Trace element SIMS investigation of multistage garnet – Constraints on partial melting processes in crustal rocks

C. JUNG[1], S. JUNG[1], E. HELLEBRAND[2] AND E. HOFFER[1]

[1]Philipps Universität Marburg, FRG, Fachbereich Geowissenschaften (jungs@staff.uni-marburg.de)
[2]University of Hawaii, USA, Dept. of Geology and Geophysics (ericwgh@hawaii.edu)

The basement dominated granulite-facies part of the central Damara orogen (Namibia) hosts abundant migmatites that originated by partial melting of metapelitic or, less abundant, meta-igneous sources. A migmatitic orthogneiss shows the growth of garnet within the host gneiss (A), the leucosomes (B) and cross-cutting granite dykes (C). Based on microstructural features and microprobe data, garnet A is considered to be metamorphic and garnet B and C are considered to be anatectic and igneous, resp. Rb/Sr and Sm/Nd whole rock isotope data confirm the suggestion that the gneiss belongs to the Pre-Damara basement. Sr isotope data are heterogeneous but assigning an age of 550 Ma for the gneiss, 500 Ma for the leucosomes and 493 Ma for the dykes results in similar initial $^{87}Sr/^{86}Sr$ ratios of ca. 0.730. These results suggest high-grade metamorphic conditions at ca. 550 Ma, followed by in-situ partial melting at ca. 500 Ma and intrusion of granitic dykes at ca. 493 Ma. All garnets have a 10^4-10^5 CI-normalized range in REE abundances and steep LREE-depleted and HREE-enriched element patterns. Garnet from A, B, and C are zoned in Y, HREE, Sr and Ti in which garnet A shows a small core with HREE, Y, Sr and Ti enrichment and a broad rim with trace element depletion. Garnet B has a core enriched in Yb+Y but depleted in Er and Dy and an outermost rim even more depleted in these elements. Garnet C has a broad core with enrichment in Yb+Y and depletion in Er and Dy. The rim is enriched in HREE+Y. LREE (Sm, Nd) profiles are similar to HREE profiles for garnet B and C but garnet A shows the opposite of HREE zoning with a LREE-depleted core and a LREE-enriched rim. These features indicate that HREE fractionation of garnet A follows a Rayleigh fractionation scheme but Nd and Sm concentration profiles are modified by volume diffusion at high temperatures. Garnet B shows evidence for a two-step growth history (melt absent vs. melt-present?) evidenced by the marked hump between core and rim. The trace element pattern of garnet C can be explained by a combination of a Rayleigh fractionation process and a liquid diffusion controlled process. The data show that trace elements may potentially be more sensitive to chemical changes in rocks than major elements in which an accurate interpretation leads to an improved understanding of p-T paths of metamorphism and melting.

High-precision Lu-Hf garnet ages from granulite-facies migmatites (Damara orogen, Namibia)

S. JUNG[1] AND E.E. SCHERER[2]

[1]Fachbereich Geowissenschaften, Philipps Universität Marburg, FRG (jungs@staff.uni-marburg.de)
[2]Institut für Mineralogie, Universität Münster, FRG (escherer@uni-muenster.de)

The basement dominated granulite-facies part of the central Damara orogen (Namibia) hosts abundant migmatites formed by partial melting of metapelitic sources during intrusion of hot granitic melts. Centimeter-sized garnet is a common product of incongruent melting reactions and has been dated with the Sm-Nd and U-Pb methods. In addition, the U-Pb ages of matrix monazite have also been determined for the majority of the samples. In general, Sm-Nd garnet whole rock ages are precise (better than 1%) and agree with the Pb-Pb ages of the garnets, although the latter are relatively imprecise (2-8%) due to low $^{206}Pb/^{204}Pb$ ratios. Collectively, the Pb-Pb garnet data define an age of 540±40 Ma, whereas the Sm-Nd garnet-whole rock ages range from 530±3 Ma to 506±2 Ma. These age estimates agree with previous Sm-Nd grt-WR ages and U-Pb monazite ages from elswhere in the orogen and are interpreted to constrain the time span of high-grade metamorphism and melting. To better resolve the relationship between high grade metamorphism and melting and garnet growth, and to improve upon the precisions of the Sm-Nd and Pb-Pb age determinations, garnets were dated with the Lu-Hf technique. All garnets display similar Lu-Hf isotope systematics, with high Lu (16-40 ppm) and high Hf (0.9-1.5 ppm) contents, moderately high $^{176}Lu/^{177}Hf$ ratios (1.7-7.3), and radiogenic $^{176}Hf/^{177}Hf$ ratios (0.30059-0.35467). Due to these characteristics, the internal isochron ages are precise (0.2-1.0%), and range from 531±1 Ma to 514±5 Ma. For all samples, the Lu-Hf grt-WR ages are similar to—or lower than—the U-Pb monazite ages and are also similar to (with one exception) the Sm-Nd grt-WR ages from the same sample. The similarity among Lu-Hf and Sm-Nd grt-WR ages, Pb-Pb garnet ages, and U-Pb monazite ages imply relatively fast cooling rates immediately after the peak of regional metamorphism, which was probably related to fast uplift of the basement-dominated part of the orogen.