Dating deposition and low-grade metamorphism by in situ U-Pb geochronology of titanite

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Titanite ($CaTiSiO_5$) is a widespread accessory mineral, composed of major rock-forming elements, that incorporates sufficient U into its structure for U–Pb geochronology. It occurs in felsic to imtermediate igneous rocks, in very low to high-grade metamorphic rocks, in sedimentary rocks and in hydrothermal ore deposits. Because titanite can form at temperatures below 700°C, its closure temperature for the diffusion of Pb, it can provide ages for a wide range of low- to moderate temperature geological processes. Although titanite forms detrital and authigenic grains in sedimentary rocks, it has rarely been used to date deposition, diagenesis or low-grade metamorphism.

Two generations of titanite are preserved in tuffaceous rocks of the Paleoproterozoic Timeball Hill Formation, southern Africa: euhedral, brown crystals with apatite inclusions, and colorless, pore-filling cement. The brown titanite has elevated U, Th and Fe and low Al, consistent with a magmatic origin, whereas the colorless titanite has high Al and F and low Fe contents, suggestive of a diagenetitc or metamorphic paragenesis. In situ SHRIMP geochronology of brown titanite from a tuff bed gives a weighted mean $^{207}Pb/^{206}Pb$ age of ~2275 Ma and is interpreted to provide a reliable estimate for depositional age.

Authigenic titanite has been reported as pore-filling cement in a number of sandstone units worldwide but has not previously been dated. Fe contents vary widely, and some examples have elevated amounts of high-field-strength elements. The compositions may reflect local metamorphic or hydrothermal fluid compositions. In situ U–Pb dating of intergranular titanite from a tuffaceous sandstone in the Timeball Hill Formation yields an age of ~2145 Ma, which corresponds with previous estimates for a low-grade tectonothermal event in southern Africa.

Our results demonstrate that titanite is a versatile chronometer that can be used to constrain depositional ages, and those of diagenesis and low-grade metamorphism. It has the potential to increase the number of sedimentary rock units that can be dated, and to elucidate the histories of low-temperature geological processes in depositional basins.

An EBSD study of textural evolution across a shear zone in the Bergen Arcs, Western Norway

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The interaction between fluid infiltration, mineral reactions and rock deformation has been the subject of much debate and raises fundamental issues such as the mechanism of fluid transport in nominally impermeable rocks. Localisation of deformation in shear zones provides an opportunity to study the textural and mineralogical evolution from relatively undeformed wall rocks through to the highly strained shear zone and to evaluate the various mechanical and chemical processes which result in rock weakening. Rock strength or rheology is a critical parameter in geodynamic models for collision and subduction zones.

The present study was carried out from cross sections through an amphibolite facies shear zone associated with the Caledonian Orogeny (~420Ma) that transects older anorthositic granulite facies rocks (~930Ma) in the Bergen Arcs, western Norway. In this region, it is possible to study the textural and chemical changes from the relatively unaltered granulites which retain the high grade mineralogy and texture, through to highly strained and hydrated minerals within the shear zones.

Our SEM observations of the cross sections showed that the granulite facies rock is composed of plagioclase (An_{50}), garnet and an Al-rich clinopyroxene, with minor scapolite. Closer to the shear zone, the original granulitic plagioclase is replaced by a 2-phase feldspar intergrowth composed of an Na-rich and Ca-rich network where the Na-rich domains (composition ~An_{24}) are surrounded by thinner "veins" of Ca-rich plagioclase (An_{64}). At the same time the garnet grains develop Fe-richer rims of variable width and involve the production of amphibole crystals at the boundary with the plagioclase. Lastly, in the shear zone, polygonal plagioclase retaining the 2-phase structure and foliated amphibole crystals were observed.

In the present study, we investigated in detail the evolution of the microtextures by electron back scattered diffraction (EBSD). Especially, we focused on their crystal preferred orientations (CPOs) which can be related to the deformation mechanisms.

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