

Short Note

The Milluachaqui Epithermal Silver District of Northern Peru

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The mines in the Milluachaqui district, located near Salpo in the northern part of Peru, show a vertically zoned, epithermal silver-gold mineralization. Colonial production was obtained from oxidized, high-grade ores, consisting mostly of native silver and cerargyrite. More modern development exposed, from the top of ore shoots to their base, the "bonanza" ores (the pyrargyrite-polybasite-acanthite zone), silver-copper ores (the tetrahedrite zone), silver-lead ores (the galena-sphalerite zone), and the basal zone ores (the sphalerite zone). The ratio of gold to silver in the "bonanza" ores was about 1 to 100, by weight. Interpretation of mineralogical textures and the composition of minerals in the sulfide zone suggests that supergene movement and enrichment of silver at Milluachaqui was not a significant factor. Silver tended to be fixed in place during weathering as the chloride and native mineral. The "bonanza" ores are interpreted to be hypogene sulfide accumulations. These findings contrast to hypotheses proposed for some epithermal districts in the U. S. which assume supergene activity to have been significant in the accumulation of high grade, near-surface silver ores.

INTRODUCTION

The Milluachaqui epithermal silver-gold district is noteworthy for its well-developed hypogene vertical metal zoning and for persuasive field evidence against substantial supergene enrichment as a mechanism for the formation of "bonanza" ores. The district lies in the Department of La Libertad, Province of Otuzco, in the northern part of Peru. From all past production, the mines may have produced in the order of 3,000,000 kilograms of silver and 30,000 kilograms of gold. Its two main periods of production were from Colonial oxidized ores (mostly native silver and cerargyrite) and modern (1922 to present) from sulfide ores.

Milluachaqui was studied by the authors in 1954, 1959 and again 1962-63. Ad-

ditional data collected by Mr. Paul Kents were available for this study.

GENERAL GEOLOGY

Regional

The Milluachaqui district lies near a composite diorite-quartz diorite-granodiorite stock dated by Stewart et al. (1974) at 26 m. y. which is intrusive into flat-lying Calipuy andesite formation of Cossio (1964). It is one of a number of young centers of mineralization which occur near the margin of the Calipuy andesite.

The Calipuy formation unconformably overlies folded Upper Cretaceous and older sedimentary rocks on the north and east margins and Coastal batholith rocks dated about 43 and 53 m. y. (Ste-

wart et al., 1974) on the west. Coarse and fine clastic rocks of Cretaceous age underlie the Calipuy at a shallow depth in the vicinity of Milluachaqui and are penetrated by mine workings.

Local

Structure: The veins at Milluachaqui generally trend northwest and dip 45° to vertically. They are fault structures which include a component of left lateral movement. Tectonic voids in the fault trace were filled with vein matter to form the ore shoots. These are separated by heavy fault gouge and breccia where tectonic openings failed to appear. The ore shoots contain mostly quartz with subordinate sulfide and non-quartz gangue minerals in a variety of structure types. A vuggy quartz breccia is commonly well-developed. This may grade into a massive or ribbon vein structure. Sulfide occurs in the quartz breccia ordinarily as a matrix mineral. In the massive veins, it occurs as blebs, pods and disseminations. Sulfide appears as streaks, veinlets and disseminations in the ribbon veins. Mineral textures in the vein suggest that pre- and intro-mineral fault movements provided openings for the filling by vein matter, but that subsequent fault movement crushed or distorted the deposited material in some parts of the veins.

Alteration: Argillization and propylitization of vein walls were the only megascopically noted alteration at Milluachaqui. Argillic alteration, including a "bleaching" of the host rock, most commonly occurs in the vein walls within one meter of the vein. Analytical determinations made by Northern Peru Mining Corp. (J. Caceres, personal communication, 1957) show that clay separates from argillized rock contain large amounts of the alkali metals, but no mineralogic determinations were made. Minor pyrite is also found. The argillized rock includes both Calipuy andesite and Cretaceous marine shale and argillaceous quartzite. Argillization apparently did not alter the walls of the veins in the shale greatly.

Propylitization of the walls is much more widespread. It consists mostly of a pervasive development of chlorite, epidote and calcite. Pyrite is not a significant component of the propylitically altered rock. Propylitization may be hydrothermal, but it may also reflect regional alteration in the volcanic rocks. Argillic altered rock grades into propylitic alteration away from the vein, but the propylitic assemblage is most easily discerned where the walls are andesitic.

Hypogene Mineralization: Quartz predominates as vein filling throughout the district. Other gangue minerals identified in various parts of the district include subordinate barite, calcite, rhodochrosite, gypsum and fluorite. Sulfide minerals ubiquitously scattered through the veins in minor amounts include pyrite, lesser marcasite and rare arsenopyrite. No other sulfide has been found that occurs throughout the veins in all metal zones. Neither pyrite nor marcasite makes up more than 10% of any vein, and they may be less than 5% by volume.

Gold was important economically, and direct shipments of crude "bonanza" ore sometimes contained 30 to 50 oz per ton. Although accurate figures are not available, it appeared that the gold to silver ratio may have been in the order of 1 to 100, by weight; or nearly 1 to 2 in gross value. The ratio probably remained constant for "bonanza" ores whether they were oxidized or sulfide. The Au:Ag ratio appears to have decreased slightly with depth, and even in the principal mine, La Guardia, values in both elements nearly disappear in the lowest levels. The economic minerals are gold and sulfides or sulfosalts of silver, copper, lead and zinc. These are arranged in a zonal pattern with, from the top down, pyrargyrite dominant, tetrahedrite dominant, galena dominant and zinc dominant mixtures. Each zone grades one into another vertically. The zones have economic significance because the pyrargyrite and tetrahedrite zones have provided most of the past production. Silver content drops erratically but sharply from zone to zone as depth is gained.

Mineralization occurs along the vein structures for thousands of meters on strike, but it is a shallow phenomenon. Little sulfide mineralization extended more than 400 meters below the present surface. The telescoped nature of the zoning suggest dumping by boiling. Ore textures indicate a simple sulfide paragenesis from the tetrahedrite zone downward. Early pyrite and marcasite was overlapped and succeeded by sphalerite. Sphalerite was in turn overlapped and succeeded by galena. Tetrahedrite followed the galena. Paragenesis above the tetrahedrite zone is confused. Ore texture indicate a simple filling of tectonic openings by sulfides, but vugs lined with silver rich minerals suggest late introduction of this metal.

The pyrargyrite zone is abruptly superimposed on the top of the tetrahedrite zone, and it was intersected by the present erosion surface. Characteristic sulfide mineralogy is pyrargyrite-polybasite-acanthite-pyrite intergrowths, with one or several of these minerals missing from parts of a shoot. Marcasite may occur with the pyrite. Spectacular vug linings of large crystals of silver sulfosalts intergrown with octahedral acanthite suggest original deposition under thermal conditions. The acanthite is interpreted as an inversion of originally deposited argentite. Although the physics and chemistry of the silver-antimony-sulfur systems (Craig and Barton, 1973; Skinner et al., 1972) indicate that the "bonanza" ores could have developed either as hypogene or supergene systems, the presence of acanthite pseudomorphing octahedral argentite (intergrown with polybasite and pyrargyrite) suggests the sulfosalts are hypogene at Milluachaqui.

Tetrahedrite, accompanied by lesser galena and rare chalcopyrite, characterizes metallic ores underlying the "bonanza" ore zone. These ores accounted for most of the district production, and tetrahedrite was volumetrically the most important silver-bearing mineral. Silver:copper ratios vary haphazardly in tetrahedrite from 2 to 126 ounces silver to each one percent copper. The reason for

such a variance in the Ag:Cu ratio was never determined.

As depth is gained, tetrahedrite decreased in importance as a vein constituent, but galena becomes increasingly important. The galena carries an average one ounce silver to each one percent lead, and the galena zone has been exploited if the galena is accompanied by enough other sulfides. Sphalerite commonly is present in minor amounts in the galena zone, as are erratic traces of tetrahedrite.

The galena zone grades downward into a sphalerite dominant zone in which galena is either subordinate or missing. Iron sulfides become proportionately more important.

Supergene Mineralization: Oxidation of the pyrargyrite zone minerals has resulted in native silver-cerargyrite rich mixtures. The richness of these secondary silver mineral accumulations imply little leaching or long distance transport of the silver during weathering. Further evidence against substantial transport of the hypogene silver deposits during weathering may be seen in the leaner ores. Silver present in most oxidized hypogene ores exposed in surface stopes was fixed in place during weathering, and workings below the oxide section showed no enrichment in the sulfide zone over the oxide. The Ipres section is typical of most veins in Milluachaqui in that silver grade does not improve when moving from the weathered to sulfide ores. The secondary minerals do not necessarily form pseudomorphs after sulfides, suggesting partial mobilization of silver during weathering. The probable constancy of the gold-silver ratio in both oxide and sulfide ores also suggests minimal supergene mobilization.

Rarely, however, acanthite may be found coating tetrahedrite or other sulfide close to the oxide-sulfide interface. This mode of occurrence of the Ag_2S is compatible with minor supergene silver mobilization near the oxide-sulfide boundary. The coatings are the latest mineral deposited, and they do not persist into

the sulfide zone more than 10 meters below the oxide zone. The absence of sulfosalts as supergene products coating sulfides with the acanthite further infers these complex minerals are only of hypogene origin.

Supergene copper sulfide coatings are also rarely found near the oxide-sulfide interface. The paucity of such coatings implies negligible transport for copper in supergene conditions.

CONCLUSIONS

Evidence cited above is interpreted to show silver sulfosalts formed entirely as hypogene minerals, and that the silver sulfide largely formed under hypogene conditions. The Ag_2S formed mostly as argentite and inverted to acanthite as heat was lost from the system. Field evidence against large-scale supergene transport of silver is compelling.

Supergene transport of silver has been demonstrated in other districts, however. It seems possible that the presence of reactive wall rock silicates rich in alkali metal bearing clays may have been an inhibiting factor at Milluachaqui. Clays and other loosely-bonded hydrated silicates would have kept the groundwater pH at or near 7. If montmorillonite is an important component of the clay fraction, it is conceivable that hydration by ground water could also have resulted in a volume expansion. Any such tendency would have inhibited access of ground water to the vein sulfides and have lessened the ability of ground water to transport metals. Silver would not have been able to move substantially under these conditions in solutions with dilute anion concentrations.

Abundant chloride ion is available in the fine Cretaceous marine clastics which underlie the district. A dilute concentration of silver ions would quickly be precipitated as chloride because of the probable pervasive presence of chloride ion from this source. Observation of cerargyrite as a dominant secondary mineral in the weathered zone supports such reasoning. Rapid precipitation of silver as chloride during weathering would also have discouraged widespread supergene movement.

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