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Ultra-high temperature granulite-facies metamorphic rocks from the Mozambique belt of SW Tanzania

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ABSTRACT

The metamorphic rocks in the Neoproterozoic (Pan-African) Mozambique belt of southwestern Tanzania, around the town of Songea, can be subdivided into one- and two pyroxene bearing charnockitic gneisses, migmatitic granitoid gneisses and amphibolite-facies metapelites. Lower-grade amphibolite-facies rocks are rare and can be classified as sillimanite- and/or garnet-bearing metapelites. Most of the studied charnockitic gneisses show excellent corona textures with large orthopyroxene grains rimmed by clinopyroxene, followed by quartz and well developed garnet rims due to the reaction Opx + Pl = Grt + Cpx + Qtz that formed during isobaric cooling. These and other charnockitic gneisses show symplectites of orthopyroxene and An-rich plagioclase that resulted from the breakdown of garnet during isothermal decompression due to the reaction Grt + Cpx + Qtz = Opx + Pl. Geothermobarometric calculations yield up to ~1050 °C and up to ~12 kbar for peak metamorphic conditions. These are higher temperature and slightly lower pressure conditions than reported for other granulite-facies terrains in the Mozambique belt of Tanzania. Single zircon Pb–Pb evaporation and U-Pb SHRIMP ages for magmatic zircons extracted from two charnockitic and two granitic gneisses cluster in two groups, one at ~750 Ma and one at ~1150 Ma with the older reflecting the time of emplacement of the igneous precursors, and the younger approximating the time of charnockitization. These protolith ages are similar to those farther east in the Masasi area of southern Tanzania, as well as in northern Mozambique and in southern Malawi, and suggest that the Mozambique belt consists of chronologically heterogeneous assemblages whose pre-metamorphic tectonic setting remains obscure.

1. Introduction

The Neoproterozoic high-grade terrains of the Mozambique belt (MB; Holmes, 1951) in East Africa and Madagascar, together with the lower grade Arabian-Nubian Shield of NE Africa and Arabia, make up the East African Orogen (EAO; Johnson et al., 2011; Stern, 1994). Several authors discussed the southern continuation of the EAO into East Antarctica, and the southern extension through India into Antarctica (Collins and Pisarevsky, 2005; Collins and Windley, 2002; Jacobs et al., 1998; Pant et al., 2012).

Shackleton (1986) suggested that the MB is a complex assemblage of Proterozoic belts of different ages and may thus be polyorogenic. Emplacement ages for magmatic precursors of the granulites in the MB range between ~800 and ~2900 Ma from northern, central and southern Tanzania (Fig. 1A; Table 1; Supplement Table 1; De Waele et al., 2006; Kröner et al., 2003; Maboko, 2000; Maboko and Nakamura, 1996; Möller et al., 2000; Muhongo et al., 2001; Sommer et al., 2003, 2005a,b, 2008; Spooner et al., 1970; Thomas et al., 2013), whereas metamorphic zircons and monazite record a major high-grade metamorphic event during the late Neoproterozoic at 620–650 Ma and a second metamorphic event at ~550 Ma (Supplement Table 1, Sommer et al., 2003, 2005b). The granulite-facies rocks of the MB in southwestern Tanzania have not previously been investigated because of their complex metamorphic history and remote location. To reconstruct the metamorphic history of the study area, a combined approach of field mapping, petrology and geochronology was used. We report *P–T* data and single zircon ages for high-grade metamorphic rocks around the town of Songea (Figs. 1A, B) and compare these data with those reported from similar high-grade rocks elsewhere in Tanzania, Mozambique, Malawi, and Madagascar.

2. Geological setting

The MB of Tanzania (Fig. 1A; Table 1) consists of a Neoproterozoic crustal domain that is predominantly composed of granulite- and amphibolite-facies rocks (Appel et al., 1998; Harpum, 1970; Muhongo, 1994, 1999; Pinna, 1995; Quennell et al., 1956; Sommer et al., 2003, 2008). To its west, medium- to high-grade rocks and undeformed granitoids and volcanic rocks of Palaeoproterozoic age make up the

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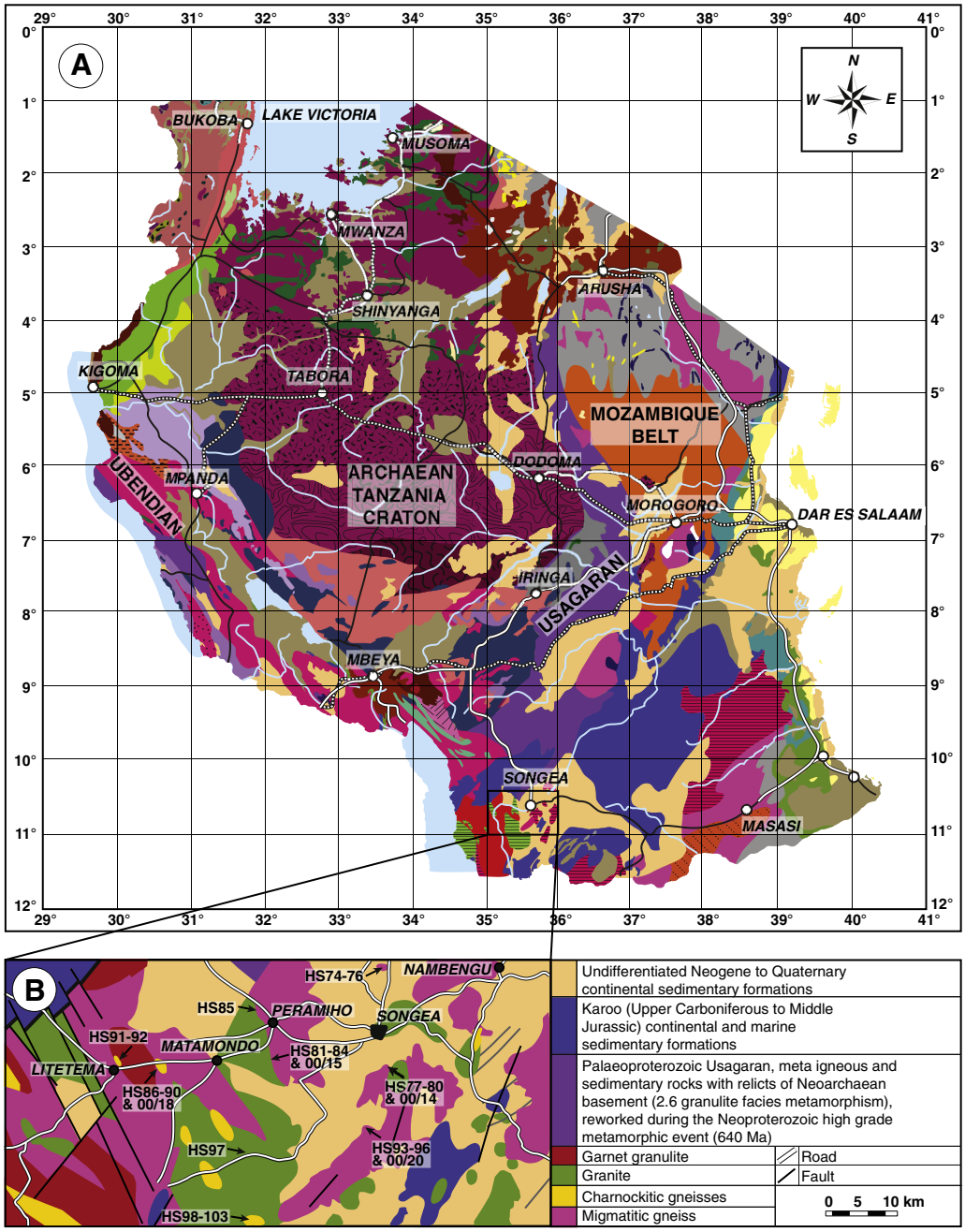

Fig. 1. (A) Geological map of Tanzania showing the main geological terrains: Cenozoic domains, Paleozoic and Mesozoic basins, Neoproterozoic domains, Neoproterozoic Mozambique Belt, Mesoproterozoic belts, Palaeoproterozoic Ubendian and Usagaran belt and Archaean basement (modified after Pinna et al., 2004). (B) Geological overview map of the study around the town of Songea showing major rock units and sample locations.

Ubendian–Usagaran belt that borders the Archaean Tanzania Craton along its southeastern margin (Fig. 1A; Table 1; Collins and Pisarevsky, 2005; Reddy et al., 2003, 2004; Sommer et al., 2005b). The formation of Neoproterozoic high-temperature and high-pressure (HT/HP) rocks in the MB of East Africa and Madagascar has been interpreted as the result of Neoproterozoic terrane amalgamation and collision, characterized by recumbent, isoclinal folds, thrusts, nappe structures, high-temperature ductile strike–slip shear zones and pervasive down-dip stretching lineations (Fritz et al., 2005, 2009; Hepworth, 1972; Muhongo, 1994; Shackleton, 1986, 1993, 1996 and references therein). The age of regional granulite-facies metamorphism is well constrained by zircon U–Pb SHRIMP and Pb–Pb evaporation ages as well as U–Pb monazite ages of around 620–650 Ma (Kröner et al., 2003; Möller et al., 2000; Muhongo et al., 2001; Sommer et al., 2003, 2005a). A summary of previous geochronology on high-grade rocks is given in Supplement Table 1. Granulite-facies rocks in the MB of northern Mozambique, southern Malawi, and Madagascar yielded metamorphic ages between 615 and 550 Ma (Bingen et al., 2009; Kröner, 2001, 2000; Kröner et al., 2001; Thomas et al., 2010). Thus, it is now well documented that two distinct metamorphic event occurred within the MB, one at 620–650 Ma and a second at ~550 Ma. Consequently, both granulite-facies metamorphic events in the MB have been punctuated (Kröner, 2001; Muhongo et al., 2001; Sommer et al., 2003, 2005a).

Much of the Songea area is covered by Karoo and Neogene sediments, which obscure many of the underlying Proterozoic high-grade