MULTISTAGE KUROKO-TYPE PALEO-HYDROTHERMAL EVOLUTION AND ASSOCIATED HIGHLY POSITIVE OXYGEN ISOTOPE ANOMALIES IN VOLCANIC ROCKS OF THE MESOPROTEROZOIC SERRA DO ITABERABA GROUP, SÃO PAULO, BRAZIL

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INTRODUCTION

A multistage hydrothermal history could be characterized within the Mesoproterozoic metamorphosed volcano-sedimentary Serra do Itaberaba Group (SIG), which is part of the Ribeira Fold Belt (Almeida et al., 1973; Juliani & Beljavskis, 1995; Juliani et al., 2000). This volcano-sedimentary sequence is partially covered by the Neoproterozoic siliciclastic São Roque Group (Juliani et al., 1986; Hackspacher, 1999), being the whole sequence of supracrustal rocks crosscut by several Neoproterozoic to Phanerozoic granitic plutons, and affected by several NE-SW trending shear zones (Almeida et al., 1981). The SIG was affected by two progressive medium- to low-grade regional metamorphic events, which occurred during the Mesoproterozoic and the Neoproterozoic.

The paleo-hydrothermal systems were developed in a mid-ocean ridge environment and in a following back-arc basin stage associated with the emplacement of relative small andesitic to rhyodacitic intrusions (Pérez-Aguilar et al., 2000; Pérez-Aguilar, 2001). Genetically associated to paleo-hydrothermal systems, are found the metamorphic products of a large chloritic alteration zone (CZ1) and restrict chloritic (CZ2), argillic, and advanced argillic alteration zones, which crosscut CZ1. These hydrothermal alteration zones are similar to those present in Kuroko-type deposits (Franklin, 1993; Ohmoto, 1996). Also present are metamorphosed carbonatization, potassification, and silicification alteration zones, Algoma type BIFs, tourmalinites, gold-bearing graphite/sulfide pelites, and Cu and Zn soil anomalies (Juliani, 1993; Juliani et al., 1992; Pérez Aguilar, 2001; Pérez-Aguilar et al., in press).

RESULTS

For the igneous metabasites (+5.9 to +16.9‰), basic metavolcaniclastic rocks (+8.3 to 10.1‰), intermediate meta-igneous (+14.1 to 17.6‰) and meta-volcaniclastic (+15.3 to 17.8‰) rocks from the CZ1, the oxygen isotope data reflect well-defined trends of increasing $\delta^{18}O$ values with progressive intensity of the hydrothermal alteration processes. Samples from CZ2 yield whole-rock $\delta^{18}O$ values of +9.0 and +10.6‰, and δD value of –88‰. Plagioclase margarite corundum schist (marundite) from argillic alteration zone shows $\delta^{18}O$ value of +9.7‰ and δD of –55‰ (Pérez-Aguilar et al., in press).

The $\delta^{18}O$ values for the fluid in equilibrium with quartz from strongly altered rocks of the CZ1 (+5.8 to +14.4‰) were calculated for a range of temperatures between 200 to 300 ^{o}C, consistent with those of chloritic alteration zones. The calculated oxygen and hydrogen fluid composition in equilibrium with muscovite ($\delta^{18}O$ = +3.2 to 8.5‰; δD = –32‰) and margarite ($\delta^{18}O$ = +5.4 to 8.5‰; δD = –20 to –32‰) from rocks associated to marundites were calculated for a temperature interval compatible with those of pre-metamorphic argillic and advanced argillic alteration (~200 to 300 ^{o}C).

MULTISTAGE HYDROTHERMAL EVOLUTION

Integrated geological, petrological, and oxygen and hydrogen stable isotopes help to constrain four different hydrothermal alteration events (Pérez-Aguilar et al., in press). The first hydrothermal alteration event was associated to a nonsteady, essentially fracture-controlled, ocean crust cooling that established a widespread exchange of seafloor rocks with marine water at low temperatures and high water/rock ratios. This process resulted in a heterogeneous ^{18}O whole-rock enrichment (up to +15.5‰) and minor chemical changes. A second hydrothermal alteration event occurred in a deeper crustal level, during which seawater underwent isotopic exchange with previous heterogeneously ^{18}O enriched rocks, at high temperatures and low water/rock ratios, becoming fluids extremely enriched in heavy oxygen. The third and fourth stages were genetically linked to the emplacement of shallow andesitic to rhyodacitic intrusions in the back-arc basin environment. The estimated oxygen isotope composition of the fluid in equilibrium with quartz from CZ1 rocks, which were formed at the third alteration event, reflects ^{18}O-enriched fluid, which is mostly likely interpreted as ^{18}O-evolved seawater inherited from previous second stage. This third stage is characterized as a steady convective system associated with the discharge of hot ^{18}O enriched evolved seawater, which underwent isotopic exchange with relative cold

rocks at different water/rock ratios. High water/rock ratios favored strong rock alteration and extremely high heavy oxygen rock anomalies. The fourth stage was associated with higher temperature fluids if compared with those of previous alteration stages, mainly composed by evolved seawater with a subordinate magmatic component.

Related metamorphic products from the CZ1 are characterized by the presence of rocks with different amounts of anthopyllite and/or cummingtonite (cummingtonite-anthopyllite rocks), which are similar to those described in metamorphosed volcanogenic massive sulfide deposits (James et al., 1978; Riverin and Hodgson, 1980; Elliot-Meadows and Appleyard, 1991). Relative high $\delta^{18}O$ whole-rock values have also been observed in wall-rocks associated to massive sulfide deposits of Aljustrel in the Carboniferous Iberia Pyrite Belt (Spain), the Silurian Blue Hill (Maine, USA), and Kidd Creek and Mobrun in the Archean Abitibi greenstone belt (Canada) (Barriga and Kerrich, 1984; Beaty et al., 1988; Munhá et al., 1986; Hoy, 1993). These values have been interpreted as evidence of high ^{18}O ore-forming fluids and/or due to a first low temperature near seafloor alteration stage (Barriga and Kerrich, 1984; Beaty et al., 1988; Munhá et al., 1986; Hoy, 1993).

CONCLUDING REMARKS

Geological, petrological and stable isotope data strongly support a multistage paleo-hydrothermal evolution in the Mesoproterozoic SIG. The systematic stable isotope variations, represented by well-defined trends of increasing $\delta^{18}O$ values with progressive alteration intensity, are evidence that, in the SIG, hydrothermal isotope signatures were preserved, despite the overprinting of two medium- to low-grade metamorphic events that affected these rocks.. The extremely high $\delta^{18}O$ anomalies from the CZ1 rocks and related hydrothermal fluids were achieved due to a long-lived hydrothermal system. The identification of several pre-metamorphic hydrothermally altered zones and superimposed hydrothermal events in this group, similar to those observed in Kuroko-type base metal mineralizations, so as different hydrothermal events associated with gold mineralization (Beljavskis et al., 1999), expands the mineral potential for the occurrence of base metal deposits in the Serra do Itaberaba Group and in the volcano-sedimentary sequences of the Ribeira Fold Belt.

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