Crustal evolution and hydrothermal gold mineralization in the Katuma Block of the Paleoproterozoic Ubendian Belt, Tanzania

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Abstract
Orogenic belts are regions of the Earth's continental crust, in which regional metamorphic rocks occur that may have formed in the deep crust of an orogen. Studies of metamorphic belts are thus important to an understanding of processes that are taking place in roots of mountain belts. In order to determine the formation and crustal evolution of the linear Paleoproterozoic Ubendian Belt in Tanzania and the age and origin of its precious base metal deposits, the rocks in the Katuma Block of the northwestern Ubendian Belt were geochemically and petrologically investigated and their U-Pb zircon and U-Th-total Pb monazite ages determined using Laser Ablation Inductively Coupled Plasma Mass Spectrometer and an Electron Probe Micro Analyser, respectively. Internal textures of the zircon grains in combination with their U-Pb ages indicate that the magmatic formation of the protoliths of the orthogneisses and metabasites of the Katuma Block occurred mostly in the Neoarchean (ca. 2.71-2.64 Ga) but also during the Paleoproterozoic (2.05-1.94 Ga). These two periods are separated for about 600 Ma and are interpreted as active continental margin stages at the border of the Tanzania Craton, as deduced by the calc alkaline nature and trace element geochemistry of the metabasites and orthogneisses. The granulite facies corona assemblages in metabasites consisting of garnet, clinopyroxene, quartz and hornblende replacing magmatic orthopyroxene and plagioclase indicate that the magmatic protoliths experienced a near isobaric cooling after their intrusion into the deep crust during a tectonically quite period (< 2.64 Ga). The detrital zircon grains from the metasediments of the Katuma Block gave ages ranging between 2.64 and 2.05 Ga, similar to the magmatic formation ages of rocks of the Katuma Block, suggesting that the Katuma Block itself was most likely the source for the detritus. The time interval of sedimentation is constrained by the oldest age of the detrital zircon at about 2680 Ma and the age of the first metamorphism of the sediments at about 1960 Ma. This event is documented by the age of metamorphic zircon rims and that of monazite cores. The stage of sedimentation and the near isobaric cooling of the metabasites in the deep crust is ascribed to a passive continental margin stage of the Tanzania Craton between 2.65 and 2.05 Ga. In contrast to the post magmatic cooling nature of the Archean metamorphism of the metabasites, the common occurrence of sillimanite pseudomorphs after cm sized kyanite crystals in migmatitic metapelites provides evidence for two stages of prograde metamorphism associated with Paleoproterozoic crustal thickening events. An early stage of metamorphism took place in the kyanite stability field whereas the subsequent peak metamorphism is characterised by the stability of the mineral assemblage sillimanite-garnet/cordierite-K-feldspar. Pseudosection modelling of the XMg ratios for garnet in combination with GASP barometry revealed that the formation of the compositionally homogenous cores of garnet porphyroblasts formed at conditions of about 7 kbar and 770 ℃. The formation of late stage plagioclase coronas around garnet in metapelites and the decrease of XMg and of the spessartine component in rims of garnet porphyroblasts point to a near isothermal uplift after peak metamorphism and thus to a crustal thickening event that preceded the peak metamorphism. The U-Th-total Pb monazite ages suggest that during the Paleoproterozoic time the Katuma metapelites experienced two separate metamorphic events at about 1.96 Ga and

1.84 Ga. As the two ages of monazite growth zones (cores and rims) are found in monazite grains of the rock matrix and in inclusions in garnet porphyroblasts, the garnet growth must have occurred during or after the second metamorphic event at 1840 Ma. This interpretation is in agreement with the increasing depletion of HREE and Y in the monazite rims indicating concurrent growth of the monazite rims and the garnet porphyroblasts. The second, high-grade event at ca. 1840 Ma is correlated with the formation of the Ubendian Belt during the collision between the Tanzania Craton and the Bangwelu Block. The first metamorphic event at ca. 1960 Ma that preceded the collision for about 120 Ma is attributed to the kyanite grade metamorphism during accretionary processes and associated calc alkaline magmatism (2.05-1.94 Ga) along the active continental margin of the Tanzania Craton. U-Th-total Pb dating of hydrothermally altered monazite grains from hydrothermally altered metapelites hosting the Au-Cu-Pb bearing veins of the Mpanda Mineral Field in the Katuma Block yielded a Mesoproterozoic age (1171 ± 17 Ma). This age coincides with the first, amphibolite grade metamorphism of metasediments in the Wakole Block adjoining the Katuma Block to the southwest. The obtained age provides a link between the metamorphism of the Wakole metasediments and the generation of hydrothermal fluids responsible for the formation of the gold copper lead bearing veins in the Katuma Block.