

Isotopic zonation in zircon as a recorder of progressive metamorphism

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Zircon and garnet share some common traits: both are typical metamorphic phases in granulites; both are important sinks for heavy REEs; and both tend to preserve complex compositional zoning that reflects growth behaviour during high-temperature metamorphism. Whereas growth stages recorded in garnet porphyroblasts are widely used to characterize stages along a metamorphic P-T path, zircon tends to be treated as a single stage mineral, with growth (and consequently age estimates from U-Pb isotopic dating) tied to a poorly defined thermal maximum. This is in contradiction to the complex zoning commonly seen in metamorphic zircon grains, especially those in metapelitic migmatites. Such zoning can be understood through the same methods by which garnet is studied; i.e. compositional mapping and micropetrographic relationships. Zircon grains from metapelite samples of the granulite-grade Lützow-Holm Complex of east Antarctica show a complex range of textures and ages. Whereas previous SHRIMP ages from zircon grain separates concentrate around 530-550Ma, and were interpreted as timing peak metamorphism, further detailed analysis yields a spread of age estimates from 500 to 630Ma. In-situ analyses of zircon inclusions in garnet porphyroblasts reveal a stage of U-rich zircon growth at c.600Ma, with flat HREE-MREE profiles indicating prograde growth in the presence of garnet. Zircon preserved in a garnet megacryst from felsic pegmatite that fills boudin necks in a metapelitic layer show multiple stages of growth (Fig.), with c.600Ma flat H-MREE (garnet-equilibrated) cores, c.570Ma rims with outward steep to flat H-MREE growth zoning, and resorption prior to incorporation in the garnet megacryst and crystallization of the felsic pegmatite at c.550Ma. Although the 100Ma spread of zircon ages could be interpreted as recording separate metamorphic events, the textural and chemical associations between zircon, garnet and felsic melt suggests that zircon growth was progressive through a prolonged metamorphic event, and that a large proportion of zircon growth at 530-550Ma occurred during retrograde rather than peak metamorphism.

A bacterial model for studying interactions between microorganisms and CO₂ injected in the subsurface

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Geological storage of CO₂ in the subsurface will likely become an important industrial process since it is an option envisaged to mitigate the increase of atmospheric CO₂ in the coming decades. The potentialities of some subsurface microorganisms to induce CO₂ mineralization into carbonates could strongly enhance the stability of the CO₂ containment or could also have adverse effects on the injectivity. In order to study this process, we have carried out experiments of biotransformation of CO₂ into solid carbonates using *Bacillus pasteurii*, an ureolytic model strain. The strain was inoculated in an artificial ground water based on the composition of actual deep groundwaters from the basin of Paris, France. Experiments were performed in a specially designed circulation cell. The complex pH evolution, induced by the strain in the artificial groundwater, could be modelled using the geochemical software Chess 3.6, from Ecole des Mines de Paris, including enzymatic kinetics of ureolysis, kinetics of gas-solution transfer, and rate of calcite precipitation. Alkalinization due to the enzymatic hydrolysis of urea, part of which was shown to occur by extracellular processes, reached a plateau once a dynamical equilibrium was established with the rate of CO₂ transfer into the aqueous solution. Calcite precipitation induced a decrease in pH as well as a strong cellular mortality due to nucleation of carbonates on bacteria followed by the embedding of cells within the carbonate crystals, as evidenced by SEM, X-ray synchrotron imaging and TEM studies. The implications of this model for CO₂ biomineralization in subsurface environments are finally discussed in the light of subsurface metabolisms, which might often imply local pH increases (e.g. dissimilatory sulphate reduction).

