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Post-collisional Pan-African granitoids and rare metal pegmatites in western Nigeria: Age, petrogenesis, and the 'pegmatite conundrum'

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ABSTRACT

The Minna area of western Nigeria lies within a Pan-African orogenic belt that extends along the margin of the West African Craton, from Algeria southwards through Nigeria, Benin and Ghana, and into the Borborema Province of Brazil. This belt is characterised by voluminous post-collisional granitoid plutons that are well exposed around the city of Minna. In this paper we present new information about their age and petrogenesis.
The Pan-African plutons around Minna can be divided into two main groups: a group of largely peraluminous biotite–muscovite granites that show varying levels of deformation in late Pan-African shear zones; and a younger group of relatively undeformed, predominantly metaluminous hornblende granitoids. Pegmatites, including both barren and rare-metal types, occur at the margins of some of the plutons.
New U–Pb zircon dating presented here, in combination with published data, indicates an early phase of magmatism at c. 790–760 Ma in the Minna area. This magmatism could be related either to continental rifting, or to subduction around the margins of an existing continent. The peraluminous biotite–muscovite granites were intruded at c. 650–600 Ma during regional shearing in the orogenic belt, and are likely to have formed largely by crustal melting. Subsequent emplacement of metaluminous granitoids at c. 590 Ma indicates the onset of post-orogenic extension in this area, with a contribution from mantle-derived magmas. The rare-metal pegmatites represent the youngest intrusions in this area and thus are likely to have formed in a separate magmatic episode, post-dating granite intrusion.

1. Introduction

A network of Pan-African orogenic belts, formed during the Neoproterozoic to Cambrian amalgamation of Gondwana, extends across the African continent and into the Brasiliano orogen of South America (Black and Liégeois, 1993; Castaing et al., 1994; de Wit et al., 2008; Jacobs and Thomas, 2004; Stern, 1994). These belts are typically composed of Archaean and Proterozoic rocks that were reworked by Neoproterozoic to Cambrian orogenesis, together with a variable proportion of juvenile material. Many of the belts are characterised by extensive post-collisional granitoid plutons (Black and Liégeois, 1993; Küster and Harms, 1998). These plutons are typically potassic and their parental magmas are likely to be derived from mixed mantle and crustal sources (Black and Liégeois, 1993; Bonin, 2004; Küster and Harms, 1998; Liégeois et al., 1998). They thus represent major additions to the upper crust during amalgamation of Gondwana.

Alkaline igneous plutons, including those in post-collisional settings, are increasingly of interest as potential sources of 'critical metals' used in a range of advanced technologies. These critical metals include the Rare Earth Elements (REE), niobium and tantalum, which are commonly enriched in alkaline magmas. The increase in demand for these metals makes a reappraisal of the controls on magmatism and the potential for mineralisation worthwhile.

In West Africa, the Pan-African Dahomeyide orogenic belt separates the Archaean to Mesoproterozoic West African and Congo cratons, and is exposed in an area known as the Benin–Nigeria Shield (Ajibade and Wright, 1989). Northwards, this belt continues into the Hoggar Massif of Algeria; southwards, prior to Atlantic opening, it was connected to the Borborema Province of north-east Brazil (Arthaud et al., 2008; Caby, 1989; Castaing et al., 1994; Dada, 2008; de Wit et al., 2008; Neves, 2003).

In Nigeria, the Dahomeyide orogenic belt has been divided into eastern and western terranes separated by a major north-south lineament that has been recognised from remote sensing, but not studied in detail (Ajibade et al., 1987; Ananaba and Ajakaiye, 1987; Ferré et al., 1996; Fitches et al., 1985; Woakes et al., 1987) (Fig. 1). The basement of the western terrane is dominated by Archaean migmatitic gneisses, with Proterozoic schist belts composed of low-metamorphic grade, highly deformed, metasedimentary and metavolcanic rocks (Ajibade et al.,

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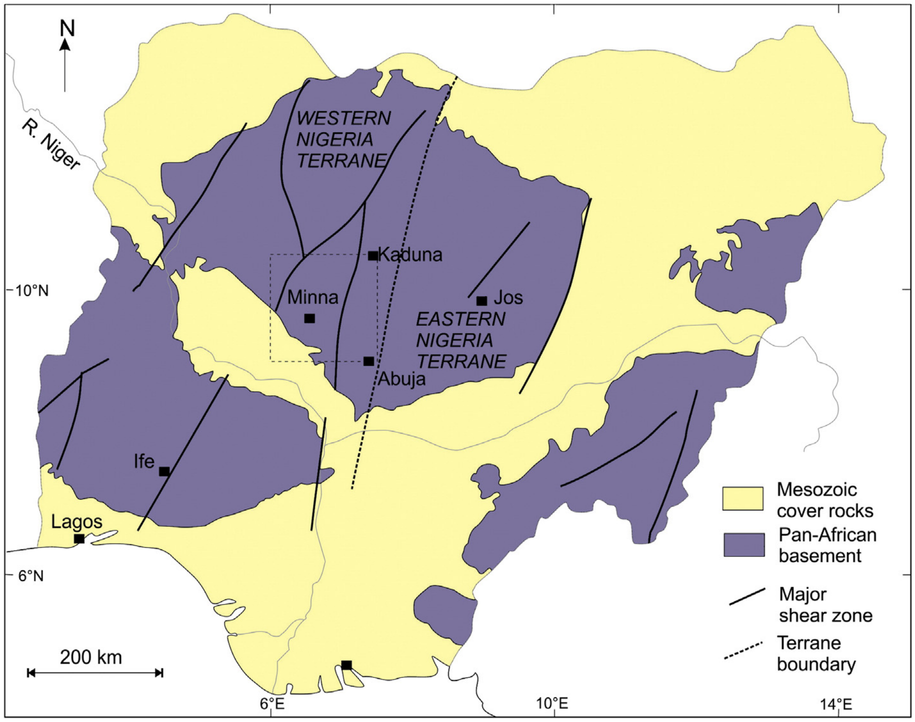

Fig. 1. Simplified map of the geology of Nigeria, after Ferré et al. (1996) and Key et al. (2012). Box indicates the area shown in Fig. 2.

1987; Arthaud et al., 2008; Bruguier et al., 1994; Dada, 2008; Fitches et al., 1985). The eastern terrane is characterised by high-grade (high-temperature amphibolite to granulite-facies), migmatitic metamorphic rocks that have Palaeoproterozoic protoliths but were migmatised during the Neoproterozoic (Ajibade et al., 1987; Ferré et al., 1996, 2002). Proterozoic schist belts are not recognised in the eastern terrane. Both terranes are cut by a number of NNE–SSW-trending ductile shear zones that are tens to hundreds of kilometres in length, and can be correlated with similar shear zones in the Borborema Province in Brazil (Caby, 1989; Ferré et al., 2002).

Neoproterozoic magmatism at c. 780–770 Ma has been recorded in volcano-sedimentary sequences of the Borborema Province. This has been interpreted as related either to active subduction around continental margins, or to rifting (Arthaud et al., 2008; Fetter et al., 2003). Magmatism of this age has been recorded by relatively imprecise Rb–Sr dating in western Nigeria (Fitches et al., 1985).

The Nigerian basement is intruded by many Pan-African syn- to post-collisional plutons, which are more voluminous in the eastern terrane than the west, and which are known as the Older Granites. In eastern Nigeria, two suites of Older Granite plutonism have been recognised; an earlier (c. 640–600 Ma) suite of peraluminous biotite–muscovite granites, and a later (c. 600–580 Ma) suite of trans-alkaline hornblende–biotite granitoids (Ferré et al., 1998, 2002). Emplacement of the later group was typically controlled by regional NE–SW shear zones (Ferré et al., 1995). The Older Granites of the western terrane were considered to be I-type granitoids by Fitches et al. (1985) but have not previously been subdivided into suites. Hornblende-biotite granites from the western terrane have been dated at c. 630–580 Ma, similar to those in eastern Nigeria (Key et al., 2012; Tubosun et al., 1984). Within the eastern terrane, a suite of Mesozoic alkaline plutons emplaced in an intra-plate setting are known as the Younger Granites (Bowden, 1970). Mesozoic plutons have not been recognised in the western terrane.

Similar groups of Neoproterozoic granites have been recognised in the Borborema Province, where granitoid intrusions, including some S-type granites, were emplaced prior to or during the early stages of collision at c. 630–610 Ma. This was followed by emplacement of late-tectonic plutons, typically intruded into major shear zones, at 590–570 Ma (Arthaud et al., 2008; Bueno et al., 2009; Fetter et al., 2003; Neves et al., 2008). Contemporaneous granitoid plutons are also found in the Pan-African belts to the west and north of Nigeria. Westwards, in Ghana, Togo, and Benin, the overall period of granitoid magmatism lasted from c. 660–550 Ma (Kalsbeek et al., 2012) and alkaline plutons were emplaced at c. 590 Ma (Nude et al., 2009). To the north, in the Hoggar Massif of Algeria, alkaline post-collisional magmatism continued until c. 530 Ma (Caby, 2003).

The post-collisional granites in Nigeria are associated with rare metal (tin–tantalum) granitic pegmatites, some of which have been artisanally mined (Adetunji and Ocan, 2010; Garba, 2003; Kinnaird, 1984; Kuster, 1990; Matheis and Caen-Vachette, 1983; Melcher et al., 2013; Okunlola, 2005; Woakes et al., 1987). The rare metal pegmatites occur in a distinct belt that extends SW–NE from Ife to Jos, and appears to cut across the boundary between the eastern and western Nigerian terranes, although the individual pegmatite intrusions are oriented north–south (Kinnaird, 1984; Matheis and Caen-Vachette, 1983; Woakes et al., 1987). Individual pegmatites vary in length from 10 m to over 2 km, and can be up to 200 m wide (Adetunji and Ocan, 2010). Pegmatites of this type are typically associated with peraluminous or S-type granites (Cerny et al., 2012) and in western Nigeria the pegmatites are most commonly found close to the margins of peraluminous granite plutons. However, dating indicates that the pegmatites were emplaced at 560–450 Ma (Matheis and Caen-Vachette, 1983; Melcher et al., 2013), rather younger than the few previous dates for western Nigeria granites (Tubosun et al., 1984). The origin of these pegmatites is thus uncertain, although the peraluminous plutons with which they are associated have not previously been targeted for dating. Similar pegmatites occur in the Borborema Province, where they are extensively mined for tantalum (Beurlen et al., 2008). As well as the tantalum potential, gold deposits are known in the Nigerian schist belts, but their formation may pre-date the Pan-African orogeny (Dada, 2008).

Recent British Geological Survey (BGS) – Nigerian Geological Survey Agency (NGSA) geochemical mapping in the western Nigeria terrane (Key et al., 2012; Lapworth et al., 2012) has highlighted areas of enrichment in some critical metals, such as the Rare Earth Elements (REE), niobium and tantalum, around the Older Granite intrusions. This paper presents a more detailed study of these granitoids to investigate