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Brazil’s premier gold province. Part II: geology and genesis of gold deposits in the Archean Rio das Velhas greenstone belt, Quadrilátero Ferrífero

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Abstract Orogenic gold deposits are hosted by rocks of the Archean Rio das Velhas greenstone belt in the Quadrilátero Ferrífero region, Minas Gerais state, Brazil, one of the major gold provinces in the world. The gold deposits occur at the base of the mafic-ultramafic succession, with the most important orebodies controlled by E–W-striking, strike-slip faults. The main mineralization styles are (1) structurally controlled, sulfide replacement zones in banded iron formation (BIF); (2) disseminated sulfide minerals and gold in hydrothermally altered rocks along shear zones; and (3) auriferous quartz-carbonate–sulfide veins and veínlets in mafic, ultramafic, and felsic volcanic rocks, and also in clastic sedimentary rocks. The most common host rocks for ore are metamorphosed oxide- and carbonate-facies banded iron (+ iron-rich metachert) formations (e.g., the Cuiabá, São Bento and Raposos deposits) and the lapa seca unit, which is a local term for intensely carbonatized rock (e.g., the giant Morro Velho mine with > 450 t of contained gold). Metabasalts host most of the remaining gold deposits. Mineralogical characteristics and fluid inclusion studies suggest variations in the H₂O/CO₂ ratio of a low-salinity, near-neutral, reducing, sulfur-bearing, ore fluid. The presence of abundant CH₄-rich inclusions is related to reduction of the original H₂O–CO₂ fluid via interaction with carbonaceous matter in the wallrocks. Oxygen fugacity was close to that of graphite saturation, with variations likely to have been influenced by reaction with the carbonaceous matter. Carbon-rich phyllites and schists, which commonly bound ore-bearing horizons, seem to have played both a physical and chemical role in localizing hydrothermal mineral deposition. Microtextural studies indicate that gold deposition was mainly related to desulfidation reactions, and was paragenetically coeval with precipitation of arsenic-rich iron sulfide minerals. Carbon isotope data are compatible with dissolution of CO₂ from pre-existing mantle-derived carbonation zones, and indicate fluids of metamorphic origin. A major episode of hydrothermal fluid introduction into different rock types caused epigenetic gold formation and wallrock alteration at about 300 to 400 °C during the late stages of regional deformation and metamorphism of the greenstone belt. The age of gold mineralization is constrained to be younger than 2.698 and perhaps closer to 2.670 Ma.

Introduction

The Quadrilátero Ferrífero region was the most important Brazilian gold producing area from the early 18th century, until the late 1970s, and represents a world-class gold province. Historical gold production amounts to more than 1,000 tonnes of gold (t Au), which is roughly 40% of the total gold production of Brazil (Ribeiro-Rodrigues et al. 2000). Among the many primary gold deposits, the giant underground Morro Velho mine produced about 450 t Au, and was mined to a depth of almost 2,500 m over a length of 100 years. These orogenic gold deposits (terminology after Groves et al. 1998), are hosted by rocks of the Archean Rio das
Velhas Supergroup. The most important deposits, located in the northern part of the Quadrilátero Ferrífero (Figs. 1, 2, and 3, and also Fig. 2 of Lobato et al. 2001, this volume), include Cuiabá, Morro Velho (Grande and Velha), Raposos, São Bento, Faria, Bicalho, and Bela Fama (e.g., Ladeira 1991; Scarpelli 1991; Vieira 1991; Ribeiro-Rodrigues et al. 1996a; Lobato et al. 1998b).

Proterozoic successions host other types of gold deposits in the Quadrilátero Ferrífero (e.g., Ribeiro-Rodrigues et al. 2000), but these are not the focus of the present contribution.

The Rio das Velhas Supergroup comprises a typical greenstone-belt-type succession, the Rio das Velhas greenstone belt, most of which is within the Quadrilátero Ferrífero region, located in the southernmost part of the São Francisco craton (Fig. 1 of Lobato et al. 2001, this volume). The greenstone-hosted orogenic gold deposits occur within the rocks of the Nova Lima Group, at the base of the Rio das Velhas Supergroup. The group, exposed in four main lithostructural domains (Fig. 3 of Lobato et al. 2001, this volume) is subdivided into five lithological associations, designated, from bottom to top, the (1) mafic-ultramafic volcanic, (2) volcanic-chemical, (3) clastic-chemical, (4) volcanioclastic, and (5) resedimented associations (Zucchetti and Baltazar 1998; Lobato et al. 2001, this volume). Much of the gold production, including the giant Morro Velho mine, is from orebodies hosted by a hydrothermally altered unit referred to as lapa seca and by metamorphosed oxide- and carbonate-facies banded iron formations (BIF). Subordinately, metabasalts and clastic metasedimentary rocks host the remainder of the orebodies. The gold

Fig. 1 Simplified geological map of the region surrounding Nova Lima, with location of gold deposits mentioned in the text (modified after Vieira and Oliveira 1988, and adapted according to Zucchetti and Baltazar 1998. Nova Lima rock associations adapted from the work by Baltazar and Pedreira 1998. Surface projection of a horizontal section of the Morro Velho–Mina Grande deposit is shown in Fig. 4)