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Geochemistry and U-Pb zircon geochronology of the pegmatites in Ede area, southwestern Nigeria: A newly discovered oldest Pan African rock in southwestern Nigeria

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Field and petrographic studies, whole rock geochemistry and *in-situ* LA-ICP-MS geochemical and isotopic U-Pb measurements on zircons have been performed on granitic pegmatites of Ede area, southwestern Nigeria with a view to characterize them, determining their mineralization potentials, petrogenetic attributes and emplacement age. The pegmatites are hosted by migmatite gneiss complex, biotite-muscovite schist and associated quartzite. The textural and mineralogical characteristics of these pegmatites indicate the occurrence of two main varieties, namely, muscovite pegmatite and garnet pegmatite. Of less importance are inclusions and pods of graphic granite, quartz-microcline aplitic and pegmatitic bodies. At the present level of erosion, the parent igneous rocks of the pegmatites are not exposed. The two dominant pegmatite varieties show slightly different chemical peculiarities but similar peraluminous character. The average K/Rb ratios of 165 and 163, respectively, for muscovite and garnet pegmatites combined with other trace element compositions are indicative of affinity to muscovite class of pegmatite which are generally not promising for rare elements mineralization. However, the unusually high concentration of bismuth in the zircons indicates Bi mineralization in the area which can either be in the pegmatites or host rocks.

The Nb/Ta ratios for both muscovite and garnet pegmatites range from 0.7 to 15.2 and 1.0 to 14.8, respectively. These Nb/Ta ratios and Eu anomalies are statistically similar for both pegmatites. These probably indicate the pegmatites crystallized from a common source but separated into crystallization paths that produced different pegmatite varieties through liquid-liquid immiscibity mechanism. *In-situ* measurements of REE, P, Y, Nb, Hf, Ta, Bi, Th and U of individual zircon grains show the existence of two chemically and texturally different domains which are indicative of alteration that may be due to interface-coupled dissolution-precipitation promoted by microfractures induced by metamictization. Notwithstanding, the $(Sm/La)_{N\ vs.}$ La plot for zircon, weak positive Ce and variable europium anomaly (Eu*) are suggestive of pegmatites of hydrothermal origin. The pegmatites yielded a discordant U-Pb zircon age with upper concordia intercept of 709 +27/−19 (at 2σ, MSWD = 1.5) Ma which can be attributed to their emplacement. This age represents the oldest Pan African magmatic event reported so far in southwestern Nigeria.

1. Introduction

Pegmatites are widespread throughout the basement complex (rocks of the Precambrian age) of southwestern Nigeria. In terms of rare elements (e.g. Nb, Ta, Li, W, Sn, Be, B, Cs, Rb) mineralization, two distinct pegmatite populations could be recognized: the mineralized and the non-mineralized. The rare elements bearing group has a restricted occurrence within the basement complex and has received more attention in recent years while the other non-mineralized, more abundant and widely distributed group has almost been neglected due to its barren nature. Within these largely non mineralized pegmatites, two categories that differ in form and dimensions could be distinguished. One category occurs

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as small veins and dykes within the migmatite-gneiss complex and appears to be related to migmatization. The second category which is a more voluminous and important occurs as larger bodies which only could be ascribed to crystallization from large voluminous magma. Some of them are so large (150 km^2 or more) that they are represented on the published geological map of Nigeria on scale 1:250,000 (e.g. Carter, 1966). The pegmatites in Ede area belong to this large voluminous category. The chemistry of few bodies that have been studied was only for comparison with rare element bearing variety (e.g. Matheis and Caen-Vachette, 1983).

Most published articles have been focused on geochemistry of the rare elements bearing pegmatites and these have appeared chiefly in local journals while few have been made known to international geological audience (e.g. Schuiling, 1967; Wright, 1970; Matheis, 1987; Matheis and Caen-Vachette, 1983; Kinnaird, 1984; Kuster, 1990; Garba, 2002; Okunlola, 2005; Okunlola and Jimba, 2006; Adekeye and Adedoyin, 2007; Adekeye and Akintola, 2007; Akintola and Adekeye, 2008; Adetunji et al., 2008; Adetunji and Ocan, 2010a, 2010b; Omada et al., 2015). The only published work on the pegmatite of Ede area is that of Akintola et al. (2011). Both the petrographic and geochemical data in this article could not be relied on. For example, the authors got an average K/Rb ratio of about 0.004 which was calculated by directly dividing K (wt %) with Rb (ppm) without conversion to the same unit. The interpretation of the mineralization potentials and characterization of the pegmatites were based on this K/Rb ratio. The available ages of the Pan-African granites and associated pegmatites in southwestern Nigeria are all bracketed between 620 and 580 Ma (Jacobson et al., 1963; Snelling, 1966; Matheis and Caen-Vachettee, 1983; Tubosun et al., 1984; Rahaman, 1988; Rahaman et al., 1991; Dada et al., 1993; Dada, 1998).

The objectives of the present study therefore, are to characterize, evaluate mineralization potentials, deduce some petrogenetic attributes and determine the age of the pegmatites in Ede area where there have been speculations of rare elements mineralization, using field geology, petrography, pegmatite whole rock and zircon geochemistry, and *in-situ* U-Pb zircon dating.

2. Geological setting

Ede area is part of the Precambrian basement terrane that was reactivated during the Pan African orogeny (600 ± 150 Ma). The basement terrane is situated between West African craton to the west, Congo craton to the southeast and East Saharan block (Fig. 1), and is part of a 4000 km long and several hundreds of kilometers wide orogen extending from the Hoggar to Brazil (Caby, 1989). The entire north-south trending block boundary is collectively called the Trans Saharan fold belt. This fold belt was formed in the Neoproterozoic, between 750 and 500 Ma by continental collision between the converging West African craton, Congo craton and East Saharan block (Ferre et al., 2002; Dada, 2006). The Trans-Saharan belt is characterized by high-grade metamorphism, early thrust-nappe development, numerous granite intrusions and late orogen-parallel tectonics (e.g. Black and Liégeois, 1993). The northern section is divided into zones such as the Pharusian belt, LATEA micro continent (Liégeois et al., 2003) and Eastern Hoggar. The LATEA was formerly described as polycyclic Central Hoggar. The Aïr–Hoggar segment of this belt (Fig. 1) is formed by oblique collision of north-south elongated terranes (e.g. Liégeois et al., 1994). The initial lithospheric plate convergence was accommodated along a Neoproterozoic east-dipping subduction zone with the main Pan African suture marked in Mali by 620 Ma ultra high pressure rocks (e.g. Caby, 1989).

The southern part is the Dahomeyide which stretches from the eastern margin of the West African craton to the border of the Congo craton. The Dahomeyide is made up of several continental blocks amalgamated during oblique collision (Ajibade and Wright, 1989) similar to that of the Aïr-Hoggar (Liégeois et al., 1994). The Nigeria sector of the Dahomeyide is divided into western and eastern domains on the basis of some petrological attributes (Ferre et al., 1996).

This basement complex in the western domain comprises gneisses, migmatites, supracrustal rocks largely of greenschist to amphibolite facies, Pan African granites and undeformed dykes (Rahaman, 1988). The first three of these have yielded Archaean and Proterozoic ages (e.g. Bruguier et al., 1994; Annor, 1995; Okonkwo and Ganev, 2012) and bears the imprints of Liberian (*ca* 2700 Ma), Eburnean (*ca* 2000 Ma) and Pan African (*ca* 600 Ma) orogenic events (Grant, 1970; Oversby, 1975; Van Breemen et al., 1977; Fitches et al., 1985; Rahaman, 1988; Dada, 1998). Both the Pan African granites and undeformed dykes have yielded upper Proterozoic ages (Tubosun et al., 1984; Dada et al., 1993; Dada, 1998; Ige and Holness, 2002). However, the basement rocks were regrouped into four units by Dada (2006) and Obaje (2009). Detailed geology of Ede area is presented in Fig. 2.

3. Geology of the pegmatites – occurrence and mineralogical features

The pegmatites in Ede area show interesting features in terms of exposures and other petrological attributes. The pegmatites outcrop with irregular shape. The body forms a north-south elongated asymmetric dome-like massif that covers approximately 117 km^2. The body is hosted by migmatite-gneiss complex, biotite-muscovite schist and associated quartzite. In few places, aplites have been observed to be associated with the pegmatites. The contacts of the pegmatites with the host rocks have not been exposed due to extensive lateritic cover. In several places, there are number of inclusions of the host rocks in the pegmatites. However, up to 1.5 m wide pegmatite dykes cut the foliation of the host gneissic rocks in many places. Two major pegmatite varieties were recognized, namely, muscovite pegmatite and garnet pegmatite with subordinate quartz-microcline pegmatite, graphic granite and quartz-microcline aplitic unit. The contacts between the main pegmatite varieties are not exposed on the surface due to the thick lateritic cover. The minor varieties mainly occur as small tabular bodies, inclusions and pods in the more widespread pegmatite varieties. In few cases, graphic granite outcrops as small elongate bodies of about two meters wide and tens of meters long. The main varieties have undergone heterogeneous deformation manifested at the outcrop scale by localized crude alignment of micas and folds on mesoscopic scale. Similarly deformed pegmatites have been recognized in Egbe area of southwestern Nigeria (Adekeye and Adedoyin, 2007).

Mineralogically, the muscovite pegmatite consists of quartz, microcline, plagioclase, colorless muscovite, ±biotite, tourmaline, ±beryl, zircon and traces of opaque minerals. On the other hand, assemblage in the garnet pegmatite consists of quartz, microcline, plagioclase, pale green muscovite, tourmaline, garnet, zircon and traces of opaque minerals. Apart from these mineralogical differences, the muscovite pegmatite is of coarser grains than the garnet pegmatite. In the two pegmatite varieties, quartz is smoky, milky, rosy or colorless. Muscovite predominantly occurs as colorless flakes in the muscovite pegmatite. Smaller grains are intergrown with quartz in some cases. In many outcrops, it is associated with biotite. Muscovite is pale greenish and is of smaller grain size in the garnet pegmatite than in the muscovite pegmatite. Biotite is completely absent in the garnet pegmatite but prominent in the other pegmatite variety. Black tourmaline is present in both pegmatite varieties. However, those of the garnet pegmatite are