CAMBRIAN U-Pb ISOTOPE RESETTING AND REMAGNETIZATION OF THE NEOPROTEROZOIC BAMBUÍ CARBONATES, BRAZIL

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INTRODUCTION

Pervasive remagnetization seems to be frequent in carbonate rocks. These remagnetization events are closely linked to migration of warmed and chemically active fluids from orogenic belts toward the cratonic sedimentary basins (McCabe and Elmore, 1989). These fluids are considered responsible for Mississsippi Valley type deposit genesis, diagenesis of clay minerals and petroleum migration (Oliver, 1986). Intriguingly, strongly remagnetized limestones from North America yielded depositional U-Pb ages, suggesting that the isotopic system was not affected by the remagnetization event (DeWolf and Halliday, 1991). In the Bambuí carbonates (São Francisco basin) we found a different scenario: U-Pb and Pb-Pb ages, rock magnetism and paleomagnetism data suggest that a simultaneous event caused the resetting of the isotopic and magnetic records in the Cambrian time.

GEOLOGICAL SETTING AND SAMPLING

The southern part of the Neoproterozoic São Francisco basin can be divided into three structural domains: (a) the central part of the basin where rocks are undeformed; (b) the western domain where rocks have been deformed by the ca. 600 Ma Brasília fold belt, and (c) the eastern domain where rocks have been affected by the ca. 600 Ma Araçuaí fold belt (Chemale et al., 1993). The depositional age of the carbonates is still disputable since results from the various isotopic dating methods led to conflicting interpretations. Rb-Sr ages on clays and whole-rock samples range from 695 ± 12 Ma to 465 ± 21 Ma and K-Ar ages on clays range from 576 ± 14 Ma to ca. 478 Ma (Thomaz-Filho et al., 1998 and references therein). Recently Misi and Veizer (1998) proposed a sedimentation age of about 600 Ma for the carbonatic sequences of the Bambuí and Una Groups based on $^{87}Sr/^{86}SrSr$ ratios.

For this study carbonate rocks from the southern São Francisco basin were sampled, comprising mainly the basal unit of the Bambuí Group (Sete Lagoas Formation). Detailed sampling for Pb isotope study was carried out on 8 outcrops from regions with different degrees of deformation; these rocks were analyzed for Pb isotopic compositions and U and Pb concentrations. Four outcrops are located on the stable area of the basin (MF-6, MF-7, MF-10 and MF-17); three outcrops (MF-3, MF-5 and MF-11) are from the area where the rocks have been affected by the Araçuaí fold belt and one outcrop (MF-9) is located on the area affected by the Brasília fold belt. For paleomagnetic purposes 46 nearly horizontal stratigraphic layers (46 sites) of limestones and carbonatic shales were sampled at four quarries (PM-1, PM-2, PM-5 and PM-6), at outcrops along a hill (shales) close to the Arcos-Formiga road (PM-3), and at an outcrop along a road in the Pompeu region (PM-4), comprising more than one hundred meters of the sedimentary sequence from the undeformed area. Six or seven cylinders were extracted from each stratigraphic layer.

RESULTS AND DISCUSSION

Based on the Pb isotopic compositions and U/Pb ratios of the carbonates, four types of Pb were determined and classified as Type I, II, III and IV. Type I Pb has high U/Pb ratios (>1) and it represents in situ growth of radiogenic Pb; it is the only type of

Pb that can yield reliable isochron ages. Type II Pb has low U/Pb ratios (< 0.1); it is non-radiogenic crustal Pb. Type III Pb has also low U/Pb ratios, but it represents radiogenic crustal Pb derived from the Archean/Paleoproterozoic basement. Type IV Pb represents a mixture of Types I and III Pb.

The ^{207}Pb-^{206}Pb isochron ages obtained from mesoscopically undeformed carbonates containing Type I Pb are 686 ± 69 Ma (MF-7) and 520 ± 53 Ma (MF-10). The ^{238}U-^{206}Pb age determined for the MF-10 outcrop is 603 ± 80 Ma; MF-7 samples do not show any alignment on the U-Pb diagram. Because the older age (686 ± 69 Ma) was determined on the same outcrop (MF-7) where "detrital" Pb was also detected (Types III and IV, which were presumably incorporated into the carbonates during the Brasiliano orogeny), this age is considered as the minimum depositional age for the carbonates from the Sete Lagoas Formation (Bambuí Group basal unit). The younger age (520 ± 53 Ma) was determined on carbonates which are stratigraphically below outcrop MF-7, so that this age should represent the time of the re-homogeneization of the isotopic system during a post-depositional event. Carbonates showing deformation (MF-3 and MF-9) yielded ^{207}Pb-^{206}Pb ages of 842 ± 240 Ma and 872 ± 290 Ma, and ^{238}U-^{206}Pb ages of 545 ± 210 Ma and 621 ± 160 Ma, respectively. Although the ages present large errors, the U-Pb ages also point to an isotopic resetting at ca. 550-500 Ma. This resetting event is shown by both deformed and underformed rocks and could have been promoted by percolation of fluids generated during the Brasiliano orogeny.

The studied samples have a rock magnetic signature of remagnetized carbonates (McCabe and Channell, 1994). Lowrie-Fuller and Cisowki tests performed for 10 samples showed typical contradictory results. Hysteresis loops performed for 38 samples show a wasp-waisted shape, and the hysteresis ratios are in the range defined by Jackson (1990) for remagnetized carbonates of North America. Thermomagnetic curves with a strong decrease in the magnetic susceptibility at around 580 °C and preliminary results from scanning electron microscopy (SEM) and electron dispersive spectrometer (EDS) suggest authigenic magnetite as the main carrier of remanent magnetization.

Two slightly different components (B and C) were isolated from high coercivities and temperatures after alternating field and thermal cleaning. Some characteristics of these magnetic components suggest that they are due to remagnetization. The samples displayed a single magnetic polarity. The low angular dispersion calculated from these components suggest that secular variation of the geomagnetic field seems to have not been fully recorded throughout the sampled profiles, although they may be as thick as 100 m, which could imply that remanence was acquired in a short time interval. On the other hand, moderate to high paleolatitudes inferred from paleomagnetic data for the study area would require a different climate pattern during the sedimentation of the wide carbonate platforms. The components B and C are similar to that obtained from the Salitre Formation (Una Group) carbonates (D'Agrella-Filho, 1995), northern São Francisco basin, suggesting that the acquisition of these characteristic magnetizations was contemporaneous. The paleomagnetic pole for the Piquete metamorphic rocks (D'Agrella-Filho et al., 1986), southern São Francisco craton, also plots close to the Bambui poles. The Piquete rocks yield typical Brasiliano K-Ar ages in the range 532 ± 13 Ma to 467 ± 15 Ma, with a peak in the 500-490 Ma interval. These results were compared to high quality Gondwanan poles for the time interval 550-475 Ma (Meert et al., 1995; Grunow, 1995). All the São Francisco craton poles plot very close to the 522 ± 13 Ma Ntonya Ring (NR) pole, the ~ 515 Ma Sϕr Rondane Intrusions pole and the 510 ± 15 Ma Central Australia mean pole, suggesting that the characteristic magnetization obtained in the southern and northern parts of the basin, as well as in the surrounding metamorphic rocks, were acquired at 530-500 Ma, during the last stage of the Brasiliano orogeny.

Fluid inclusion studies done in the fluorites and willemites (Dardenne and Freitas-Silva, 1998) from the carbonates indicate temperatures between 100 and 200 °C for the fluids that percolated in the basin. These studies also showed hydrocarbons fluids and solid bitumen in some of the fluid inclusions. Previous analyses of Thermal Alteration of palinomorphs incorporated in the sedimentary rocks (equivalent to Vitrinite Refletion Index), and carbon isotopic compositions of methane recovered from the central area of the basin suggested that the rocks were not submitted to temperatures higher than 200 °C (Babinski et al., 1989). These results together with the authigenic magnetites observed in the SEM images and the rock magnetic properties support a chemical

remagnetization due to percolation of hydrocarbon-bearing fluids (e.g., McCabe and Elmore, 1989).

Pb-Pb and the U-Pb ages obtained in the deformed as well as in undeformed carbontes fall in the same range (considering the analytical errors). Because of that we interpret these ages as post-depositional ages. Furthermore, carbonates containing Pb-type III ("detrital" Pb) are found in the central portion of the basin which was not submitted to deformation and high temperatures. This indicates that the Pb-type III, derived from the Archean/Paleoproterozoic basement, was incorporated through fluids which also formed sulphites and promoted a severe remagnetization in the carbonates. The trend defined by Pb isotopic compositions of Pb-types III and II intercepts the Stacey & Kramers Pb evolution curve at about 2100 and 520 Ma, suggesting that the fluid percolation event took place at ca. 500-550 Ma. The paleomagnetic results permit further constraint on these ages to the 530-500 Ma interval by correlations with high quality paleomagnetic poles in the 550-475 Ma Gondwana APWP.

The similarity between paleomagnetic results from the Bambuí and the ca. 1000 km far north Salitre Formation (Una Group) carbonates implies in a large scale fluid percolation event that simultaneously affected the whole basin. Preliminary Pb isotope results from carbonates of the northern part of the basin corroborate this hypothesis. The paths of these fluids may have been along old basement faults reactivated during the last stage of the Brasiliano orogeny.

REFERENCES

Babinski, N.A.,Santos, R.C.R. and Chang, H.K., 1989. Hydrocarbon occurence in the Proterozoic São Francisco basin, Brazil. In: Intern. Geol. Cong., Washington, USA, Proceedings, v.1, p. 67-68.

D'Agrella-Filho, 1995. Paleomagnetism of carbonatic sedimentary sequences of the Salitre Formation, Chapada Diamantina - Bahia. 4° Congr. Intern. da Sociedade Brasil. de Geofísica. Extended Abstracts, v.1: 262-265.

D'Agrella-Filho, M.S., Pacca, I.G. and Sato, K., 1986. Paleomagnetism of metamorphic rocks from the Piquete region - Ribeira Valley, Southeastern Brazil. Rev. Bras. Geofísica, 4: 79-84.

Dardenne, M.A. and Freitas-Silva, F.H., 1998. Depósitos Pb-Zn-F-Ba do Supergrupo São Francisco. In: Congr. Bras. Geol., 40, Belo Horizonte. Anais, SBG., p.133.

DeWolf, C.P. and Halliday, A.N., 1991. U-Pb dating of a remagnetizad Paleozoic limestone. Geophys. Res. Letters, 18: 1445-1448.

Grunow, A.M., 1995. Implications for Gondwana of new Ordovician paleomagnetic data from igneous rocks in southern Victoria Land, East Antarctica. J. Geophys. Res., 100: 12589-12603.

Jackson, M., 1990. Diagenetic sources of stable remanence in remagnetized Paleozoic cratonic carbonates: a rock magnetic study. J. Geophys. Res., 95: 2753-2761.

McCabe, C. and Channell, J.E.T., 1994. Late Paleozoic remagnetization in limestones of the Craven basin (northern England) and the rock magnetic fingerprint of remagnetized sedimentary carbonates. J. Geophys. Res., 99: 4603-4612.

McCabe, C. and Elmore, R.D., 1989. The occurrence and origin of Late Paleozoic remagnetization in the sedimentary rocks of North America. Rev. Geophys., 27: 471-494.

Meert, J.G., Van der Voo, R. and Ayub, S., 1995. Paleomagnetic investigation of the Neoproterozoic Gagwe lavas and Mbozi complex, Tamzania and the assembly of Gondwana. Prec. Res., 74: 225-244.

Misi, A. and Veizer, J., 1998. Neoproterozoic carbonate sequences of the Una Group, Irecê basin, Brazil: chemostratigraphy, age and correlations. Prec. Res., 89: 87-100.

Oliver, J., 1986. Fluids expelled tectonically from orogenic belts: Their role in hidrocarbon migration and other geologic phonomena. Geology, 14:99-102.

Stacey, J.C., Kramers, J.D., 1975. Approximation of terrestrial lead isotope evolution by a two-stage model. Earth Planet. Sci. Lett., 26:207-221.

Thomaz-Filho, A., Kawashita, K. and Cordani, U.G., 1998. A origem do Grupo Bambuí no contexto da evolução geotectônica e de idades radiométricas. An. Acad. Bras. Ciên., 70 (3): 527-548.