OXYGEN ISOTOPE HALOES IN OCEANIC MESOPROTEROZOIC PALEO-HYDROTHERMAL SYSTEMS FROM THE SERRA DO ITABERABA GROUP, SÃO PAULO, BRAZIL, AND ITS POTENTIAL APPLICATION TO MINERAL EXPLORATION

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Mesoproterozoic (Juliani et al., 2000) paleo-hydrothermal oceanic systems are present northeast of São Paulo city making part of the Serra do Itaberaba Group (SIG) (Juliani, 1993; Juliani & Beljavkis,1995).

In the SIG, the basal Morro da Pedra Preta Fm. is a metamophosed volcano-sedimentary sequence, composed mainly of N-MORB type metabasites and schists. Overlying is the Nhangucu Formation, with iron-manganesifeous schists, andalusite-rich schists, and lenses of meta-calcpelites and marbles. The Pirucaia Formation, with quartzites and quartz-rich schists, is a marginal facies of the Nhangucu Formation. These sequences are strongly deformed and were affected by two medium-grade and a low-grade metamorphic events during Mesoproterozoic and Neoproterozic orogenic events (Juliani, 1993; Juliani & Beljavskis, 1995).

The Morro da Pedra Preta Fm. was mostly deposited in an extensional regime, but also, together with the Nhanguçu Formation, during the subsequent installation of a back-arc basin, in a compressive regime (Juliani, 1993).

The paleo-hydrothermal systems developed during the installation of the back-arc basin, in the compressive regime, associated to intrusions with compositions varying from intermediate to felsic composition, and to which they are genetically linked (Juliani et al., 1992; Pérez-Aguilar, 1996, 2001).

Rocks constituted by cummingtonite and/or anthophillyte are the metamorphic product of variable hydrothermalized basic and intermediate/felsic protoliths, corresponding to pre-metamorphic propylitic hydrothermal alteration zones (Hemley & Jones, 1964; Meyer & Hemley, 1967; Rose, 1970; Pirajno, 1992).

These rocks formed by cummingtonite/anthophillyte are distributed in the interface between the Morro da Pedra Preta Fm. and the Nhanguçu Formation and are interpreted as formed by paleo-hydrothermal oceanic systems (Pérez-Aguilar et al., 2000; Pérez-Aguilar, 2001).

Surrounding intensely deformed intrusions of andesites/rhyodacites, due to tectonic transpositions, there is a zoned sequence of lithotypes that show a complete gradation between unaltered to strongly altered rocks, represented by groups of unaltered rocks, weakly altered rocks (typically with small amounts of metamorphic cordierite and/or cummingtonite), transitional rocks (where characteristically two ore three different metamorphic amphiboles coexist), moderately altered rocks (typically, in the metamorphic assemblage, all the hornblende was substituted by cummingtonite; also small amounts of cordierite and garnet may be present), and strongly altered rocks. Strongly altered rocks have a mineral association with cummingtonite and/or anthophillite + magnesian cordierite ± almandinic garnet ± quartz ± magnetite ± ilmenite ± rutile ± staurolite ± biotite ± chlorita. (Pérez-Aguilar, 1996, 2001).

Associated to these rocks are also observed layers of carbonatized rocks (constituted essentially by carbonate + epidote + actinolite + diopside), that typically occur under intermediate to felsic intrusions, marundites (rocks with corindon ± margarite ± muscovite ± rutile ± plagioclase ± tourmaline), hornblende-garnet amphibolites and meta-chloritites, that include, as an extreme cation lixiviation process, cummingtonite-garnet-chlorite schists. All of the above mentioned rocks are the metamorphic product of different types of hydrothermal alteration processes also present in the Morro da Pedra Preta Fm. Algoma type BIFs, sulfide-rich metapelites that were formed, at least, partially, by mineralizing pre-metamorphic processes, and extensive zones of rocks mineralized in gold are also present.

WHOLE-ROCK ISOTOPE DATA

The whole-rock oxygen isotope ratios are reported in values compared with the Standard Mean Ocean Water value (SMOW).

In the group of not altered and altered igneous metabasites, $\delta^{18}O$ values vary from 5.9‰ to 16.9‰. In the group of not altered and altered pyroclastic metabasites, genetically associated to igneous metabasites, these values range from 8.3‰ to 10.1‰, in altered meta-intermediate igneous rocks from 14.1‰ to 17.6‰, and in most meta-intermediate volcaniclastic rocks from 15.3‰ to 17.8‰. Finally, in meta-chloritites, formed after the alteration of igneous basic rocks, $\delta^{18}O$ values range from 9.0‰ to 10.6‰. A characteristic that can be observed in the groups of igneous metabasites, pyroclastic rocks, and meta-intermediate igneous rocks, are well-defined trends of increasing values of $\delta^{18}O$ with progressive intensity in alteration process.

Meanwhile, the meta-chloritites, that are the product of a more intense cation lixiviation process, show relative lower values of $\delta^{18}O$ (9.0‰ to 10.6‰), if compared with $\delta^{18}O$ values observed in strongly altered igneous rocks (11.8‰ to 16.9‰).

Regional zoning in the $\delta^{18}O$ values are present in the Kuroko type volcanogenic sulfide deposits, showing a progressive enrichment of theses values in the wallrocks around the mineralized zone (Cathles, 1993; Barrett & MacLean, 1994), as observed in $\delta^{18}O$ values obtained for the groups of igneous metabasites, pyroclastic rocks, and meta-intermediate igneous rocks here studied, and a progressive decreasing of them in direction to the mineralized zone (Vásquez et al., 1998; Gemmel et al., 1998; Cartwright, 1999), represented, in this case, by $\delta^{18}O$ data from meta-chloritites. These regional zoning produce concentric alteration haloes, characterized by positive anomalies of $\delta^{18}O$ in the rocks that regionally surround mineralized zone, and negative anomalies of $\delta^{18}O$ in the rocks near mineralized zones.

Decreasing values of $\delta^{18}O$ of rocks near mineralized zone would be produced by intense seawater circulation, typically with $\delta^{18}O$ close to 0‰, near hot intrusive bodies. In this situation, the thermal anomaly associated to intrusions would reduce the isotopic fractionation factor between rocks and seawater, producing isotopic anomalies in which the fluids become isotopically heavier and altered rocks isotopically more light (Cathles, 1983).

Regional enrichments of the $\delta^{18}O$ values of altered rocks can be produced by the circulation of hot fluids towards the colder parts of the system, in distal portions related to intrusions. In this situation, the isotopic fractionation factor between rocks and water increase very much so fluids become istopically light and altered rocks isotopically heavy (Cathles, 1983; Green et al. 1983; Cathles, 1993)

The values of $\delta^{18}O$ obtained for most of the meta-intermediate volcaniclastic rocks (15.3‰ to 17.8‰) are much higher as those observed in not altered intermediate rocks, in which values can vary from 6.0 to 10‰ (Paradis et al., 1993). The narrow interval of $\delta^{18}O$ values may indicate that these rocks achieved a relative isotopic homogenization due to hydrothermal alteration, independent of how strong was metasomatic event that affected them. This was probably due to the high porosity, permeability and relative abundance of volcanic glass that can be present in volcaniclastic material (Staudigel et al., 1995).

CONCLUSIONS

Isotopic data obtained in the igneous metabasites, meta-intermediate igneous rocks and in the pyroclastic rocks, indicate that original hydrothermal systems isotopic signatures were, at least, partially preserved, indicating that the different superimposed metamorphic events were not responsible, in these samples, for an homogenizations of isotopic values.

The high anomalies of positive $\delta^{18}O$ values are possible due to the long lifetime of hydrothermal system, caused by the discharge of hot fluids, that came from more deeper parts of the system, towards distal parts, so as observed in discharges responsible for the formation for the white smokers in actual back-arc basins.

Comparing the $\delta^{18}O$ values obtained for meta-chloritites with those of associated altered rocks, it is possible to infer higher fluid temperatures in alteration process, and consequently, re lative lower $\delta^{18}O$ values, indicating a regional distribution nearer to mineralization zone.

In this context, the zones of the black smokers may correspond to the metaleferous meta-sediments, especially those sulfide-rich, that are present in the interface between the Morro da Pedra Preta and Nhangucu Fms, and where, potentially, gold and base metal deposits could be found.

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