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Petrography and geochemistry of the primary ore zone of the Kenticha rare metal granite-pegmatite field, Adola Belt, Southern Ethiopia: Implications for ore genesis and tectonic setting

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ABSTRACT

The aim of this work is to evaluate the genesis and tectonic setting of the Kenticha rare metal granite-pegmatite deposit using petrography and whole-rock geochemical analysis. The samples were analysed for major elements, and trace and rare earth elements by ICP-AES and ICP-MS, respectively. The Kenticha rare metal granite-pegmatite deposit is controlled by the N-S deep-seated normal fault that allow the emplacement of the granite-pegmatite in the study area. Six main mineral assemblages have been identified: (a) alaskitic granite (quartz + microcline + albite with subordinate muscovite), (b) aplitic layer (quartz + albite), (c) muscovite-quartz-microcline-albite pegmatite, (d) spodumene-microcline-albite pegmatite, partly albitized or greisenized, (e) microcline-albite-green and pink spodumene pegmatite with quartz-microcline block, which is partly albitized and greisenized, and (f) quartz core. This mineralogical zonation is also accompanied by variation in Ta ore concentration and trace and rare earth elements content. The Kenticha granite-pegmatite is strongly differentiated with high SiO2 (72–84 wt %) and enriched with Rb (~689 ppm), Be (~196 ppm), Nb (~129 ppm), Ta (~92 ppm) and Cs (~150 ppm) and depleted in Ba and Sr. The rare earth element (REE) patterns of the primary ore zone (below 60 m depth) shows moderate enrichment in light REE ($(La/Yb)_N$ = ~8, and LREE/HREE = ~9.96) and negative Eu-anomaly (Eu/Eu^* = ~0.4). The whole-rock geochemical data display the Within Plate Granite (WPG) and syn-Collisional Granite (syn-COLG) suites and interpret as its formation is crustal related melting. The mineralogical assemblage, tectonic setting and geochemical signatures implies that the Kenticha rare metal bearing granite pegmatite is formed by partial melting of metasedimentary rocks during post-Gondwana assembly and further tantalite enrichment through later hydrothermal-metasomatic processes.

1. Introduction

Despite considerable research works that have been done on the petrogenesis and chemistry of Ta-Nb oxides (e.g., Abdalla et al., 1998; Baumgartner et al., 2006; Belkasmi et al., 2000; Cèrny and Ercit, 1985; Galliski and Černý, 2006; Küster et al., 2009; Van Lichtervelde et al., 2007), their mineralogy, trace elements composition and ore-forming processes remain poorly understood (Melcher et al., 2015; Badanina et al., 2015; Van Lichtervelde et al., 2007). The mechanism of ore-forming processes through anatexis and the role of chemical quenching in deep-seated pegmatites are still also poorly investigated (Simmons, 2007). In addition, there is still unresolved puzzle of how and when pegmatites are separated from their source granites and how comagmatic dikes acquire an increasing chemical fractionation from their distant source (London and Morgan, 2012).

In the 1920s, different models have been proposed to explain the internal evolution of granitic pegmatites, such as (a) fractional crystallization of the melt from the margin of the pegmatite body towards the centre (Cameron, 1949) and (b) segregation of aqueous fluids from the silicate melt are the two well-known models (Jahns and Burnham, 1969). Moreover, two styles of mineralizations i.e., magmatic origin and metasomatic-hydrothermal alteration, have

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been suggested by Černý (2005) and Van Lichtervelde et al. (2007).

The Kenticha rare metal pegmatite and granite intruded into ultrabasic rocks of serpentinite, talc and talc-actinolite (Tadesse, 2001). Other rocks surrounding the host rocks include schists and gneisses of varying compositions. Küster et al. (2009) discussed the geochemistry of the Kenticha granite-pegmatite and described it as related with I- and S-type granites. Tadesse (2001) on the other hand interpreted granite-pegmatite of Kenticha as formed in a volcanic arc environment. Hence, there is a pressing need to understand and investigate the tectonic setting and the formation of the Kenticha granite-pegmatite.

This work aims to elucidate the genesis and tectonic setting of the Kenticha tantalite deposit, located in the Adola Belt, southern Ethiopia within the Arabia Nubian Shield (Fig. 1). Field work, petrographic analysis, and trace, REE and major elements analyses were carried out using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). The petrography, tectonic setting and previous U/Pb tantalite dating allowed us to associate the granite-pegmatite of Kenticha to later crustal accretion after the closure of the Mozambique Ocean. Magmatic fractionation and later hydrothermal-metasomatic alteration caused enrichment/depletion of minerals at different zones of the pegmatite leading to ore mineralization.

2. Geological setting

The Arabian-Nubian Shield (ANS), in the northern part of the East African Orogen (EAO), developed through horizontal crustal accretion during the closure of the Mozambique Ocean (Fig. 1a). It is recognized by ophiolites and their dismembered fragments, and chemically distinct island-arc volcanic and plutonic complexes (Kusky, 2003). Following the amalgamation of the Gondwana Supercontinent (680 - 640 Ma), the proto-Arabian Nubian Shield was affected by regional exhumation, erosion and subsidence. Granitic magmatism (~610 Ma) occurred by increasing the amounts of alkali-feldspar granite and alkali granite production (Johnson et al., 2011). Juvenile crust and/or depleted mantle are magma sources of Late Cryogenian-Ediacaran granitoids, mostly originated in anorogenic, post-collisional, commonly extensional settings (Johnson et al., 2011). These juvenile crusts were formed by melting and fractionation of (1) anhydrous, high-grade metamorphosed lower crust, mafic-to intermediate calc-alkaline crust, and/or (2) subduction-modified mantle wedges associated with slab break-off or delamination (Johnson et al., 2011). Further granitic magmatism continued until 565-560 Ma and the East African Orogeny ceased by 550 My ago. Most geochemical studies on granitoids in the ANS have indicated that the early magmatic calc-alkaline granitoids were formed within evolving arc setting (e.g., Hargrove et al., 2006). The youngest late-to post-collisional alkaline granitoids suite have formed during the decay of the previously consolidated orogen, possibly involving sub-continental lithospheric delamination (e.g., Farahat et al., 2007; Johnson et al., 2011).

The Kenticha rare metal pegmatite, in the Adola Belt of southern Ethiopia (Fig. 1b and c), is emplaced as a dome and lenticular shaped biotite-muscovite and alaskitic post-orogenic granitic intrusions into ultrabasic rocks such as serpentinite, talc and talc-actinolite rocks. Other rocks in the surrounding areas include metamorphic rocks dominantly composed of gneisses and schists (Tadesse, 2001). The emplacement of the pegmatite bodies are controlled by deep-seated N-S trending faults (Desta et al., 1995; Tadesse, 1998). The Kenticha granite-pegmatites are compositionally peraluminous and fertile with varieties of minerals such as biotite, muscovite, tourmaline, spessartite and almandine garnets, corderite and topaz.

The Kenticha area contains three different types of granites: biotite granite, two-mica granite and alaskitic granite. Biotite-granite and two-mica granites are the parent rocks for alaskitic

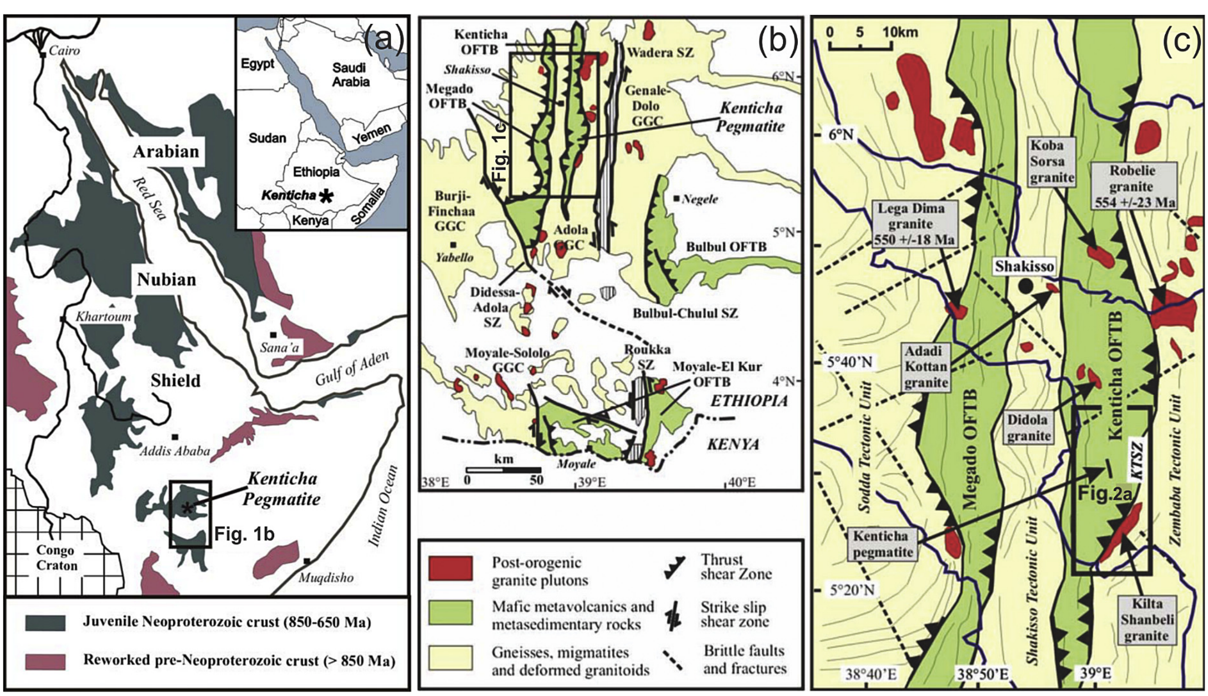

Fig. 1. (a) Geological sketch map of northeastern Africa and Arabia showing major crustal segments and the locations of tantalum deposits and mineralization, including the Adola Belt (black rectangle) and the Kenticha pegmatite. (b) Simplified geological maps of a southern Ethiopia (after Tsige and Abdelsalam, 2005; Worku and Schandelmeier, 1996; Yibas et al., 2002) and (b) the Adola Belt (simplified after Kozyrev et al., 1988; Worku and Schandelmeier, 1996). Note: GGC: Granite–Gneiss Complexes; OFTB: Ophiolitic Fold and Thrust Belts; SZ: Shear Zone; KTSZ: Kenticha Thrust Shear zone.