrin quartz monzonite

Sketch Section
About ½ Mile South of Signal Peak
Section Trends E W Along Cloudburst Wash
N W of San Manual Mine

LOOKING NORTH
SCALE 1" = 2000' by JHC

Circa 1963

AMERICAN SMELTING AND REFINING COMPANY
SOUTHWESTERN EXPLORATION DEPARTMENT
P. O. BOX 5795, TUCSON, ARIZONA 85703

ASARCO

J. H. COURTRIGHT
CHIEF GEOLOGIST
L. P. ENTWISTLE
ASSISTANT CHIEF GEOLOGIST
W. E. SAEGART
ASSISTANT CHIEF GEOLOGIST

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

April 4, 1967

Mr. L. A. Heindl, Executive Secretary
U. S. National Committee for the
International Hydrological Decade
National Academy of Sciences
2101 Constitution Avenue
Washington, D. C. 20418

Dear Leo:

This will acknowledge your letter of March 9 with brochures describing the IHD objectives. I note that Kenyon Richard has written a letter of support for your program.

Enclosed is a longitudinal section and 2 cross sections of the San Manuel-Kalamazoo deposits. A number of mining companies have been approached by Quintana and thus may have more or less complete information on the Kalamazoo; however, please keep the source of this section unidentified.

Although the Cloudburst formation is shown overlying the qm and grd porphyry in depositional contact, Dave Lowell is not certain of this interpretation, nor of the existence of the Cloudburst in this position. Recently a hole located about 7000' southwest of the San Manuel twin shafts encountered the top of the ore zone at 4250' which falls approximately on the projected top of the Kalamazoo, as shown on the section. Since the grade of the ore is essentially equivalent to the grade of the San Manuel orebody, and in view of the structural picture, there appears to be little doubt that the Kalamazoo is the upper half of a cylindrical body with a low grade core. Lowell's concept was, prior to the drilling (and still is), that a near-upright cylinder, or pipe, was progressively tilted northeastward and then sliced longitudinally by the San Manuel fault.

You may recall on your last visit out here that I briefly discussed the subject of intrusive welded tuffs and other intrusive rocks of volcanic texture, and mentioned that during his doctor's work at Silver Bell, Barry Watson discovered welded tuffs with textbook eutaxitic texture intruding the Silver Bell formation. This discovery helped to explain a number of anomalous features in the Silver Bell area, and I believe such an origin is true of various "ribbon rock" occurrences elsewhere in the Southwest. A common feature to intrusive volcanics is the presence of gradational boundaries. The dacite porphyry at Silver Bell is such an intrusive, and you will recall the gradational boundary with the overlying Claflin Ranch arkose. In fact, the entire mass of welded tuff at Silver Bell (and in the Tucson Mts.) may be a sill, or sills!

However, various USGS geologists working in the Santa Ritas, Patagonias, and the Huachuca Mountains (Simons, Drewes, etc) have mapped all ribbon rock and related occurrences as extrusive rocks --- simply because they possess the textures of volcanics under the microscope. A preview of their work was published recently in Professional Paper 550-D, Geological Survey Research, 1966, Chapter D. On page 18 they show maps of the American Mine-Hardshell Mine area and of the Flux Mine area. I spent 6 months in 1950 in these areas and consider their interpretations to be in gross error, absurd in fact. I won't bore you with the details, but I believe the principal source of confusion is the practice of assuming rocks with volcanic textures to be extrusive in all cases. As you no doubt have already guessed, I am also referring to the "Illusive intrusives" and/or ribbon rock on the Papago Reservation.

If there is any further assistance I can give you, please let me know.

With best regards,

J. H. Courtright

J. H. COURTRIGHT

JHC/kw
Enclosure

GEOCHEMICAL OFFICE - EXPLORATION DEPARTMENT
3422 South 700 West
Salt Lake City, Utah 84119

August 30, 1976

RECEIVED
SEP 2 1976
EXPLORATION DEPT.

J. H. C.
SEP 2 1976

MEMORANDUM TO: J. H. Courtright
W. L. Kurtz
J. C. Balla
D. P. Cadwell
R. E. Gale
F. T. Graybeal
S. VonFay

Attached is a copy of a paper entitled "The Zonal Distribution of Selected Elements Above the Kalamazoo Porphyry Copper Deposit, San Manuel District, Pinal County, Arizona" by Maurice A. Chaffee, which appeared in the May 1976 issue of Journal of Geochemical Exploration. This is an updated version of a paper originally presented at the AIME meeting in New York, February 1975.

L. D. James.

L. D. JAMES

LDJ:db
Encl.

J. H. Courtright

Journal of Geochemical Exploration, 5 (1976) 145—165

THE ZONAL DISTRIBUTION OF SELECTED ELEMENTS ABOVE THE KALAMAZOO PORPHYRY COPPER DEPOSIT, SAN MANUEL DISTRICT, PINAL COUNTY, ARIZONA

rm 11p.


SW

GEOTHERMOMETRY, GEOCHEMISTRY, AND ALTERATION AT THE SAN MANUEL PORPHYRY COPPER OREBODY, SAN MANUEL, ARIZONA

by

Jerry Dean Davis

A dissertation submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 7 4

ABSTRACT

The San Manuel-Kalamazoo porphyry copper orebody in southern Arizona, with the combination of a well developed, symmetrical alteration-mineralization zoning pattern and an orebody positioned to facilitate three-dimensional access, provides a uniquely excellent subject for study. A three-part investigation was undertaken. Integrated fluid inclusion, petrographic, and geochemical studies of closely spaced samples in three arrays across the system have been used to test the proposed models of porphyry copper deposit origin. These models include (1) an orthomagmatic-hydrothermal origin, (2) intrusion of a water deficient magma and sudden pressure release, (3) boiling of meteorically derived brines beneath a vapor-dominated thermal system, and (4) development from an immiscible silicate-sulfide melt.

Primary and secondary fluid inclusions in quartz from the mineralized and altered system were studied by general microscopy and on a heating stage. This approach provided information on fluid compositions in time and space, the thermal profile and thermal evolution of the deposit, fluid densities, and geobarometric characteristics.

This data suggests there was a prolonged evolution of hydrothermal fluids depositing mostly barren quartz at 600°C and 40-60 wt. per cent salinities through a protracted period of boiling, equally saline fluids associated with major ore deposition, feldspathization, and sericitization at 425-275°C. A terminal, mostly barren stage of dilute (less than 26 wt. per cent) solutions is associated with sericitization and propylitization below about 275°C. No thermal or salinity discontinuities across alteration zone boundaries as suggested by a boiling meteoric brine genetic model are apparent. Apparently primary fluid inclusions in magmatic quartz are identical in appearance to high temperature primary and early secondary fluid inclusions in veinlet quartz. Geobarometry suggests emplacement of the top of the ore system at a depth of roughly one mile.

Petrographic study of alteration assemblages indicates their initial zonal formation and development was followed during waning hydrothermal activity by retrogressive encroachment of outer upon inner zones. X-ray and electron microprobe study of the secondary alteration feldspars coexisting with fluids entrapped in inclusions, when interpreted in view of previously existing thermochemical data, strongly suggest that feldspar-fluid equilibria limit and control the alkali content and

Na^+/K^+ of the hydrothermal fluid. Failure to maintain high salinity conditions in the wall rocks as long as they were maintained in the intrusive rock may explain the relatively smaller number of highly saline fluid inclusions and higher ore grade in the former. ?

Plots of variation of chemical abundance versus drill hole depth suggest that systematic changes in abundance of selenium, chlorine, rubidium, and strontium may be a guide to ore.

It is concluded that the orthomagmatic-hydrothermal model of porphyry copper deposit formation, with an endogenetic generation of the ore carrying brines, is adequate to explain the San Manuel-Kalamazoo ore deposit. Potassic alteration, much of the phyllic alteration, and the economic mineralization appear to have preceeded introduction of cool, dilute, probably meteoric waters into the system. The relative length of time that high fluid salinities were maintained in different parts of the system may have helped determine the distribution of the pervasive alteration envelopes. The close relationship in time and space of highly saline fluids to porphyry copper ore deposition at San Manuel suggests that mapping the distribution of similar fluids elsewhere, as preserved in fluid inclusions, could be a useful exploration tool.

CHAPTER IV

GENETIC MODELS OF PORPHYRY COPPER DEPOSITS

A prime purpose of this study is to use the integrated fluid inclusion, petrographic, and geochemical data to test the several proposed genetic models relating the similar characteristics of porphyry copper-molydenum deposits. The most important differences between these models relate to the depths of emplacement, relative importance in involvement and timing of introduction of external versus magmatically cogenetic fluids, and the sequence of mineralization-alteration events. The models presently most popular and considered here are (1) the orthomagmatic model, (2) intrusion of a water-unsaturated melt, (3) boiling brines below a vapor-dominated thermal system adjacent to an igneous heat source, and (4) dispersed immiscible silicate-sulfide melts.

(1) Burnham (1967), Holland (1972), and Kilinc and Burnham (1972) are among the most recent proponents of the orthomagmatic model. This model depends upon derivation of a magma at depth, its intrusion to shallow depths where it becomes saturated with water, and the release of internal water when internal pressure exceeds the lithostatic load

or when the system is subjected to external stress. Early marginal crystallization forms a solid shell which subsequently ruptures, producing the commonly observed porphyritic textures within the body of the intrusive rock. The separation and release of volatiles may be either a quenching or quasi-continuous process. Augmented by diffusion, fluids migrate outward along fractures. Alkali chlorides and metal complexes preferentially partition into the separating aqueous phase. Changes in temperature, pressure, and/or solution chemistry lead to precipitation of the ore minerals and wall rock alteration.

(2) Fournier (1968) proposes that an initially water-deficient source magma is intruded to shallow depths in the crust, partially crystallizes, and is ruptured by faulting, causing a sudden release of volatiles and quenching of the remaining melt. Argillic alteration is believed to be a subsequent development associated with circulating meteoric water.

(3) White (1968), and White, Muffler and Truesdell (1971) suggest that porphyry copper deposits may form in a zone of concentrated brines below a vapor-dominated thermal system. Metals would be leached from the magma or from the hot intrusive body which provides the heat engine to drive the thermal system by waters of recent surface origin whose high residual alkali chloride content is a result of

boiling. Alternatively, the high chloride and metal content may be produced by leaching them out of feldspars and ferromagnesian minerals external to the intrusive rock. In contrast to models (1) and (2), the source of the fluids and perhaps the metals is external to the magmatic system, with convective overturn of circulating brines producing the alteration-mineralization zoning.

(4) Mauger (1966) uses fractional magmatic crystallization instead of hypogene hydrothermal alteration-mineralization to explain the large scale zonal envelopes in porphyry copper deposits. An immiscible liquid chalcopyrite-rich solution is postulated to account for the disseminated mineralization. Hence, the majority of the mineralization is believed to be magmatically primary. Local concentration of fluid components in structural discontinuities accounts for veinlet mineralization. Much of the associated wall rock alteration results from reaction of trapped pore fluids with crystallizing silicates.

inclusions at temperatures less than 275°C may be representative of these post ore, largely meteoric waters. The late-stage encroachment of outer alteration zones upon inner alteration zones with waning hydrothermal activity agrees with this thesis. The absence of sedimentary or volcanic rocks in the vicinity of the orebody conducive to the production of highly saline fluids dictates that the high salinity fluids associated with the pre-ore to ore stages of development be internally derived. The ultimate source of the waters entrapped in high temperature primary and secondary fluid inclusions associated with mineralization, feldspathization, biotitization, and early sericitization is unknown, but it seems unlikely that it is truely juvenile, especially if anatexis is involved. The presence in primary quartz of primary-appearing fluid and solid inclusions which are compositionally identical to those in secondary quartz associated with mineralization suggests a similar origin for each related to separation and evolution of an aqueous phase from the associated magma.

The orthomagmatic theory of porphyry copper deposit origin is concluded to be in excellent health. Specifically, the San Manuel-Kalamazoo ore deposit is determined to be the end product of dominantly endogenetic magmatic-hydrothermal evolution. A magma relatively rich in Cl^- and copper, but not necessarily in water, was intruded to a depth of roughly one mile from the earth's surface. Cooling and pressure release attendant upon shallow intrusion resulted in separation of an aqueous phase rich in alkali and metal chlorides leached from the magma and crystallizing phases. Barren secondary quartz veins were deposited from the fluids at temperatures approaching 600°C. Thermal equilibriation with the wall rocks occurred during this stage and was relatively rapid. Further cooling to about 425°C and an increase of internal water pressure resulted in boiling of the ore fluids as fracturing and crackling began to open up the system and release the increasing internal water pressure. Commencement of major ore deposition coincided with the onset of fluid boiling at about 425°C, and termination of major ore deposition coincided with the cessation of boiling at about 275°C. Temperatures across the deposit appear to have decreased gradually and continually as the system evolved and to have smoothly transected alteration zone boundaries. A high salinity of the ore fluids appears to have been maintained longer in the potassic than in the outlying alteration zones, perhaps because of the reservoir of Na in the potassic zone feldspar. The initial development of alteration zones was subsequently followed by the encroachment of outer upon central zones. With waning hydrothermal activity and intensity, and the cessation of boiling and important ore mineralization, meteoric waters invaded the system, resulting in propylitization, argillization, and late stage sericitization. This regressive stage of development is marked by the inward invasion of relatively fresh, low temperature fluids and retrogressive encroachment of the propylitic and phyllic alteration zones upon successively inner zones. Placement of the ore shell and alteration zones appears to be more dependent upon chemical and time of reaction factors than upon thermal gradients within any time period.

Suggestions for Exploration

Because high temperature, multi-phase fluid inclusions showing precipitated sulfides and halides of distinct appearance are intimately associated both in space and time with the ore-bearing fluids, while less saline, relatively low temperature fluid inclusions are not, compilation of distribution maps of fluid inclusion types are explorationally valuable. Haloes of distribution of high salinity fluid inclusions appear to present a larger target than either potassic or phyllic alteration, yet are still closely related to the ore zone. Petrographic study of thin section traverses can be made at minimal cost and does not require a heating stage. High salinities of fluids at some point might also be indicated by the presence of rocks with anomalously high chlorine contents as determined by chemical analysis. On the basis of preliminary information, positive selenium anomalies and negative strontium and rubidium anomalies may be explorationally useful tools.