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Anorthosites in the Eastern Granulites of Tanzania—New SIMS zircon U–Pb age data, petrography and geochemistry

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Abstract

Several occurrences of anorthosites are known in the Neoproterozoic Mozambique Belt in Tanzania. These are tectonically incorporated into a suite of enderbitic rocks and migmatitic orthogneisses of the Eastern Granulites. Two larger anorthosite bodies and associated rocks from the Pare Mountains and the Uluguru Mountains have been chosen for a comparative study regarding their formation age, age of subsequent metamorphic processes, mineral chemistry and rock chemistry. All the investigated magmatic bodies were overprinted by Neoproterozoic high-pressure granulite facies metamorphism and deformation, documented by similar petrography and mineralogy, metamorphic textures and deformational characteristics. However, mineral chemistry, geochemistry and geochronology reveal major differences between the two occurrences. The Pare anorthosite contains igneous zircons that yield Archean formation ages of ca. 2.64 Ga and a more calcic mineral and rock chemistry that is typical for Archean-type anorthosites. Extremely narrow metamorphic rims around zircons could not be dated but may have grown during the Neoproterozoic metamorphic overprint. In contrast, the Uluguru anorthosite contains igneous zircon cores with U/Pb ages of 880–820 Ma. A broad metamorphic rim was dated at ca. 640–650 Ma. The adjacent migmatitic basement gneisses yield formation ages of ca. 986 Ma followed by Pb-loss. Early Neoproterozoic events can also be inferred from both anorthosite suite and basement samples of the Mahenge Mountains. There U/Pb ages from zircon cores cluster around 730–800 Ma. Well-developed metamorphic rims yield Neoproterozoic ages of 650 Ma. The basement gneisses are related to a destructive plate margin setting. The anorthosites may have formed when parts of Central Madagascar rifted off East Africa at the time considered.

Keywords: Anorthosites; Eastern Granulites; SIMS U–Pb geochronology; Geochemistry; Archean and Proterozoic anorthosites

1. Introduction

Anorthosites are magmatic rocks that consist of at least 90% plagioclase and represent an important rock type in many Precambrian terranes. Anorthosites occur in both Archean and Proterozoic with the different eons having distinctive anorthosite characteristics. About 70 occurrences of Archean anorthosites are known worldwide that are sill-like bodies characterized by calcic plagioclase megacrysts. More voluminous Proterozoic anorthosite massifs (therefore massif-type) are known from ca. 130 locations and exhibit different mineralogy

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Table 1
Overview of age data from recent literature for East African and some Gondwanan anorthosites

Age domains	Reference	Age	M/X	Method
Archean Ages				
Sittampundi Complex (South India)	Bashkar et al. (1996)	2935 ± 60 Ma	X	Sm–NdWR
Bhavani Complex (South India)	Bashkar et al. (1996)	2899 ± 28 Ma	X	Sm–NdWR
Proterozoic Ages				
Tete Complex—Mozambique	Evans et al. (1999)	1025 ± 79 Ma	X	Sm–NdWR
Anorthosites—Madagascar	Ashwal et al. (1998)	660 ± 60 Ma	X	Sm–Nd
Anorthosites—Madagascar	Ashwal et al. (1998)	ca. 950 Ma	X	T_{DM} model age
Antarctica	Jacobs et al. (1998)	ca. 600 Ma	X	U/Pb Shrimp
Uluguru Anorthosite	Maboko (1995)	1.36–1.65 Ga	X	T_{DM} model age
Uluguru Anorthosite	Muhongo and Lenoir (1994)	695 ± 4 Ma	X	U/Pb
Uluguru Anorthosite	Maboko and Nakamura (1995)	633 ± 7 Ma	M	Sm–Nd (Grt)
Kunene Complex (Namibia)	Mayer et al. (2004)	1371 ± 2.5 Ma	X	U/Pb
Kunene Complex (Namibia)	Mayer et al. (2004)	1470 ± 25 Ma	X	Sm–Nd
Kunene Complex (Namibia)	Mayer et al. (2004)	1319 ± 28 Ma	X	Sm–Nd

Abbreviations in the row M/X are used for the subdivision of metamorphic (‘M’) vs. crystallization (‘X’) ages as interpreted in literature.

and rock chemistry from their Archean counterparts. The characteristics of all known anorthosites have been nicely compiled by Ashwal (1993). From these abundant northern hemisphere anorthosites are known and extensively studied (Duchesne et al., 1999a; Ashwal, 1993). In the southern hemisphere anorthosite complexes there is still a lack of data. The largest southern anorthosite is the Kunene Complex of Angola that covers 15,000 km^2 (Ashwal and Twist, 1994; Mayer et al., 2004; Drüppel et al., 2005) although small dispersed intrusions are more typical. Such smaller dispersed anorthosite bodies are common in the high-grade Neoproterozoic mobile belts of the East African Orogen (Ashwal, 1993). Some of these anorthosites have been investigated in recent years (see ages and references in Table 1). However, the geochemical and geochronological database for anorthosites in Gondwana is still largely incomplete. Well-defined age data are especially scarce.

Tanzania hosts several smaller anorthosite bodies tectonically incorporated in the meta-igneous sequences of the roughly north-south striking chain of the Eastern Granulites, which are part of the late Neoproterozoic Mozambique Belt (Fig. 1). The anorthosites are a characteristic feature of the Eastern Granulites and have been mapped in the North Pare Mountains (Dundas, 1965), the Uluguru Mountains (Sampson and Wright, 1964), the Mahenge Mountains (Birch and Stephens, 1962) and on Mwega Hill close to the village of Mkata (Salisbury, 1963; Chao, 1972) (Fig. 1). The Eastern Granulites, including the anorthosites, experienced high-pressure granulite facies metamorphism during the East African orogeny around 640 Ma (Muhongo et al., 2001). Nevertheless, we use the term ‘anorthosite’ instead of ‘meta-anorthosite’, as most of worldwide occurrences, which are termed ‘anorthosite’ are overprinted by metamorphism to various degrees.

During the East African orogeny, the Eastern Granulites were thrust onto the basement of the Tanzania Craton and Usagaran Belt (Fritz et al., 2005). This led to a complex distribution of Archean and Proterozoic ages in the Mozambique Belt and opened the debate about how much juvenile crust exists in this orogen. Möller et al. (1998) found that only the Eastern Granulites contain juvenile Neoproterozoic crust and interpreted a fundamental crustal age domain boundary in the Uluguru Mountains. However, the database of in situ U/Pb crystallization ages of zircons in the Eastern Granulites is still scarce, as shown below. Amongst the anorthosites in Tanzania, only those of the Uluguru Mountains have been studied geochronologically in some detail (Table 1). Apart from descriptive studies (Sampson and Wright, 1964), few isotope data are available. Muhongo and Lenoir (1994) dated a zircon fraction that gave a U/Pb (concordia upper intercept) age of 695 ± 4 Ma, interpreted as the crystallization age of the body. A Neoproterozoic metamorphic age (633 ± 7 Ma) from a garnet fraction in the anorthosite was published by Maboko and Nakamura (1995) and T_{DM} model ages from the Uluguru anorthosites range between 1.36 and 1.64 Ga (Maboko, 1995).

In this paper we present for the first time crystallization ages of the anorthosites from three mountains ranges that belong of the Eastern Granulites (Pare, Uluguru and Mahenge Mountains). We used the ion microprobe for the determination of U/Pb-isotopic ratios of individual zircon grains of anorthosites and associated rocks.