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Combining in Situ Zircon REE and U-Th-Pb Geochronology: A Petrogenetic Dating Tool

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In spite the pre-eminent role of zircon as a geochronometer, the processes controlling its crystallisation and/or recrystallisation under metamorphic conditions remain poorly understood. Characterisation of the trace-element, and particularly rare-earth element contents of zircons from a variety of settings is beginning to reveal the importance of such studies for addressing the question of zircon growth related to petrogenesis. In igneous systems, the trivalent REE's generally exhibit a steep increase from La to Lu which is controlled primarily by ionic radius, reflecting the ability of heavy REE's to fit better into the zircon lattice. However, the REE profile of zircon will also be strongly dependent on the availability of particular elements. In metamorphic systems, the supply of Zr will be controlled to a large degree by breakdown of Zr-bearing minerals (e.g. hornblende, biotite, garnet) which themselves have very distinctive REE characters, particularly with respect to the heavy REE's. Breakdown and/or growth of particular minerals at the same time as zircon will exert a marked influence of the REE pattern. Other REE-rich accessory phases will also have an influence (e.g. monazite growth/breakdown affecting light REE's).

This presentation focuses on high-spatial resolution ion-microprobe measurements of REE's in zircon which have been performed on the same sites as U-Th-Pb dating. Such an approach permits unambiguous assignment of the growth of specific phases in complex (as revealed by CL and/or BSE imaging) zircons to given events in the history of the host rock. Figure 1 presents an example from a complex polyphase zircon from a late-Archean diorite in the northern Outer Hebridean Lewisian Complex of NW Scotland. CL imaging reveals very complex growth and/or reworking structures in these zircons which consist of (1) internal, growth banded, late-Archean (ca. 2.8 Ga) cores, (2) homogeneous, CL-bright overgrowths/reworking zones which yield discordant ages spreading between 2.8 Ga and 2.0 Ga and (3) growth banded, euhedral tips which formed at 1.87 Ga. Chondrite normalised REE patterns are shown for a typical crystal in Fig. 1 and it reveals dramatic differences between the growth zones. The core shows a typical igneous zircon REE pattern of steep light to heavy REE's (high Lu(n)/La(n), high Lu(n)/Gd(n), strong positive Ce anomaly, due to Ce(IV) affinity for the zircon lattice, and a minor negative Eu anomaly. The reworked part of the crystal shows a markedly different pattern characterised especially by almost flat middle to heavy REE's (Lu(n)/Gd(n) ~ 1). This pattern suggests zircon (re-)crystallisation at the same time as a heavy-REE bearing mineral, most likely garnet. The 1.87 Ga tips show a similar pattern to the igneous core, although at a ca. 10x lower concentration and might reflect small degrees of partial melting. However, the light-REE's (La - Nd) are relatively flat and this probably indicates breakdown of a light-REE bearing mineral concurrent with zircon growth.

It is clear from this example, and others that will be discussed, that the combined application of high-spatial resolution trace-element and geochronological studies can yield valuable information about the precise timing of particular metamorphic reactions which are occurring simultaneously with zircon growth. The increase of in situ geochronology by SIMS and laser ICP-MS methods, and the increasing awareness of the complexities of zircon growth as revealed by imaging will be ideally complemented in future by such studies.

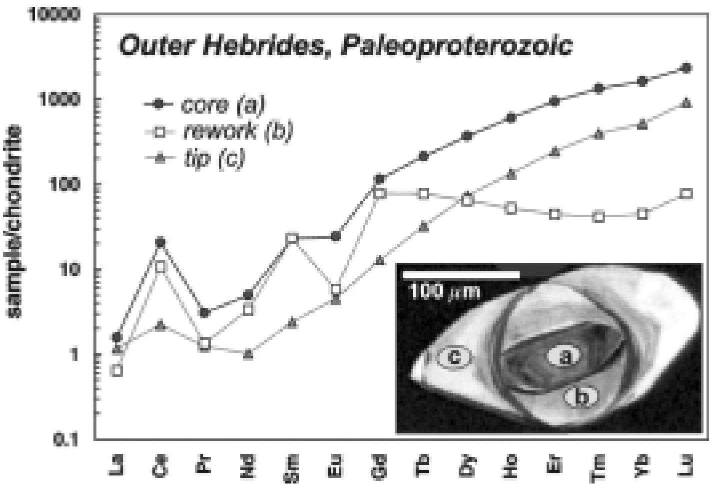

Figure 1: REE profile and CL image for a zircon from the Lewisian Complex.