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New isotopic constraints on age and origin of Mesoarchean charnockite, trondhjemite and amphibolite in the Ntem Complex of NW Congo Craton, southern Cameroon

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ABSTRACT

Integrated *in-situ* analyses of zircon U–Pb ages and Hf–O isotopes are reported for charnockite, trondhjemite and associated amphibolite in the Archean Ntem Complex of the NW Congo Craton, southern Cameroon. The charnockite crystallized at ~2.92 Ga, coincident with the timing of extensive occurrence of high-temperature magmatism possibly related to mantle plume activity worldwide. They are characterized by zircon $\delta^{18}O$ values of ~5.9‰ and $\varepsilon Hf(t)$ values of ~0.0, with Hf model ages of ~3.5–3.3 Ga. On the basis of the new isotopic and literature data we suggest that the charnockites were generated by partial melting of a Paleoarchean mafic crustal source possibly triggered by 2.92 Ga mantle plume activity. The trondhjemite and associated amphibolite protolith crystallized synchronously at ~2.87–2.86 Ga. The trondhjemite exhibits zircon $\delta^{18}O$ values of ~6.0‰ and negative $\varepsilon Hf(t)$ values of ca. −3.7, with Hf model ages of ~3.8–3.5 Ga, whereas the amphibolite has positive zircon $\varepsilon Hf(t)$ values of ~2.3 and $\delta^{18}O$ values of ~4.6‰, lower than that (~5.3‰) of zircons from juvenile mantle-derived magmas. The trondhjemite was most likely generated by high-pressure partial melting of an Eoarchean crustal protolith possibly triggered by the synchronous mafic magmatism. An ancient ~3.8 Ga-old proto-crust may have existed in the NW Congo Craton.

1. Introduction

Charnockites of magmatic origin are hypersthene-bearing granitoid rocks originating through magmatic processes (e.g. Frost and Frost, 2008), and commonly form in high temperature and anhydrous regimes (e.g. Frost et al., 2000; Zhang et al., 2010; Yang and Santosh, 2015). TTGs (tonalite–trondhjemite–granodiorite) are the most voluminous rock type in the preserved Archean crust (e.g. Condie, 2005). They are thought to be products formed by partial melting of basaltic crustal rocks at pressures high enough to stabilize garnet (e.g. Drummond and Defant, 1990; Martin, 1999). High-temperature charnockites and high-pressure TTGs are spatially associated with each other in the Archean Ntem Complex, southern Cameroon. Investigations of the chronology and petrogenesis of these rocks as well as their genetic relationship have significant implications for understanding not only processes in the deep crust and mantle-crust interactions, but also the formation and evolution of the Archean continental crust. Considerable work has been conducted on the Ntem Complex since the 1960s (e.g. Rocci, 1965; Clifford and Gass, 1970; Cahen et al., 1976; Maurizot et al., 1986). However, the age and origin of these charnockitic and TTG suite rocks are still an issue of debate, because these rocks have been subjected to intense post-magmatic reworking processes that influenced their radiogenic isotopic systems to varying degrees (Shang et al., 2010). Early Rb–Sr and Sm–Nd isochron dating of the charnockitic and TTG suite rocks in the Ntem Complex was imprecise (e.g., Delhal and Ledent, 1975; Lasserre and Soba, 1979; Toteu et al., 1994; Shang et al., 2004a). More recently, zircon U–Pb and Pb–Pb dating resulted in a wide range of ages from 2883 to 3265 Ma for the charnockites (Shang et al., 2004b; Takam et al., 2009). Several workers documented that TTGs in this complex were emplaced at ca. 2830 Ma (Shang et al., 2004b; Pouclet et al., 2007), which, however, is much younger than a SHRIMP zircon age of 2865 ± 4 Ma (Tchameni et al., 2010). It has been demonstrated that the charnockitic and TTG suite rocks in the Ntem Complex share coherent geochemical and similar Nd isotopic compositions (Shang

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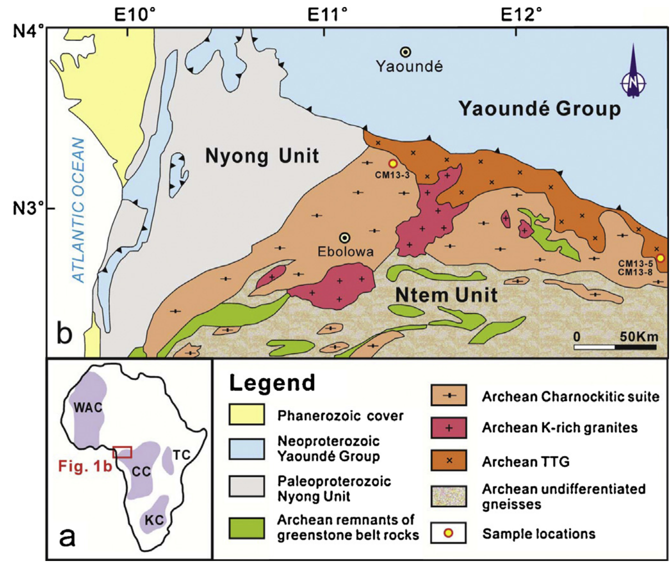

Fig. 1. Geological sketch map of southwestern Cameroon (modified after Maurizot et al., 1986; Tchameni et al., 2010) showing the major Precambrian units and sample locations. WAC: West African Craton; CC: Congo Craton; TC: Tanzanian Craton; KC: Kaapvaal Craton.

et al., 2004a; Pouclet et al., 2007). Thus, these rocks are thought to be products generated by different partial melting processes of similar primitive basaltic crust in a subduction-related convergent regime, either hot slab subduction, or intra-oceanic stacking (Pouclet et al., 2007), or flat subduction (Shang et al., 2004a). It is noticed that the proposed oceanic slab is characterized by nearly chondritic Nd isotopes, i.e., small positive and negative initial $\varepsilon Nd(t)$ values for the charnockites and TTG, respectively (Shang et al., 2004a; Pouclet et al., 2007). Also noted is that the charnockites have clearly lower Sr/Y and higher Y contents than the TTGs (Shang et al., 2004a; Pouclet et al., 2007). The question is whether the current petrogenetic models for the charnockitic and TTG suite rocks can account for their slightly different Nd isotopes but clearly distinct trace element features.

Zircon is a very useful accessory mineral, as it provides U–Pb geochronology, as well as Hf and O isotopic compositions of magmas from which zircon crystallized, and constrains on the petrogenesis and protoliths of host rocks (e.g., Valley, 2003). Zircon is retentive under intense metamorphism, deformation, subsolidus hydrothermal alteration and prolonged sedimentary recycling (e.g., Hanchar and Hoskin, 2003; Valley et al., 2003; Zheng et al., 2004; Hawkesworth et al., 2010). We carried out integrated *in-situ* analyses of zircon U–Pb age and Hf–O isotopes for the charnockite, trondhjemite and associated amphibolite from the Ntem Complex, with aims at (1) providing further isotopic constraints on age and origin of these Mesoarchean rocks, and (2) shedding new light on early continental crust evolution of the NW Congo Craton.

2. Geological background and sample descriptions

Southern Cameroon consists of two major Precambrian units bounded by major thrusts, i.e., the Neoproterozoic Pan-African mobile belt represented by the Yaoundé Group to the north, and the Ntem Complex to the south (Fig. 1). The Ntem Complex represents the northwestern part of the Congo Craton in Central Africa (e.g., Clifford and Gass, 1970; Maurizot et al., 1986; Tchameni et al., 2000), comprising the Paleoproterozoic Nyong Unit to the northwest and the Archean Ntem Unit to southeast. The Nyong Unit consists mainly of metasedimentary and metavolcanic rocks as well as some syn- to late-tectonic intrusive rocks (e.g. Toteu et al., 1994, 2001). The Ntem Unit includes an Intrusive Series and a Banded Series as well as minor amount of supracrustal rocks (e.g., Maurizot et al., 1986; Shang et al., 2004a; Pouclet et al., 2007). The Intrusive Series is essentially exposed in the northern part of the Ntem Complex and is strongly mylonitized and retrogressed along the thrust boundary with the Pan-African Yaounde Group (Takam et al., 2009). It is dominated by a magmatic charnockitic suite and a TTG suite. The Banded Series outcrops over the southern part of the Ntem Complex and is dominated by strongly deformed granitic gneisses. Charnockitic enclaves are found within the gneisses of the Banded Series. Supracrustal rocks include banded iron formations (BIF) and sillimanite-bearing paragneisses occurring as xenoliths in the TTG; they are thought to be the remnants of greenstone belts (Suh et al., 2008; Chombong and Suh, 2013). K-rich granitoid rocks and dolerite dikes intrude the TTG and greenstone belts (e.g. Toteu et al., 1994; Tchameni et al., 2000; Shang et al., 2007, 2010).

Three samples were collected from the Ntem Unit for integrated *in-situ* analyses of zircon U–Pb age and O–Hf isotopes. A charnockite sample (CM13-3) was collected at a major road (Mbalmayo-Ebolowa) cut near Menguémé (N03°17′22″, E11°26′27″). It is characteristically dark gray to dark brown with bluish quartz luster (Fig. 2a), consisting of coarse-grained (1–5 mm) hypersthene (8%), K-feldspar (35%), plagioclase (30%) and quartz (25%), with minor medium-grained (0.1–0.5 mm) amphibole, magnetite, apatite and zircon. The hypersthene commonly shows subhedral and short column shape and reddish in color (Fig. 2b), most likely corresponding to an igneous origin. Several hypersthene grains are occasionally included in plagioclase, but no inclusions are found in the hypersthene grains, implying that they were formed in the early stage of magma crystallization. The apatite typically occurs as inclusions in feldspar or as a matrix phase, showing an equilibrium texture with orthopyroxene.

A deformed trondhjemite (CM13-5) and an amphibolite (CM13-8) were collected in a large quarry ca. 5 km to the east of Djoum town (N02°40′06″, E12°43′12″). The trondhjemite shows a medium- to fine-grained (0.05–0.4 mm) gneissic structure (Fig. 2c), consisting mainly of biotite (5%), plagioclase (65%) and quartz (25%), with accessory minerals of K-feldspar, orthopyroxene, apatite, ilmenite, sphene and zircon. Biotite commonly occurs as aggregates, whereas plagioclase and quartz show well developed equilibrium granoblastic polygonal fabrics (Fig. 2d). Amphibolite occurs in various size and irregular shapes within the trondhjemite (Fig. 2e). The amphibolite sample CM13-8 consists of amphibole (60%), plagioclase (25%) and quartz (10%), with accessory biotite, titanite, apatite and zircon (Fig. 2f). Medium-grained (0.2–0.6 mm) amphibole displays green color and anhedral shape. Needle-shaped biotite and anhedral titanite are commonly included in, or in contact with, amphibole (Fig. 2f).

3. Analytical methods

Zircon concentrates were separated from ca. 2 kg of charnockite and trondhjemite samples and ca. 5 kg of amphibolite sample using standard density and magnetic separation techniques. Zircon grains, together with zircon standards, were mounted in epoxy mounts that were then polished to expose the interior of crystals for analysis. All zircon grains were documented with transmitted and reflected light photomicroscopy and cathodoluminescence (CL) image to find suitable areas for analyses. The mount was vacuum-coated with high-purity gold to reach <20 Ω resistance prior to SIMS analysis.

3.1. Zircon U–Pb dating

Measurements of zircon U, Th and Pb isotopes were conducted using a Cameca IMS-1280 SIMS at the Institute of Geology and