Constraints on age and duration of metamorphic events from *in-situ* U-Pb dating and geochemical characterization of zircon

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Significant progress has been made in recent years in the interpretation of U-(Th)-Pb ages of zircon in meta-morphic rocks: i) through in-situ dating by ion microprobe and relating geochronlogical data to metamorphic textures and P-T data [1]; ii) by trace analyses of zirconium in rock forming and accessory minerals (e.g. garnet, ilmenite, rutile) and thus identification of possible zircon-forming metamorphic reactions [2, 3, 4]; iii) by a better under-standing for the Th-U systematics of zircon instead of an over-simplified division into metamorphic low Th/U and magmatic high Th/U zircons [5]; iv) by studies on the trace element systematics, esp. REE, of zircon under different conditions that enable equilibrium with other minerals to be investigated, e.g. garnet [6]; v) by recognition and detailed knowledge of possible modification and alteration processes of zircon prior to and during metamorphism, e.g. recrystallization with or with fluid, dissolution-reprecipi-tation and metamictisation [7, 8].

Examples from ultra-high temperature metamorphic areas in Norway, Brazil and Uganda illustrate several of these points: the resistance of zircon to 'resetting' by volume diffusion to at least 950°C; how inclusion textures can be related to U-Pb in-situ analysis and constrain ages of metamorphic stages; how trace elements in zircon help provide additional constraints on the P-T-t evolution and the mechanisms of zircon growth or modification. The results are also geologically signifcant: for the duration/ timescale of UHT metamorphic events, possible heat sources and the geodynamic settings.

References

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Timing of zircon growth during high-grade metamorphism: Constraints from garnet-zircon REE.

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The problem of relating U-Pb zircon ages to processes and hence geological events is central to understanding orogensis and crustal evolution. Supporting textural and mineral chemical criteria are essential in order to place zircon ages in a P-T, reaction and assemblage context, and to discriminate between various processes of metamorphic zircon formation. Rare earth element (REE) signatures in zircon and co-existing metamorphic minerals such as garnet are key to addressing such problems.

Zircon/garnet REE partitioning coefficients were calculated empirically using zircon and garnet that crystallised in equilibrium in garnet-bearing UHT leucosome (Napier Complex, east Antarctica). D_{REE} (Zrc/Grt) are in the range 1.0 (Eu) decreasing to 0.7 (Yb). The influence of garnet on zircon REE patterns, and proposed equilibrium D_{REE} criteria have been used to interpret zircon ages from two complex terranes.

Felsic orthogneiss from the Napier Complex, previously interpreted as 'syn-D_1', preserves S_1 garnet-orthopyroxene. ~2990 Ma magmatic zircon has steep REE profiles, whereas ~2840 Ma metamorphic overgrowths have steeper, MREE-depleted / HREE enriched patterns. ~2485 Ma sector zoned grains have flat, HREE-depleted patterns, similar to S_1 orthopyroxene, suggesting growth in the presence of garnet. Therefore, intrusion at ~2990 Ma occurred prior to the development of S_1 at ~2485 Ma. Furthermore, the metamorphism that affected the rocks at ~2840 Ma did not produce garnet in this rock composition.

The Rauer Group, east Antarctica, contains Archaean crustal components that were reworked during metamorphism at >2500 Ma, 1030-990 Ma and 530-510 Ma. Garnet-bearing metagabbro contains ~2840 Ma magmatic zircons that have rims with geometries that suggest modification during fluid influx and recrystallisation. In comparison to magmatic zircon cores, rims have steep M-HREE-depleted profiles. Partially reacted garnet has cores with flat M-HREE profiles and more HREE-enriched rims. Calculated zircon/garnet D_{REE} indicates that zircon rims do not attain REE equilibrium even with garnet rims. Therefore, these zircon rims do not date metamorphic equilibration of the coarse-grained granulite assemblage in these rocks.