Proceedings Chapter

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Reference

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Early mineralization at Cerro de Pasco (central Peru) revisited

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Abstract. The large Cerro de Pasco Cordilleran base metal deposit in central Peru is located on the eastern margin of a Middle Miocene diatreme-dome complex. A striking characteristic is the presence of a N-S trending massive funnel-shape pyrrhotite-quartz replacement ore body that contains pyrrhotite pipes grading outwards to lead-zinc replacement bodies, along the eastern contact of the diatreme-dome complex. Earlier workers interpreted the pyrrhotite pipes as postdating the pyrite-quartz body. This study, that has been possible through access to new mining areas and drill cores, allows an alternative interpretation. The new data strongly suggest that the pyrrhotite pipes and their associated lead-zinc replacement bodies predated the formation of the pyrite-quartz body.

Keywords. polymetallic, base metals, pyrrhotite, pyrite, Cerro de Pasco

1 Introduction

Cerro de Pasco, central Peru, is a large Cordilleran base metal deposit located on the eastern margin of a diatreme-dome complex (15.36 ± 0.03 Ma, Baumgartner et al., 2009) which is part of the Miocene metallogenic belt of central and northern Peru. Previous studies (Lacy 1949, Ward 1961, Einaudi 1968, 1977, Baumgartner 2007, Baumgartner et al., 2008) defined two main mineralization stages. According to this interpretation, during the first stage, a N-S trending funnel shape, ~1.5 km in length, 250 m wide and more than 550 m deep massive body consisting mainly of pyrite and quartz was formed. It includes a number of pyrrhotite pipes that grade outwards into massive Fe-rich sphalerite and galena replacement bodies. The inner parts of the pipes contain minor amounts of arsenopyrite and Fe-rich sphalerite as well as traces of chalcopyrite, galena and stannite. The massive body replaces mainly an Upper Triassic-Lower Jurassic carbonate sequence (Pucará Group), along the eastern contact of the diatreme-dome complex, as well as, subordinately, the diatreme-dome complex itself (Fig. 1). A quartz-sericite alteration halo is observed in the diatreme rocks along the pyrite-quartz body. The pyrrhotite pipes are known to replace only the carbonate sequence. The second mineralization stage took place, in the western part of the deposit, as a set of E-W–trending Cu-Ag-(Au-Zn-Pb) enargite-pyrite veins hosted by the diatreme breccia, and, in the eastern part, as large well-zoned Zn-Pb-(Bi-Ag-Cu) carbonate replacement bodies (Fig. 1).

Recent studies by Baumgartner (2007) and Baumgartner et al. (2008) characterized the second stage of mineralization. However, no comprehensive study has been done on the first mineralization stage since seminal Einaudi's work (1968, 1977). According to previous studies, the pyrite-quartz body was thought to have been first emplaced, followed by the pyrrhotite pipes and their outer zone of sphalerite and galena. However, this study had access to new mining areas and drill cores, allowing observations that have led to the alternative interpretation that the massive pyrite-quartz body is emplaced after the pyrrhotite pipes and belongs to the second stage.

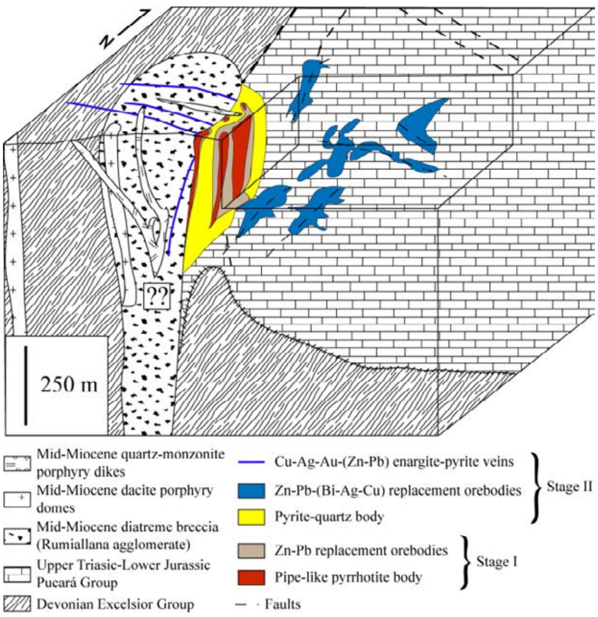

Figure 1: Block diagram, showing the Cerro de Pasco deposit (modified after Baumgartner et al., 2008).

2 Pyrrhotite-pyrite relationships

This study focuses on the contact of the pyrrhotite pipes with the pyrite-quartz body. At the meter scale, a replacement front of pyrrhotite by pyrite is observable. From the pyrrhotite pipes to the pyrite-quartz body the following main textural patterns are seen. Inside the pyrrhotite pipes, near the contact, patches of porous fine-grained pyrite occur (Fig. 2 A-C). Follows a part of

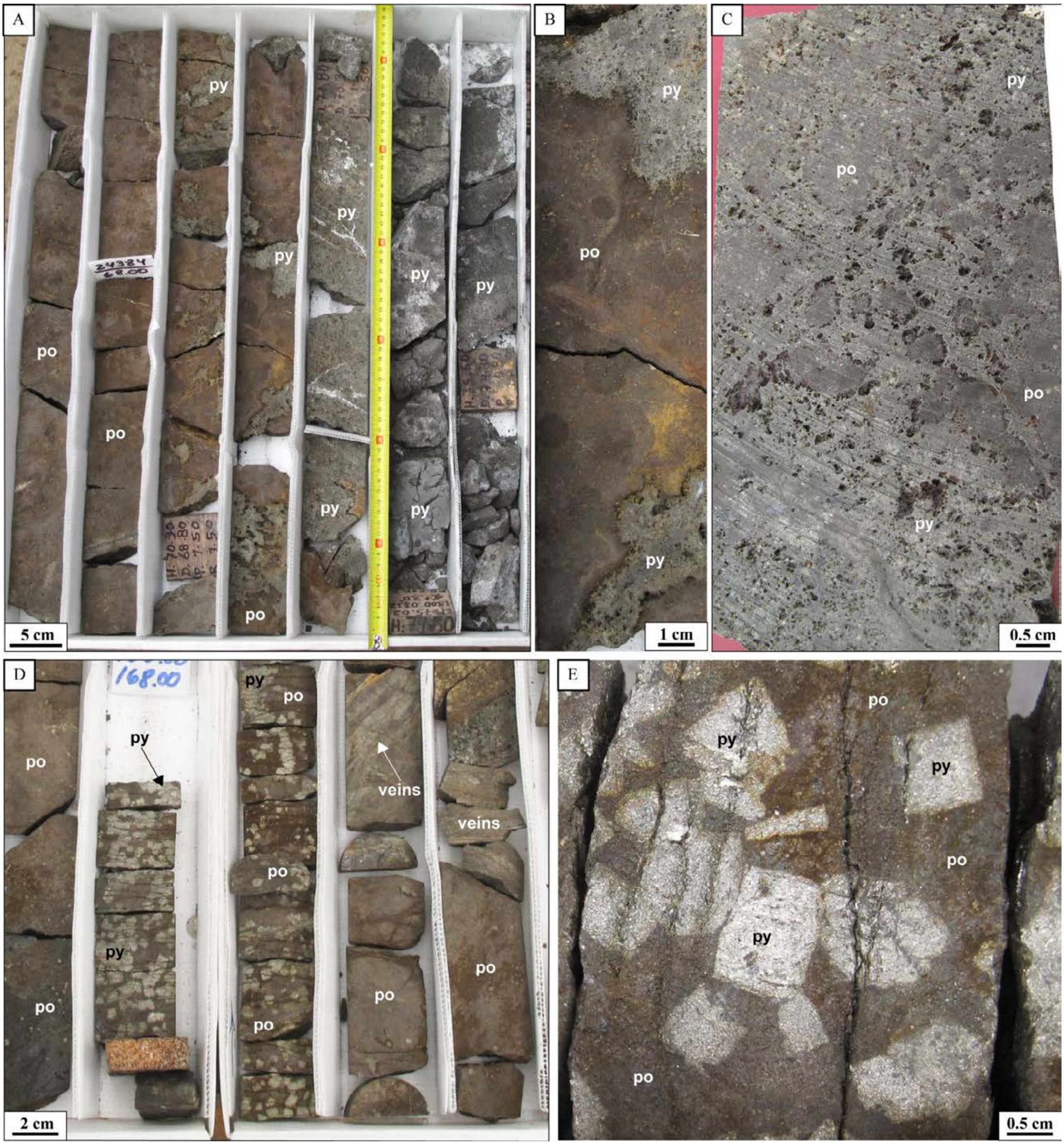

Figure 2: A) Cores of the contact between a pyrrhotite pipe and the pyrite-quartz body (borehole n°1800-08-18). B) Progressive replacement of pyrrhotite by pyrite C) Part of a core where pyrrhotite is replaced by pyrite (sample CP-12-BR-46), note the spongy replacement texture of pyrite. D) Large euhedral pyrite crystals and centimetric veins of pyrite, marcasite, sphalerite, and minor galena in pyrrhotite (borehole n°1600-08-12). E) Large euhedral pyrite in pyrrhotite (sample CP-12-BR-63) *Abbreviations:* po – pyrrhotite, py – pyrite.

pyrrhotite-free porous fine-grained pyrite with some euhedral pyrite that grades to the pyrite-quartz body. In the places where an outer zone, mainly constituted by Fe-rich sphalerite and galena, exist, it is observed that pyrite also partly replaces galena, (Fig. 3E) but the replacement front is less clear than in the pyrrothite pipes. Sphalerite remains systematically unaffected.

Centimeter-scale euhedral pyrite is present throughout all parts of the pyrrhotite pipes. These crystals are spatially related to numerous veins (up to 15 mm thick) of pyrite, marcasite, Fe-rich sphalerite, and minor galena (Fig. 2 D-E, Fig. 3 G-H) that crosscut the pyrrhotite pipes.

The up to 1-1.5 cm in size euhedral pyrite (Fig. 3 A, C-D), is rich in inclusions, mainly pyrrhotite, minor amounts of arsenopyrite, chalcopyrite, Fe-rich sphalerite, galena, and stannite, reflecting the initial mineralogy of the pyrrhotite pipe. Groups of pyrrhotite inclusions present synchronous extinction evidencing that they are relicts of larger pyrrhotite grains. Euhedral pyrite crystals are randomly oriented and commonly show a rim of fine-grained mixture of pyrite and marcasite (Fig. 3D). Lacy (1949) and Einaudi (1968, 1977) designated

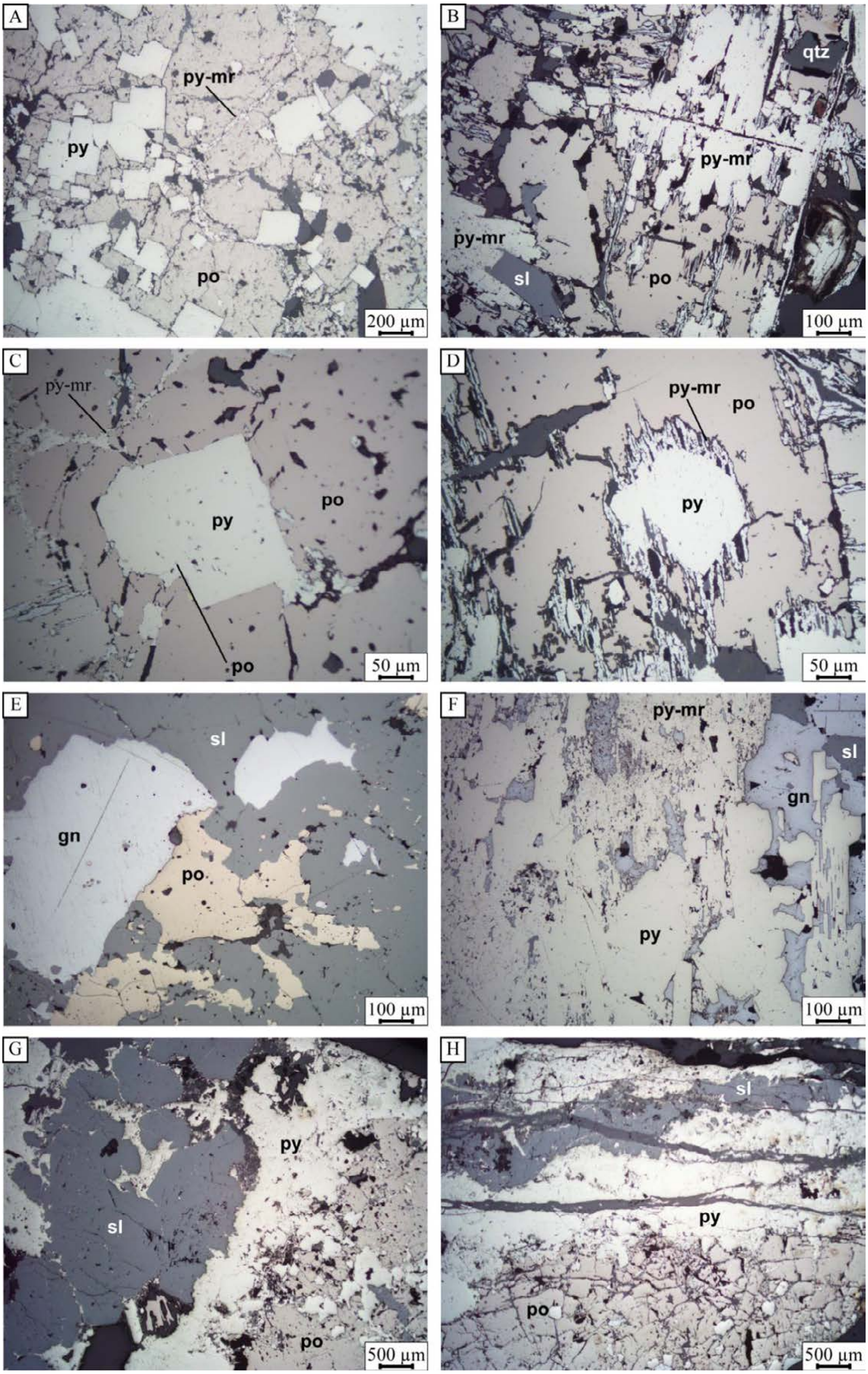

Figure 3: Typical textural patterns observed in pyrrhotite pipes and their outer Fe-rich sphalerite galena zone. A-D) Euhedral pyrite and fine-grained mixture of pyrite and marcasite replacing pyrrhotite, (A-sample CP-12-BR-53, B-sample CP-12-BR-56, C-sample CP-12-BR-118 and D-sample CP-12-BR-56); E) Pyrrhotite-sphalerite-galena assemblage from an Fe-rich sphalerite-galena body (sample CP-12-BR-41) not affected by pyrite replacement; F) Pyrite and marcasite replacing galena in a Fe-rich sphalerite-galena body (sample CP-12-BR-73); G) Pyrite-sphalerite vein within pyrrhotite (sample CP-12-BR-44); H) Pyrite-sphalerite vein crosscutting pyrrhotite crosscut by late siderite veins (sample CP-12-BR-46). *Abbreviations:* gn – galena, mr – marcasite, po – pyrrhotite, py – pyrite, qtz – quartz, sl – sphalerite.

this euhedral pyrite as "pyrite 1". They reported pyrrhotite crosscutting this euhedral pyrite and used this observation to support the interpretation that the euhedral pyrite and by inference the massive pyrite-quartz body were previous to the pyrrhotite pipes. During the present study, the observation of pyrrhotite crosscutting euhedral pyrite could not be reproduced despite careful search. Moreover, as explained above, all studied textures strongly suggest that euhedral pyrite postdates pyrrothite.

Fine-grained mixture of pyrite and marcasite also replaces pyrrhotite. This mixture is generally present along cracks, grain boundaries, and also inside the pyrrhotite grains where they replace the pyrrhotite and form the typical "intermediate product" texture (Fig. 3 A-D; Ramdohr, 1980).

Transformation of pyrrhotite in non-porous pyrite is a low-temperature replacement process indicative of input of additional reduced sulfur and more acidic conditions, according to Murowchick (1992) and Quian et al (2011).

3 Conclusions

The new data suggest an early emplacement of the pyrrhotite pipes inside the Pucará carbonate sequence. These pipes evolve outward to Pb-Zn replacement bodies. Similar pipe morphology and mineral associations are known in other polymetallic nearby deposits with low-sulfidation assemblages like Vinchos (Lavado and Farfán 2008) and Atacocha, located 20 and 10 km north of Cerro de Pasco. A N¬S corridor is recognized in the field. The three deposits of Vinchos, Atacocha, Cerro de Pasco and other similar deposit are within this corridor along major N-S and NNW-SSE faults.

Cordilleran deposits with high-sulfidation assemblages like Colquijirca and Morococha (Bendezú Juarez 2007, Bendezú and Fontboté 2009, Catchpole et al., 2011) show an early mineralization stage of pyrite-quartz replacement bodies and veins. The pyrite-quartz body of Cerro de Pasco has characteristics similar to the first stage of these deposits. It can be interpreted as the early expression of the magmato-hydrothermal system that subsequently produces the Cu-Ag-(Au-Zn-Pb) enargite-pyrite veins and Zn-Pb-(Bi-Ag-Cu) carbonate replacement bodies.

The large Cerro de Pasco deposit is a product of two distinct superimposed mineralizing events. A first low-sulfidation event formed the pyrrhotite pipes and the associated Fe rich sphalerite and galena replacement bodies; and a second event, with up to high-sulfidation assemblages, gave rise to the emplacement of the pyrite-quartz body, enargite-pyrite veins and Zn-Pb-(Bi-Ag-Cu) carbonate replacement bodies.

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References

Baumgartner R (2007) Sources and evolution in space and time of hydrothermal fluids at the Cerro de Pasco Cordilleran base metal deposit, Central Peru: Terre & Environnement 66: 167 p.

Baumgartner R, Fontboté L, Vennemann T (2008) Mineral zoning and geochemistry of epithermal polymetallic Zn-Pb-Ag-Cu-Bi mineralization at Cerro de Pasco, Peru. Economic Geology 103: 493-537.

Baumgartner R, Fontboté L, Spikings R, Ovtcharova M, Schneider J, Pace L, Gutjahr M (2009) Bracketing the age of magmatic-hydrothermal activity at the Cerro de Pasco epithermal polymetallic deposit, central Peru: a U-Pb and $^{40}Ar/^{39}Ar$ study. Economic Geology 104: 479-504.

Bendezú R (2007) Shallow polymetallic and precious metal mineralization associated with a Miocene diatreme-dome complex: the Colquijirca district in the Peruvian Andes. Terre & Environnement 64: 221 p.

Bendezú R, Fontboté L (2009) Cordilleran epithermal Cu-Zn-Pb-(Au-Ag) mineralization in the Colquijirca District, Central Peru: deposit-scale mineralogical patterns. Economic Geology 104: 905-944.

Catchpole H, Kouzmanov K, Fontboté L, Guillong M, Heinrich C.A (2011) Fluid evolution in zoned Cordilleran polymetallic veins - Insights from microthermometry and LA-ICP-MS of fluid inclusions: Chemical Geology 281: 293-304.

Einaudi M (1968) Pyrrhotite-pyrite-sphalerite relations at Cerro de Pasco, Peru. Unpublished Ph.D. thesis, Cambridge, MA, Harvard University, 381 p.

Einaudi M (1977) Environment of ore deposition at Cerro de Pasco, Peru. Economic Geology 72: 893–924.

Lacy W (1949) Types of pyrite and their relations to mineralization at Cerro de Pasco, Peru: Unpublished Ph.D. thesis, Cambridge, MA, Harvard University, 193 p.

Lavado M, Farfán C (2008) Reinterpretación geológica; aspectos geo-económicos; retros y logros en la explaración del yacimiento Vinchos. XIII Congreso Latinoamericano de Geología y XIV Congreso Peruano de Geología, Lima-Perú, 2008.

Murowchick J (1992) Marcasite inversion and the petrographic determination of pyrite ancestry. Economic Geology 87: 1141–1152.

Qian G, Xia F, Brugger J, Skinner W, Bei J, Chen G, Pring A (2011) Replacement of pyrrhotite by pyrite and marcasite under hydrothermal conditions up to 220 °C: An experimental study of reaction textures and mechanisms. American Mineralogist 96: 1878-1893.

Ramdohr P (1980) The ore minerals and their intergrowths Pergamon (Oxford), 1205 p.

Ward H (1961) The pyrite body and copper orebodies, Cerro de Pasco mine, central Peru. Economic Geology 56: 402-422.