Stratabound Cu-(Ag) Deposits in the Permian Mitu Red-Bed Formations, Central Peru

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1 Introduction

In central Peru, stratabound metal-sulfide concentrations of red-bed type are present throughout the stratigraphic column. Examples are:

Lower Tertiary	Casapalca Fm.	Doña Basilia
Mid Cretaceous	Goyllarisquizga Fm.	Cochas Region
Permian	Mitu Fm.	Goyllarisquizga
		Negra Huanusha

However, only descriptions of the latter have been published (Amstutz 1956; Kobe 1960), and will be summarized below.

2 General Geology

The Negra Huanusha region lies in the high pampa (approx. 4300 m alt.), 25 km NNE of La Oroya, E of La Cima (on the La Oroya-Cerro de Pasco railway line), in the source area of the Palcamayo and Tishgo Rivers respectively.

The stratigraphic sequence from bottom to top (or from E to W – see Fig. 1) is:

Excelsior Formation[2] *(Lower to Middle Paleozoic).* Sericite-(chlorite) schists with quartz veinlets, locally intercalated coarse conglomerate beds, amphibolite accompanied by chlorite schists containing magnetite in well developed octahedra (discordance).

Mitu Formation (Permian). Essentially medium- to fine-grained red sandstone or arkose with some beds of red mudstone (cross-bedding, ripple marks, shrinkage-crack patterns with fossil raindrops are occasionally observed), sandstone with abundant mud-lenses (main sulfide-bearing horizon), often bleached gray-greenish and with abundant carbonized plant remains (determined by Jongmans (1954) and by Alleman and Pfefferkorn (1988) and Pfefferkorn and Alleman (1989)). In the SE a red-violet porphyry substitutes the thinning-out sandstone

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[2] According to Mégard (1978), however, the Mitu red-beds are underlain by Precambrian schists with amphibolites and truncated by faults and thrusts along both flanks of the anticline.

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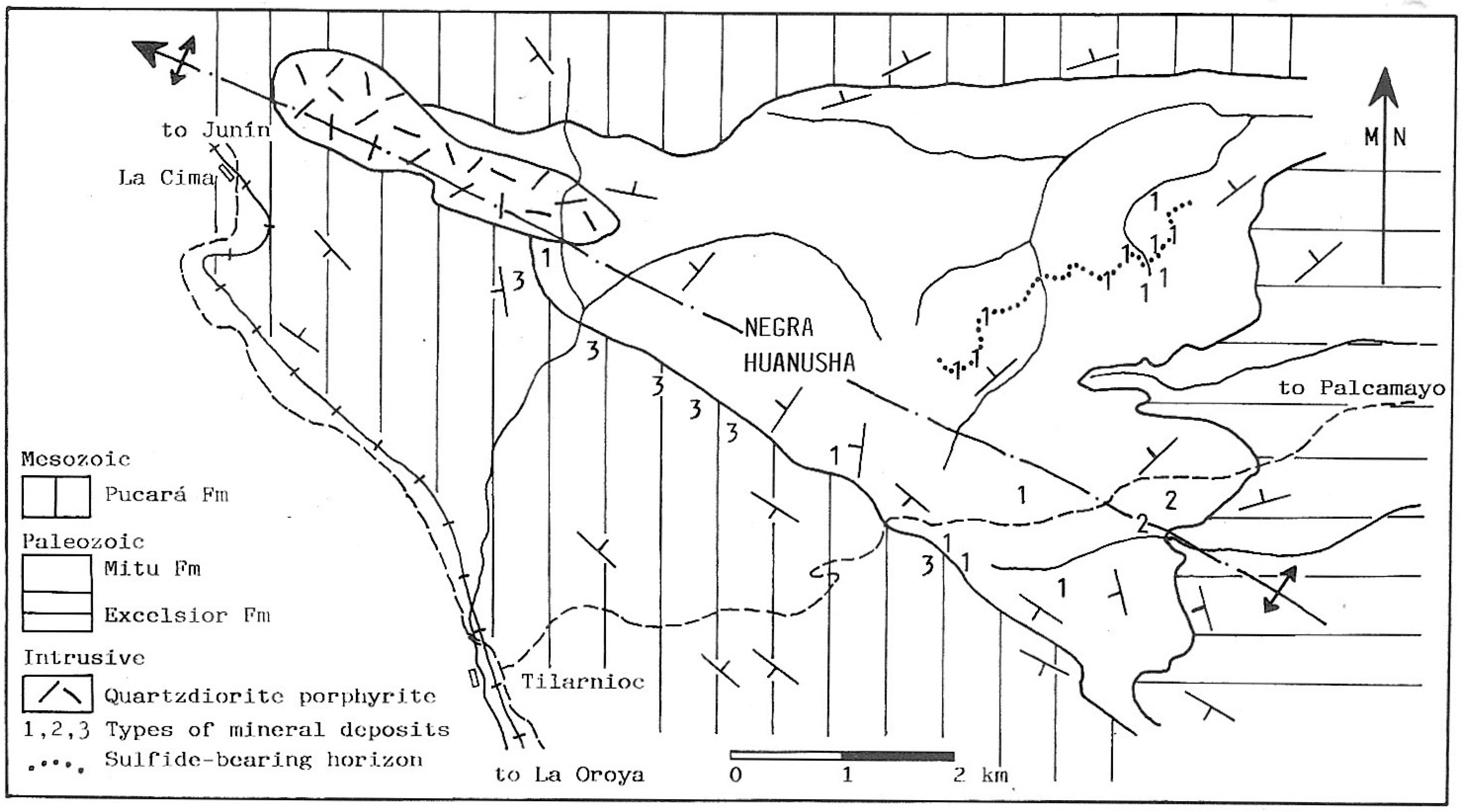

Fig. 1. Geology and metal concentrations, Negra Huanusha region (number *1* to *3* indicate types of deposits mentioned in the text)

series[2]. Discoloration is also often observed along the contact to the overlying Pucará Group (discordance).

Pucará Group (Lower Mesozoic). Thin shaly beds at the base are followed by white, massive limestone with rare undeterminable fossils.

A flat westerly plunging anticline, affecting both the Paleozoic formations and their Lower Mesozoic cover, is the main regional structure.

An intrusive stock of quartzdiorite-porphyrite lies across the contact Mitu-Pucará along the anticlinal axis. A thin contact zone against Pucará limestone in the NW indicates a post-Pucará age for this intrusive.

The Mitu Fm. thins out rapidly along both flanks of the anticline and disappears then completely towards the E (Harrison 1940)[2].

3 Mineral Deposits – Field Appearance

Three types of metal-sulfide concentrations are present in the Negra Huanusha region; two, rather similar, within the body of the Mitu sandstone formation, the third along the contact with the overlying Pucará Group (Fig. 1):

Type 1. Sulfide concentrations occur in bleached portions of the otherwise red-colored sandstone; the outlines of bleached volumes are irregular, but may follow the bedding. The largest volume of bleached and sulfide-bearing sandstone, exposed over an area of about 250×15 m at Negra Huanusha (the target of the largest mining operation in the past), appears to lie in the same stratigraphic position as the 1-km-long intermittently bleached zone 1.5 km to the NE (see Fig. 1).

Other, unrelated occurrences are much smaller (dimensions in the decameter x m range). The gray-greenish discolored rock volumes contain characteristically concentrations of carbonized plant remains. Plant leaves and branches several cm thick mark bedding planes. The coalification process has produced shrinkage cracks, now filled by calcite and malachite. Occasionally, bleached areas extend along faults and follow narrow mylonite zones. Among the disseminated sulfides which – with increasing concentration – darken the color to a dark gray, there is chalcocite with bornite and covellite. Near the surface, these may be altered to malachite.

Type 2. Copper sulfide spots and patches may occur in the red sandstone, only rarely bleached. The sulfide concentrations do not persist over more than a few meters. Here, typically magnetite/hematite accompany the Cu-sulfides.

Type 3. Along the contact Mitu-Pucará, portions of the sandstones appear irregularly tectonized, with black argillaceous shear planes. Such zones, occasionally several 100 m long but only meters wide, are the loci for a slight concentration of Cu-sulfides, mainly chalcocite, notably altered into malachite and azurite.

4 Mineral Deposits – Hand Specimen to Microscope Scale

A fairly coarse-grained, layered sandstone/arkose with mud lenses is the principal host for metal-sulfide concentrations, which appear as disseminated black specks particularly in the coarse-grained portions. Rock constituents are quartz, plagioclase, microcline, sericite/muscovite, calcite, rutile/anatase pseudomorphs after titanomagnetite, some chlorite as well as rounded volcanic fragments of andesitic composition. The red color – outside the sulfide-bearing portions – is due to hematitic-limonitic matter disseminated among the silicate grains. Bleaching would be the result of conversion of Fe^{3+} to Fe^{2+} or due to massive removal of Fe as a whole. Carbonaceous matter is restricted to larger plant remains or coaly fragments among the other constituents, but does not occur as matrix of the rock. Calcite is the only fracture-filling mineral through coaly fragments and silicates, and may occur coarse-grained among sulfide concentrations. There is little or no matrix between the mineral grains; they are in direct contact or have some c lay minerals between them.

Type 1. Chalcocite, bornite and covellite as primary sulfides, and malachite, azurite, cuprite and Cu-sulfate as secondary phases are the Cu-bearing constituents, while minor Ag-compounds are stromeyerite, polybasite and native silver. The Cu-minerals need not to be in direct contact with carbonaceous matter, although the heaviest concentration is around or within the coal (see photos in Amstutz 1956 and Kobe 1960). Chalcocite (s. l.) is the most common sulfide, disseminated with jagged outlines, smaller and of the same size as the silicate grains, occasionally with mutual penetrations. It is concentrated around coal remains and penetrates the cell structure to varying degrees, and is often accompanied by covellite. Bornite only occurs with stronger chalcocite concentrations and is always surrounded by it (e.g., as fillings of cell interiors or as graphic-myrmekitic intergrowth with chalcocite). Some silver minerals are also concentrated around coal fragments and may occur as fine, short veinlets through the arkose.

Type 2. Here, chalcocite is accumulated in spots and nodules in the barely bleached red sandstone, and particularly in a coarse-grained reddish-gray arkose. The nodules are composed mainly of quartz in a matrix of chalcocite, which contains abundant hematite prisms. In places magnetite, rutile/anatase is disseminated throughout the rock, but only rarely within the sulfide nodules. Chalcocite may substitute hematite, while hematite, rutile/anataste often replace magnetite. Coal in this type of deposit is absent or at most a very minor component.

Type 3. This type is poorly documented and comprises tectonized parts of the bleached top portion of the Mitu Formation and the overlying thin terrestrial series of the otherwise calcareous Pucará Group. Disseminated chalcocite, partly weathered to malachite and azurite, was the target for small extractive operations.

5 Metal Contents

Bulk analysis of selected rock types gave the following results:

Cu (wt.%)	
0.02	Normal, fine-grained red arkose
0.02	Layered, coarse-grained red-gray arkose
0.29	Somewhat layered, fine-grained greenish bleached arkose
2.95	Bluish-gray mud-sandstone with visible chalcocite dissemination
3.67	Bleached sandstone with coal remains and malachite stain
8.2	Blackish sandstone with high concentration of coal and Cu-sulfides

Vanadium is indicated by spectrographic analysis in the range between 0.01 and 0.1%, and uranium is below the detection limit. The ore extracted over 2 years at Negra Huanusha proper averaged a grade of 3.2% Cu and 2.9% Ag with a trace of Au, while the rock material (bleached sandstone) averaged 61% SiO_2, 16% Al_2O_3 and 2.3% Fe. This copper-bearing sandstone was mainly mined as SiO_2-addition to the copper revet smelter in La Oroya.

6 Conclusions

Interpretation of environmental conditions favorable for the accumulation of the clastic host sedimentary formations and the concentration of metal sulfides is difficult without additional investigations. However, it appears likely that the red sandstone, arkose, and mudstone were deposited in a flat river plain or near-shore flats – with vegetal remains swept together along the water courses – occasionally submerged for short periods. The climate was arid, as indicated by the shrinkage cracks and fossil raindrops and the red color of the whole formation. Contemporaneous volcanic activity is demonstrated by the lateral grading of the sediments into a porphyry as well as the volcanic fragmental content of the arkoses themselves. The detrital components (including magnetite – location of type 2 deposits closest to Excelsior Fm., see Fig. 1) were derived from the erosion of the underlying metamorphic basement and possibly the Carboniferous sedimentary formations (missing in this region) and the contemporaneous volcanites. The metals contained in the groundwater (in form of soluble sulfates and possibly chlorides) were preferentially reduced and precipitated as sulfides in and around the decaying and carbonizing vegetal matter. The activity of bacteria could have intensified this process by the production of H_2S.

The observed features suggest that the Cu-sulfide concentration was a continued process during accumulation and diagenesis of these sedimentary formations (mainly erosion products of the Paleozoic basement and contemporaneous volcanics for types 1 and 2) while renewed post-Permian erosion led to the formation of the intermittent, stratabound accumulations (type 3) at the base of the Mesozoic.

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