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Research paper

A primitive mantle source for the Neoarchean mafic rocks from the Tanzania Craton

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A B S T R A C T

Mafic rocks comprising tholeiitic pillow basalt, dolerite and minor gabbro form the basal stratigraphic unit in the ca. 2.8 to 2.6 Ga Geita Greenstone Belt situated in the NW Tanzania Craton. They outcrop mainly along the southern margin of the belt, and are at least 50 million years older than the supracrustal assemblages against which they have been juxtaposed. Geochemical analyses indicate that parts of the assemblage approach high Mg-tholeiite (more than 8 wt.% MgO). This suite of samples has a restricted compositional range suggesting derivation from a chemically homogenous reservoir. Trace element modeling suggests that the mafic rocks were derived by partial melting within the spinel peridotite field from a source rock with a primitive mantle composition. That is, trace elements maintain primitive mantle ratios (Zr/Hf = 32–35, Ti/Zr = 107–147), producing flat REE and HFSE profiles [$(La/Yb)_{pm}$ = 0.9–1.3], with abundances of 3–10 times primitive mantle and with minor negative anomalies of Nb [$(Nb/La)_{pm}$ = 0.6–0.8] and Th [$(Th/La)_{pm}$ = 0.6–0.9]. Initial isotope compositions (ε_{Nd}) range from 1.6 to 2.9 at 2.8 Ga and plot below the depleted mantle line suggesting derivation from a more enriched source compared to present day MORB mantle. The trace element composition and Nd isotopic ratios are similar to the mafic rocks outcropping ∼50 km south. The mafic rocks outcropping in the Geita area were erupted through oceanic crust over a short time period, between ∼2830 and ∼2820 Ma; are compositionally homogenous, contain little to no associated terrigenous sediments, and their trace element composition and short emplacement time resemble oceanic plateau basalts. They have been interpreted to be derived from a plume head with a primitive mantle composition.

1. Introduction

Archean greenstone belts include some of the oldest surviving fragments of supracrustal rocks, thus providing important insights into the early evolution of Earth. Some of the oldest greenstone belts include the Isua Greenstone Belt in Greenland (e.g., Myers, 2001; Polat et al., 2002), the Nuvvuagittuq Greenstone Belt in Canada (e.g., O'Neil et al., 2013), the Barberton Greenstone Belt in South Africa (e.g., Cutts et al., 2014) and the Pilbara in Australia (e.g., Green et al., 2000). Moreover, the end of the Archean was a period of widespread volcanism and greenstone belt formation in all major Archean Cratons (e.g., Kerrich et al., 1999; Manya and Maboko, 2003; Jayananda et al., 2013; Manikyamba et al., 2014). The source of this volcanism was attributed to a variety of tectonic processes from subduction settings with the mafic volcanics generated in arcs (e.g., Jayananda et al., 2013; Manikyamba et al., 2014), to plume tectonics with the mafic generated in oceanic plateaus (e.g., Bédard et al., 2014), to a combined process involving both plate tectonics and plumes (e.g., Kerrich et al., 1999). Thus, understanding the geological processes that resulted in greenstone belt formation is essential for understanding crustal growth and evolution through time.

Greenstone belts are integral components of Archaean cratons and typically comprise a greenschist to lower amphibolite facies assemblage of complexly interlayered (ultra-)mafic volcanics, sediments and evolved volcanic deposits, which are intruded by igneous bodies and bordered by extensive granites and gneisses. Debate surrounds the types of environment in which Archean greenstone belts formed and hence the tectonic processes that led to development of Earth's early crust, prior to widespread TTG

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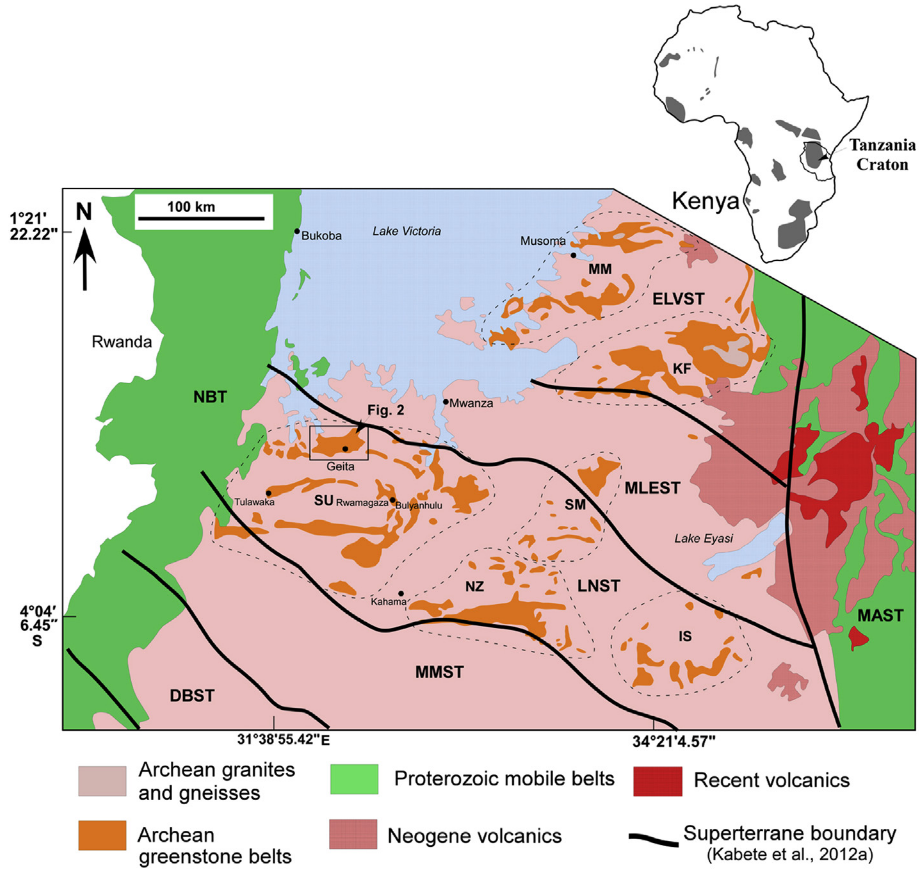

Figure 1. Map of the Tanzania Craton showing the location of the six greenstone belts defined by Borg and Shackelton (1997) and the main tectonic units. SU – Sukumaland Greenstone Belt, SM – Shinyanga-Malita Greenstone Belt, MM – Musoma-Mara Greenstone Belt, KF – Kilimafedha Greenstone Belt, NZ – Nzega Greenstone Belt, IS – Iramba Sekenke Greenstone Belt; Super-terrane boundaries are proposed by Kabete et al. (2012): ELVST – East Lake Victoria, MLEST – Mwanza Lake Eyasi, LNST – Lake Nyanza, MMST – Moyowosi-Manyoni, DBST – Dodoma Basement, MAST – Mbulu-Masai, NBT – Nyakahura-Burigi. Inset map of Africa shows the location of Archean blocks in gray.

intrusion and cratonisation around 2700 Ma (e.g., Condie, 2003; Korenaga, 2006; Van Hunen and Moyen, 2012).

The extensive mafic volcanics and associated rocks that occur commonly in the oldest parts of greenstone belts are central to understanding whether the belts initially formed by eruption of juvenile mantle-derived magmas through older continental crust or in ocean basins and whether they are autochthonous, or incorporated by lateral accretion from an oceanic environment involving subduction-accretion-type processes (e.g., Kusky, 2004; Pearce, 2008; Stott and Mueller, 2009; Bédard et al., 2014).

The volcanic components of greenstone belts commonly show evidence of ocean arc and plateau settings, with or without the influence of plume activity (e.g., Puchtel et al., 1999; Polat and Kerrich, 2000; Parman et al., 2001; Arndt, 2003; Naqvi et al., 2009; Bédard et al., 2014). The high strain zones that occur at the base of volcanic sequences were interpreted to result from lateral accretion of oceanic deposits onto the continent (Kusky and Kidd, 1992; Kusky and Winsky, 1995; Bédard et al., 2014) or as decollements (e.g., Chardon et al., 1996, 1998). Sedimentary and structural data have been used to infer a foreland-type sedimentary basin environment and an allochthonous origin for some greenstone sequences (e.g., Hofmann et al., 2001a, b; Hofmann et al., 2003), and mantle plumes have also been invoked in continental environments (eg., Ohtani et al., 1989; Arndt et al., 1997; Kerrich and Xie, 2002; Arndt, 2003). Evidence for eruption directly onto continental basement includes xenocrysts of lower crustal garnet (Shimizu et al., 2005), crustal geochemical contamination, indicated by changes in the incompatible trace element ratios when compared to well documented oceanic basalts (Green et al., 2000; Bolhar et al., 2003; Shimizu et al., 2005; Pearce, 2008) and field relations analogous to continental flood basalts such as associated continental sediments (e.g., Choukroune et al., 1995; Hunter et al., 1998; Hollings and Kerrich, 1999; Hollings et al., 1999). It is worth noting that some authors argue that not all greenstone sequences are the same, thus each greenstone belt must be treated independently (e.g., Jelsma and Dirks, 2002). This is particularly well illustrated in the Superior Province where both continental-margin volcanic sequences built on older crustal fragments and juvenile oceanic domains are well documented (e.g., Percival et al., 2006, 2012). In contrast, the greenstone belts of the Tanzania Craton are seriously understudied and there is very limited geological data documenting their stratigraphic, intrusive and deformation histories (e.g., Sanislav et al., 2014). It is generally accepted that the base of the stratigraphy of the greenstone belts from northern Tanzania is formed by mafic volcanics (e.g., Borg, 1992; Manya and Maboko, 2003, 2008) and the available zircon ages (e.g., Sanislav et al., 2014), younger than 2800 Ma, indicate that the mafic volcanics are the oldest rocks in the northern half of Tanzania with no basement rocks identified so far. This may indicate that the mafic volcanics were erupted through oceanic crust thus the potential for crustal contamination is very small.

Mafic volcanic rocks such as basalt represent melt derived from the mantle; therefore, their geochemical composition can provide important insights into the state of the mantle throughout Earth history. For example, modern basalt geochemical composition indicates that the mantle is heterogeneous in composition as a result