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Chemical and Sr–Nd isotopic compositions and zircon U–Pb ages of the Birimian granitoids from NE Burkina Faso, West African Craton: Implications on the geodynamic setting and crustal evolution

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ABSTRACT

The West African Craton was the site of massive juvenile crustal addition in the early Proterozoic during the Eburnean orogeny (2.1 Ga). In this study, we determined chemical and isotopic compositions as well as zircon U–Pb ages of granitoid samples from NE Burkina Faso. These data were then used to constrain the chemical characteristics, emplacement age and tectonic environment of these rocks in the context of the West African Craton evolution. Birimian (Paleoproterozoic) granitoids of NE Burkina Faso are associated with volcanic and volcano-sedimentary sequences of the greenstone belts. Analyses indicate that the Na-rich Birimian granitoids of tonalite–trondhjemite–granodiorite (TTG) composition were generated by partial melting of a garnet-bearing amphibolite crust. Granite intrusions derived from partial re-melting of the deep basement of felsic calc-alkaline nature with contribution of metasediments. Zircon U–Pb isotopic analyses yielded ages between 2122 ± 15 Ma and 2181 ± 7 Ma for the Birimian Na-rich granitoids and 2151 ± 10 Ma for a biotite granite (IJ10). Sr–Nd isotopic data show very low initial Sr composition (I_{Sr} (T) ≤ 0.7007), positive epsilon neodymium values (εNd (T) = +0.7 to +2.5) and Sm–Nd model ages (T_{DM}) of 2363–2558 Ma). These data are similar to those of mafic rocks of the Pissila greenstone belt: (I_{Sr} (T) = 0.7003–0.7015, εNd (T) = +3.2 to +4.1, T_{DM} = 2336–2552 Ma), and further suggest that the Na-rich granitoids are of juvenile nature. The present study together with published data on the Birimian volcanics and meta-sedimentary rocks of the West African Craton preclude contamination of the juvenile Birimian rocks of NE Burkina Faso by reworked Archean materials. The Birimian granitoids of NE Burkina Faso were mostly emplaced during the early stage (2.19–2.15 Ga) of a large scale crustal growth event (2.2–2.0 Ga) where large amount of juvenile materials were added to the crust from the depleted mantle in a tectonic environment comparable to modern volcanic arcs.

1. Introduction

The Leo Rise, in the West African Craton (WAC), is composed of a Paleoproterozoic domain (Baoulé-Mossi domain) to the east, and an Archean domain (the Kenema-Man domain) to the west. The Paleoproterozoic terrains of the Baoulé-Mossi domain are recognizable by the linear to arcuate greenstone belts of volcanic and volcano-sedimentary sequences, the voluminous granitoids, as well as the narrow sedimentary basins (Fig. 1).

The Birimian volcanic and volcano-sedimentary sequences of the Baoulé-Mossi domain were intruded by several generations of granitoids (Ama Salah et al., 1996; Doumbia et al., 1998; Feybesse et al., 2006; Hirdes et al., 1996; Leube et al., 1990; Liégeois et al., 1991; Pawlig et al., 2006). Birimian volcanic and volcano-sedimentary belts and associated granitoids were formed between 2250 and 1980 Ma (Feybesse et al., 2006) and were accreted onto the Archean continental crust around 2100 Ma (Abouchami et al., 1990; Boher et al., 1992; Hirdes et al., 1996; Liégeois et al., 1991; Taylor et al., 1992).

Previously debated, the lithostragraphic succession of the Birimian volcanic and volcano-sedimentary sequences is now well established (Ama Salah et al., 1996; Béziat et al., 2000; Feybesse et al., 2006; Hein, 2010; Hirdes et al., 1996; Pouclet et al., 1996; Sylvester and Attoh, 1992; Vidal et al., 1996). The Birimian sequences consist of (1) a Lower Birimian composed of a thick sequence of tholeiitic basalts that are locally pillowed, gabbros and dolerites, with intercalated immature metasediments and

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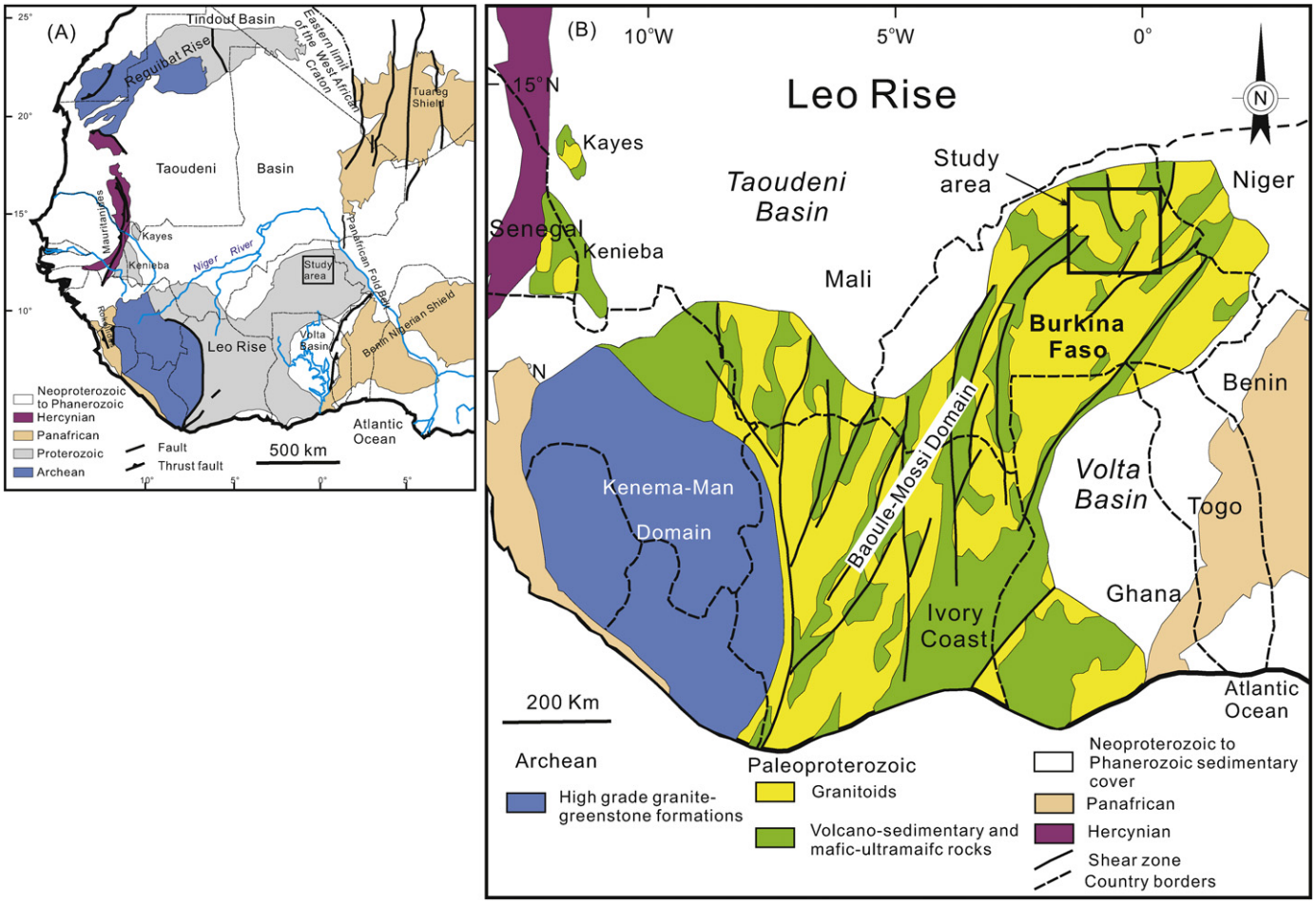

Fig. 1. Simplified geologic map of the West African Craton (A) and the Leo Rise (B) showing geological units and the location of the study area (after Boher et al., 1992; Doumbia et al., 1998; Hein et al., 2004; Naba et al., 2004).

carbonates, and (2) volcaniclastics, turbidites, shales interbedded with calc-alkaline volcanites form the Upper Birimian.

In the West African Craton, the context of crustal accretion of the Birimian formations has been a matter of contrasted interpretation. (1) For Abouchami et al. (1990), Boher et al. (1992), Pawlig et al. (2006), Pouclet et al. (1996); the tholeiitic magmatism of the Lower Birimian was emplaced in an oceanic plateau context and the calc-alkaline magmatism of the Upper Birimian is related to intra-oceanic subduction beneath the oceanic plateaus. (2) Ama Salah et al. (1996), Béziat et al. (2000) and Sylvester and Attoh (1992) favor an island arc environment for the entire Birimian crust. The tectonic regime that prevailed in the WAC is attributed either to modern plate tectonics with dominant collision and thrusting (Allibone et al., 2002; Feybesse and Milési, 1994; Feybesse et al., 2006; Ledru et al., 1994) or to Archean-like tectonics with dominantly transcurrent shearing and diapirism without any evidence of collision (Caby et al., 2000; Doumbia et al., 1998; Lompo, 2010; Vidal et al., 2009).

The West African Craton, during the Eburnean orogeny (2.1 Ga) was the site of a major crust-forming event remote of any Archean basement influence (Abouchami et al., 1990; Boher et al., 1992; Egal et al., 2002; Liégeois et al., 1991). However, genesis of some granitoids may have involved recycling of a 2.3 Ga pre-Birimian component (Gasquet et al., 2003) and a stronger Archean influence is occasionally detected in the vicinity of the Archean basement (Kouamelan et al., 1997; Taylor et al., 1992).

Hirdes et al. (1992) suggested that the term Birimian be used for the 2150–2190 Ma belt volcanism and coeval belt plutonism, and Bandamian for the 2105 Ma old rocks of the WAC. The term Eburnean referring to the major tectono-thermal event is dated at approximately 2090–2100 Ma. Consequently, following usage of these terms would be as suggested by these authors.

In NE Burkina Faso, three main lithological units are exposed:

1. The greenstone belts (Pissila or Bouroum-Yalogo, Goren, and Bogandé-Sebba belts) consist of meta-volcanic and volcano-sedimentary sequences.
2. The granitoids plutons that intrude the greenstone belts.
3. The dolerite dykes crosscut all other rock types in NW–SE and E–W directions.

This paper presents standard geochemical techniques including zircon U–Pb age determination, chemical and Sr–Nd analyses that are used to constrain the Birimian crust-forming event in NE Burkina Faso, and the tectonic implications for the emplacement of the Birimian granitoids in this part of the Baoulé-Mossi domain.

2. Geological background

The lithostratigraphy of northeast Burkina Faso is characterized by Birimian meta-volcanic and meta-sedimentary sequences that form the greenstone belts (Pissila or Bouroum-Yalogo, Goren, Bogandé-Sebba) and generally oriented NW–SE and NE–SW (Fig. 2). These belts are intruded by granitoid plutons, characteristic of the Baoulé-Mossi domain of the West African Craton. The