

## C-O-H isotopic evidences for fluid sources of granulites in Ribeira Belt, SE Brazil

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Combined C-O-H isotopes with fluid inclusion and  $fO_2$  results in Ribeira Belt (SE Brazil) granulites reveal that metamorphic peak fluids evolved under high  $fO_2$  conditions (QFM +1) coeval with  $CO_2$ - $N_2$  (0 to 11 mol%) high to medium density (1.01 – 0.59 g/cm<sup>3</sup>) fluids at  $T \sim 800$  °C [1] and  $X_{H_2O} < 0.05$  [2], whereas retrograde low density (0.19 to 0.29 g/cm<sup>3</sup>)  $CO_2$ - $N_2$  (0 to 36 mol%),  $CO_2$  (94 to 95 mol%) –  $N_2$  (3 mol%) –  $CH_4$  (2 to 3 mol%) –  $H_2O$  (Flw = 0.1) (in graphitic granulites),  $N_2$  (95 mol%) –  $CH_4$  (5 mol%),  $H_2O$ - $CO_2$  and late  $H_2O$  fluids were reduced  $fO_2$  (QFM -1 to -3) at  $T \sim 600$  °C [1] and  $X_{H_2O} > 0.1$  [2].

$\delta^{18}O$  quartz results of 10.3 – 10.7‰ imply high-temperature  $CO_2$   $\delta^{18}O$  values of 14.4 to 14.8‰, suggesting the involvement of a metamorphic fluid, whereas lower temperature biotite  $\delta^{18}O$  and  $\delta D$  values of 7.5 – 8.5‰ and -54 to -67‰, respectively imply  $H_2O$   $\delta^{18}O$  values of 10 to 11‰ and  $\delta D_{H_2O}$  of -23 to -36‰, suggesting  $\delta^{18}O$  depletion and increasing fluid/rock ratio from metamorphic peak to retrograde conditions. Isotopic results are compatible with low-temperature  $H_2O$  influx and  $fO_2$  decrease that promoted graphitic deposition in retrograde granulites, simultaneous with low density  $CO_2$ - $N_2$  and  $CO_2$ - $N_2$ - $CH_4$ - $H_2O$  fluid inclusions at  $T = 450 - 330$  °C. Graphite  $\delta^{13}C$  results of -10.9 to -11.4‰, imply  $CO_2$   $\delta^{13}C$  values of -0.8 to -1.3‰ suggesting decarbonation of Cambrian marine carbonates [3] with small admixture of lighter biogenic or mantle derived fluids.

Results suggest that peak fluids were  $^{18}O$  enriched metamorphic fluids derived from deep-seated carbonated sources. Rapid pressure and temperature drop during retrograde metamorphism induced  $fO_2$  decrease by fluid admixture with shallower waters, turning peak carbonic fluids into  $CO_2$ - $H_2O$  and depleting biotite  $\delta^{18}O$  and  $\delta D$  values, and as low-salinity  $H_2O$  fluids progressively became dominant, late-graphite deposited at shallower crustal levels.

[1] Bento dos Santos *et al.* (2007) *Geochimica et Cosmochimica Acta* **71**, 15, Sup. 1, A79. [2] Bento dos Santos *et al.* (2008) *Geophysical Research Abstracts* **10**, EGU2008-A-00262. [3] Veizer *et al.* (1999) *Chemical Geology* **161**, 59–88.

## STXM-based study of microbial fossils in recent and ancient rocks

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We will review studies we performed on bacteria fossilized in the laboratory (e.g. 1) and on modern stromatolites (2) using a combination of nanoscale spectroscopy and microscopy techniques, mostly synchrotron-based X-ray microscopy (STXM) and Transmission Electron Microscopy (TEM). Those results will be compared with similar analyses performed on Archean stromatolites from Tumbiana (3) and on fossils preserved in high-grade metamorphic rocks from the Alps (4). STXM and TEM provide information on the chemical composition for major elements and on the speciation of elements such as carbon, oxygen, nitrogen, calcium, iron etc. at the few tens of nanometer scale. This opens new avenues for the search of a past biological activity in rocks. Indeed, it has been increasingly shown that what was formerly considered as unambiguous bio-signatures could actually be produced by abiotic processes as well. One way to better determine what might be truly biogenic consists in characterizing as exhaustively as possible the systems of interest at the nm-scale. Bulk organic geochemistry has been a very powerful technique in this kind of studies so far. The capability to complement this approach at the submicrometer-scale is a unique way to assess potential contamination and to gain additional information on the role of minerals in organic preservation.

[1] Benzerara *et al.* (2004) *Geobiology*, **2**, 249-259. [2] Benzerara K. *et al.* (2006) *Proc. Natl. Acad. Sci. USA* **103**, 9440-9445. [3] Lepou K., Benzerara K., Brown Jr. G.E. & Philippot P. (2008) *Nature Geoscience* **1**, 118 - 121. [4] Bernard S. *et al.* (2007) *Earth Planet. Sci. Lett.* **262**, 257-272.