

Palaeoproterozoic metamorphism in the Limpopo Belt: New petrological and geochronological constraints

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Metasediments closely associated with the 3.28 Ga Sand River gneiss of the Central Zone of the Limpopo Belt, South Africa, were deposited after 2.615 Ga and underwent a structural- metamorphic overprint at 2.035-2.025 Ga. This is supported by CL-images in combination with *in situ* LA-ICP(MC)-MS U-Pb, and new petrological results. Zircon core analyses reveal that the investigated metasediment succession consists of detritus of weathered Archean granitoids, predominately formed at ~2.61 Ga and minor at ~3.3 Ga. Zircon overgrowths yield an age of 2027 ± 6 Ma, which is interpreted to reflect the timing of the high-grade metamorphic overprint. This age is identical within error with an U-Pb monazite ages of 2036 ± 8 Ma, but distinctly younger than U-Pb monazite ages of ~2.61-2.64 Ga analysed from the same respective sample. The Neoarchean monazite grains are interpreted to be of detrital origin. This is supported by the finding of both monazite generations enclosed in syndeformative garnet. These structure-age relationships unambiguously show that the observed mineral assemblage sequence: Grt+Bt, Grt+St+Bt, Grt+St+Ky+Bt, Grt+Bt+Ksp/Liq., and Grt+Bt+Ksp/Liq.+Crd was formed during a single orogeny at ~2.03 Ga, characterized by a prograde *P-T* path from 600°C/5kbar to 800°C/10 kbar, and followed by decompression and cooling to 750°/5kbar.

Lithium isotopes in geothermal systems

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We measured the lithium isotopic composition of water samples (geothermal wells, thermal springs, thermal submarine springs and surface waters) and rock samples from different geothermal reservoirs. The overall objective of the present work was to establish the nature, extent and mechanism of Li isotope fractionation between 100 and 250°C during water/rock interaction.

For that purpose, a new analytical procedure was developed, based on the Neptune multi-collector ICP-MS in operation at BRGM, that enabled the analysis of Li isotopic ratios in liquid (water) and solid (rock) matrices with a level of precision of $\pm 0.5\%$ (2 standard deviation) for $\delta^7\text{Li}$ values on quantities of 10-50 ng of Li.

Geothermal reservoirs located in the French West Indies (Guadeloupe and Martinique islands) were studied and particular emphasis was placed on the characterization of the behavior of Li isotopes during water/rock interaction in a volcanic context at high temperature. In addition, we also determined Li, B and Sr isotope compositions on waters collected from different geothermal sites in metropolitan France in order to characterize geothermal reservoirs by coupling a multi-isotopic approach with in-depth temperature of the reservoir calculated using chemical geothermometers.

The deep waters collected from geothermal wells and thermal springs in the Guadeloupe and Martinique islands indicate that Li isotopic signatures are very homogeneous for a given site but remain however very different from one site to another, probably due to not only lithological differences (reservoir rocks) but also highly variable water/rock interaction temperatures (90-120°C, 180-200°C and 250-260°C) for the Lamentin plain, the Diamant-Mount Pelée areas and the Bouillante geothermal fields, respectively.

Experiments of seawater/basalt interaction were also carried out at different temperatures (from 25° to 250°C) and the results of isotope exchange experiments confirm the temperature dependence of Li isotope fractionation, ranging from +19.5 to +6.8‰ ($\Delta_{\text{solution-basalt}}$) between 25° and 250°C, in agreement with field and experimental data reported in the literature.

The variations in B and Sr isotope tracers in geothermal waters appear to be largely controlled by the dominant host lithologies. In contrast, temperature plays an important role in controlling the lithium isotope composition of the geothermal fluids. This result seems to prove that lithium isotopic systematics represents a useful tool suitable for the study of geothermal waters and suggests that the $\delta^7\text{Li}$ composition of geothermal waters may be utilised not only to characterize the geothermal reservoir (lithology, depth) but also to constrain the temperature of water/rock interaction.