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Comparative Anatomy of Epithermal Precious- and

Base-Metal Districts Hosted by Volcanic Rocks:

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by

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Abstract[1]

In order to distinguish dissimilar from similar features of epithermal districts, lithotectonic, mineralogical and geochemical traits are compiled for 15 such districts. The districts occur in structurally complex settings associated with silicic to intermediate volcanics. Affiliation with subduction environments on a continental scale and caldera settings on a regional scale is common but is not demonstrable for all districts. Most deposits formed near the end of major volcanism, but some formed considerably later. Paleodepth to the top of the ore is 300-600m for most districts, although Au-rich districts appear to be shallower. The lateral extent of the ore zone is highly variable and far exceeds the limited vertical range (300-800m). Most ore was deposited from dominantly meteoric fluids ranging in temperature from 220°-290°C. Salinities ranged from 0-13 wt % NaCl equiv., and typical values were 1-3 wt %. Although noted for eight deposits, boiling is clearly associated with precious-metal deposition in only two deposits. Four districts, typified by Goldfield, Nev., are characterized by a highly sulfidized mineral assemblage, advanced argillic alteration, and ore deposition closely following emplacement of the host rock. The remaining eleven districts highlight a second, discrete type of deposit. They contain adularia, exhibit sericitic ± argillic alteration, and were mineralized significantly after emplacement of the host rock. The latter category includes two subgroups: Ag- and base-metal-rich deposits (e.g., Creede, Colo.), and Au-rich, base-metal-poor deposits (e.g., Round Mtn., Nev.).

[1] Slides are at times slightly out of sequence because some color slides
have been grouped together to reduce the reproduction cost to the public.

The data I am presenting are based on a detailed study of the
characteristics of fifteen Tertiary epithermal precious- and base-metal
districts hosted primarily by volcanic rocks. This slide (slide 1) from
Roger Ashley shows the inspiration for this kind of study. It shows high-
grade gold ore on silicified wall rock from Goldfield, Nevada. My coauthors
and I have compared and contrasted the mineralogical, lithotectonic, and
geochemical characteristics of these districts in order to identify unifying
and discriminating themes through which models can be evaluated. We began
the study with hopes of looking at 40 districts of assorted ages and geographic
locations, but it very soon became apparent that this number was unrealistic.
Not only are data limited with respect to separating observation from
interpretation, much data is nonexistent or unavailable. So we limited
this initial study to fifteen districts (slide 2) associated with Tertiary
volcanic rocks. We view these data as a base to which additional near-
surface precious-metal districts can and should be integrated as time and
availability of data permit.

This slide (slide 2) shows the locations of the districts we studied.
These specific fifteen were selected because they are typical, and in some
cases, classic examples of near-surface, low-temperature ore deposits.
Also critical was the existence and accessibility of published geological
and geochemical data. Two of the districts are located in Peru, two in
Mexico and the remaining 11 in the western United States. We have done an
intensive field and laboratory study of the Creede district, Colorado and
have gathered information on the other districts through study of the literature
and personal communications with geologists who have worked in the districts.

Some districts which have been excluded merit a comment in passing.
We have for now excluded districts in which telluride ores are dominant (e.g.,
Cripple Creek) because we think these may be a distinctive class of their
own, and that documentation should be a subsequent stage in this study.
Districts such as Park City, Utah, Providencia, Mexico, and Carlin, Nevada,
were excluded on this round because they are primarily hosted by sediments.
Undoubtedly, many of the ore-forming processes in these sediment-hosted gold
deposits will be the same as for epithermal volcanic-hosted deposits;
studies are needed to evaluate the specific influence of the chemical and
physical parameters of different host rocks on these near-surface hydrothermal
systems.

Based on the 15 epithermal districts studied, we have identified 2
major groups (slide 3), those which contain a highly sulfidized mineral
assemblage and those which contain a less highly sulfidized mineral assemblage.
Each of these groups contain a gold-rich and a silver-rich subset. For
the highly sulfidized group, coded in warm colors, Julcani, Peru (in yellow)
is representative of the Ag-rich member and Goldfield, Nevada (in red),
the Au-rich. For the less sulfidized group, coded in cool colors, Creede,
Colorado (in green) is the Ag-rich example and Round Mountain, Nevada (in
blue) represents the Au-rich member. There appears to be a further breakdown
of the Ag-rich less sulfidized group on the basis of higher and lower
base-metal production, exemplified by Colqui, Peru and Tonopah, Nevada.
However, because additional documentation is limited for this distinction,
I will only be making brief mention of it.

The next slide shows some of these groupings with respect to production value (slide 4). This figure was prepared by taking available production figures and converting them to their dollar value using 1973 prices. Dollar value is plotted here; the normalizing numbers used are in the upper right hand corner. This figure is really two figures - one showing Ag-Au-(Pb-Zn) ternary diagram and the other showing a Ag-Cu-(Pb+Zn) ternary diagram. Districts for which the copper production reported is insignificant have not been plotted on the Ag-Cu-(Pb+Zn) ternary diagram. I believe these data are qualitatively significant in spite of numerous limitations of the figure. The Ag and Au production numbers should be pretty reliable; however, the base-metal numbers are much less reliable because many companies were not and are not interested in the less valuable base metals and so often did not report them. Also, readily available production data for five of the districts is only for a limited number of years. 1973 metal prices were chosen because they are prior to the wild fluctuations in precious-metal prices; using values from other years, however, does not significantly change the distribution of districts in the figure. The highly sulfidized districts, in red (Goldfield, Nev. and Summitville, Col.) and yellow (Julcani, Peru and Red Mtn., Col.), are all uniquely higher in copper. The gold-rich districts of both the highly sulfidized group (in red) (Goldfield, Nev. and Summitville, Col.) and the less sulfidized group (in blue) (Oatman and Round Mtn.) are well separated from all the Ag-rich districts. Amongst the silver-rich districts, there is a distinctive high base-metal group (Red Mtn., Lake City, and Eureka, Col., and Colqui, Peru). Lake City, Col. is shown in green and yellow because it contains two mineral assemblages, discrete in space and in time, which appear to fall into two different categories.

The areal size range of the 15 districts we looked at is large, from roughly 4 to 200 square km. The lateral extent of each district far exceeds the vertical extent, which is on the order of 200-1000 meters. So these districts are geometrically like pancakes. In general, areal size and production size of a district do not appear to have a linear relationship. This slide (slide 5) shows the mineralized veins in red at Guanajuato, Mexico and the productive zone at Tonopah, Nevada, outlined in red dots. Both districts are shown at the same scale. Guanajuato is obviously many many square kilometers larger than Tonopah but has only produced about five times in value what Tonopah has produced, as indicated by the relative areas of the circles.

One of the most critical distinctions among the epithermal districts we have evaluated is the mineralogy (slide 6). Unique to the highly sulfidized group, shown in red and yellow, is the occurrence of enargite (slide 7). Enargite is not present in any of the other districts, shown in blue and green. Advanced argillic alteration, which is characterized by extreme base leaching is also unique to these districts, in red and yellow. The minerals alunite and kaolinite, which are typical of this kind of alteration, are common within all these districts. Dickite and zunyite (also typifying advanced argillic alteration) are present at Red Mtn., Col. Very minor zunyite has also been reported in the Sunnyside mine, Eureka district which was surprising to us, because there are no other indications of advanced argillic alteration. Primary alunite is not

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found in any of the other districts we looked at, although secondary alunite is present at Creede, Col. and Round Mtn., Nev.

Within the less sulfidized group of districts, shown in blue and green, Oatman, Ariz., and Round Mtn., Nev., in blue, are distinctive because they contain major native gold and silver and only rare base metals. In fact the native gold and silver are the only minerals of economic importance in these districts. The green subdivision shows districts containing not only native gold and silver, but also numerous sulfosalts, especially the tetrahedrite-tennatite series and also silver and gold selenides in those districts with fewer base metals. Base-metal bearing minerals, such as sphalerite, galena, and chalcopyrite, are common and form a major constituent of the veins at Colqui, Pachuca, Eureka, Creede and the earlier deposits of Lake City. With respect to gangue minerals, the presence of potassium feldspar, often identified as adularia, is characteristic of the green and the blue group--that is, all the less sulfidized districts--although it has not been identified at Colqui. Adularia is notably absent from any districts of the highly sulfidized group.

Quartz and pyrite are the only minerals that occur in all the districts we examined. Barite is present in most of the districts but is notably absent from the high-Au, less-sulfidized group, in blue. Fluorite and some variety of carbonate occur in many of the districts in all the color subsets. Hematite is invariably the iron-oxide stable in the veins, occurring in almost all the districts; in a few, it has been identified as secondary. Sericite and/or illite or illite-smectite mixed-layer clays have been identified in all the districts except Round Mtn., Nev.

The temporal and spatial variations in mineral assemblages in a district are fingerprints of the evolution of the ore fluid. These variations should provide insights into important variations in ore-depositing processes which result in differences among epithermal precious-metal districts. Unfortunately, detailed documentation of the temporal and spatial variations is often lacking, and generalizations are difficult to support. Even when a good paragenetic sequence is defined, it often can be applied only to one or two localities within a district, so much paragenetic data must be used with caution. In general, precious metals do occur later than most base metals in many of the districts we have studied (slide 8) (e.g. Guanajuato, Mexico and the Sunnyside mine, Eureka district, Col.). However, there is really no clear cut rule. At Creede, Col. and Colqui, Peru, for example, precious-metal deposition took place earlier than much of the base-metal deposition. This doubly polished thin section from the Creede district (slide 9) shows the early, relatively fine-grained generation of sphalerite, galena and silver-bearing tetrahedrite overlain by a coarse-grained sphalerite generation which is barren of silver. Of course, there is a real problem if there have been multiple mineral depositing systems such as at Lake City, Col. Although the precious metals appear to have been deposited late in the paragenetic sequence at Lake City, Slack in 1980 has also suggested that the precious-metal ores could have been an early part of a second distinctive ore-depositing system.

With respect to vertical spatial zonation, amounts of base metal tend to increase in depth in many of the districts, although this is well documented

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in only a few of the 15 districts (e.g. Creede, Guanajuato). Gold and silver tend to be more abundant higher in the districts as compared with the base-metal distribution (e.g. Summitville, Goldfield).

Lateral spatial zonation in mineralogy is consistently distinctive with respect to alteration assemblages. Few generalizations can be made with respect to ore mineral distribution although several deposits display a lateral zonation of silver and base-metals (i.e., Colqui). With respect to alteration (slide 10), the most intense alteration is, of course, closest to the vein structures. In the case of the highly sulfidized group of districts, silicification occurs nearest to the vein, surrounded by advanced argillic alteration. This zone is surrounded by a zone of argillic alteration, which is characterized by clay minerals such as montmorillonite and kaolinite. Sericitic alteration (which denotes the presence of mica type minerals like illite) sometimes occurs within this argillic zone. Further outward, this alteration grades into a pre-ore regional propylitic alteration. For the less highly sulfidized group of districts, silicic alteration, often with K-feldspar present, occurs closest to the vein. This grades outward into sericitic alteration. Further from the veins, argillic alteration may be present enclosed by regional propylitic alteration. I have noted the possible presence of mixed-layer clays within the sericitic zone because sericite is such a broad field term and, at least in the case of Creede, Col., the supposed sericitic alteration is actually mixed-layer illite-smectite. In the case of Creede, the pre-ore regional alteration was K-metasomatism, which may have precluded propylitic alteration or may have been a substitute for it. This issue deserves further studies.

Lithotectonic setting does not appear to provide a useful means of distinguishing among the 15 epithermal districts we examined. The host rocks for these districts are rhyolitic to andesitic in composition (slide 11). The specific composition of the host rock appears to be important only in that it reflects that shallow precious-metal-bearing hydrothermal systems commonly develop in silicic, calc-alkalic volcanic environments. A rock unit of one composition frequently hosts all the ore, which probably mainly reflects the permeability of the unit and a fortuitous location. Among the 15 districts we looked at, rhyodacite is the most typical host rock.

In general, ore deposition took place close to the end of volcanism in the district (slide 12). For 10 of the 15 districts in this study, there was no volcanism or very minor volcanism subsequent to ore deposition. This timing could suggest that only when the magmatic system has waned can an ore-bearing hydrothermal system maintain itself long enough, and at the appropriate low temperatures, to form a significant ore deposit. On the other hand, deposits from hydrothermal systems which may have developed earlier in the volcanic cycle may be less common because they have less likelihood of preservation due to continued explosive volcanic activity.

The structural setting is not a determinant for distinguishing among the epithermal precious-metal districts evaluated. For example, the most common setting in our study is the caldera (slide 13), and both the highly sulfidized group (red) and the less sulfidized group (green and blue) occur within that setting. Both groups also occur in areas of silicic dome

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development, exemplified by a more highly sulfidized district, Julcani, and a less sulfidized district, Silver City, Idaho. I do not want to overemphasize the importance of the caldera setting, because as Ed McKee pointed out in 1979 in Nevada, not all calderas, indeed, relatively few percentage-wise, appear to have been mineralized. Jim Rytuba in 1981 also documented the lack of known mineralization associated with most calderas in the western United States. This slide (slide 14), taken from Steven and Eaton's 1975 paper, shows the calderas developed in the San Juan Mtns. of Colorado. Only 1/3 of them have associated economic mineralization, as indicated by the stippled pattern. Pete Lipman, Tom Steven and co-authors in 1976 noted that the role of the calderas with respect to mineralization in the San Juan Mtns. was one of formation of zones of weakness above a magma chamber. The point really is that calderas can and do provide an excellent plumbing system for ore-depositing hydrothermal systems when they do develop. The ores at Goldfield, Nevada, for example are approximately 8 m.y. younger than the caldera along whose ring fracture they occur.

Where we do see a consistent distinction among the epithermal districts we have examined is in the relative timing of emplacement of the host rock and of ore deposition (slide 15). Deposition of the more highly sulfidized ores such as at Goldfield and Julcani appear to have very closely followed emplacement of the host rock. The genesis of the host rock and of the ore-bearing hydrothermal system appears therefore to be related for the more highly sulfidized group. In contrast, deposition of the less sulfidized ores, exemplified by Creede, Colorado, usually took place more than 1 m.y. subsequent to the formation of the host rock. In the Eureka district, Colorado, the time gap is as long as 10 to 15 m.y. Ambiguities in some districts remain as indicated by the less than 1 m.y. category; two less sulfidized districts, Silver City and Round Mtn., have times of mineralization and of host emplacement differing by about 1/2 m.y., but there is overlap in the dates if analytical uncertainty is taken into account.

The geochemical parameters of the ore fluid as determined mainly through isotopic and fluid inclusion studies[1] are fairly similar between the highly sulfidized and less sulfidized groups. Among the fifteen districts, three very detailed oxygen and deuterium isotope studies and five limited studies have been done. The studies suggest that the ore-bearing fluids were made up dominantly of meteoric water. This does not preclude the presence of a magmatic component of 5 or 10%. Some evidence does exist for this magmatic component. This slide (slide 16), for the Creede district, Col., is an oxygen/deuterium diagram and includes the meteoric water line and the box where waters of deep seated origin are conventionally believed to fall. The circles represent samples for which both $\delta^{18}O$ and δD have been determined; the triangles are samples for which only $\delta^{18}O$ have been determined. The early rhodochrosite (yellow) appears to have had a deep-seated, possibly magmatic origin, although the sphalerite (red), quartz (green) and alteration minerals (blue) have meteoric water signatures.

[1] The compiled geochemical data for the fifteen districts is available in USGS open-file report 83-450.

Temperatures of mineral deposition (slide 17) range from about 140°C to 325°C but during metal bearing stages typically range between 230° and 270°C. Late-stage, cooler, metal-poor fluids typically deposited minerals at temperatures between 200° and 140°C. Salinities range from near 0 to 13 wt. % NaCl equiv., with typical values close to 1 to 3 and 6 to 8 wt. % NaCl equiv. This slide (slide 18) shows the temperatures and salinities determined from fluid inclusions plotted against paragenetic sequence for the Colqui district, Peru, from a paper by Kamilli and Ohmoto in 1977. It shows the typical temperature range from early temperatures close to 300°C down to 140°C late in the evolution of the system. The salinity range is from 0 to 12 equiv. wt. % NaCl and is clearly bimodal in nature. Recent work by Foley, Bethke and Rye (1982) in the Creede district Col., where the salinities have a similar bimodal nature, shows that the lower salinity waters for Creede come from pseudosecondary inclusions resulting from periodic flushings of the system with barren groundwaters. Therefore, the ore-depositing fluids at Creede are those with the higher salinity, averaging between 4 and 8 equiv. wt. % NaCl. The bubbles in slide 18 represent boiling, which in the case of Colqui, occurred during precious-metal deposition as shown by the "$" sign. Boiling certainly is an effective mechanism for depositing ores. However, boiling unequivocally associated with precious-metal deposition has been demonstrated for only two of the fifteen districts. Precious-metal deposition due to boiling has been proposed for other districts based on less definitive evidence (Guanajuato, Tonopah). It remains to be seen whether it is always a requirement for precious-metal deposition. Of course, the common fine-grained nature of many epithermal precious metal ores makes documentation of boiling difficult. Boiling also has been noted at numerous deposits during times other than precious metal deposition (slide 19), as at the Sunnyside mine in the Eureka district, in the later barren stage. This suggests that caution should be used when applying evidence for boiling as an indicator of precious-metal deposition.

This slide (slide 20) shows paleodepths to the top of the ore, estimated either from a geologic reconstruction of the area (shown by the solid circles) and/or from pressure-temperature-composition conditions determined from fluid inclusion studies (shown by the open circles). Both methods have considerable uncertainties. Depth-pressure estimates based on fluid inclusion studies require assumptions with respect to the pressure-controlling medium (i.e., hydrostatic or lithostatic); in addition, pressure estimates from fluid inclusions could be too low if small amounts of CO_2 or other noncondensible gases are present. Bodnar and Kuehn (pers. comm., 1982) have shown that small amounts of CO_2 typically would not be visible in fluid inclusions or detected by freezing studies. Most deposits formed at depths between 300 and 600 meters. Colqui, and possibly the Sunnyside mine, Eureka district and Red Mtn. are thought to have formed deeper. At the Sunnyside mine, Eureka, the deeper value is for the first five stages and the shallow value is for the final, sixth stage. Casedevall and Ohmoto (1977) proposed that this large change in paleodepth to the top of the ore may have been due to extensive erosion--although 1000 meters is a little eyebrow raising. Another possibility that they recognized is that pressure conditions may have changed from lithostatic to hydrostatic. This kind of geologic dilemma in the data is just one of many which still need to be addressed for epithermal districts. The most gold-rich districts - the

less sulfidized Oatman and Round Mountain districts (in blue) and the more highly sulfidized Summitville and Goldfield districts (in red) - appear to have formed generally at shallower depths, usually less than 300 meters. Round Mtn. may have formed as shallow as 50 meters and sinters are still preserved there. Delamar is the only apparently shallow silver-rich district, for which I have no explanation. Most of these shallow values are based on geologic reconstruction estimates which have large uncertainties. Fluid inclusion studies would help to document these shallow paleodepths better.

In summary, these 15 epithermal districts studied have some similar (slide 21) and some distinctive characteristics (slide 22). They occur in similar petrotectonic settings (although, of course, one of the selection criteria was a volcanic host), have similar temperature and salinity ranges, have similar vertical ranges of ore, have fairly similar calculated paleodepths to the top of the ore, and were deposited from dominantly meteoric waters. Other unique characteristics distinguish a highly sulfidized group and a less sulfidized group, each with gold-rich and silver-rich members. The highly sulfidized group is distinctive with respect to the higher sulfur vein-mineral assemblage, typified by enargite, the presence of advanced argillic alteration, the close timing of ore deposition and emplacement of host rock and noteworthy Cu production. The less sulfidized group has, obviously, a lower sulfur vein-mineral assemblage; enargite is absent and tetrahedrite is the common Ag-bearing sulfosalt. Alteration in this less sulfidized group is typified by sericitic and argillic alteration, and adularia is a stable vein mineral; primary alunite is absent. Ore deposition took place considerably later than emplacement of the host rock, and Cu production is low.

Not surprisingly, this study raises more questions than it answers. For example, why are some hydrothermal systems richer in sulfur? Does the more recent emplacement of the host rock in the history of the ore deposit permit a higher magmatic component, resulting in more sulfur? Why do some late intrusions into the ring fractures of calderas develop associated ore-bearing hydrothermal systems while other apparently identical intrusions do not? If 220 to 290°C is an optimum temperature range for ore deposition, how do such fluids get to within 50 meters of the surface (i.e., Round Mtn.)? And just how critical is boiling for the deposition of precious metals. Need I say more than "more work is indicated" except to add that a critical part of the search for answers is to seek the right questions to ask and this can be accomplished by looking in depth at the facts that we already have.

References

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SLIDE 1

Ag RICH
ie JULCANI, PERU

Au RICH
ie GOLDFIELD, NV

HIGHLY
SULFIDIZED

HIGHER BASE METALS
ie COLQUI, PERU

LOWER BASE METALS
ie TONOPAH, NV

LESS HIGHLY
SULFIDIZED

Au RICH
ie ROUND MTN, NV
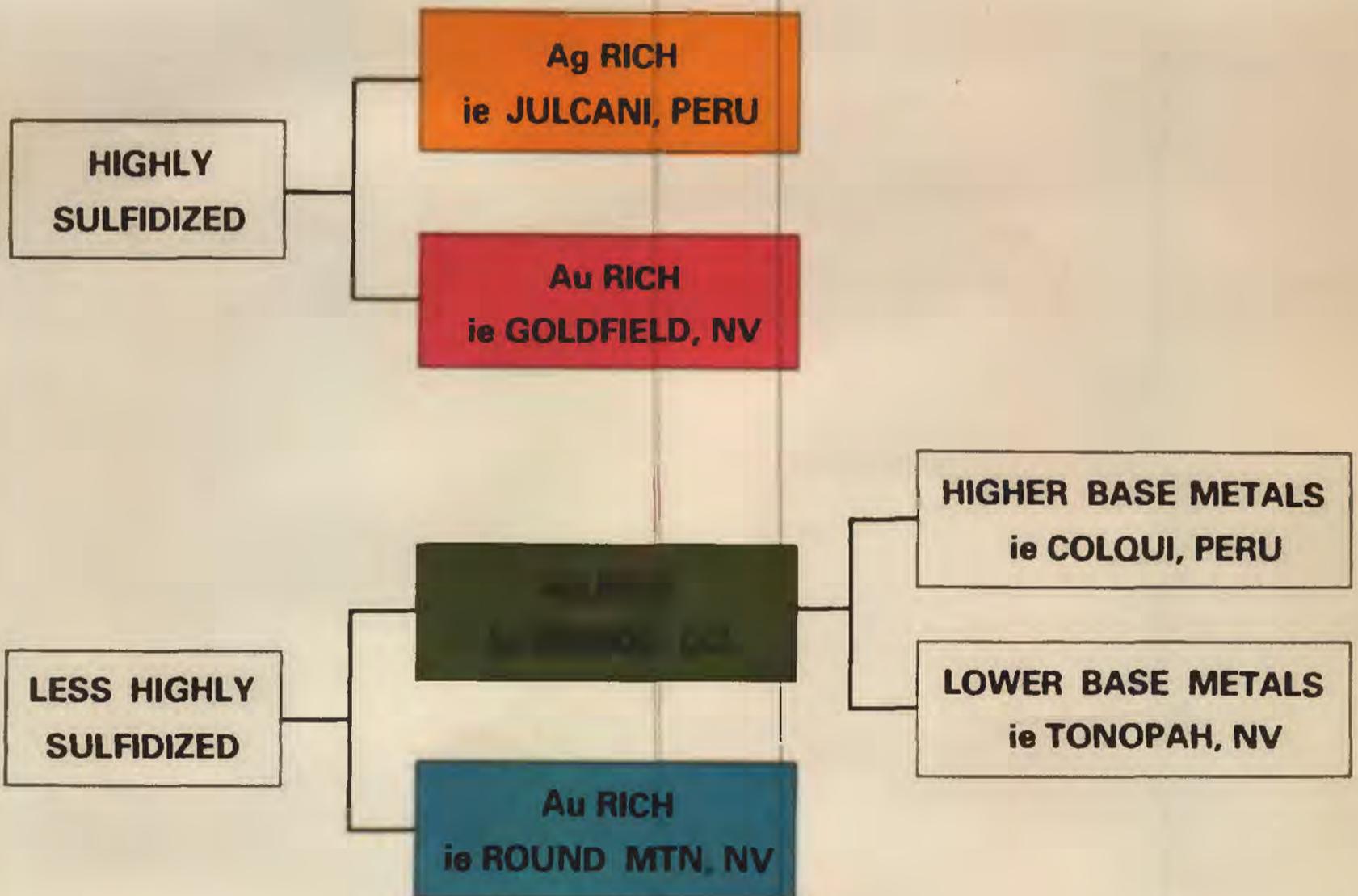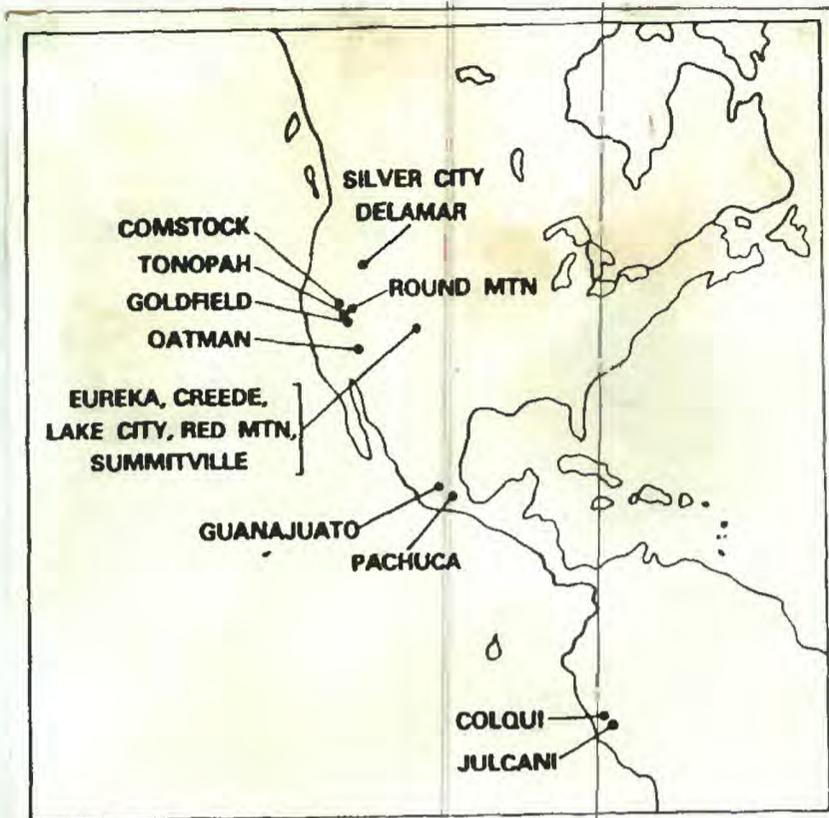
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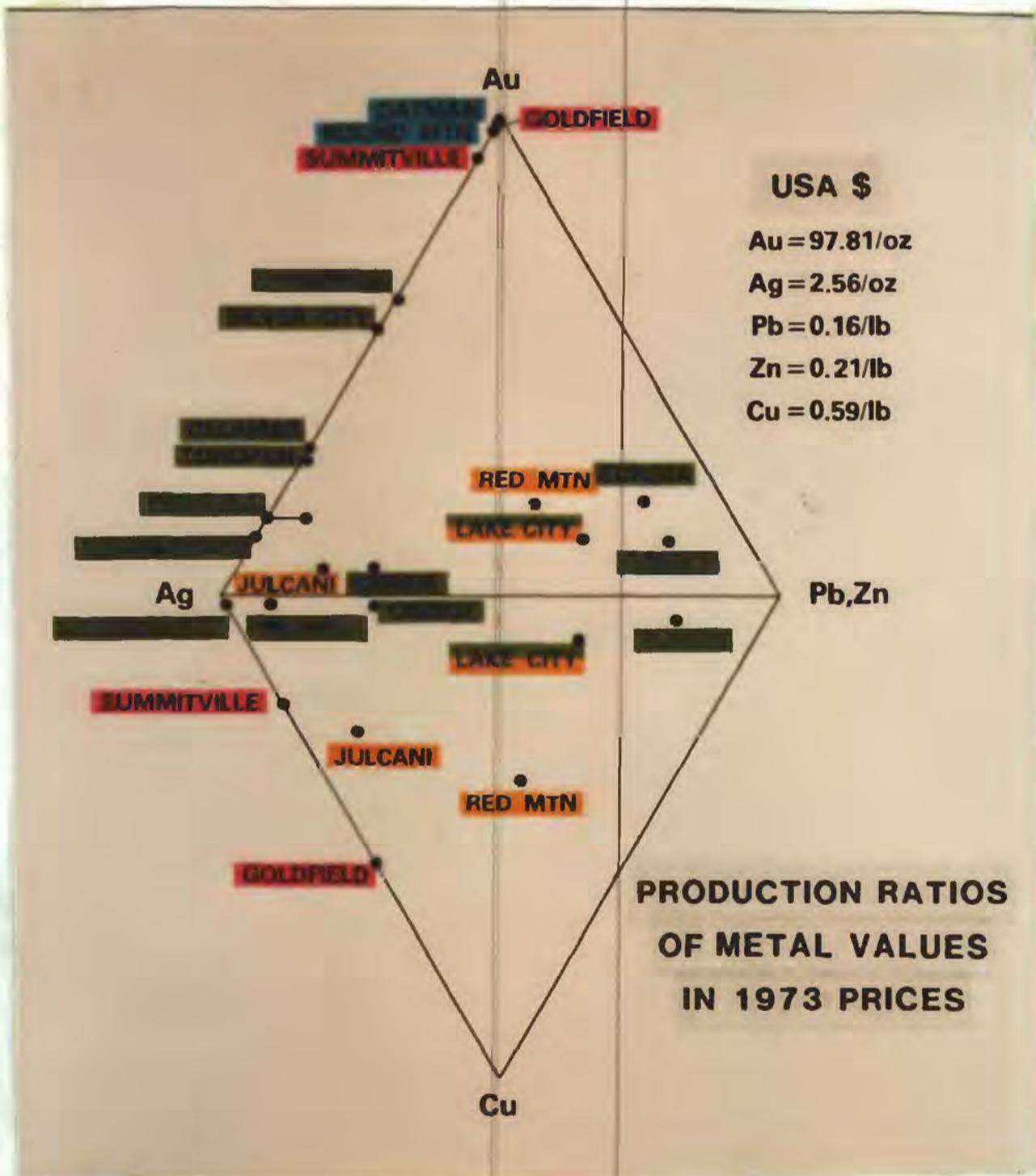
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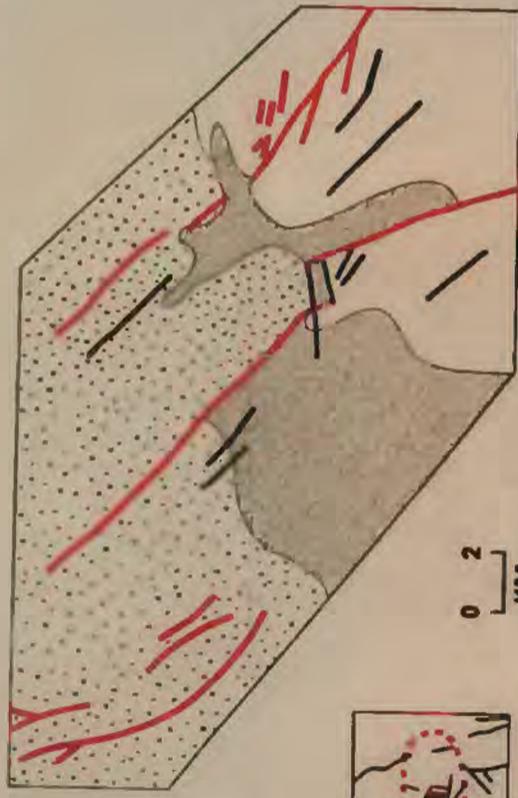
SLIDE 4

SLIDE 9

TONOPAH, NV
(AFTER SPURR, 1905;
NOLAN, 1935)

GUANAJUATO, MEX
(FROM GROSS, 1975)

0   2
KM

RELATIVE PRODUCTION
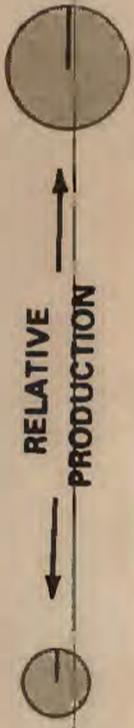
SLIDE 5

ENARGITE
HYPOGENE ALUNITE
MAJOR KAOLINITE

GOLDFIELD, NV
SUMMITVILLE, CO

RED MTN, CO
JULCANI, PERU
LAKE CITY (II), CO

MAJOR
Au° AND Ag°

OATMAN, AZ
ROUND MTN, NV

ADULARIA
Au°, Ag°, AND
BASE METALS

SLIDE 7

MINERALOGY

LITHOTECTONIC SETTING
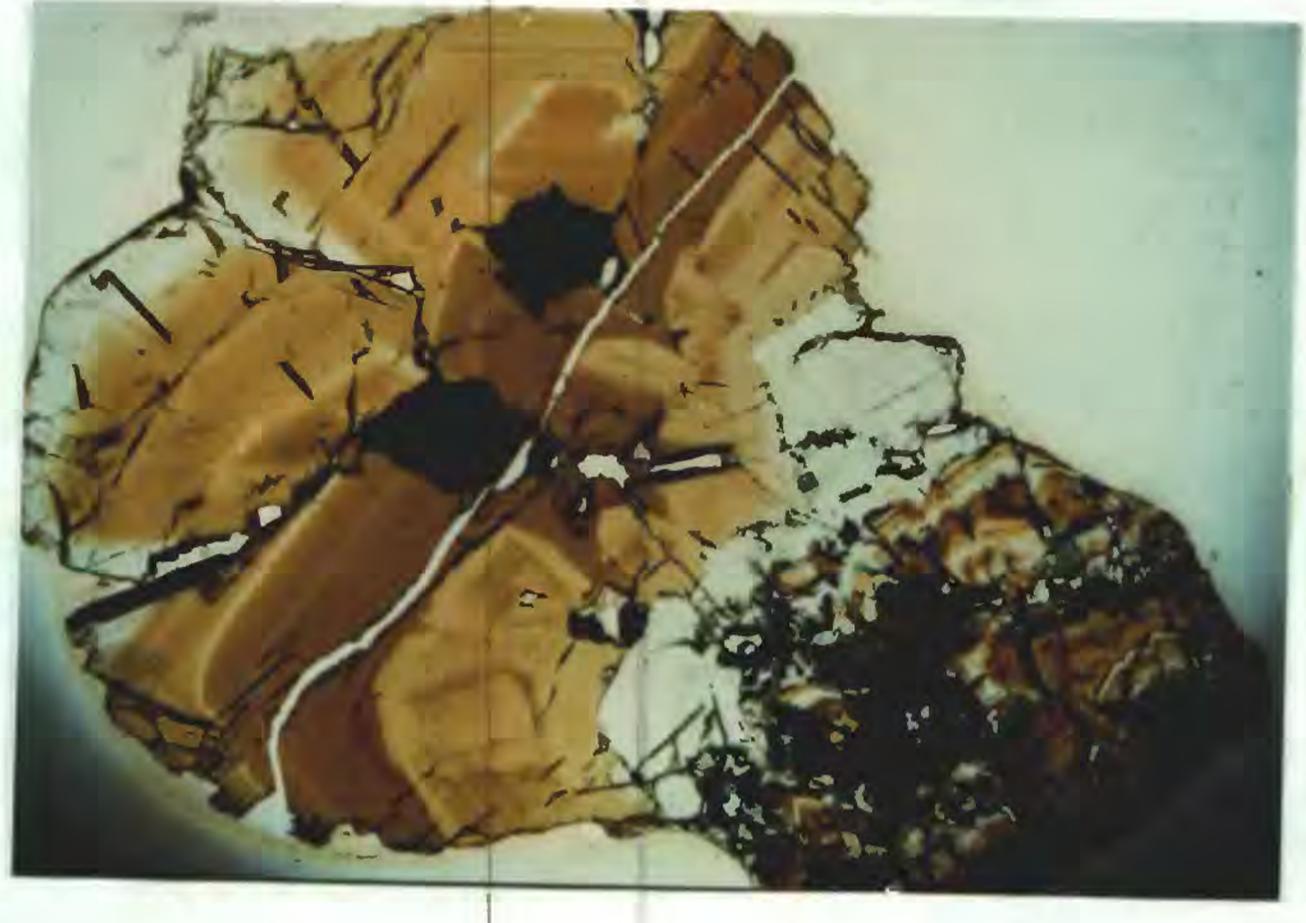
GEOCHEMISTRY

SLIDE 6

PARAGENETIC POSITION
OF PRECIOUS METALS

LATE :   ROUND MTN

GUANAJUATO, MEX

EUREKA, CO

LAKE CITY, CO

SUMMITVILLE, CO

EARLY :   CREEDE, CO

COLQUI, PERU

SLIDE 8

HIGHLY SULFIDIZED

SILICIC
↓
ADVANCED ARGILLIC
↓
ARGILLIC ± SERICITIC
↓
REGIONAL PROPYLITIC

LESS   SULFIDIZED

SILICIC ± ADULARIA
↓
SERICITIC (± MIXED-LAYER CLAY)
↓
± ARGILLIC
↓
± REGIONAL PROPYLITIC

SLIDE 10

SLIDE 11

HOST ROCK	DISTRICTS	EXAMPLE
RHYOLITE	2	CREEDE, CO
RHYODACITE	5	GOLDFIELD, NV
LATITE	1	OATMAN, AZ
ANDESITE	2	TONOPAH, NV
FELSIC TO INTERMED. VOLCS.	5	PACHUCA, MEX
VOLCS. AND SEDS.	2	GUANAJUATO, MEX

SLIDE 12

VOLC. SUBSEQUENT TO ORE DEPOSITION	DISTRICTS	EXAMPLE
NONE	6	CREEDE, CO
BAS. ± RHY.	4	GOLDFIELD, NV
ANDES. ± BAS.	3	JULCANI, PERU
BAS., ANDES., RHY.	1	TONOPAH, NV
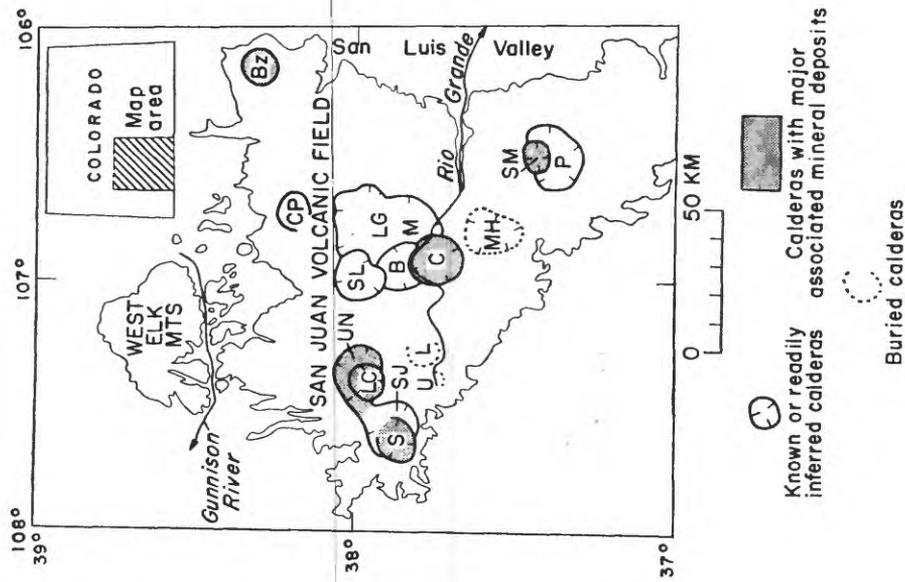
SLIDE 14

TECTONIC SETTING	DISTRICTS	EXAMPLE
CALDERA	6(+3?)	GOLDFIELD, NV
		CREEDE CO
		7 ROUND MTN, NV
SILICIC DOMES	2	JULCANI, PERU
		SILVER CITY, ID
EXTRUSIVE CENTER	1	COMSTOCK, NV
FOLDS AND FAULTS	1	GOLDJU, PERU

RELATIVE TIMING OF
DEPOSITION OF HOST ROCK AND ORE

TIME RELATIONS	DISTRICTS	EXAMPLE
VERY CLOSE TIMING	4	GOLDFIELD, NV
		JULCANI, PERU
< 1 MY	2	SILVER CITY, ID
		ROUND MTN, NV
> 1 MY	5	CREEDE CO

EXPLANATION

SPHALERITE FIELD
ALTERATION-MINERAL FIELD
CARBONATE FIELD
QUARTZ FIELD • PRIMARY + PSEUDOSEC
• $\delta^{18}O$ AND δD DETERMINED
▼ ONLY $\delta^{18}O$ DETERMINED
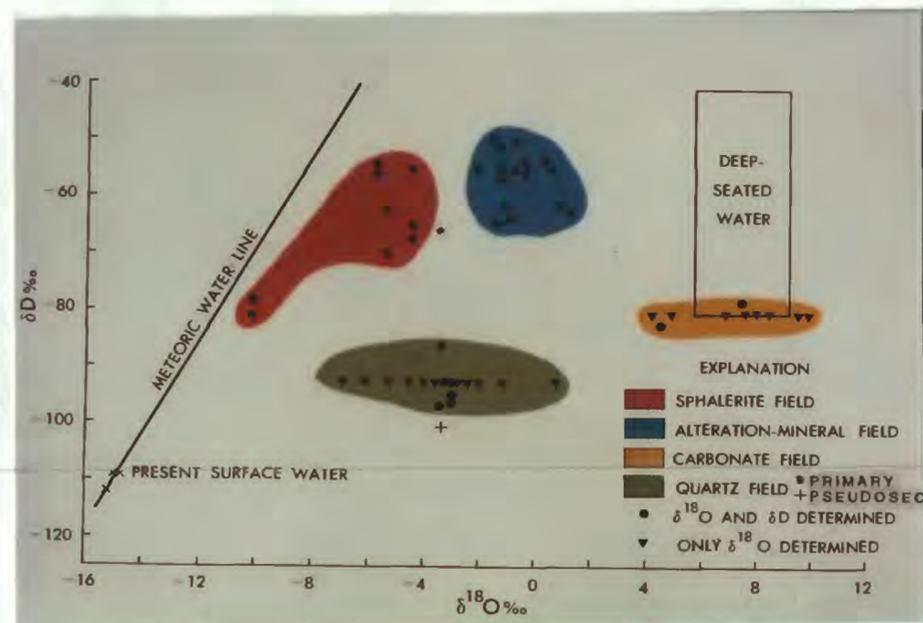
	OVERALL RANGE	TYPICAL RANGE DURING PRECIOUS-METAL DEPOSITION
TEMPERATURE (°C)	140°-325°	230°-270°
SALINITY (EQ. WT. % NaCl)	0-13	1-3 6-8

SLIDE 17

TEMP. (°C)
300
200
120

SALINITY (EQ. WT. % NaCl)
8
4
0

I II III IV V VI VII

COLQUI, PERU

SLIDE 18

TEMP. (°C)
300
200
120

SALINITY (EQ. WT. % NaCl)
8
4
0

I II III IV V VI

SUNNYSIDE MINE EUREKA, CO
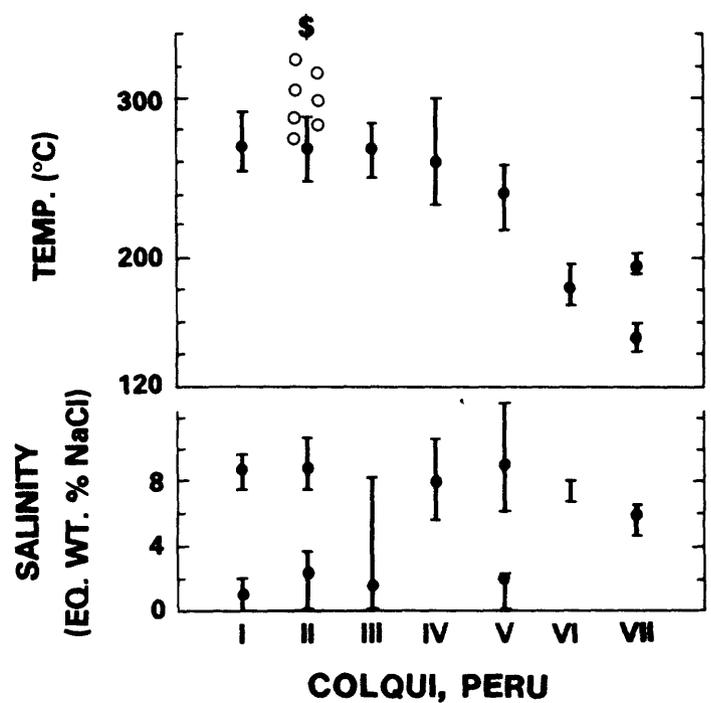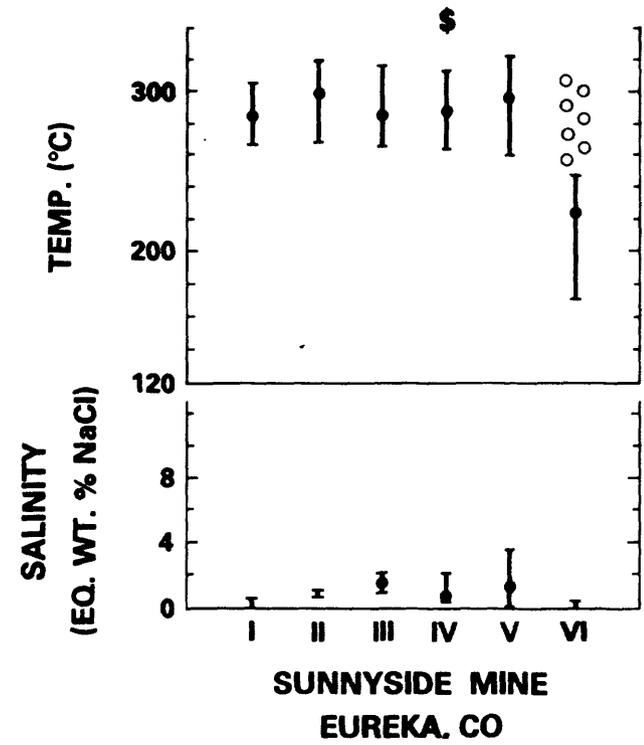
## SLIDE 19
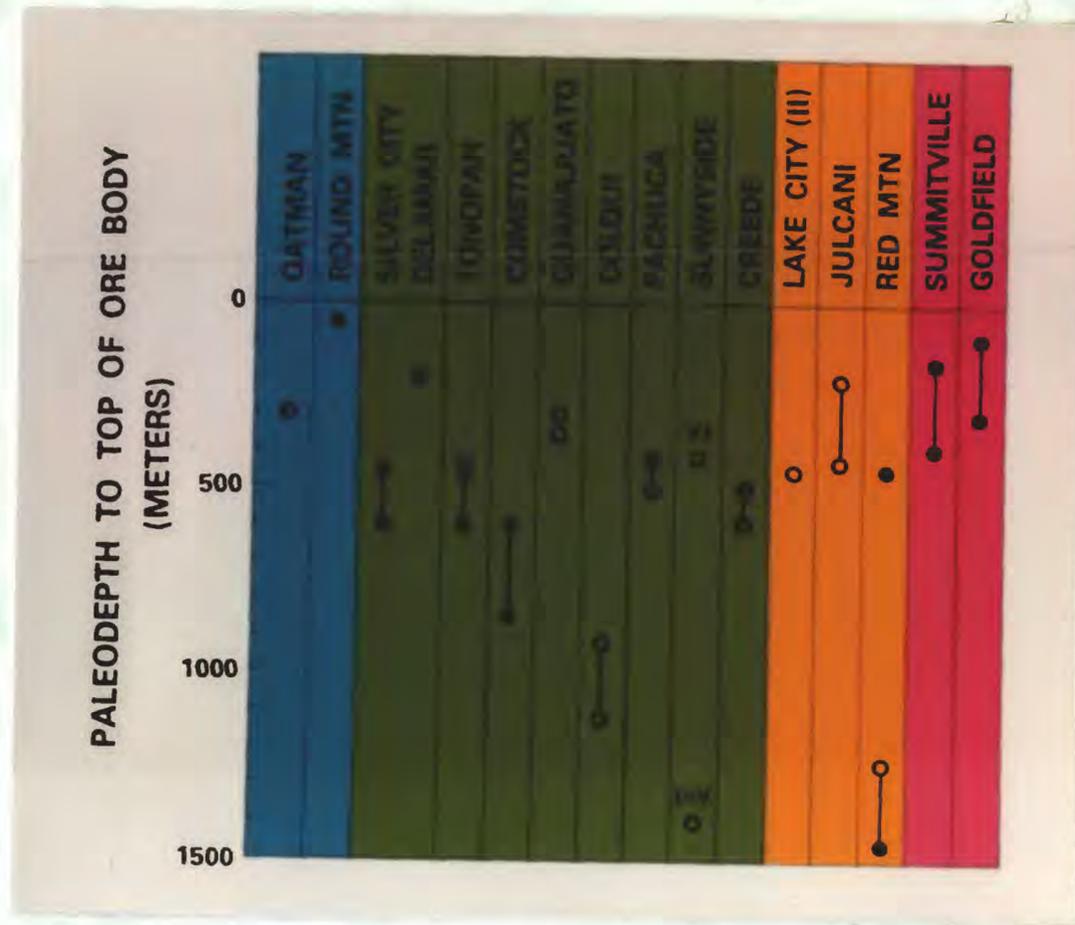
SLIDE 20

SIMILAR CHARACTERISTICS

- LITHOTECTONIC SETTING
- TEMPERATURE RANGE
- SALINITY RANGE
- VERTICAL RANGE OF ORE
- PALEODEPTH TO TOP OF ORE
- METEORIC WATERS DOMINANT

SLIDE 21

DISTINCTIVE CHARACTERISTICS

HIGHLY SULFIDIZED	LESS SULFIDIZED
ie GOLDFIELD, NV	ie ROUND MTN, NV
ie JULCANI, PERU	ie CREEDE, CO
HIGHER SULFUR MIN. ASS.	LOWER SULFUR MIN. ASS.
ADVANCED ARGILLIC ALT.	SERICITIC–ARGILLIC ALT.
CLOSE AGES OF HOST AND ORE	AGES OF HOST AND ORE DISTINCT
NOTEWORTHY Cu PRODUCTION	LOW Cu PRODUCTION

SLIDE 22