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Three Proterozoic orogenic cycles in the Livingstone Mountains, Tanzania: Evidence from petrology and ion microprobe dating of zircon and monazite

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The Livingstone Mountains at Lake Nyasa in southern Tanzania are situated in an area where three orogenic belts seem to be overlapping: the Ubendian-Usagaran belts, the Irumide Belt and the East African Orogen, whose formations are linked to the assembly of the Proterozoic supercontinents of Columbia, Rodinia and Gondwana. Granulite-facies migmatitic metapelites and two orthogneisses were studied petrologically and by ion microprobe dating of monazite and zircon to decipher their tectono-metamorphic history and to find out if and to which degree the rocks of the Livingstone Mountains were affected by the different orogenies.

Zircon dating of orthogneiss yielded a magmatic age of ca. 2.2 Ga. Texturally controlled ion microprobe U-Pb dating of monazite inclusions in garnet of a Grt-Sil-Bt migmatite in combination with discordant zircon data point to sillimanite-garnet grade metamorphism at 1857±27 Ma during the Ubendian-Usagaran orogeny. Oscillatory zoned concordant zircon of another orthogneiss was dated at 997±8.6 Ma, whereas the age of monazite inclusions in garnet and matrix of a garnet-sillimanite-gneiss revealed an associated high-grade metamorphism at 1067±20 Ma during the Irumide orogeny. Low Th/U overgrowths on orthogneiss zircon and concordant matrix monazite in metapelite are dated at 653±9.1 Ma, which is in agreement with the known ages of Pan-African events in the East African Orogen and in the Ubendian Belt (655-550 Ma) (Möller et al., 2000; Boniface et al, 2012).

Garnet is homogeneous in Fe and Mg, but cores are mantled by Ca-rich garnet which shows rim-ward depletion in Ca. Thermobarometry using compositions of garnet rims and matrix minerals yielded 770-820 °C and 7-8 kbar, which we interpret to represent conditions during the Neoproterozoic metamorphic event. The high-grossular mantle might reflect earlier conditions of kyanite-grade metamorphism tentatively correlated with high-pressure metamorphism during the Mesoproterozoic Irumide orogeny, or the early stages of the Neoproterozoic event. Garnet cores, some of which preserve Paleoproterozoic monazite inclusions, have compositions similar to the rims and indicate similar conditions during Paleoproterozoic and Neoproterozoic metamorphism at garnet-grade. Garnet breakdown to kyanite-biotite-plagioclase-quartz reflects late-stage cooling under relatively high pressures following Neoproterozoic peak-metamorphism previously reported for the so-called eastern granulites of the East African Orogen (Appel et al., 1998). In summary, texturally controlled dating of monazite and zircon reveals that the Livingstone Mountains represent a crustal block that was overprinted by three high-grade metamorphic events of which at least two were associated with granitoid magmatism.