Stratabound Ore Deposits of Hualgayoc, Cajamarca, Peru

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1 Introduction

Hualgayoc is one of the typical "complex mining districts" of the Central Andes, characterized by the influence of many superimposed geologic events and ore-forming processes.

It has been worked since Spanish colonial times. Initially, Hualgayoc was famous for the silver ores which were extracted principally from the upper parts of the ore deposits. The zones of oxidation and supergene enrichment of many deposits have already been removed by early mining.

With time, the production of the district became more polymetallic (zinc, lead, and copper as well as silver). Many mines are being operated by several small companies and some mining ventures of the "mediana minería". There are up to five flotation plants, with a total capacity of about 800 t/day.

Although this important mining district has been the object of a large number of geologic studies by many geologists, we are far from understanding the origin of many of its ore deposits, especially those of the stratabound type.

The purpose of this chapter is to describe the geologic, mineralogic and geometric characteristics of the stratabound ore deposits of this important district to improve our understanding of the complicated geologic setting of the "mantos".

Hualgayoc is situated in northern Peru, at a height of between 3500 m and 2400 m, near, and on the east zone of the continental divide of the Cordillera Occidental.

2 Geologic Setting

The Hualgayoc District is characterized by the predominance of calcareous sediments (Fig. 1). The Goyllarisquizga Formation is the oldest stratigraphic unit in the zone. It consists of sandstones with minor proportions of interlayered shales and is overlain by a thick calcareous sequence, which is considered, on stratigraphic and paleontologic grounds, to range from lower Albian to Turonian in age. This sedimentary sequence was folded during Tertiary orogenesis into a series of anticlines and synclines (Fig. 1). The folding of the area was accompanied by faulting and fracturing.

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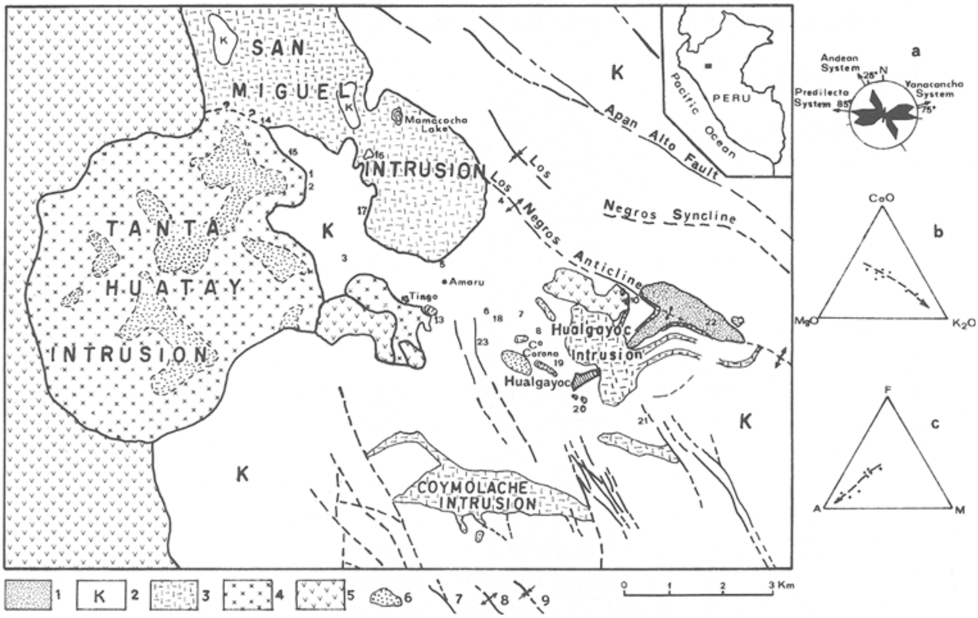


Fig. 1. Simplified geologic map of the Hualgayoc District. Diagrams: **a** Tectonic rosette. **b** CaO-MgO-K_2O diagram showing the magmatic differentiation trend. **c** AFM diagram showing the magmatic differentiation trend. Symbols: *1* Clastic sediments (Aptian); *2* limestones (Albian to Turonian); *3* quartz-diorite porphyry; *4* granodioritic porphyry; *5* volcanic rocks; *6* siliceous outcrops; *7* faults; *8* anticline; *9* syncline. Principal mines: *1* Cleopatra; *2* Tres Mosqueteros; *3* Tres Amigos; *4* Firenze; *5* Bella Unión; *6* Mechero; *7* Porcia, Predilecta; *8* Pozos Ricos; *9* Sta. Marta; *10* Los Negros; *11* El Dorado; *12* Morocha; *13* Las Coloradas-Las Gordas; *14* Sinchao-María Eugenia; *15* Volare; *16* Congas; *17* Proveedora; *18* Perené; *19* Cañón; *20* Quijote; *21* Mario; *22* Colquirrumi; *23* Arpón

Most of the axial planes of folds have an Andean strike direction (N 50 °W); some regional faults also belong to this system (e. g., Apan Alto Fault); nevertheless, many other regional faults, especially those in the south zone of the district, belong to another system with a N 25 °W general strike direction. Almost all of the mineralized faults or fractures belong either to the Yanacancha System (N70°– 80 °E) or to the Predilecta System (N 80°– 90°W) (Fig. 1 a).

Volcanic rocks of Upper Cretaceous and Tertiary age also crop out, especially at the west side of the district (Fig. 2). The area has been intruded by a number of stocks, sills, and dikes of basic to intermediate composition. Geochemical studies indicate a calc-alkaline character with important proportions of alkalis (Borredon 1982). There is a good correlation between K_2O and SiO_2 amounts, while between Na_2O and SiO_2 the correlation is poor, which characterizes calc-alkaline series of insular areas. A magmatic differentiation trend in direction of a K_2O enrichment is recognized in Hualgayoc (Fig. 1 b, c).

Borredon (1982) reports radiometric (K-Ar) ages of some igneous rocks of the district. One sample from the Hualgayoc Intrusion gives 14.5 ± 0.7 m.y., while another from the Coymolache Intrusion results 11.8 ± 0.6 m.y. On lithologic and structural grounds we could extend these ages to the San Miguel Intrusion. The

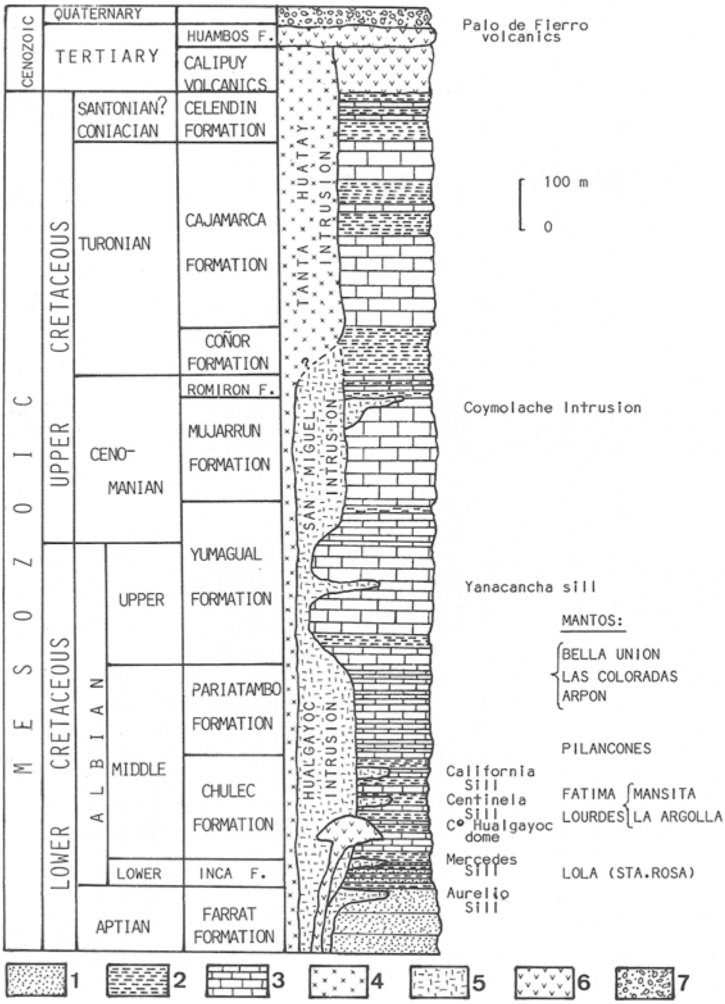


Fig. 2. Stratigraphic column of the Hualgayoc District, showing the location of the principal mantos. Symbols: *1* clastic sediments; *2* shales; *3* limestones; *4* granodioritic intrusion; *5* quartz-dioritic intrusion; *6* volcanic rocks; *7* moraines; colluvial and alluvial sediments

sills, which crop out in Hualgayoc river canyon, were dated as 10.5 ± 0.5 m.y. and the rhyolitic to dacitic extrusion of the Hualgayoc hill as 7.2 ± 0.4 m.y.

Field data suggest that Tanta Huatay Intrusion is younger than the other stocks described, but older than the volcanic extrusion. Borredon (1982) estimates the age of the vein mineralization and hydrothermal alteration to be between 10.5 and 7.2 m.y.

Valley bottoms, depressions, and gentle slopes are capped by Pleistocene moraines and more recent sediments.

On the basis of geometric and mineralogic characteristics, we can differentiate four principal types of ore deposits in Hualgayoc (Table 1). Additionally, we have

Table 1. Principal types of ore deposits in Hualgayoc

Type of deposit	Host rock	Principal characteristics	Mineralogy		Examples
			Principal	Accessory	
Concordant Fe-Zn-Pb mantos	Lower Cretaceous limestones, marls, psammites and pelites with some interlayered tuffs	– Ores in form of massive bodies, lens, accumulations (in general concordants) short veinlets and disseminated – Ore frequently associated with thin layer tuffs – Usually fine-grained minerals – Presence of sedimentary textures involving both ore and country rock – Hydrothermal alteration of host rock very weak or absent	Pyrite Quartz (including chert) Sphalerite Galena Carbonate Other Fe-sulfides	Chlorites Sericite Clay minerals Chalcopyrite Marcasite Pyrrhotite Hematite Magnetite Arsenopyrite Barite etc.	Manto Lourdes Manto Fátima Manto 1 (Mansita) Firenze (Pilancones) Mantos 8-W, 10-W (Bella Unión) Manto Arpón Manto Las Coloradas
Discordant Cu-Pb-Zn-Ag veins	Lower Cretaceous pelites, psammites, limestones and Tertiary igneous rocks	– Complex mineralogy and coarse-grained minerals – Strong hydrothermal alteration of host rocks – Copper minerals relatively abundant – Replacement textures	Chalcopyrite Pyrite Galena Sphalerite Quartz Barite Calcite Fahlore	Cu-Ag-Pb-As-Sb sulfosalts Carbonates Covellite Limonites Cu-Fe-sulfates	San Agustín Murciélago Proveedora (Predilecta) "A" and "Z" (Bella Unión) Many veins in Cerros Jesús and San Lorenzo
Fe-Cu-Ag-As Irregular ore bodies	Cretaceous limestones and intrusions	– Occur only in high topographic zones – Intensive hydrothermal alteration of host rocks – Coarse-grained minerals – Located at the contact between limestones and intrusions	Pyrite Quartz Enargite	Chalcopyrite Fahlore Alunite Clays Sericite	Cleopatra Tres Mosqueteros Tres Amigos
Zn-Pb Intrakarstic bodies	Lower Cretaceous limestones and marls	– Irregular and tabular ore bodies (veins and mantos, intergranular and interstitial fillings) – Simple mineralogy – Host rock alteration absent – Principal textures: botryoidal, banding, massive, dendritic, earthy, graphic, breccia	Sphalerite Galena Carbonates Pyrite Marcasite	Chert Barite Limonites Clays Mn-oxides	Cañón Mario Porcia Pozos Ricos

Table 2. Principal types of "Mantos" in Hualgayoc

Type	Host rock	Principal characteristics	Mineralogy		Examples
			Principal	Accessory	
Sphalerite-galena mantos	Limestone and marls	– Ores in form of massive bodies, lens, accumulations (usually concordant), short veinlets, and disseminated – Organic matter and chert, lens-like, concretion and veinlets – Generally minerals occur fine-grained – Hydrothermal alteration of host rocks very weak or absent – Presence of sedimentary textures involving both ore and country rocks – Simple mineralogy	Sphalerite Galena Carbonate Quartz (including chert) Pyrite	Sericite Clay minerals Arsenopyrite Marcasite Hematite Pyrrhotite Chalcopyrite (rare)	Manto La Argolla Manto 8-W (Bella Unión) Firenze (Pilancones)
Pyrite-quartz mantos	Limestones and marls with interlayered tuffs pelites and psammites	– Ores frequently associated with tuff beds – Hydrothermal alteration of host rocks very weak of absent – Massive ores, in part finely stratified – Usually sedimentary textures are obliterated by massive ores – Simple mineralogy	Quartz Pyrite	Chalcopyrite Sphalerite Galena Fahlore Calcite Enargite	Manto 10-W (Bella Unión) Mercedes Morocha Manto 1 (Mansita) Lola
Complex mantos	Psammites, pelites and marls with interlayered tuffs	– Complex mineralogy – Ores in form of massive bodies, lenses, veinlets, accumulations, and disseminated – Presence of sedimentary textures involving both ore and country rock – Signs of remobilization and metamorphism – Possible superposition of other mineralization events (karstic, hydrothermal)	Alternatively: Pyrite Quartz (including chert) Carbonate, other Fe-sulfides Chlorites or sericite	Chalcopyrite Sphalerite Pyrrhotite Arsenopyrite Hematite Cu-Ag-Pb-As-Sb-sulfosalts Magnetite Marcasite Colusite Barite	Manto Lourdes Manto Fátima Lola Arpón

to mention some stockwork-type bodies at the mines Las Gordas and Colorada (Tumialán et al. 1976) and Cerro Corona (Hudson et al. 1980). Some diamond drillings carried out in 1920 by the Northern Peru Mining and Smelting Company in the Tanta Huatay Intrusion suggest the presence of a low-grade porphyry copper deposit (Ericksen et al. 1956).

At the boundary between the quartz-dioritic intrusions and the limestones only insignificant zones of alteration developed. By contrast, the limestones in contact with granodioritic intrusions are more altered (silicification and marmorization) and occasionally have built up small skarn zones.

3 Description of the Mantos

3.1 Introduction

Mantos of the Hualgayoc District may be divided into three types on the basis of differing mineral assemblages (Table 2):
- Sphalerite-galena mantos,
- Pyrite-quartz mantos,
- Complex mantos.

Almost all of the mantos in Hualgayoc are hosted by Albian sediments: Inca, Chulec, and Pariatambo Formations (Fig. 2). The Inca Formation consists of interbedded brownish gray, brown-weathering, arenaceous and ferruginous limestones and yellowish to greenish brown, finely splintery, fossiliferous shales, with subordinate amounts of quartz-sandstone and siltstone (Benavides-Cáceres 1956). It rests disconformably on the shales and sands of the Goyllarisquizga Formation, the contact being more or less gradational. This formation represents the lowest deposit of the marine Albian transgression. It was deposited under shallow marine conditions. The abundance and diversity of fossils, including "lingula" and crabs, indicate a nearshore environment.

The Chulec Formation is composed of light-colored argilaceous limestones, sandstones, and fine-bedded intercalations of carbonates. This unit is very fossiliferous. It is considered to be of early-middle Albian age. Its lithology and fauna suggest that it was deposited in shallow marine conditions.

Lithologically, the Pariatambo Formation is composed of fossiliferous, platy, slabby, dark gray, bituminous marls and limestones, with some intercalations of chert. Based on fossil content, this formation has confidently been assigned to the middle Albian. It rests on the Chulec Formation and represents the culmination of the marine overlap that began sometime during the Aptian. The Pariatambo Formation grades quickly into the nodular thick-bedded limestones and marls of the Yumagual Formation, which is the lower member of the Pulluicana Group.

The Upper Cretaceous Groups, Pulluicana, Quilquiñán and Otuzco, in general consist of a monotonous sequence of thick limestone layers (see Fig. 3). Some mantos could be localized at the basis of the Pulluicana Group.

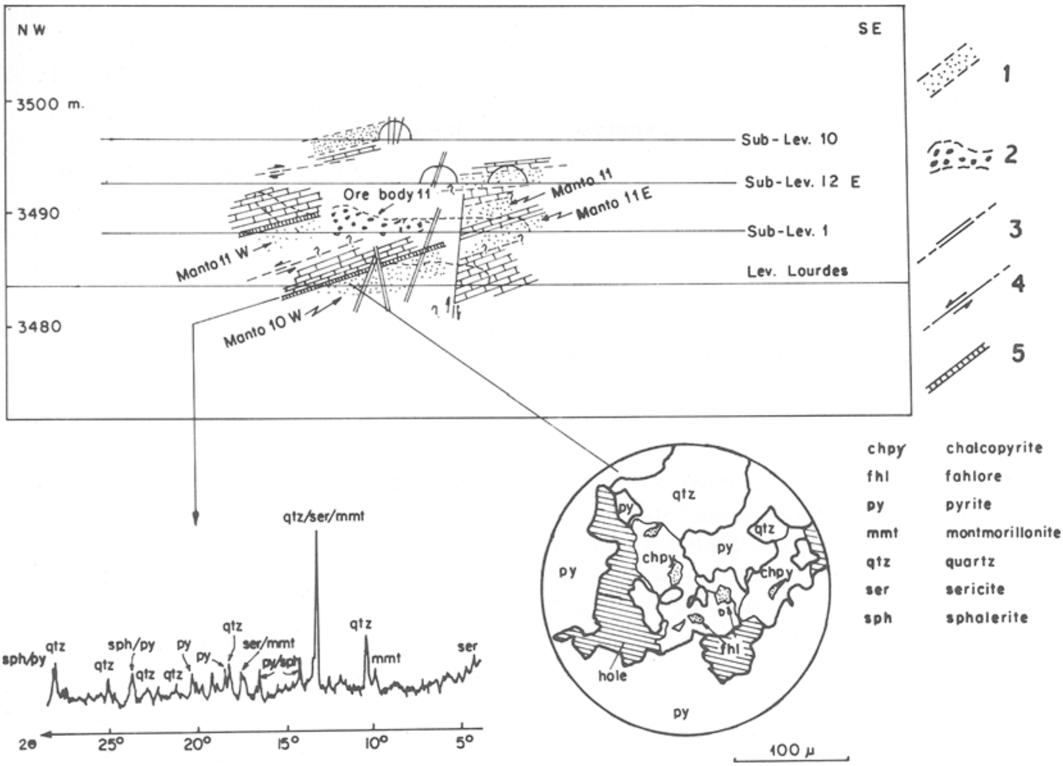


Fig. 3. Cross-section and mineralogy of the pyrite-quartz mantos in Bella Unión Mine. *1* Manto; *2* ore body; *3* vein; *4* fault; *5* tuffs. (After Canchaya 1982, 1987)

3.2 Sphalerite-Galena Mantos

A typical example of this type of manto is the "8-W", recognized at sublevel 1 of the Bella Unión Mine (Canchaya 1987). It is disrupted by faults and its bottom is not visible; however, we can estimate its thickness to be about 1.5 m. Figure 5A shows important geometric feature of this manto.

Some hundreds of meters farther to the north of the village of Pilancones, the Pb-Zn manto *Firenze* crops out. This manto shows, better than others, how both ores and gangue minerals display the same sedimentary and diagenetic textures (Fig. 5D). Pyrite framboids, which occur scattered in organic matter, form, by a subsequent blastesis process, usually cubic coarser pyrite crystals.

At the southeast zone of the district there is a persistent and continuous manto: *La Argolla*, which is found in Los Negros and Santa Marta Mines. It has a thickness of about 1 m. This manto occurs in a sequence of sandstones with intercalations of pyritized shales, overlying a thick dioritic porphyritic sill. Metallic contents in this manto average 190 g/t Ag, 9% Pb, 8% Zn, and traces of Cu (Sirna 1976).

3.3 Pyrite-Quartz Mantos

These mantos are composed essentially of pyrite and quartz with no substantial amounts of sphalerite and galena. Usually the top of these mantos are drastically limited by a thin bed of tuff (Fig. 3). Sometimes, toward both, the bottom and the roof of the mantos, there is a transition from massive and disseminated sulfides to a barren rock. This is the case of the pyritic mantos cut by some diamond drills at Mansita and Lola Mines.

Mineable parts of *Manto 10-W* average 135 g/t silver, 1.5% copper and a thickness of 1.5 m (Ocola 1978). Medina (1972) reports different values: 270 g/t silver, 2% copper and a thickness of 2.5 m. In this manto occur minor amounts of interstitial chalcopyrite, containing traces of fahlore and other sulfosalts (Fig. 3).

Sometimes pyrrhotite prevails instead of pyrite (v. gr. 88.5 m and 89 m of DDH Lola, Fig. 4); in this case, the wall rock is rather pelitic than psammitic.

Paredes (1980) gives an account of six pyrite-quartz mantos in the Morocha Mine, with average contents of 1000 ppm Pb, 300 ppm Zn, and 500 ppm Cu. Canchaya (1987) also reports other mantos in the Bella Unión Mine, which consist almost completely of pyrite and quartz, with minor quantities of chalcopyrite (Manto 12-W), and sometimes also local occurrences of chalcanthite and melanterite (Manto 12-E) and others (Mantos 11, 11 W, 11 E).

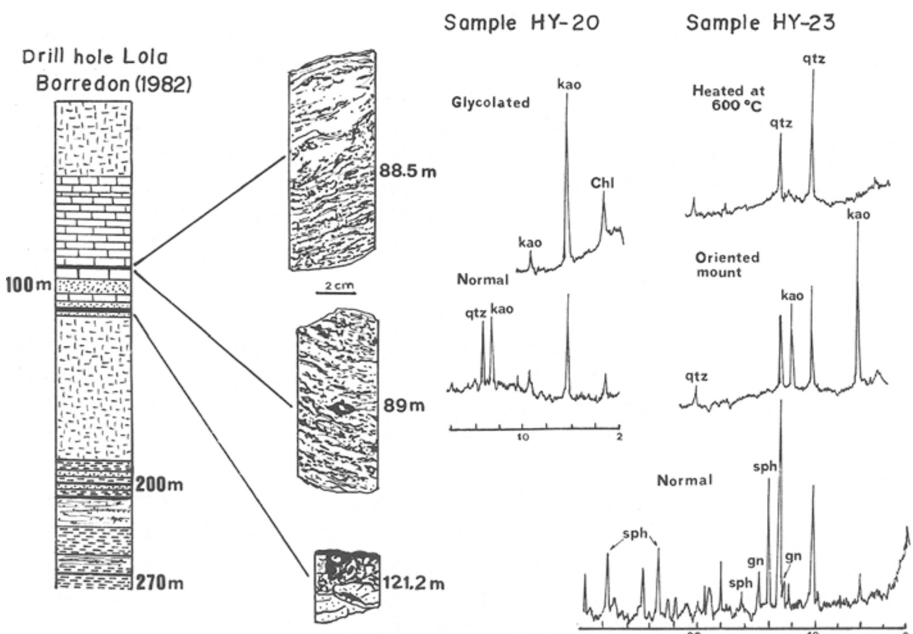


Fig. 4. Mineralogy and textures of the mantos of Lola Mine. Abbreviations: *Chl* Clorite; *gn* galena; *kao* kaolinite; *qtz* quartz; *sph* sphalerite. The *symbols* are the same as in Fig. 2. In cores: sulfides are black; psammitic-pelitic components and chert are white

3.4 Complex Mantos

Some mantos show more complex mineralogy and lateral lithological variations. One of the most typical ones is the *Lola Manto* (or Santa Rosa), which occurs some meters below the Mercedes Sill (Fig. 2), intruded approximately at the limit between the Chulec and the Inca Formation. Some sedimentary textures are especially frequent in this manto; for instance: cockade arrangements with magnetite cores and successive irregular shells of pyrite-marcasite, sphalerite-galena and interstitial kaolinite (Fig. 5B); sample HY-15 shows a typical geopetal texture and a fair concordance of the sulfides with the geometrical features of the rock (Fig. 5E).

Pyrite is the most frequent iron sulfide, but pyrrhotite and marcasite are also found. In general, when pyrrhotite predominates, the principal gangue is chlorite (sample HY-23, Fig. 4).

Figure 4 shows two diffraction patterns of samples HY-20 and HY-23 from this manto. In both cases iron sulfides were eliminated before the analysis, to avoid iron fluorescence. Sample HY-23 was glycolated to confirm the presence of chlorite. An oriented mount of sample HY-23 was heated to 600 °C to prove the presence of kaolinite. X-ray fluorescence analysis of two samples from this manto, reported by P. Soler (pers. commun.) gives the following values:

a) 10% Zn, 2% Pb, 30% Fe, 8% SiO_2, 2% Al_2O_3, 89 g/t Ag

b) 2% Zn, 0.8% Pb, 14% Fe, 51% SiO_2, 5% Al_2O_3, 22 g/t Ag.

Another important example of this type of complex mantos is the *Fátima Manto.* It crops out on the southern side of Hualgayoc River with a maximum thickness of about 8 m. This manto also shows lateral facies variation in lithology and mineralogy, which is clearly reflected by the chemical analysis. The following X-ray fluorescence values were provided by P. Soler:

a) 4% Zn, 24% Pb, 20% Fe, 0.2% CaO, 11% SiO_2 and 3.5% Al_2O_3

b) 0.2% Zn, 0.4% Pb, 5% Fe, 19% CaO, 30% SiO_2 and 7% Al_2O_3

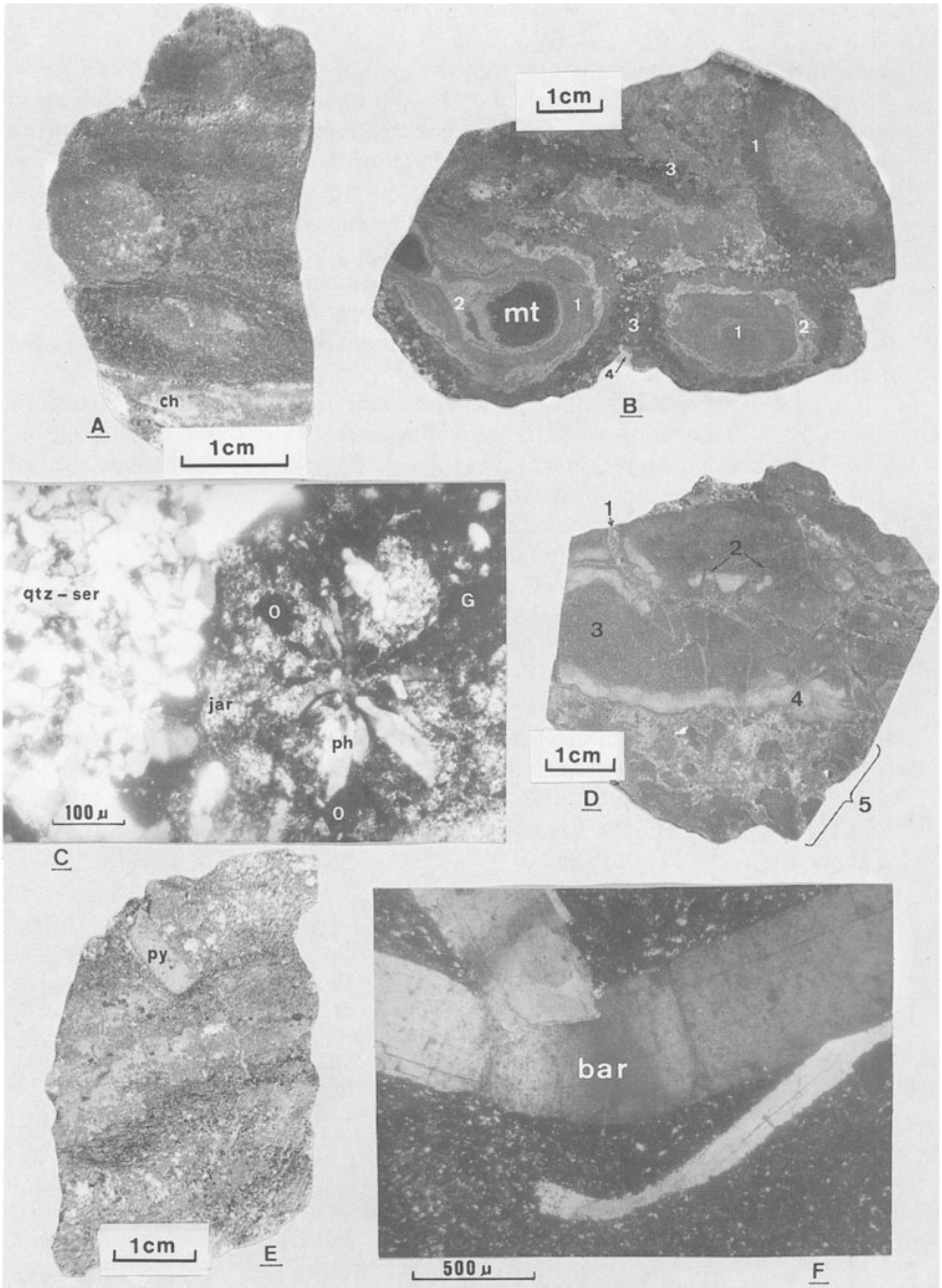
c) 0.7% Zn, 0.2% Pb, 16% Fe, 0.7% CaO, 42% SiO_2 and 5.5% Al_2O_3

The copper content is rarely above 1%. Silver occurs only in some tens of gram per ton. Gold values of primary ores are less than 1 gram per ton. The persistent occurrence of barite in small quantities is remarkable. It forms millimetric tabular crystals, which present a parallel alignment with the bedding, or as more or less rose-shaped aggregates of individuals. Some barite crystals were diagenetically deformed (Fig. 5F). Sphalerite presents a beautiful yellow-orange UV-fluorescence color, similar to that of the sphalerites from 8-W and 10-W mantos in Bella Unión.

Another important complex orebody is the *Lourdes Manto,* which also crops out on the southern side of the Hualgayoc River, but is stratigraphically below the Fátima Manto. It was found along an extension of more than 300 m, covering the mining concessions of El Dorado, Centinela and Cuña. The thickness of this manto is relatively persistent and averages 1.5 m.

X-ray fluorescence analysis of a sample from this manto collected by P. Soler gives: 7% Zn, 2.4% Pb, 2% Cu, 17% Fe, 64 g/t Ag, 33% SiO_2, 0.04% Ba, and 1.5% Al_2O_3.

At the contact with the Hualgayoc intrusive, in Cerro José, skarn and metamorphic facies were developed, affecting restricted zones of both, sediments and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mantos. Ores in mantos were seemingly remobilized and reconcentrated; chalcopyrite shows lamellar twins and star-shaped exsolutions of sphalerite; mackinawite inclusions are recognized in pyrite and chalcopyrite.

Outcrops of the mantos and sills are intensively oxidized and rich in quartz and clays. Here gold and silver have been concentrated to economic values by selective weathering.

3.5 Other Mantos

There are many other mantos in Hualgayoc, which are not described here due to lack of information. This is the case for the Manto 328 (Colquirrumi Mine), Tornamesa, and Don Paco Mantos (Bella Unión Mine), and several outcrops in Cañon, San Francisco and Santa Marta Mines. Especially important is the Manto Arpón (Carolina Mine), which was enriched in silver at the intersection with cross-cutting veins. The silica-rich mantos Las Coloradas and Las Gordas, located in the center of the district, have economic values of gold and silver in their oxidized zones. In both mines, on the top of the mantos a centimeter-thick friable tuff is recognized, similar to the bounding tuffs of pyrite-quartz mantos previously described.

4 Discussion

The spatial relation of some mantos with intrusive rocks led Ericksen et al. (1956), Canchaya and Tumialán (1976), Tumialán and Martínez (1977), Paredes (1979), Hudson et al. (1980), and Cabos (1981, 1982), to the opinion that these deposits originated by metasomatic replacement of favorable sedimentary horizons.

Fig. 5. A Manto 8-W; sample sn-45M. Millimetric alternance of sulfides (short veinlets and linear accumulations) and gangue minerals (microgranular aggregates of quartz-sericite and chert). Sphalerite: colorless to light gray; galena: black areas and bright white dots; quartz-sericite assemblages: different shades of gray; chert (*ch*): white areas. **B** Manto Lola; sample HY-21. Cockade-like texture: magnetite cores surrounded by successive shells of quartz-pyrite (*1*), pyrite-marcasite (*2*), and sphalerite-galena (*3*), with interstitial kaolinite (*4*). **C** Thin section from lithic fragments of the tuff bed on the roof of Manto 10-W; sample Tl. Radial aggregate of phillipsite (*ph*) crystals in a matrix composed by jarosite (*jar*), glass (*g*) and some opaque minerals (*o*). *Left* in the picture quartz (*qtz*) grains aggregate with interstitial sericite (*ser*). **D** Manto Firenze, sample MTP. Microgranular quartz-pyrite aggregate (*3*) with pyritic accumulations (*4*) disrupted by stylolites (*2*) and cut by sphalerite-galena veinlets (*1*). The fragments of the intraformational breccia (*5*) are composed of microgranular qtz-py aggregates, cemented by sphalerite-galena and limonites. **E** Manto Lola; sample HY-15. Load texture: subhedral pyrite grain sinking down into underlying material, whose lamination was partially deformed. Subparallel alignment of linear accumulations or lenses of pyrite (*light gray*), quartz-sericite assemblages (*different shades of gray*), organic components (*black*) and clays (*white*). **F** Manto Fátima; sample HD-4. Barite (*bar*) crystal diagenetically deformed by load of another overlying tabular crystal of barite. The matrix consists of a microgranular aggregate of organic matter (*black*), quartz-sericite clays aggregate (*light gray*) and sphalerite (*gray*). The larger barite crystal shows undulatory extinction

Cobbing et al. (1981) are of the same opinion, although they consider the possibility of a syngenetic origin of these mantos. According to Gabelman (1976) the mantos of Hualgayoc formed under mesothermal conditions. These interpretations contradict the mineralogy and texture of these mantos; besides this, there is no direct relationship between these deposits and the hydrothermal veins.

At the present state of knowledge, it is not possible to give a fully satisfactory interpretation of the geologic setting and genesis of the Hualgayoc mantos. However, we can reject the earlier purely epigenetic interpretations.

Mineralogic microscopic studies show equilibrium intergrowth patterns between sulfides, quartz, sericite, chlorites, carbonates, clays and other associated minerals. All components are usually fine-grained; only occasionally are they coarse-grained, probably due to thermal metamorphism, which is the case for the mantos at the contact with the Hualgayoc intrusive (northern parts of mantos Lola, Lourdes, Fátima, etc.).

Within the sphalerite-galena mantos organic matter is frequently recognized. Under the microscope this material appears isotropic and with low reflectance. That is, it consists of a more or less consolidated bitumen-like hydrocarbon matter, which could not have been influenced by any high temperature or pressure, since an increase in degree of coalification (by metamorphism) and consequently the increment of reflectance and anisotropy of the bitumina is not observed.

Field relations, beside mineralogic and petrographic characteristics, resumed here, support a syngenetic interpretation for the origin of these mantos, which could have been formed during sedimentary processes of Albian age, in some way associated with volcanic activity. A detailed discussion of the interpretation of many sedimentary features in the ore horizons can be found in Canchaya (1987).

A close association of many Hualgayoc mantos (especially of the quartz-pyrite mantos) with volcanic layers, their mineralogy (in particular the presence of quartz, common sulfides, clays, sericite, chlorites, barite, hematite-bearing cherts, and zeolites originated by devitrification) support the hypothesis of an exhalative sedimentary origin of these stratabound ores. According to Carpenter (1976) iron oxide-chert assemblages can be found in submarine muds up to 200 km far away from volcanic centers, which could be located, in our case, along the eugeosyncline zone. It is also important to note the occurrence of phillipsite within the tuff layers bounding the pyrite-quartz mantos in Bella Unión. In general this type of zeolite occurs in submarine environments under low temperature and low pressure conditions, usually originated by conversion of glassy components into crystalline fractions after solidification (Boles 1981).

There is a regional stratigraphical correlation between the Albian sedimentary formations of Hualgayoc (miogeosyncline) and the Lomas and Lancones Groups, farther to the west (eugeosyncline).

Following Plimer's concepts (1978), Hualgayoc mantos could be classified as "distal deposits", and according to Amstutz's scheme (1976) as krypto- or televolcanic deposits. Similar contemporaneous deposits are found in other localities in Peru (Canchaya 1987), that could support a regional distribution of this type of stratabound deposits. Unfortunately these occurrences are less known and a stratigraphic correlation is as yet uncertain.

There are also important stratabound deposits within the eugeosynclinal belt, which could be correlated in time with the Albian mantos of Hualgayoc. For example: Tambogrande, Potrobayo, and Totoral in north Peru, and Raúl, Condestable, Los Icas, Leonila-Graciela, Balducho, and Budekú in central Peru.

Five years ago, when the author reported the first results of this study at the Mineralogic-Petrographic Institute Heidelberg, Professor Amstutz, commenting about the Hualgayoc mantos, was of the opinion that they could be "a new link of the chain" of stratabound deposits in Peru. Additional studies will reveal whether we have a new metallotect with synsedimentary ores, as already defined in limestones of the Pucará Group (Triassic-Jurassic) and the Santa Formation (Lower Cretaceous).

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References

Amstutz GC (1976) Aus der Arbeit der Universitäts-Institute. Lagerstättenforschung am Mineralogisch-Petrographischen Institut (I. Lehrstuhl). Heidelberger Jb 20:169–184

Benavides-Cáceres V (1956) Cretaceous system in Northern Peru. Bull Am Mus Nat Hist 108:353–494

Boles JR (1981) Zeolites in deep-sea sediments. In: Mumpton FA (ed) Mineralogy and Geology of natural Zeolites. Book Crafters, Michigan, pp 137–163

Borredon R (1982) Etude géologique et metallogénique du district minier de Hualgayoc (Perou septentrional) à plomb-zinc-cuivre argent. Thèse Dr. 3 Cycle, Univ Paris

Cabos R (1981) Las asociaciones mineralógicas de la Mina Bella Unión (Hualgayoc). Determinaciones microscópicas y análisis mediante microsonda. Bol Soc Geol Perú 68:1–12

Cabos R (1982) Estudios microscópicos, roentgenográficos y mediante microsonda de las asociaciones mineralógicas en el distrito minero de Hualgayoc, Cajamarca-Perú. Bol Soc Geol Perú 69:1–17

Canchaya S (1982) Mineralogía y génesis de los depósitos de Cu-Ag-Pb y Zn de la Mina Bella Unión, Hualgayoc-Cajamarca. XVI Con Ing Minas, Lima-Perú (Nov 1982), 18 p

Canchaya S (1987) Lagerstättenkundlich-mineralogische Untersuchungen der Cu-Ag-Zn-Pb Lagerstätte „Bella Unión", Hualgayoc – Perú. Diplomarbeit, Univ Heidelberg, 144 p

Canchaya S, Tumialán PH (1976) Controles de mineralización en la mina Bella Unión, Hualgayoc-Cajamarca. XIII Con Ing Minas, Arequipa-Perú (Sep 1976), 9 p

Carpenter R (1976) Cursillo sobre exploración, desarrollo y evaluación de propiedades mineras. Copia int INGEMMET (unpublished)

Cobbing EJ, Pitcher W, Wilson J, Baldock J, Taylor W, McCourt W, Snelling NJ (1981) Estudio geológico de la Cordillera Occidental del norte del Perú. Bol Inst Geol Min Met, Ser D, Estuds Especs 10, 252 p

Ericksen GE, Iberico M, Petersen U (1956) Geología del distrito minero de Hualgayoc, departamento de Cajamarca. Bol Inst Nac Invest Fomento Min 15, 99 p

Gabelman JW (1976) Strata-bound ore deposits and metallotectonics. In: Wolf KH (ed) Handbook of strata-bound and stratiform ore deposits, Vol. 4. Elsevier, Amsterdam, pp 75–163

Hudson C, Cabos R, Cuadros P (1980) Informe geológico Minas Punto Victoria Seis y Cañon – Hualgayoc. Rep Priv Bella Unión Minas SA Tecnominas SRL, 49 p

Medina J (1972) Informe técnico sobre las minas "Punta Victoria Seis" y "Bella Unión", Hualgayoc-Cajamarca. Inf Int Bco Min Perú, 19 p

Ocola P (1978) Informe técnico de la unidad económica y administrativa "Bella Unión"; minas: "Punto Victoria 6", "Bella Unión" y "Don Paco", Hualgayoc-Cajamarca. Inf Int Bco Min Perú. 32 p

Paredes J (1979) Estudio geológico del distrito minero de Hualgayoc. Inf Int BRGM Lima, 80 p

Paredes J (1980) Reconnaissance gèologique, geochimique et metallogenique du domaine minier de Hualgayoc, Department de Cajamarca. Rap Mission Coop Tech BRGM – Bco Min Perú, 92 p

Plimer IR (1978) Proximal and distal stratabound ore deposits. Min Deposita 13:345–353

Sirna C (1976) Geología y reservas de la mina Los Negros, Hualgayoc-Cajamarca. Tesis Bach., Univ Nac Ing, Lima-Perú, 48 p

Tumialán PH, Martinez JC (1977) Geología económica de la mina Pozos Ricos. An II Simp Nac Min, Ayacucho-Perú, 8 p

Tumialán PH, Rivera D, Martinez P (1976) Mineralización de los yacimientos Las Gordas y Colorada, Hualgayoc-Cajamarca. An. XIII Con Ing Minas, Arequipa Perú, Secc 1–5, 3 p