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OXYGEN ISOTOPE THERMOMETRY OF HIGH- TO LOW-GRADE METASEDIMENTARY ROCKS FROM THE NAPPE SYSTEM SOUTH OF SÃO FRANCISCO CRATON, SOUTHEASTERN BRAZIL

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INTRODUCTION

The western and southern margins of the Archaen-Paleoproterozoic São Francisco Craton, Southeastern Brazil, are distinguished by a sequence of nappes roughly displaced eastward and separated by lateral ramps over which strike-slip faults evolved during a later reactivation (Campos Neto and Caby 1999a, b)– Fig. 1. The uppermost tectonic unit (Socorro-Guaxupé Nappe - SGN) is represented in the studied area by its most basal portion, which exhibits strongly deformed high-pressure and high-temperature intermediate to mafic granulites thought to be derived from a convergent magmatic arc (Sm/Nd $T_{(DM)}$ age = 1290 Ma; ε_{Nd} 0.640 = -1.2). Low-plunging WSW mineral and stretching lineations argue for a ENE mean movement sense. Northeastwards a high-pressure and high-temperature underlying unit (Três Pontas-Varginha Nappe - TPVN) consists, from top to bottom, of Sill granulites that grade downwards to grey to bluish Rut-Ky-Grt granulites with lesser quartzites, calc-silicate rocks, metabasic rocks and a few mafic-ultramafic rocks. Sm/Nd $T_{(DM)}$ ages of 1.26-155 Ma in metagraywackes are considered incompatible with a SFC origin and seem to suggest a juvenile source contribution. Mainly linear fabrics developed during high-pressure granulite facies conditions indicate a displacement direction to ENE. The Carmo da Cachoeira Nappe (CCN) rises from below this sequence and comprises metagraywackes, staurolite-free Grt-Ky-Ms micaschists, lesser gondites, calc-silicate gneisses and some mafic-ultramafic slices. Syn-metamorphic S-C fabrics and disperse mineral/stretching lineations suggest a mostly north eastward flow direction. Its southern correspondent is the Aiuruoca-Andrelândia Nappe (AAN). The allochton Carrancas-Luminárias Nappe (CLN) occurs as a pile whose lower part is formed by a quartzite sequence and is seated over granitic to granodioritic orthogneisses, migmatites and ultramafic rocks that may constitute its basement. Characteristic S-C-type structures and persistent mineral and stretching lineations refer to an eastward transport for this major western portion. To the top it grades into laminated quartzite interlayered with graphitic and aluminous metapelites.

ANALYTICAL PROCEDURES

Oxygen isotope ratios from mineral and whole-rock of twelve samples were measured at the Scottish Universities Research and Reactor Centre (SURRC). Purified chlorine trifluoride was used for oxygen extraction from samples of 1 to 2 mg in a laser fluorination system based on Sharp (1990). The oxygen was then converted to CO2 by reaction on a hot graphite rod and its isotopic composition analysed on a VG PRISM III mass-spectrometer. Oxygen isotope ($\delta^{18}O$) values are reported in the permill-notation relative to Standard Mean Ocean Water (SMOW) as defined by Craig (1961). The NBS28 quartz standard was continually tested during the course of analyses and gave satisfactory results.

RESULTS

The analyzed samples were collected along a geological profile that cross-cuts the several units compounding the nappe system. Thermometric calculations were carried out following the fractionation factors of Bottinga and Javoy (1975). Other calibrations were also tested, but did not result in any significant differences within the temperature interval studied. Oxygen isotope apparent temperatures were calculated mainly for quartz-mineral pairs and are invariably lower than those obtained from cationic thermometers. Despite of this the temperatures show a very coherent pattern that decreases toward the São Francisco Craton (Fig. 2). The different units are also represented in the thermometric profile by temperature paths that can be easily recognised.

Two of the three granulite samples taken from the base of the SGN (434b and 436d) show similar $\delta^{18}O$ values for garnet, orthopyroxene, clinopyroxene and amphibole, which is consistent with at least partial equilibrium between these minerals. Indeed, petrographic and textural observations for these samples reveal that both of them possess equilibrate mineral assemblages. The lowest equilibrium temperatures are indicated in the former for the pairs Qtz-Amp, Qtz-Cpx and Qtz-Grt (around 660° C). Higher temperatures were achieved from Qtz-Cpx, Qtz-Bt (815° C) and Qtz-Amp (748° C) pairs in the sample 436d, which also shows lower similar temperatures for Qtz-Opx and Qtz-Mgt pairs (around 635° C). The sample 436c displays heterogeneous $\delta^{18}O$ values that reflect an isotope desequilibrium between orthopyroxene, garnet and magnetite.

The higher quartz δ values (13-15 ‰) were found in the two samples from the VTPN (206a - Sill-bearing granulite- and 113f - Rut-Grt-Ky granulite) and are similar to those found in sedimentary rocks. The Sill granulite (206a) shows a great desequilibrium between the Qtz-Grt and Qtz-Bt pairs. For the Ky granulite sample (113f) the temperatures obtained (Qtz-Grt and Qtz-Bt) lie in a narrow range (722 to 672° C) but it is hard to say whether they represent reliable values or not, since biotite was selected from a melanosome portion which possibly resulted from partial melting. Qtz-Ky temperature from this rock gave a value of 1051 ° C.

To test the role of deformation on oxygen isotope composition two samples of calc-silicate rocks from the VTPN were selected (113b2 - undeformed - and 367 - deformed). Temperature values calculated for the Qtz-Amp, Qtz-Cpx and Qtz-Grt pairs show a very constant decrease from the undeformed to the deformed sample (around 580 and 460° C, respectively) and probably reflect the effects of deformation in the oxygen isotopic composition of these minerals. Whole-rock hydrogen analyses showed quite similar δ D values for both rocks and argue against any significant fluid participation during mylonitisation.

Equilibrium temperatures for Qtz-Grt, Qtz-Bt and Qtz-Ms pairs (around 520 ° C) were attained in a Ky-Grt-Bt-Ms schist from the CCN (128). This sample shows a very equilibrate mineral association which is reflected in the isotopic results.

Two samples were picked from the most external units, the first (183) from the basal quartzite nappe and the other (401a) from the quartzite/graphitic schist sequence at Serra da Bocaina. Although these rocks show more simple mineral assemblages the temperatures obtained from the Qtz-Ms pair are very coherent (442 and 319° C, respectively) and shows a decrease as it approaches the basement, to the north.

The Qtz-mineral pairs from the samples of the basement (252 and 171a) conform to a temperature path that strongly contrasts with the previous ones. Qtz-Bt values are 522 and 565° C for these rocks.

DISCUSSION

In general, local scale mineral-mineral oxygen isotope distribution provides temperatures well below the maximum metamorphic conditions as estimated using cationic thermometers in the same rocks. This can be explained by the fact that isotopic exchange between mineral phases continue even after the metamorphic peak is attained, so that the oxygen isotope thermometry would rather reflect the closure temperatures of the involved minerals than equilibrium conditions during metamorphism. The most important difference between the two exchange reactions is the pressure insensitivity of isotope partitioning. Also, textural and chemical equilibrium do not imply in isotope equilibrium between mineral phases.

Temperatures of 900° C (P=12.5 kbar) to 850° C (P=7.5 kbar) based on cationic thermometers were obtained by Campos Neto and Caby (1999a) for a Grt-Cpx-Opx-Pl-Qtz assemblage in basal granulites of the SGN. These conditions seem to have been attained during granulite metamorphism and later partial reequilibration. In this research the obtained temperatures for similar rocks are lower than those cited above and do not reflect the most extreme conditions suffered by these rocks. However, textural and petrographic investigations point out that, apart from 436c, the other two samples (434b and 436c) show granoblastic to mylonitic equilibrate mineral assemblages, which can be evidenced from the similar $\delta^{18}O$ values and equilibrium temperatures for the different phase components in a same sample.

For the underlying high-pressure nappes an inverted metamorphic model was predicted from recent thermobarometric results, according to which the lowest temperatures seem to have been achieved toward the base of the nappe system. These include data on Rut-Ky-Grt-Ms schist and metabasites of the AAN that document temperatures of 660° C (minimum P=17.5 kbar) and 650° C (P=12-14 kbar) associated with a decompression stage. From base to top of the TPVN, upward, temperatures of 680° C (P=15 kbar) and 830-950° C (P=12 kbar) were reported for Ky- and Sill-type granulites, respectively. Oxygen isotope temperature data recorded in this study for these rocks are largely compatible with this model and also describe a decreasing temperature pattern toward the northern craton.

Studies of oxygen isotope composition variation in shear zones reveal a general decrease of about 3 ‰ in the quartz $\delta^{18}O$ values from the undeformed to the deformed rocks. Results from the analysed calc-silicate samples in this work support this conclusions and point to two readily notable temperature equilibrium stages. On the basis of these studies one can predict minimal $\delta^{18}O$ values of up to 18 ‰ for the undeformed equivalents of the TPVN samples (206a and 113f), which are unlikely to indicate a cratonic source for these rocks, since the samples from SFC gave much lower quartz results (granitic-rock typical 9.3 ‰). This is in agreement with earlier Sm/Nd data reported by Campos Neto and Caby (1999b). The apparently unrealistic Qtz-Ky temperature may be reflecting early ultra-metamorphism conditions that were preserved only in the most refractory phases.

Data from metapelite samples of the quartzite nappe furnished temperatures of 620°-636° C (P=6.5 kbar). Also, studies of Si content in phengite from the upper sequences reveal an approximate temperature 500° C (P=7 kbar). This allochton sequence also shows an oxygen isotope temperature decrease as it approaches the SFC, which contrasts highly with the equilibrium temperatures reached by the analysed rocks from the basement.

REFERENCES

Bottinga, Y. and Javoy, M., 1975. Rev. of Geophys. Space Phys. 13:401-418.

Campos Neto, M. C. and Caby, R., 1999a Precambrian Research (in press).

Campos Neto, M. C. and Caby, R., 1999b. Tectonics (submitted).

Craig, H., 1961. Science. 133: 1702-1703.

Sharp, Z.D., 1990. Geochimica et Cosmochimica Acta. 54: 1353-1357.

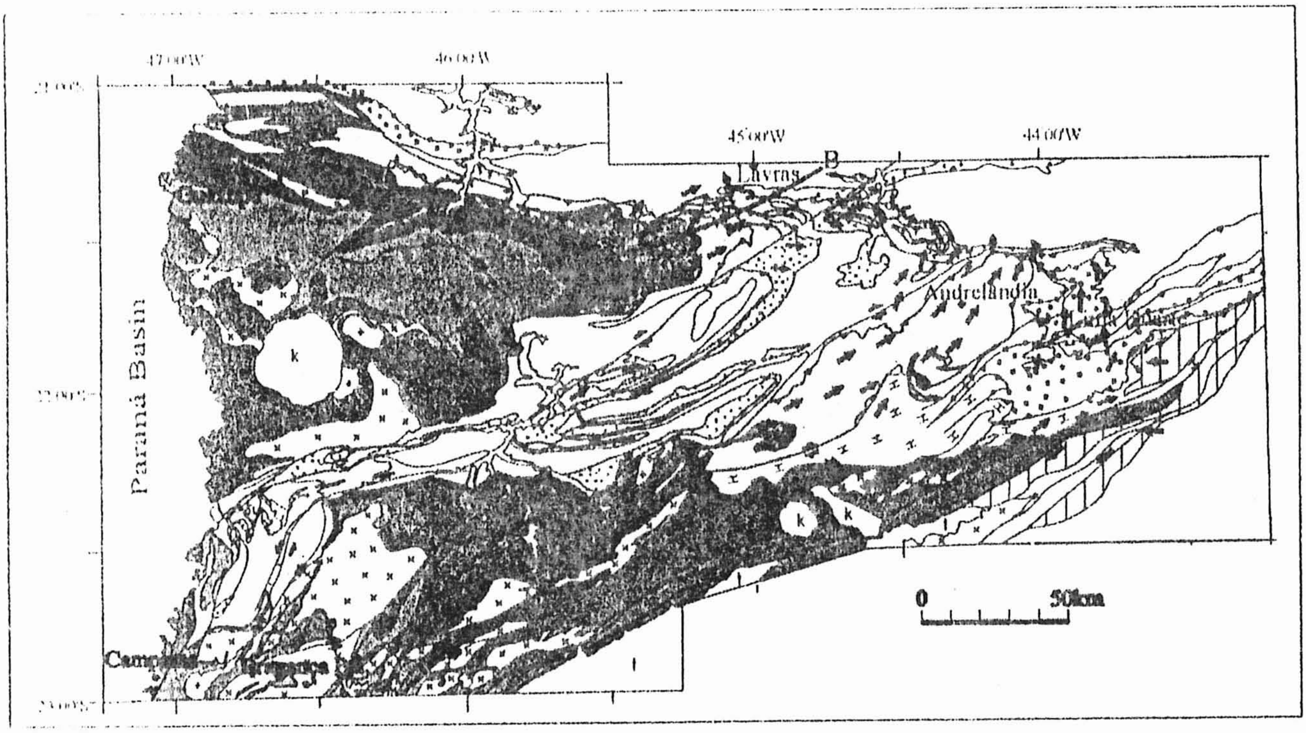

Figure 1: Simplified geological map

- Tertiary sedimentary basins
- Cretaceous alkaline plutons

Neoproterozoic magmatic-arc terrane (Socorro-Guaxupé nappe)

- Post-nappe syenites (610 Ma)
- Syn-orogenic granitoids (630-625 Ma)
- Upper Migmatitic Unit and the uppermost Schist belt
- Middle Diatexitic Unit
- Basal Granulitic Unit

Neoproterozoic high-pressure terrane

- Ky-granulite (including Três Pontas-Varginha nappe)
- Metapelites and Metagreywackes (including Carmo da Cachoeira and Aiuruoca-Andrelândia nappes)

Proterozoic passive continental margin units (medium-pressure metamorphism)

- Interlayered quartzite and metapelite from parautochtonous units
- Quartzite and graphytic metapelite (including Carrancas-Luminárias and Lima Duarte nappes)
- Sil-bearing migmatites

Proteroizic mafic-ultramafic unit

- Petúnia complex

Paleoproterozoic and Archaean

- Grey-gneisses and migmatites (including reworked southern edge of São Francisco craton)

Paleoproterozoic reworked by the Neoproterozoic-Cambrian orogeny

- Juiz de Fora terrane

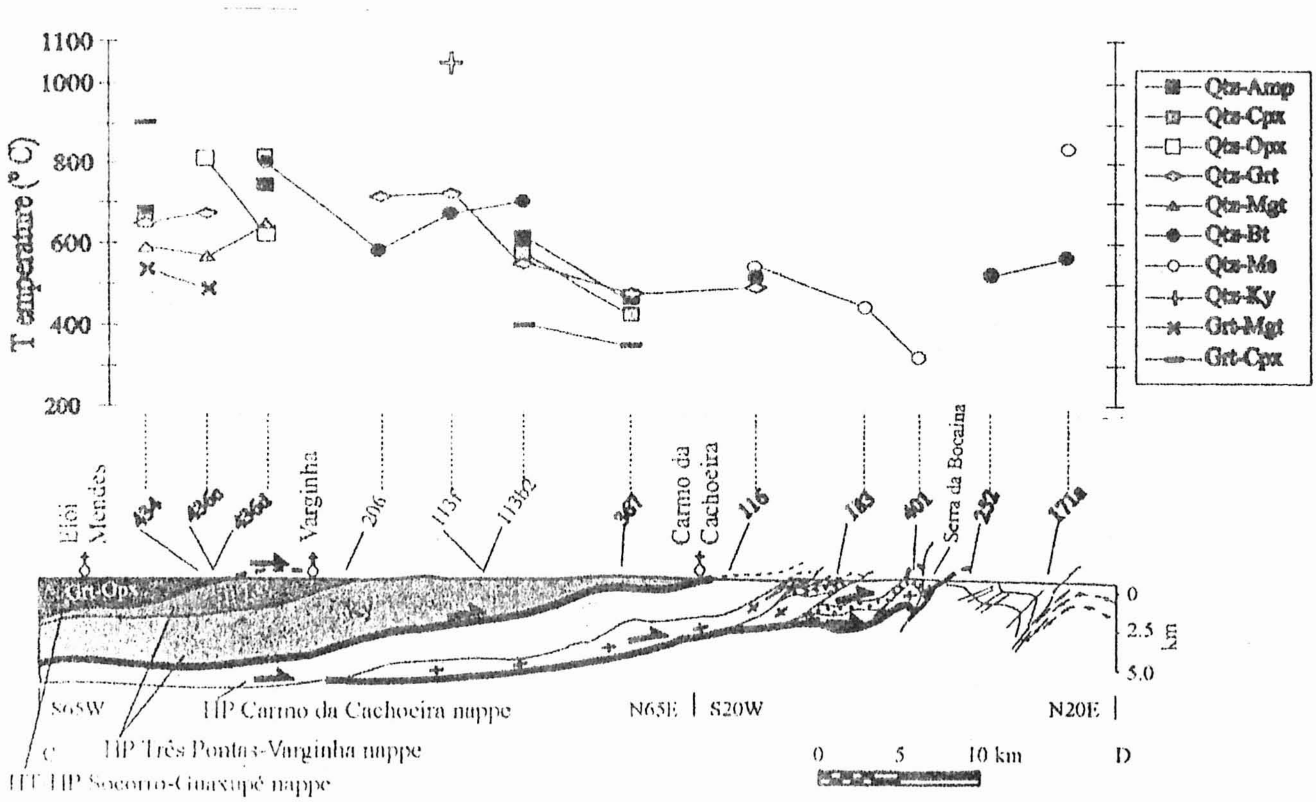

Figure 2: Oxygen isotope thermometric profile along the nappe system.