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An epigenetic origin for the Passagem de Mariana gold deposit, Quadrilátero Ferrífero, Minas Gerais, Brazil

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Abstract

The gold–tourmaline quartz–vein deposit of Passagem de Mariana, in the southeastern part of the Quadrilátero Ferrífero, produced more than 60 tonne of gold, from the end of the 17th Century until 1954. The mine has not operated since 1985. Orebodies are veins composed of white quartz (>60 vol.%), carbonate (ankerite), tourmaline, sericite and sulfides. Tourmaline (dravite), up to 10 vol.% of the vein, occurs as subhedral, coarse, commonly zoned crystals, and is concentrated along vein boundaries and on the edges of host rock inclusions in the veins. Tourmaline is present in all rock types in the mine, but the chemical composition of the host rocks determinates the intensity of tourmalinization, with the alteration being greater in sericitic phyllites, graphite–sericite phyllites, and calcareous rocks. The most abundant sulfide is arsenopyrite, which is normally associated with pyrite and pyrrhotite. Minor amounts of chalcopyrite, galena, löllingite, berthierite, and maldonite are present throughout the deposit. Sulfides are concentrated at veins boundary or are dispersed in the veins. Arsenopyrite is associated, most commonly, with calcareous rocks, and graphite–sericite phyllite. Pyrrhotite is usually found at the base of itabirites. Gold abundance is directly proportional to sulfide concentration. Hydrothermal alteration associated with the veins includes silicification, tourmalinization, and sulfidation. The mineralized zone is a shear zone associated with a bedding-parallel thrust fault that juxtaposes the itabirite (Lower Proterozoic Minas Supergroup) over other units. This shear zone/thrust fault extends for tens of km beyond the Passagem mine and hosts numerous gold deposits. The richest orebodies are along the itabirite footwall contact and within the graphite–sericite phyllite (Main orebody). Although many lithologic units were mineralized the graphite–sericite phyllite appears to have been most favorable for gold deposition.

The area underwent three phases of deformation, D_1, D_2 and D_3. Mineral assemblages indicate upper-greenschist to lower-amphibolite conditions of regional metamorphism. Retrograde metamorphism, characterized by chloritization of biotite and chloritization and biotitization of garnet, developed locally. The gold-bearing veins crosscut the main foliation and lithologic contacts at low angle and occur within, or are in contact with, all lithotypes. Field and laboratory data indicate that gold mineralization at Passagem de Mariana is epigenetic. Gold deposition occurred after the peak of metamorphism, within the late- to post-D_2 period of deformation, which is correlated with second set of structures of Trasamazonian age of Alkmim and Marshak [Alkmim, F.F., Marshak, S., 1998. Transamazonian Orogeny in the Southern São Francisco Craton Region, Minas Gerais, Brazil: evidence for Paleoproterozoic collision and collapse in the Quadrilátero Ferrífero. Precambrian Research 90, 29-58.], indicating that the gold mineralization occurred between 2.124 and 2.04 Ga. We choose to regard Passagem de Marina as an orogenic gold deposit as defined by Groves et al. [Groves, D. I., Goldfarb, R.J., Gebre-Mariam, M., Hagemann, S.G., Robert, F., 1998. Orogenic

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gold deposits: A proposed classification in the context of their crustal distribution and relationship to other gold deposit types. Ore Geology Reviews 13, 7-27.], i.e., an epigenetic, structurally-hosted lode–gold vein system in a deformed metamorphic terrane.

Keywords: Gold; Quartz vein; Arsenopyrite; Tourmaline; Passagem de Mariana; Quadrilátero Ferrífero; Brazil

1. Introduction

The Passagem de Mariana gold mine is located in the village of Passagem de Mariana, 7 km east of Ouro Preto, in the southeastern part of the Quadrilátero Ferrífero (QF), Minas Gerais, Brazil (Fig. 1). The deposit produced at least 60 tonne of gold from sulfide–tourmaline–quartz veins between the end of the 17th Century and 1954. After intermittent production from 1954 to 1985, the Companhia Minas da Passagem (CMP), owner of the property, halted mining operations. The mine is 409 m deep and is flooded below the 315 level (83 m below surface). Access is via inclined shafts, 1400 m in length and dipping 15°, generally in an easterly direction (Fig. 2).

A mineralized zone, which includes the Passagem de Mariana mine, extends more than 23 km from Ouro Preto to Antonio Pereira (Fig. 1). The following abandoned mines occur in this zone: Veloso, Palácio Velho or Chico Rey, Bom Jesus das Flores, Taquaral, Passagem de Mariana, Mata Cavalo, Morro Redondo, Morro Santana, Rocinha, and Antonio Pereira (Fig. 1). The zone follows the base of the itabirites of the Proterozoic Cauê Formation (Itabira Group). The main orebodies in the Passagem de Mariana, Mata Cavalo, and Morro Santana mines occur at the base of the itabirite. Some orebodies occur within the itabirite in the Veloso and Antonio Pereira mines, whereas smaller orebodies occur within quartzites of the Caraça Group in the Rocinha and Ouro Preto mines. Mineralization in the Veloso mine formed quartz veins and massive arsenopyrite within itabirite, both along bedding.

The geology of the Passagem de Mariana gold mine has been described by numerous authors (Hussak, 1898; Bensusan, 1910; Derby, 1911; Ferrand, 1913; Legraye, 1937; Maia, 1944; Guimarães, 1965; Fleischer, 1971; Fleischer and Routhier, 1973; Vial, 1988; Vial et al., 1988; Duarte, 1991; Fleischer and Vial, 1991, and others). The stratigraphy, structure, and genesis of the deposit have been the subject of much debate. Among these, the genesis of the ore remains the most contentious issue. Fleischer (1971) and Fleischer and Routhier (1973) proposed a syngenetic origin for the vein deposit, whereas an epigenetic origin for the deposit was favored by the other authors.

The present contribution presents the results of studies by the authors, including sampling, chemical assaying, underground mapping of 1700 m of workings at 1:100 scale, as well as petrographical and fluid inclusion studies of both mineralized and barren veins. We propose to demonstrate the unquestionable epigenetic origin of the deposit.

2. Regional geology

The southeastern part of the QF is underlain by metamorphosed Precambrian plutonic, volcanic, and sedimentary rocks comprising four major stratigraphic units (Guimarães, 1965; Dorr, 1969). These are, from oldest to youngest: (1) the Archean granitic and gneissic basement; (2) the Archean Rio das Velhas Supergroup; (3) the Lower Proterozoic Minas Supergroup; and (4) the Lower Proterozoic Itacolomi Group (Fig. 1).

The Rio das Velhas Supergroup, a greenstone belt sequence, comprises two sub-groups in the region: the Nova Lima Group (metavolcanic rocks, metapelites, and iron-rich chemical metasedimentary rocks) and the Maquiné Group (metapsammites and metapelites). The Minas Supergroup includes three groups: the Caraça Group (clastic metasedimentary rocks), the Itabira Group (chemical metasedimentary rocks), and the Piracicaba Group (a rhythmic succession of clastic and chemical metasedimentary rocks). The Caraça Group includes the Moeda Formation (metaconglomerates, quartzite, and metapelites) and the overlying Batatal Formation (carbonaceous metapelites). The Itacolomi Group is made up of mature psammites (quartzites and conglomerates).

The mine area is underlain by the Nova Lima, Caraça, and Itabira Groups (Fig. 1). The Nova Lima Group is represented by its upper portion, the Catarina Mendes Formation, composed of intercalations of feldspar–quartz–mica schist (metagraywacke), mica schist (metapelite), tourmalinite, calc-silicate rocks and tremolitite (metamarl), with rare paraconglomerate layers (Pinto and Silva, 1996; Zucchetti and Baltazar, 1998; Lobato et al., 2001).

3. Mine geology

3.1. Stratigraphy

Ten informal lithological units were identified during underground mapping of accessible workings. The relationship between units is summarized in Fig. 3. Each unit is