Gold deposits of the Tapajós and Alta Floresta Domains, Tapajós–Parima orogenic belt, Amazon Craton, Brazil

Abstract The Tapajós region is one domain of a major Paleoproterozoic orogenic belt, named Tapajós–Parima and is discussed in the context of the evolution of the Amazon Craton. The orogenic belt is composed of a back-arc sequence, four volcano-plutonic arcs, intra-arc sedimentation and is limited to the east by the cratonic rocks of the Central Amazon Province. The evolution and timing of the main events is established by zircon, baddeleyite, and titanite SHRIMP U–Pb geochronology of 29 rock samples, while lead and argon isotopes are used to study the age and source of the gold mineralization. Based on the mesosopic nature of the orebodies, and, in some cases, on microthermometric and stable isotope data, the Tapajós gold deposits are classified as (1) orogenic and (2) intrusion-related, and may be grouped into four deposit-type categories: (1) orogenic, turbidite-hosted: disseminated and quartz–pyrite veinlet deposits, hosted by metaturbidites (lower greenschist-facies, Jacareacanga Group) and emplaced in ductile structures; (2) orogenic, magmatic arc-hosted: disseminated and pyrite–quartz–carbonate vein deposits, hosted by metamorphic rocks (Cuíú-Cuiú Complex) and formed under a ductile–brittle regime, with the Ouro Roxo deposit as a type example; (3) intrusion-related, epizonal quartz-vein deposits: vertical to subvertical quartz-pyrite veins and pyrite disseminations filling extensional brittle faults; and (4) intrusion-related, epizonal, disseminated/ stockwork deposits, the type-example being the Serrinha deposit. Gold mineralization of type 3 is similar to that of Korean-type, while type 4 mineralization shows some similarities to porphyry-type deposits. Galena Pb–Pb and muscovite Ar–Ar data indicate an age of ~1,860 Ma for the intrusion-related gold mineralization. Preliminary Pb isotope data on K-feldspar indicate that the fluid source was more likely to have been from within the Jacareacanga, Cuíú-Cuiú and Tropas units than the Creporizão, Maloquinha, and Iriri units. This study shows the existence of two main types (orogenic and intrusion-related) of gold deposits, which are related to specific tectono-magmatic events that occurred during a limited period of time in the orogenic belt evolution. This information may be useful as a guide for gold exploration along the orogenic belt.

Introduction

The aim of this paper is to define the geological evolution of the Tapajós gold province and the nature and timing of the associated gold deposits.

Small-scale alluvial mining in the Amazon Craton has been the main source of gold in Brazil during the last three decades. Nilço Pinheiro discovered gold at the mouth of the Tropas River in 1958. This triggered the discovery of several other alluvial gold deposits during the 1960s (e.g. Cuíú-Cuiú, Porto Alegre, Patrocínio, Agua Branca and Porto Rico). The Tapajós gold province became the main gold producer in Brazil in the 1970s into the 1990s. About 430 landing airstrips were cleared to support the work of 80,000 miners in a very remote region covered by jungle. The annual gold production
during 1975–1990 was in the 60–80 t range, despite the fact that only a small portion of the gold being mined was officially reported by the Departamento Nacional da Produção Mineral.

The impressive gold production attracted the attention of several Brazilian companies. About 20 engineering and transportation companies created new mining subsidiaries to explore the Tapajós gold fields. None achieved success because of the adoption of a poor exploration philosophy that targeted only the alluvial deposits, which are usually high-grade but low tonnage deposits. Following exhaustion of some of the alluvial-cluval deposits, small-scale mining switched to primary ores, with the discovery of a few hundred lode gold occurrences in the Paleoproterozoic Tapajós–Parima Province, mainly in the Tapajós and Alta Floresta domains. Mining companies have evaluated several deposits (Ouro Roxo, São Jorge, Serrinha, Abacaxis, Limão, Crepóri and Castelo dos Sonhos). All these deposits have estimated reserves that vary from 5 to 60 t of gold.

The Brazilian Geological Survey has registered 178 sites of exposed primary ores; 140 in the Tapajós domain and 38 in the Alta Floresta domain. Normally, only the supergene zones above the fresh rock, approximately 15 to 120 m thick, are mined by open pit, although in a few cases, underground mining has been attempted. Underground mining has usually failed because of the lack of adequate investment, inappropriate technology, and excess underground water. Since 1995, several mining companies (e.g. Rio Tinto Zinc, Matapi, Barrick, Golden Star, Western Mining, Pegasus, and New Bullet) have explored the region, always surrounding a known mine site. In some areas, exploration has reached the drilling and deposit evaluation phase, as in the Limão, Ouro Roxo, São Jorge, Jutai, Castelo dos Sonhos, Abacaxis and Serrinha gold deposits. New data collected from drill cores, combined with fieldwork and new geological and geophysical regional maps produced by the Brazilian Geological Survey (Almeida et al. 2000; Klein and Vasques 2000; Bahia and Quadros 2000), have provided the background information for this study.

Regional tectonic setting

The Tapajós gold province is located in the south-central part of the Amazon Craton (Fig. 1). Numerous structural, geochronological, and metalliclogenic similarities with the Peixoto de Azevedo (Mato Grosso state) and Parima (Roraima state) gold provinces led Santos et al. (2000) to include the three domains in the same orogenic belt, named the Tapajós–Parima orogenic belt. This belt is 1,900 km long and 180–280 km wide, and includes a fourth domain, named Uaimiri and is mostly covered by the Uaimiri–Atroari Indian Reservation. These four domains (Parima, Uaimiri, Tapajós and Alta Floresta) are separated by sedimentary basins and the K’Mudku mobile belt (Fig. 1). Despite the scarcity of geological data from the Parima and Uaimiri domains, the four domains show the same main features: (1) evolution mainly between 2,030–1,870 Ga (Orosirian Period of the Paleoproterozoic); (2) a prominent north–northwest trend; (3) mainly calc-alkalic, magnetie-arc rocks (with lesser metasedimentary rock sequences); and (4) comparable gold metallogeny.

The belt is bordered to the west by younger Paleoproterozoic provinces that were accreted to the craton at ~1.85–1.70 Ga (Rio Negro and Rondônia–Jurua provinces). Underthrust rocks from the Tapajós–Parima belt may have been the partial source for the granitoids intruding the younger provinces, as indicated by Sm–Nd data (Santos et al. 2000).

The Tapajós–Parima orogenic belt represents new crust added to the Archean Central Amazon province (Archean) during the formation of the Paleoproterozoic (2.10–1.87 Ga) (Santos et al. 2000). Accreted sedimentary rocks and oceanic basaltic are present only in the western part of the belt. Calc-alkalic, arc-related granitoids generated mainly during four main magmatic pulses – 2.02, 1.96, 1.90 and 1.88 Ga (Santos et al. 2000; this work) – mainly dominate the orogenic belt. Intracratonic A-type granites of the Malaquinha (1.87 Ga) and Teles Pires (1.78 Ga) suites are intrusive into the rocks of the Tapajós–Parima orogenic belt.

Geology of the Tapajós and Alta Floresta Domains

The stratigraphy of the Tapajós and Alta Floresta Domains is summarized in Table 1. Bizinella et al. (1981) proposed the subdivision of the basement (Xingu Complex of Santos et al. 1975) into four main units, with distinctive ages, geochemistry and metallogeny: (1) Jacareacanga Group, a metavolcanoclastic sequence; (2) Cuiú-Cuiú Complex, composed mainly of tonalite-granodiorite and anorthosite, which are metamorphosed to amphibolite facies; (3) Parauari Intrusive Suite, comprising bimodal to ignimbrite, ranging from tonalite to syenogranite and dominated by unmetamorphosed monzogranites and granodiorites; and (4) Ingaranha Gabbro, representing augite gabbro that intruded the previous two units. Pessoa et al. (1977) considered that the gold mineralization was related to the two granitoid suites above, and that tin and niobium mineralization was associated with the subsequent Malaquinha intrusive suite.

The geologic knowledge of the Alta Floresta Domain is poorer than that of the Tapajós Domain, but four main units are interpreted as the same in both domains. Santos and Reis Neto (1982) integrated the Juruena Granodiorite (Alta Floresta Domain) into the Parauari suite, Moura et al. (1997b) and Valente (1998) recognized most of the Tapajós Domain units in the Alta Floresta Domain: Cuiú-Cuiú Complex, Parauari suite, Iziri Group and Teles Pires suite (Table 1, Fig. 2). Equivalent rocks to the Jacareacanga Group are locally present (Tabinao schists), but not shown in Fig. 2.

To improve the regional stratigraphy in a region lacking iso-topic information, 32 mineral samples (zircon, titanite and baddeleyite) were dated by U–Pb to determine the age of all Proterozoic units of the province. SHRIMP investigations were undertaken at Curtin University of Technology, Western Australia, following the procedures of Smith et al. (1998). Other U–Pb and Sm–Nd data used to interpret the regional geology are from Sato and Tassiani (1997) and Santos et al. (2000).

Supracrustal rocks

The Jacareacanga Group is a metamorphosed volcano-sedimentary sequence with a north–northwest structural trend exposed in the westernmost part of the orogenic belt (Figs. 1 and 3). The main metamorphic minerals in the Jacareacanga sequence are sericite in the metasedimentary rocks and actinolite in the metabasalts, indicating greenschist-facies metamorphism. However, in the areas with higher strain, the metamorphic grade reached the biotite zone.

This unit was previously considered to be a greenstone terrane, possibly Archean in age (Bizzinella et al. 1981). However, the geometric relationship between the supracrustal rocks and the syn-tectonic granitoids (Cuiú-Cuiú Complex) does not have the typical granitoid-greenstone dome-and-keel pattern, which is observed in the Trans-Amazonic and Carajás Provinces. Additionally, the volume of preserved basalts is small, leading Santos et al. (2000) to redefine the Jacareacanga Group as more probably an accretionary