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The geology of the Morro Velho gold deposit in the Archean Rio das Velhas greenstone belt, Quadrilátero Ferrífero, Brazil

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Abstract

The Morro Velho gold deposit, Quadrilátero Ferrífero region, Minas Gerais, Brazil, is hosted by rocks at the base of the Archean Rio das Velhas greenstone belt. The deposit occurs within a thick carbonaceous phyllite package, containing intercalations of felsic and intermediate volcaniclastic rocks and dolomites. Considering the temporal and spatial association of the deposit with the Rio das Velhas orogeny, and location in close proximity to a major NNW-trending fault zone, it can be classified as an orogenic gold deposit. Hydrothermal activity was characterized by intense enrichment in alteration zones of carbonates, sulfides, chlorite, white mica±biotite, albite and quartz, as described in other Archean lode-type gold ores. Two types of ore occur in the deposit: dark gray quartz veins and sulfide-rich gold orebodies. The sulfide-rich orebodies range from disseminated concentrations of sulfide minerals to massive sulfide bodies. The sulfide assemblage comprises (by volume), on average, 74% pyrrhotite, 17% arsenopyrite, 8% pyrite and 1% chalcopyrite. The orebodies have a long axis parallel to the local stretching lineation, with continuity down the plunge of fold axis for at least 4.8 km. The group of rocks hosting the Morro Velho gold mineralization is locally referred to as *lapa seca*. These were isoclinally folded and metamorphosed prior to gold mineralization. The *lapa seca* and the orebodies it hosts are distributed in five main tight folds related to F1 (the best examples are the X, Main and South orebodies, in level 25), which are disrupted by NE- to E-striking shear zones. Textural features indicate that the sulfide mineralization postdated regional peak metamorphism, and that the massive sulfide ore has subsequently been neither metamorphosed nor deformed. Lead isotope ratios indicate a model age of 2.82±0.05 Ga for both sulfide and gold mineralization. The *lapa seca* are interpreted as the results of a pre-gold alteration process and may be divided into carbonatic, micaceous and quartzose types. The carbonatic *lapa seca* is subdivided into gray and brown subtypes. Non-mineralized, gray carbonatic *lapa seca* forms the hanging wall to the orebodies, and is interpreted as the product of extreme CO_2 metasomatism during hydrothermal alteration. This dolomitic *lapa seca* ranges in composition from relatively pure limestone and dolomite to silty limestone and dolomite. The brown carbonatic and micaceous *lapa secas* are the host rocks to gold. These units are interpreted to correspond to the sheared and hydrothermal products of metamorphosed volcaniclastic and/or volcanic rocks of varying composition from dacitic to andesitic, forming various types of schists and phyllites. The high-grade, massive sulfide orebodies occur at the base of the gray carbonatic *lapa seca*. Both disseminated mineralization and quartz veins are hosted by micaceous *lapa seca*. The data are consistent with a model of

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epigenetic mineralization for the *lapa seca*, from a hydrothermal fluid derived in part from the Archean basement or older crust material.

Keywords: Orogenic Archean gold; Quadrilátero Ferrífero; Brazil; Greenstone belt; *Lapa seca*

1. Introduction

The Morro Velho gold deposit is located in the town of Nova Lima, in the northern sector of the Quadrilátero Ferrífero (QF) region, 12 km southeast of Belo Horizonte, the state capital of Minas Gerais, Brazil (Fig. 1). The deposit is hosted by rocks at the base of the Archean Rio das Velhas greenstone belt.

Gold was first recovered at Morro Velho by Domingos da Fonseca Leme in 1700, and the deposit has supported continuous mining since 1834, when the St. John D'El Rey Mining Co. began mechanized operations in the area. The mine reached a depth of 2400 m in 1929. For operational reasons, mining at Morro Velho was carried out from two underground mines, working the same orebody. The upper mine, Mina Velha, has a depth of 156 m above sea level (600 m deep), whereas the lower mine, Mina Grande, is at 1610 m below sea level, with a total depth of 2453 m at level 27, reached in 1929. Mining at the Mina Grande mine ceased in 1995, but Mina Velha operated until 2004. Production to date at Morro Velho amounts to more than 400 tonnes of gold.

Graton and Bjorge (1929), Guimarães (1970), Ladeira (1980), Oliveira et al. (1983) and Lobato et al. (2001c) have described geological relationships and mineralization at the Morro Velho deposit. This contribution describes the orebodies and the lithological sequence, based on detailed underground geological maps of level 10 at Mina Velha and levels 7, 22 and 25 at Mina Grande (Vial, 1981a,b, 1982). The discussion in this paper addresses the controversy regarding the Morro Velho gold mineralization and how it relates to the origin of its host rocks, known in the region as *lapa seca*. Other notable controversies refer to the age of the gold mineralization and consequently its origin by syngenetic or alternatively, epigenetic processes. The aim of this work is to address these questions and present new insights that provide plausible answers.

2. Regional geology

The QF is located in the southernmost São Francisco Craton (e.g., Almeida, 1967; Almeida and Hasui, 1984; Marshak et al., 1992; Baltazar and Zuchetti, 2007-this volume). The QF comprises crystalline basement rocks, i.e., granitoid–gneissic terranes of Archean age, and two overlying supracrustal units. These units are: 1) Archean greenstone belts, including the Rio das Velhas Supergroup; and 2) the Paleo- and Meso-Proterozoic metasedimentary Minas Supergroup, Itacolomi Group and Espinhaço Supergroup (Dorr, 1969; Noce, 1995). The Rio das Velhas Supergroup is divided into the upper Maquiné Group (mainly quartzite, conglomerate and phyllite) and the basal Nova Lima Group. The latter comprises metamorphosed volcanic, chemical and clastic sedimentary rocks. Pinto and Silva (1996), Zucchetti and Baltazar (1998) and Zucchetti et al. (2000) divide the Nova Lima Group into four tectono-stratigraphic domains, from bottom to top (Fig. 2):

1) mafic–ultramafic rocks, characterized by the Córrego Ouro Fino (massive, amigdaloidal and variolitic metabasalts, oxide-facies banded iron-formation (BIF), metachert and carbonaceous schist), Córrego dos Boiadeiros (tholeiitic units intercalated with minor, variolitic komatiitic basalt flows) and Quebra Osso Formations (peridotitic komatiites with spinifex texture and cumulate sills with minor banded iron-formation).
2) volcaniclastic and metasedimentary rocks of the Ribeirão Vermelho Formation, including pyroclastic dacitic tuffs and agglomeratic units with minor lava flows;
3) volcanogenic and metasedimentary rocks of the Mestre Caetano Formation, comprising intercalations of felsic pyroclastic and epiclastic horizons (graywackes) with minor carbonaceous schist, and carbonate schist (including *lapa seca*);
4) metasedimentary rocks, comprising the Córrego do Sítio, Mindá, Catarina Mendes, Córrego da Paina, Fazenda Velha and Pau D'Óleo Formations, encompassing quartz–white mica–chlorite schist (metapsammites), feldspar–quartz schist (metagraywackes), and carbonaceous schist (metapsammites).

The Paleoproterozoic Minas Supergroup (Babinski et al., 1995) is divided into the Caraça, Itabira, and Piracicaba Groups with mica schists, quartzite, marble, phyllite and Lake Superior-type BIF (Dorr, 1969). The