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Paleoproterozoic basaltic rocks related to plumes in the Gorouol belt (Liptako West Niger)

Mallam Mamane Hallarou [1], Konaté Moussa [2], Yacouba Ahmed [3], Mahamane Moustapha Sanda Chékaraou[4] Sofiyane Abdourahamane Attourabi [5], Lawali Idi Chamsi [6], Gambo Ranaou Noura[7]

[1, 2,3,4,5,6,7]Abdou Moumouni University, Faculty of Sciences and Technology, Department of Geology, Laboratory of Geology: Basins and Georesources Team, BP: 10662, Niamey (NIGER).

Abstract:

The Gorouol greenstone belt is located at the northern end of the Nigerien Liptako. The latter corresponds to the northeastern portion of the Man Ridge of the West African Craton. However, since the preliminary work carried out in the 1980s, no detailed study has been undertaken, especially concerning the petrogenesis and geochemical nature of the volcanic rocks of the Gorouol belt. The present study proposes to characterize the setting of the basaltic rocks of the Gorouol belt by the Sm-Nd isotope study. The basalts have low initial Sr isotope ratios and positive εNd values. Isotopic analysis on Sm-Nd and Rb-Sr at the metabasalts of the Gorouol belt shows that these rocks are directly derived from a mantle plume originating from the depleted primitive mantle and emplaced in an oceanic shelf context or MORB-N.

Keywords: petrogenesis, basalts, Niger, oceanic plateau, mantle plume.

1. Introduction

In the Baoulé Mossi domain (West African Craton), the basic magmatic rocks belong to two successive lineages. These are a tholeiitic lineage and a calc-alkaline lineage [1], [2]. However, the geodynamic context of the genesis of tholeiitic basaltic rocks is subject to discussion. According to the authors, the tholeiitic magmatism of the base of the Birimian would be related to an environment of MORB-type oceanic domain [3]; oceanic plateau domain [4] and island arc domain [5], [6], [7], [8]. In addition, all authors admit that calc-alkaline rocks are related to the subduction context. The basaltic rocks of the greenstone belt of Gorouol, the subject of the present study, have never been the subject of a thorough geochemical study to date. To determine the origin of these basaltic rocks, an isotopic study was adopted. The results of this study have been compared with previous work in the West African Craton regions. The emplacement of basaltic rocks in the Gorouol belt is related to the mantle plume.

2. Geological setting

The Birimian formations, of the Paleoproterozoic age, cover a large area of the West African Craton [9]. They are mainly located east part of the Man Ridge (**Fig.1**). The Paleoproterozoic formations of the Man Ridge (or Baule-Mossi domain) cover Burkina Faso, Ghana, part of Côte d'Ivoire, Mali, Guinea, Niger and Togo. They are separated from the Archean Kénéma-Man domain by the Sassandra transcurrent fault [10]. The Paleoproterozoic terrains of the Man Ridge consist of alternating greenstone belts and volcano-sedimentary basins, intruded by different generations of granitoids [11], [12], [3], [13], [14], [15]. Birimian greenstone belts are also composed of tholeiitic basalt sequences overlain by detrital sediments, including intercalations of calc-alkaline volcanic rocks [4], [7], [6], [16]. These greenstones formed during the Eburnian cycle dated between 2.25 and 1.98 Ga [17]. The tectonic accretion phases, which reflect the approximation between the West African Craton and the Guiana Craton [18], [19], are preceded by a magmatic accretion phase contributing to the emplacement of a new continental crust.

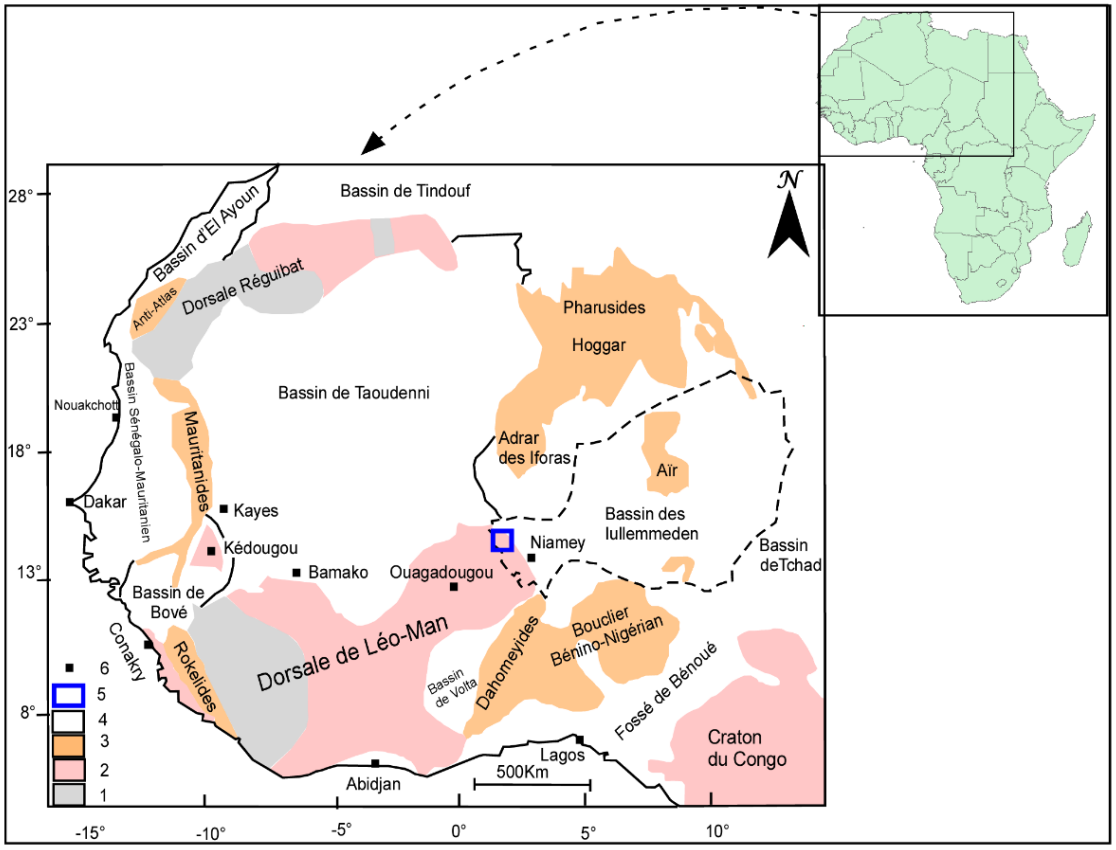

Figure 1: Simplified geological map of West Africa, showing the location of the study area (after [20], modified). 1: Archean; 2: Birimian; 3: Pan-African mobile zones; 4: Neoproterozoic to Paleozoic sedimentary basins; 5: Study area; 6: Cities.

3. Methodological Approach

Five samples of basaltic rocks from the Gorouol belt were analyzed. Analyses were performed at the Centre for Geochronological Research and Isotopic Geochemistry (CRGGI) of Carleton University (Ottawa, Canada) to determine the ratios $^{87}Sr/^{86}Sr$, $^{87}Rb/^{86}Sr$, $^{147}Sm/^{144}Nd$, ^{143}Nd / ^{144}Nd which were recalculated at 2.2 Ga to determine the εNd (2.2 Ga) and 87Sr/86Sr (2.2 Ga). Analyses were performed by a Thermal Ionization Mass Spectrometer (TIMS) following the method of [21]. The results will allow evaluating the crustal contamination and the mantle evolution of the system leading to the establishment of basalts.

4. Results and discussion

4.1. Geodynamic context of the plume

To determine the mantle or crustal origin of the magmatic material of the Gorouol belt metabasalts, the isotopic ratios of the Sm-Nd and Rb-Sr systems were determined. The results obtained are reported in Table I. The initial $^{87}Sr/^{86}Sr$ ratios and Nd values were calculated from 2.2 Ga to the present chondritic values of $^{143}Nd/^{144}Nd = 0.512640$ and $^{147}Sm/^{144}Nd = 0.1967$ [1], [2]. Grades range from 1 to 7.5 ppm for Rb and 122.5 to 132 ppm for Sr, respectively. Concentrations range from 6.7 to 8.4 ppm for Nd and 2.07 to 2.81 ppm for Sm. The Gorouol belt is characterized by an initial $^{87}Sr/^{86}Sr$ ratio ranging from 0.699522 to 0.701568 (**Table 1**). Initial Nd isotope ratios range from 0.512742 to 0.512803 and have positive εNd values ranging from 2.57 to 2.87 at 2.2 Ga. The primitive mantle source can be determined by the εNd values [22]. [1] and [2] established the depleted mantle composition for birimian basalts with εNd values ranging from 1.1 to 4.2. In this study, the εNd values range from 2.57 to 2.87. indicating that the magma in the Gorouol Belt metabasalts, originated from a depleted primitive mantle source (PM).

Tableau 1 : Compositions isotopiques en Rb-Sr et en Sm-Nd pour les métabasaltes (BGM) de la ceinture des roches vertes du Gorouol.

Samples	BGM1	BGM2	BGM3	BGM4	BGM5
Rb (ppm)	7.5	0.4	3.3	1	0.6
Sr (ppm)	132	122.5	124.5	114.5	126.5
Sm (ppm)	2.81	2.14	2.47	2.07	2.23
Nd (ppm)	8.4	6.7	7.6	7	6.9
$87Rb/^{86}Sr$	0.164	0.009	0.077	0.025	0.014
$87Sr/^{86}Sr$	0.705433	0.701868	0.701954	0.701788	0.701901
± 2σ	0.000019	0.000013	0.000032	0.000017	0.000037
$147Sm/^{144}Nd$	0.1948	0.1964	0.1966	0.1990	0.1964
$143Nd/^{144}Nd$	0.512742	0.512772	0.512767	0.512803	0.512780
εNd (2,2Ga)	2.57	2.71	2.58	2.57	2.87
$^{87}Sr/^{86}Sr$ (2,2Ga)	0.700217	0.701568	0.699522	0.700967	0.701466

4.2. Indices of crustal contamination

The isotopic compositions in Sr ($^{87}Sr/^{86}Sr$), in Nd ($^{143}Nd/^{144}Nd$), in εNd as well as in Pb (not presented here) of the basalts bring precious information, complementary to the trace elements, on the indices of crustal contamination [23]. As a reminder, ^{87}Sr and ^{143}Nd are two radiogenic isotopes derived, respectively, from the decay of ^{87}Rb and ^{147}Sm. In general, $^{87}Sr/^{86}Sr$ ratios > 0.710 indicate a crustal origin (rock resulting from the melting of the continental crust), whereas $^{87}Sr/^{86}Sr$ ratios ≤ 0.704 indicate a mantle origin (rock resulting from a direct partial melting of the mantle). In addition, when εNd value are positive, the terrain studied shows no evidence of crustal contamination by Archean crust [1], [2].

In the present study, all samples are characterized by positive εNd values with $^{87}Sr/^{86}Sr(i)$ isotope ratios between 0.699522 and 0.701568 (**Table 1**). The positive εNd values (2.2 Ga) emphasize the absence of contamination of the mantle source by a crustal component.

The composition of samples from this area is isotopically close to that of the concurrently depleted mantle of [23] and falls within the birimian basalt and granitoid field proposed by [1],

[2], [24], and [25]. Geochemical and isotopic data obtained in the metabasalts of the Gorouol belt show a similar composition to the birimian metabasalts of the West African Craton and the Guiana Shield in South America [1], [2], [24], [25]. The results obtained by the present study are also close to the results obtained by [1], [2], [26], [27], [17], [24], [28].

5. Conclusion

In conclusion, the initial $^{87}Sr/^{86}Sr$, $^{144}Nd/^{144}Nd$ and εNd ratios were calculated for an age of 2.2 Ga considered as the age of formation (or accretion) of the Paleoproterozoic crust during the Eburnian orogeny. The positive εNd values, indicates that the magma of the Gorouol belt metabasalts originates from a depleted primitive mantle source (PM), emplaced in an oceanic plateau-like domain. In addition, these positive εNd values underline the absence of contamination of the mantle source by a crustal component. However, the Gorouol belt is a good example of Paleoproterozoic oceanic shelf crust accreted in the WAC birimian terrains, confirming some previous studies in Burkina Faso, Niger, Mauritania, Senegal and Ivory Coast.

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Author Profile

Mallam Mamane Hallarou: Doctor in department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Sciences and Technology, Abdou Moumouni University Niamey/Niger.

Konaté Moussa: Professor, Department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Science and Technology, Abdou Moumouni University, Niamey/Niger.

Yacouba Ahmed Liboré: Associate professor, in department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Sciences and Technology, Abdou Moumouni University Niamey/Niger

Mahamane Moustapha Sanda Chékaraou: PhD student in department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Sciences and Technology, Abdou Moumouni University Niamey/Niger

Sofiyane Abdourahamane Attourabi: PhD student in department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Sciences and Technology, Abdou Moumouni University Niamey/Niger

Lawali Idi Chamsi: PhD student in department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Sciences and Technology, Abdou Moumouni University Niamey/Niger

Gambo Ranaou Noura: PhD student in department of Geology, Laboratory of Groundwater and Georesources. Geology, Faculty of Sciences and Technology, Abdou Moumouni University Niamey/Niger