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U/Pb SHRIMP ZIRCON AGES OF MIGMATITES FROM THE BASEMENT OF THE EMBÚ COMPLEX, RIBEIRA FOLD BELT, BRAZIL: INDICATIONS FOR ~1.4-1.3 Ga Pb-Pb AND Rb-Sr "ISOCHRON" AGES OF NO GEOLOGICAL MEANING

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INTRODUCTION

The Neoproterozoic Ribeira Fold Belt (Almeida et al., 1973) occurs along the southeastern Brazil and comprises part of an orogenic system which borders the São Francisco and Congo Cratons, as well as an inferred cratonic block that actually occurs under the Paleozoic sedimentary rocks of the Paraná Basin. The Ribeira orogenic system was active during the later stages of the Brasiliano cycle and is composed of Archean, Paleo- and Mesoproterozoic rocks, reworked between 700 – 470 Ma during the amalgamation of the Gondwana Supercontinent.

The central segment of Ribeira Fold Belt, in São Paulo State, is composed by three different geological domains named Costeiro, Embú and São Roque, separated by major shear zones, which differ from each other in (a) the age of their respective crustal protholiths, (b) lithological assemblages, and (c) geological histories. The Embú domain consists mainly of large extensions of Archean - Paleoproterozoic crust, strongly reworked by high grade metamorphism and partial melting processes during the Brasiliano Orogeny. The metamorphic rocks are intruded by Neoproterozoic late to post-tectonic granitoids (Fernandes, 1991).

Rb-Sr and Pb-Pb whole rocks geochronological studies on the migmatites of the basement of the Embú Complex gave an indication (high MSWD "errochrons") that they were also affected by high grade metamorphism at ca. 1.3-1.4 Ga (Babinski, 1988; Tassinari, 1988). Our objective wa to date the same rocks using U/Pb SHRIMP method on zircons to search for evidence of a ca. 1.3-1.4 Ga metamorphic event in the Ribeira belt.

GEOLOGICAL SETTING

The migmatite samples were collected 20 km south of São José dos Campos, São Paulo state, Brazil. These rocks form the regional basement of the Embú Complex. The main rock types of the complex are orthogneisses, migmatites and metasediments. Intrusive granitoids of Brasiliano age (ca. 600 Ma) are commonly found in the region. The migmatites show irregularly-layered and nebulitic structures, where the paleosome is made up by biotite gneisses and biotite-hornblende gneisses of granitic to tonalitic composition (Fernandes, 1991). From cross-cutting relations two generations of neosome can be distinguished: an earlier light grey, fine to medium grained one, and an younger pink, coarse grained one (mostly composed by K-feldspar and quartz). The samples do not show evidence of meteoric alteration.

ANALYTICAL PROCEDURES

Whole rock Rb-Sr, Pb-Pb and Sm-Nd analyses were carried out at the Centro de Pesquisas Geocronológicas (for details see Babinski, 1988; Tassinari, 1988, Sato et al., 1995). Zircon U/Pb data were obtained from the Australian National University (ANU) SHRIMP I instrument. Details of the analytical procedure are presented by Stern (1998) and Williams (1998)

RESULTS

Pb-Pb and Rb-Sr data

Pb-Pb and Rb-Sr isotopic studies were done on the paleosome and ligh gray neosome by Babinski (1988) and Tassinari (1988). The Pb-Pb errochron age

obtained on seven paleosome samples was 2341 ± 150 Ma (MSWD = 3.5), with a μ_1 value of 8.33. A Rb-Sr errochron age of 1965 ± 670 Ma (MSWD = 86), with initial Sr composition of 0.72, was determined on the same samples. Five gray neosome samples yielded a Pb-Pb errochron age of 1314 ± 220 Ma (MSWD = 1.5),), with a μ_1 value of 8.15. These samples also show a large scatter in the Rb-Sr isochron diagram and indicate an apparent age of 1434 ± 270 Ma (MSWD = 43), with a high Sr initial ratio (ca. 0.74).

According to these data Babinski (1988) to suggest that the paleosome was formed at ca. 2400 Ma, and the high μ_1 value indicated that it was formed by melting of old crustal rocks. It was also proposed by Babinski (1988) and Tassinari (1988) that the gray neosome of these migmatites formed during a ca. 1.3-1.4 Ga Mesoproterozoic orogenic event, usually known as Uruaçuano Cycle in Brazil.

Sm-Nd data

Sm-Nd isotopes in the whole rock samples were analyzed and the T_{DM} age (DePaolo, 1981) of the paleosome is ca. 2950 Ma, and for the gray neosome is ca. 2800 Ma. The $^{147}Sm/^{144}Nd$ ratio determined for the pink neosome is highly fractioned and no T_{DM} age could be calculated. However, a double stage calculation would yield an age of ca. 3.1 Ga. These similar Sm-Nd T_{DM} ages suggest that the three rocks could represent melts of similar Archean protholith.

U-Pb SHRIMP zircon data

Zircons were separated from the paleosome, gray neosome and pink neosome (later phase). A reconnaissance dating programme was undertaken, with choice of analytical sites guided by cathodoluminescence (CL) images.

CL images of the paleosome zircons show diverse internal structures. Apparently, dominant are grains that appear dull and homogenous, or show faint indications of oscillatory zoning. Some of these can display partial or complete overgrowths which are bright homogeneous or dull homogeneous in CL images. Also, there was a single grain which appeared brightest in the CL images. This displayed oscillatory zoning parallel to grain margins, but is partly disrupted by dark, homogenous recrystallization domains. Seven analyses were done on six grains. All analyzed grains, except the brightest one are characterized by high U content. Four analyses on four grains gave Paleoproterozoic dates; two of these with the smallest common Pb component yielded close to concordant age of 2004 ± 13 Ma. This clearly defines a ca. 2000 Ma component in this sample. The remaining three sites yielded Neoproterozoic ages, and display small to moderate amounts of common Pb. The two analyses of oscillatory-zoned, lowest-U grain yielded a mean age of 614 ± 21 Ma. Another grain gave a Neoproterozoic age of 575 ± 22 Ma. These results indicate the presence of a ca. 600 Ma event(s), which may correspond to the high-grade metamorphism(s) that caused the migmatization.

The gray neosome yielded a heteregeneous population of brown/opaque to pale yellow/clear corroded prismatic to ovoid and anhedral 100 to 200 μm long zircons; in CL images further diversity is revealed. Some prismatic grains consist entirely of one generation of zircon, which is homogenous/dull to weakly oscillatory-zoned in the images. Other prismatic grains consist of a shell of such zircons, within which there is a structural core with brighter, truncated oscillatory zoning. Others have an outer shell that appears bright and homogenous on CL images. Seven analyses were undertaken on five grains. Two analyses of cores of oscillatory zoned zircons have a low U content and yielded close to concordant late Archean, but not in agreement with each other (ca. 2.9 Ga and 2.74 Ga). The whole grains and shells of zircon that appear homogeneous/dull to weakly oscillatory zoned in CL images show a higher U content and Paleoproterozoic dates, between 2000-2200 Ma. All these analyses are discordant (Pb loss due to high U content) and do not agree with each other within error. The two oldest $^{207}Pb/^{206}Pb$ Paleoproterozoic dates yielded a weighted mean of 2179 ± 110 Ma. One single analysis of a bright homogenous rim yielded a Neoproterozoic age (516 ± 20 Ma), which is the evidence of a metamorphic event also recorded on the zircons separated from the paleosome.

The pink neosome yielded partly turbid generally prismatic zircons, with possible inherited cores present. Analyses concentrated on oscillatory zoned to homogeneous domains on the exterior of the grains, thought to be of igneous origen. Six analyses formed an array which defines an upper intercept age of 2154 ± 16 Ma, and a lower intercept age of 757 ± 130 Ma. No ca. 600 Ma metamorphic overgrowth was observed on the zircons. We suggest that the pink neosome was formed during the same event that formed the gray neosome, but marginally later in the process. The U/Pb zircon ages obtained from the pink neosome (mostly composed by K-feldspar and quartz) suggest that the magma was generated by in situ melting of the Paleoproterozoic rocks.

DISCUSSIONS AND CONCLUSIONS

The U/Pb SHRIMP ages on different portions of the migmatite indicate that the paleosome has an age of ca. 2000 Ma and the melt that formed from had an Archean component as suggested by the T_{DM} age of ca. 2.9. During the Neoproterozoic in situ melting generated the neosomes. Field relationships indicate that the gray neosome is older that the pink one. Three types of zircons could be discerned in the gray neosome: a) crystals with Archean cores and Paleoproterozoic shells; b) homogenous Paleoproterozoic crystals; and Paleoproterozoic cores with Neoproterozoic metamorphic rims. These three types suggest that the gray neosome was formed by in situ melting of the paleosome. The Neoproterozoic ages of the rims is the main evidence of the metamorphic event. The T_{DM} age of 2.8 Ga, similar to that of the paleosome, and the irregularly banded and nebulitic structures presented on the migmatites support this idea. The upper intercept Paleoproterozoic age and the the lower intercept Neoproterozoic age, although imprecise, defined by the zircons recovered from the pink neosome permit us to interprete that this neosome was formed in the same metamorphic event, but in the later phases of the process.

Our U/Pb SHRIMP study could not detect any Mesoproterozoic ages suggesting that the ca. 1.3–1.4 Ga Rb-Sr and Pb-Pb errochron ages represent mixtures of magmas with Paleo and Neoproterozoic ages and/or that the Rb-Sr and Pb-Pb systems were partially opened during the Neoproterozoic metamorphic event yielding pseudo-isochrons with geologically meaningless ages.

Recent geochronological studies on the Embú Complex have shown that it has had a complex geological history which started at ca. 800 Ma as a magmatic arc (Cordani et al., 2000) and was later subjected to metamorphic events in the late Neoproterozoic, during the evolution of the Ribeira fold belt (Cordani et al., 2000; Hackpacher et al., 2000). The regional cooling of this area took place at ca. 470 Ma, as shown by the K-Ar ages obtained in biotites (Minioli, 1974)

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