Scientific Research Publishing

Open Journal of Geology, 2024, 14, 19-28
https://www.scirp.org/journal/ojg
ISSN Online: 2161-7589
ISSN Print: 2161-7570

Insight from Lithostructural and Aeromagnetic Data from the Léo Square Degree, Central-Western Burkina Faso

Adama Ouédraogo Yaméogo[1,2*], Pascal Ouiya[2,3], Gounwendmanaghré Hubert Zongo[2,4], Omar Akonyiré[2], Abraham Seydoux Traoré[2], Saga Sawadogo[2], Séta Naba[2]

[1]Unité de Formation et de Recherche en Sciences et Technologies, Département des Sciences de la Vie et de la Terre, Université Norbert Zongo, Koudougou, Burkina Faso
[2]Unité de Formation et de Recherche en Sciences de la Vie et de la Terre, Laboratoire Géosciences et Environnement (LaGE), Département des Sciences de la Terre, Université Joseph Ki-Zerbo, Ouaga, Burkina Faso
[3]Ecole Normale Supérieure (ENS)/Institut des Sciences et de Technologie (IST), Ouaga, Burkina Faso
[4]Ecole Supérieure d'Ingénieries, Université de Fada N'gourma, Fada N'Gourma, Burkina Faso
Email: *ayameogofr@yahoo.fr

How to cite this paper: Yaméogo, A.O., Ouiya, P., Zongo, G.H., Akonyiré, O., Traoré, A.S., Sawadogo, S. and Naba, S. (2024) Insight from Lithostructural and Aeromagnetic Data from the Léo Square Degree, Central-Western Burkina Faso. *Open Journal of Geology*, **14**, 19-28.
https://doi.org/10.4236/ojg.2024.141002

Received: December 14, 2023
Accepted: January 9, 2024
Published: January 12, 2024

Abstract

This study, carried out in the Léo square degree (west-central Burkina Faso) in the Palaeoproterozoic domain of the Man/Léo ridge, aims to define the shapes and positions of granitic plutons and the organisation of deformation structures using aeromagnetic data. These data have shown that there are small sub-circular granitic bodies to the north of the granitic masses in this region, and a large sub-circular granitic body to the south, around which are other smaller granitic bodies. The lineament map shows that the deformation structures are organised along three main directions and largely form these sub-circular plutonic bodies. We suggest that the granitic plutons are coalescent, pending identification of the internal structures of these granites to further refine the geodynamic model.

Keywords

Burkina Faso, Lineaments, Belts Rocks, Leo's Leaf, Granitoïd, Airbornes Magnétics

1. Introduction

The Paleoproterozoic basement of the Man/Leo shield, also known as the Baoulé-Mossi domain (Figure 1), consists of belts of greenstone and granitoids that represent interesting targets for mining exploration [1]. The emplacement of biotite-granite plutons is very often related to the functioning of the large

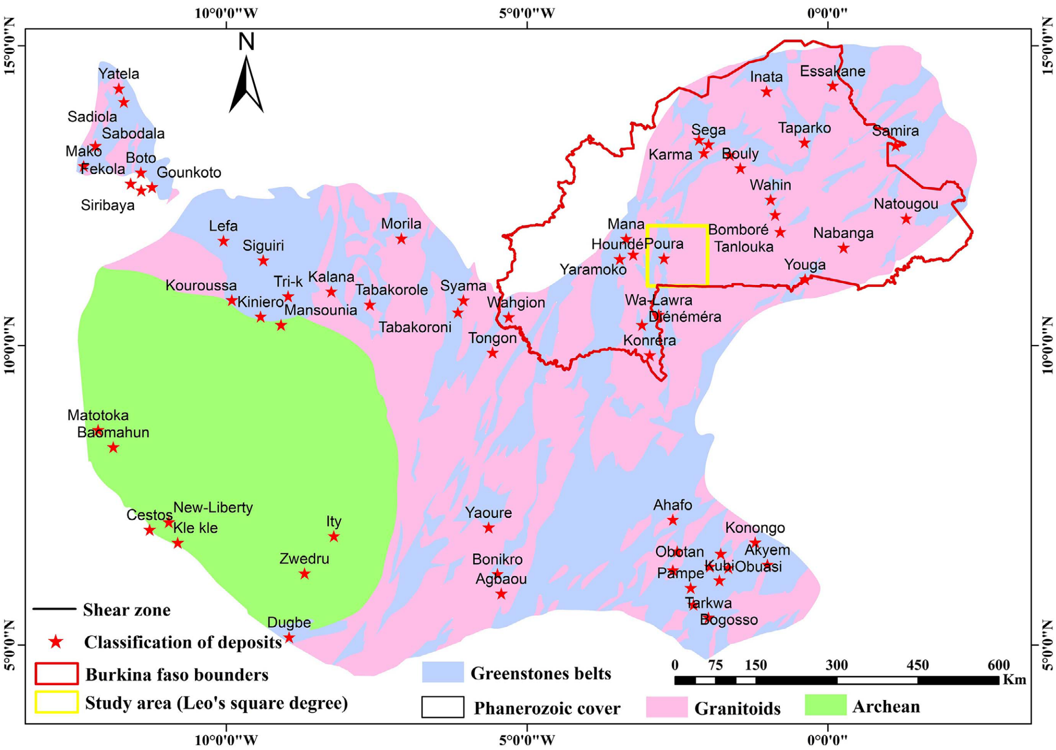

Figure 1. Map of the Man/Leo Shield.

transcurrent shear zones that characterise Eburnian tectonics [2] [3] [4]. These large transcurrent shear zones are also known for their importance in the history of gold mineralisation [5]-[12]. Examples show that these are often close to deposits of economic size, such as the Essakane gold mine in Burkina Faso, the Kiaka deposit in Burkina Faso, the Sissingué gold mine in Côte d'Ivoire, ... (**Figure 1**). However, in certain areas of the Baoulé-Mossi region, most of the geological formations and many of the deformation structures that affect them are covered by thick layers of sedimentary rock, making geological mapping and mining exploration difficult [13] [14]. Therefore, the use of aeromagnetic data is a solution to study these types of terrain.

Aeromagnetic data are an essential source of information for regional geological mapping and the exploration of mineral and water resources. These data can be easily integrated into all stages of geological mapping, and the various treatments of the magnetic field make it possible to define geophysical anomalies associated with the presence of geological formations and deformation structures.

This study focuses on the Léo square degree in Burkina Faso, where the basement formations are largely covered by sedimentary formations. Pending detailed field investigations, this work helps to determine the shape and position of the granitoids and to define the major and/or secondary structures likely to be associated with the emplacement of these granitoids.

2. Geological Setting

The Leo square degree covers part of west-central Burkina Faso, between 2˚ and

3˚ west longitude and between 11˚ and 12˚ north latitude (**Figure 2**). The Leo square degree consists of Paleoproterozoic formations that represent a period of major crustal accretion during the Eburnian orogeny. These formations are essentially composed of volcanic-sedimentary and plutonic terrains metamorphosed during the Eburnian and plutonic formations intrusive into the latter [15].

The Eburnian metamorphosed volcano-sedimentary and plutonic formations outcrop in the north-south trending Boromo belt to the west of the (**Figure 2**). The intrusive plutonic formations consist of TTG granitoids and biotite granites, which outcrop over most of the sheet (**Figure 2**).

Outcrop conditions are generally poor. Nevertheless, deformation structures can be observed and measured in the outcrops. These structural features take the form of contacts, planar structures and ductile detachment corridors. The work of [15] highlighted major shear zones, including the Boromo shear zone to the west of the Léo sheet. The functioning of this shear zone has induced secondary shear zones in the geological formations. The belt formations are highly deformed and oriented approximately north-south along the major shear corridor. The outcropping TTG granitoids are affected by a ribboning pattern running roughly in this direction. Overall, the biotite granites show no measurable structures.

3. Methodology

Aeromagnetic data are used in geological mapping studies and offer the advantage of rapid coverage of large study areas with the possibility of investigation at depth. The aeromagnetic data acquired by BUMIGEB were processed using GEOSOFT's OASIS MONTAJ software. The use of filters is essential in order to obtain accurate and meaningful images suitable for the interpretation of geological formations and structures. The following processing operations were carried out at this stage:

- Pole reduction (RTP) is an operation that transforms an asymmetric anomaly measured at any latitude into a simulated symmetric anomaly at the pole. This transformation corresponds to a calculation of the change in phase of the magnetic signal that returns the magnetic anomaly to its source.
- The vertical derivative (first vertical derivative) or vertical gradient is the vertical gradient of the residual magnetic field. It assesses the rate of change of the magnetic field of the sources with depth. The vertical gradient map is based on the detection of surface structures, *i.e.* it is a digital high-pass filter.
- The analysis signal allows the distribution of lithologies and their magnetic properties to be observed. Conversely, information about the structures is lost.
- Shading is an additional processing that enhances the hue of the black and white image to highlight structures and regional anomalies.

The second phase of the study involved an interpretation of the major lineaments in the study area as revealed by the magnetic signatures.

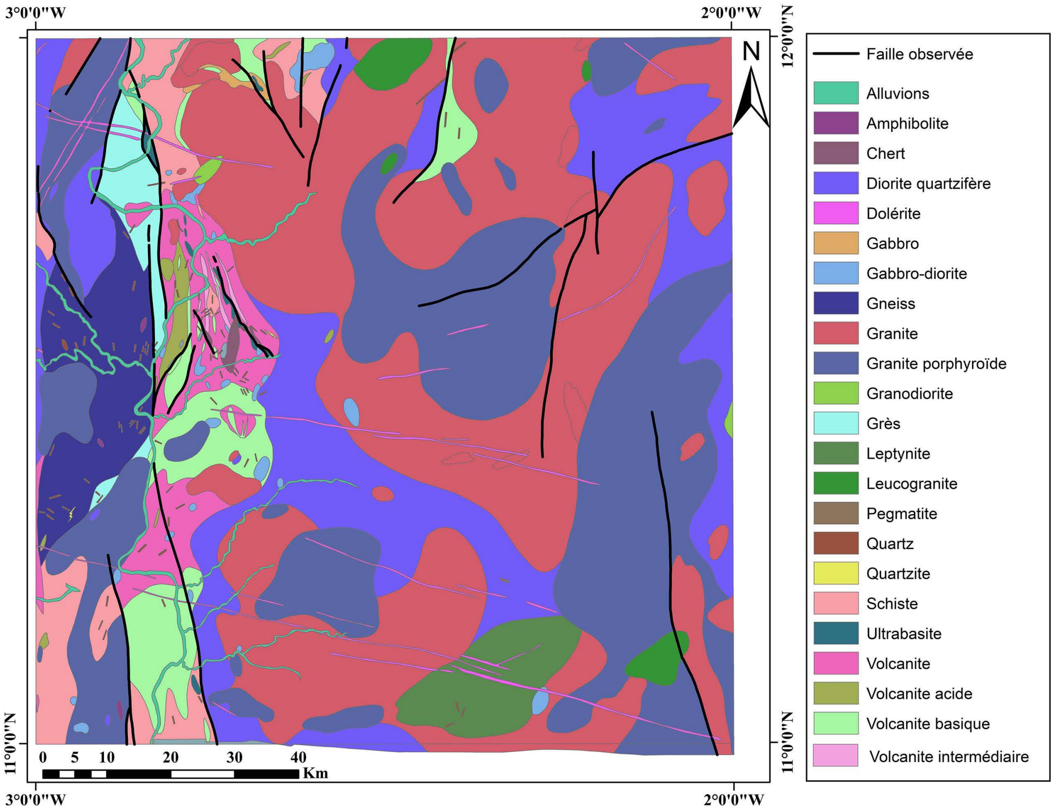

Figure 2. Geological map of the Léo (Castaing *et al.*, 2003, modified).

4. Results

The total magnetic field map shows that the strongest anomalies are observed in the western and central parts of the Léo sheet (**Figure 3**). These strong magnetic anomalies are associated with basic and ultrabasic rocks.

In places, short negative anomalies cross the geological formations in a NW-SE direction, clearly visible on the total magnetic field map and highlighted on the 45˚ shaded analytical signal map. Their orientation coincides with that of the dolerite dykes.

Weak to non-magnetic anomalies occur to the north and south of the square degree and generally correspond to acidic rocks (**Figure 3**). The 45˚ shaded analytical signal map shows sub-circular bodies corresponding to zones of weak to non-magnetic anomalies, which are confirmed by significant uranium anomalies on the U-Th-K ternary maps (**Figure 4(a)** and **Figure 4(b)**). This feature is unique to felsic bodies.

Strong magnetic anomalies corresponding to more or less elongated bodies are clearly highlighted on the 45˚ shaded analytical signal map (**Figure 4(a)** and **Figure 4(b)**). On the U-Th-K ternary maps, the dark areas correspond to basic to ultrabasic formations with low levels of natural radioactivity. However, there is a strong uranium anomaly to the west of the square degree at the location of the belt rocks, probably due to rainwater drainage of the granitoid alteration products (**Figure 4(b)**).

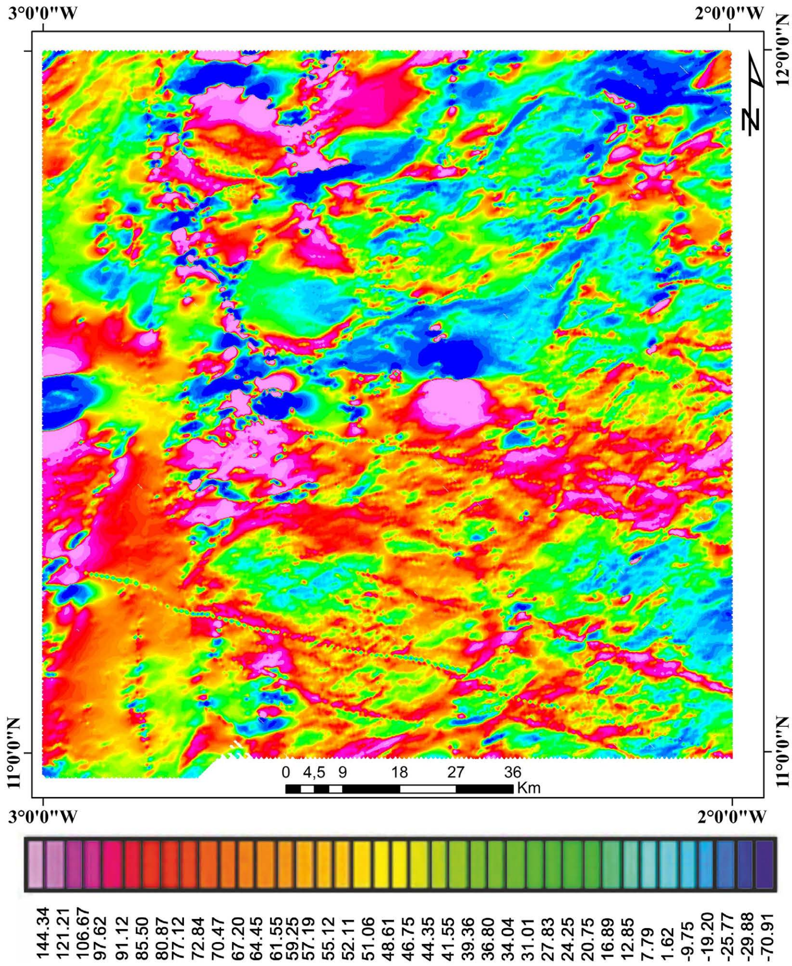

Figure 3. Total magnetic field map of the square degree of Léo.

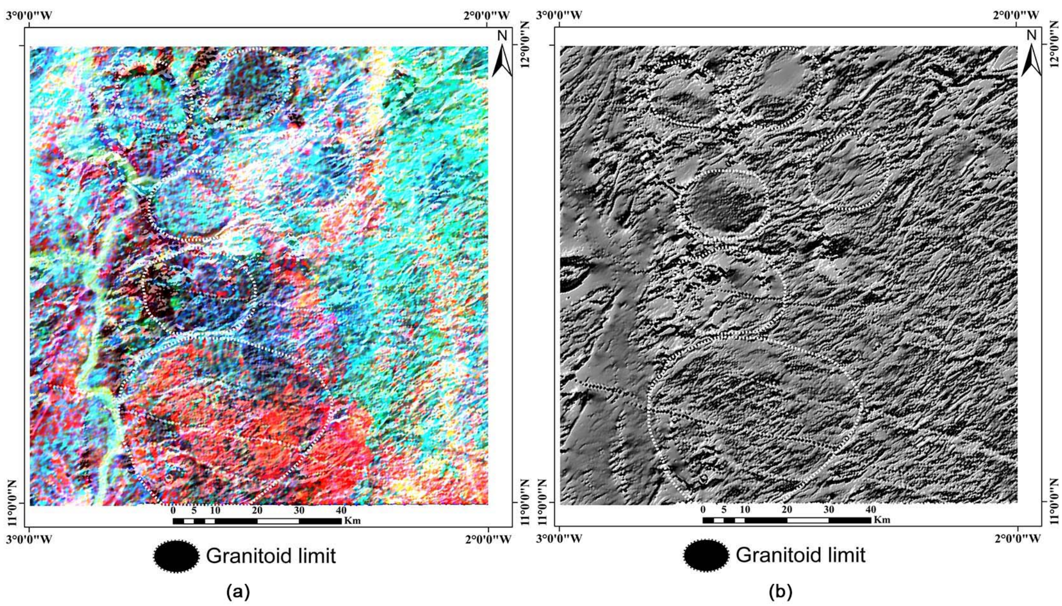

Figure 4. Shape and position of granites on: (a) U-Th-K ternary map and (b) 45˚ shaded analytical signal map.

The Léo sheet is affected by intense deformation. These are expressed by structures that can be observed on the lineament map and are organised in three main directions (**Figure 5**). On the 45˚ shaded analytical signal map, certain structures mould the subcircular bodies, which are clearly the granitoids. The main directions are : NNE-SSW, NE-SW and NW-SE.

5. Discussion

By superimposing the aeromagnetic data (magnetic field) on the 1:200,000 geological map of the Léo sheet [15], the strong magnetic anomalies correspond to basic rocks and the weak magnetic anomalies to acidic rocks [16] [17] [18]. Using aeromagnetic data, petrographic facies can be clearly distinguished and the lithology of the Léo sheet confirmed (**Figure 2**, **Figure 3**). The mainly NW-SE-trending dolerite dykes have been identified on the aeromagnetic maps by their strong, linear signal (e.g., [19] [20]).

This lithology is diverse and largely dominated by a large mass of granitoids, particularly biotite granites of variable texture. On the map of the analytical signal shaded at 45˚, we can see that in this large mass of granitoids, the subcircular bodies moulded by curvilinear structures are clearly visible. In the field, this feature is not observable because of the thick layer of weathering in the area. On the

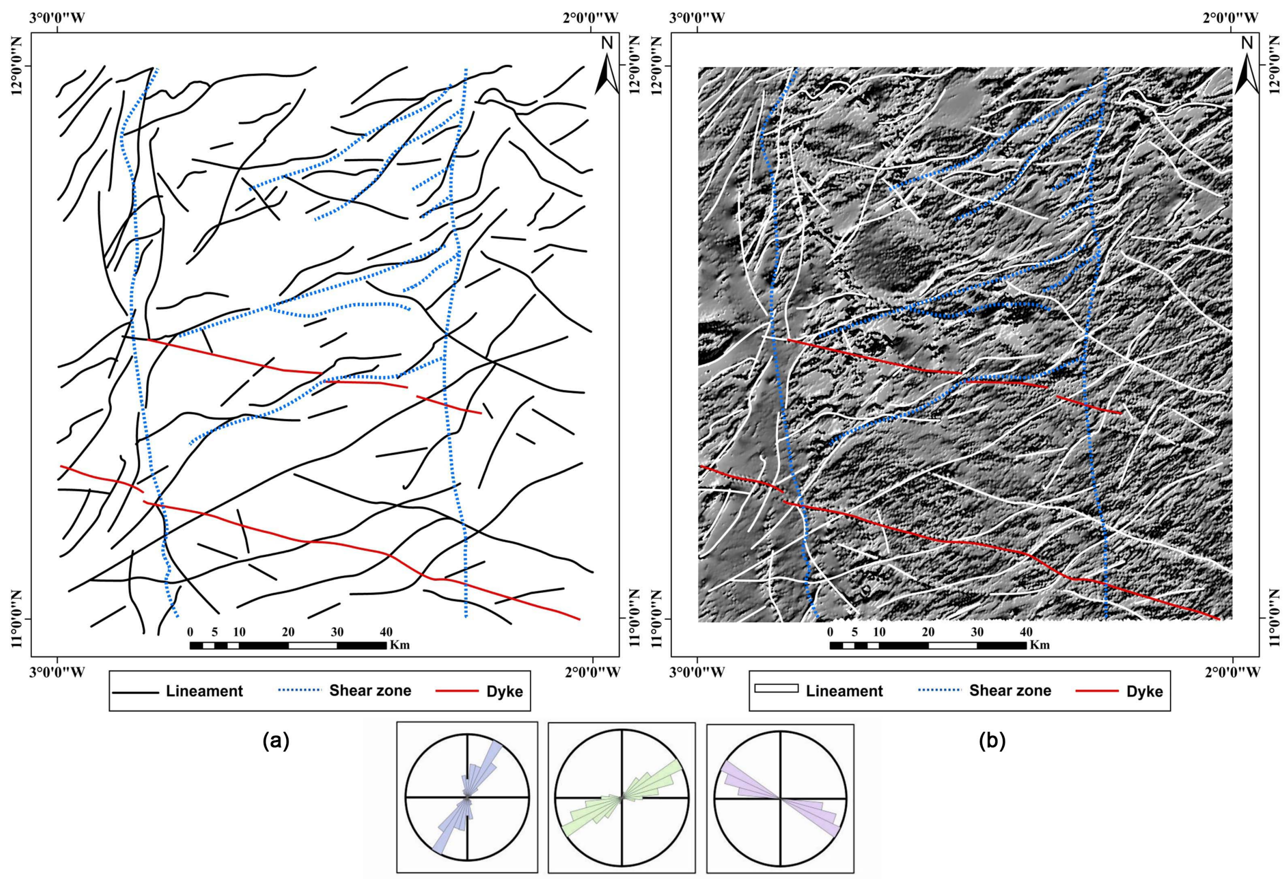

Figure 5. (a) Map of magnetic lineaments; (b) Map of the analytical signal shaded at 45˚ bearing lineaments.

basis of previous work [3] [4] [21] which has explained similar situations, we suggest that the presence of subcircular granitic bodies associated with curvilinear structures could be explained by coalescence. On the basis of the organisation of lineaments around biotite granites and their internal structures in the Dori region, Yaméogo *et al.* 2023 [4] show that the Gorom-Gorom granite, which appears homogeneous from field observation, consists of coalescing plutons. In this case, we do not have the internal structures of biotite granites.

The lineament map clearly shows that the flow schistosity (S1) is taken up by the N-S to NE-SW shear. In the volcanic sedimentary formations, the structures are vertical schistosities of variable intensity [15]. These structures are related to D1 and D2. D1 deformation phase structures are characterised in Burkina Faso and elsewhere in the West African craton by major faults, foliations and folds, and thrusts [9] [10] [22]-[27]. D2 deformation phase structures are N-S to NE trending sub-vertical shear zones in Burkina-Faso [22] [23].

6. Conclusion

The magnetic data have highlighted the diversity of the geological formations of the square degree of Leo through their magnetic signatures. The study clearly shows that the granite plutons of the square degree of Leo, which appear homogeneous in the field, are coalescing. Lineament analysis also indicates several deformation structures, some of which are organised around the biotite granites. Further studies using Anisotropy of Magnetic Susceptibility (AMS) and microstructural studies will clarify the internal structures of the biotite granites. At this stage, we will be able to show the relationship between the emplacement of the biotite granites and the functioning of the shear zones.

Acknowledgements

We are very grateful to Prof. NABA Séta of the Joseph Ki-Zerbo University for his invaluable contribution to this work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Sawadogo, S., Naba, S., Ilboudo, H., Traoré, A.S., Nakolendoussé, S. and Lompo, M. (2018) The Belahourou Granite Pluton (Djibo Greenstone Belt, Burkina Faso): Emplacement Mechanism and Implication for Gold Mineralization along a Shear Zone. *Journal of African Earth Sciences*, **148**, 59-68. https://doi.org/10.1016/j.jafrearsci.2018.04.009

[2] Naba, S., Lompo, M., Debat, P., Bouchez, J.L. and Beziat, D. (2004) Structure and Emplacement Model for Late-Orogenic Palaeoproterozoic Granitoids: The Tenkodogo-Yamba Elongate Pluton (Eastern Burkina Faso). *Journal of African Earth Sciences*, **38**, 41-57. https://doi.org/10.1016/j.jafrearsci.2003.09.004

[3] Vegas, N., Naba, S., Bouchez, J.L. and Jessell, M.W. (2008) Structure and Emplacement of Granite Plutons in the Paleoproterozoic Crust of Eastern Burkina Faso: Rheological Implications. *International Journal of Earth Sciences*, **97**, 1165-1180. https://doi.org/10.1007/s00531-007-0205-z

[4] Yaméogo, A.O., Ouiya, P., Traoré, S.A., Sawadogo, S., Naba, S., Rousse, S. and Macouin, M. (2023) Rheological Context of Emplacement of the Dori, Gorom-Gorom and Touka Bayèl Granitic Plutons (Northeast Burkina Faso, West African Craton). *Journal of African Earth Sciences*, **208**, Article ID: 105081. https://doi.org/10.1016/j.jafrearsci.2023.105081

[5] Milési, J.P., Ledru, P., Feybesse, J.L., Dommanget, A. and Marcoux, E. (1992) Early Proterozoic Ore Deposits and Tectonics of the Birimian Orogenic Belt, West Africa. *Precambrian Research*, **58**, 305-344. https://doi.org/10.1016/0301-9268(92)90123-6

[6] Allibone, A.H., McCuaig, T.C., Harris, D., Etheridge, M., Munroe, S., Byrne, D., Amanor, J. and Gyapong, W. (2002) Structural Controls on Gold Mineralization at the Ashanti Gold Deposit, Obuasi, Ghana. In: Goldfarb, R.J. and Nielsen, R.L., Eds., *Integrated Methods for Discovery: Global Exploration in the Twenty-First Century*, Society of Economic Geologists, Special Publications, Littleton, 65-93. https://doi.org/10.5382/SP.09.04

[7] Feybesse, J.L., Billa, M., Guerrot, C., Duguey, E., Lescuyer, J.L., Milesi, J.P. and Bouchot, V. (2006) The Paleoproterozoic Ghanaian Province: Geodynamic Model and Ore Controls, Including Regional Stress Modeling. *Precambrian Research*, **149**, 149-196. https://doi.org/10.1016/j.precamres.2006.06.003

[8] Béziat, D., Dubois, M., Debat, P., Nikiéma, S., Salvi, S. and Tollon, F. (2008) Gold Metallogeny in the Birimian Craton of Burkina Faso (West Africa). *Journal of African Earth Sciences*, **50**, 215-233. https://doi.org/10.1016/j.jafrearsci.2007.09.017

[9] Amponsah, P.O., Salvi, S., Beziat, D., Jessell, M.W., Siebenaller, L. and Baratoux, L. (2015) Geology and Geochemistry of the Shear-Hosted Julie Deposit, NW Ghana. *Journal of African Earth Sciences*, **112**, 505-523. https://doi.org/10.1016/j.jafrearsci.2015.06.013

[10] Amponsah, P.O., Salvi, S., Beziat, D., Baratoux, L., Siebenaller, L., Nude, P.M., Nyarko, R.S. and Jessell, M.W. (2016) The Bepkong Gold Deposit, Northwestern Ghana. *Ore Geology Reviews*, **78**, 718-723. https://doi.org/10.1016/j.oregeorev.2015.06.022

[11] Markwitz, V., Hein, K.A.A., Jessell, M.W. and Miller, J. (2016) Metallogenic Portfolio of the West Africa Craton. *Ore Geology Reviews*, **78**, 558-563. https://doi.org/10.1016/j.oregeorev.2015.10.024

[12] Goldfarb, R.J., Andre-Mayer, A.S., Jowitt, S.M. and Mudd, G.M. (2017) West Africa: The World's Premier Paleoproterozoic Gold Province. *Economic Geology*, **112**, 123-143. https://doi.org/10.2113/econgeo.112.1.123

[13] Diallo, M., Baratoux, L., Dufréchoua, G., Jessell, M.W., Vanderhaeghe, O., Ly, S. and Baratoux, D. (2019) Structure of the Paleoproterozoic Kédougou-Kéniéba Inlier (Senegal-Mali) Deduced from Gravity and Aeromagnetic Data. *Journal of African Earth Sciences*, **162**, Article ID: 103732. https://doi.org/10.1016/j.jafrearsci.2019.103732

[14] Siagné, Z.H., Aïfa, T., Kouamelan, A.N., Houssou, N.N., Digbeu, W., Kakou, B.K.F. and Couderc, P. (2022) New Lithostructural Map of the Doropo Region, Northeast Côte d'Ivoire: Insight from Structural and Aeromagnetic Data. *Journal of African Earth Sciences*, **196**, Article ID: 104680. https://doi.org/10.1016/j.jafrearsci.2022.104680

[15] Castaing, C., Billa, M., Milési, J.P., Thiéblemont, D., Le Métour, J., Egal, E., Donzeau, M., Guerrot, C., Cocherie, A., Chèvremont, P., Tegyey, M., Itard, Y., Zida, B., Ouédraogo, I., Koté, S., Kaboré, B.E., Ouédraogo, C., Ki, J.C. and Zunino, C. (2003) Notice explicative de la carte géologique et minière du Burkina Faso à 1/1 000 000. BRGM, Orléans.

[16] García, A., Chiappini, M., Blanco-Montenegro, I., *et al.* (2007) High Resolution Aeromagnetic Anomaly Map of Tenerife, Canary Islands. *Annales of Geophysics*, **50**, 689-697.

[17] Randrianasolo, E.B. (2009) Nouvelles méthodes de cartographie sur le socle protérozoïque du sud de Madagascar. Nature et géométrie de la croûte continentale d'un domaine orogénique en convergence, implications économiques. Master's Thesis, Université Joseph Fourier, Grenoble.

[18] Dao, R.A.I., Ilboudo, H. and Naba, S. (2022) Nouvelles données lithologiques et structurales du secteur de Nindangou dans le prolongement Est de la ceinture de Goren (Burkina Faso-Afrique de l'Ouest). *Bulletin de l'Institut Scientifique*, *Rabat*, *Section Sciences de la Terre*, No. 44, 93-103.

[19] Jessell, M.W., Santoul, J., Baratoux, L., Youbi, N., Ernst, R.E., Metelka, V., Miller, J. and Perrouty, S. (2015) An Updated Map of West African Mafic Dykes. *Journal of African Earth Sciences*, **112**, 440-450. https://doi.org/10.1016/j.jafrearsci.2015.01.007

[20] Baratoux, L., Soderlund, U., Ernst, R.E., de Roever, E., Jessell, M.W., Kamo, S., Naba, S., Perrouty, S., Metelka, V., Yatte, D., Grenholm, M., Diallo, D.P., Ndiaye, P.M., Dioh, E., Cournede, C., Benoit, M., Baratoux, D., Youbi, N., Rousse, S. and Bendaoud, A. (2019) New U-Pb Baddeleyite Ages of Mafic Dyke Swarms of the West African and Amazonian Cratons: Implication for Their Configuration in Supercontinents through Time. In: Srivastava, R.K., Ernst, R.E. and Peng, P., Eds., *Dyke Swarms of the World*: *A Modern Perspective*, Springer, Singapore, 263-314. https://doi.org/10.1007/978-981-13-1666-1_7

[21] Pons, J., Barbey, P., Dupuis, D. and Léger, J.M. (1995) Mechanisms of Pluton Emplacement and Structural Evolution of a 2.1 Ga Juvenile Continental Crust: The Birimian of Southwestern Niger. *Precambrian Research*, **70**, 281-301. https://doi.org/10.1016/0301-9268(94)00048-V

[22] Baratoux, L., Metelka, V., Naba, S., Jessell, M.W., Gregoire, M. and Ganne, J. (2011) Juvenile Paleoproterozoic Crust Evolution during the Eburnean Orogeny (~2.2-2.0 Ga), Western Burkina Faso. *Precambrian Research*, **191**, 18-45. https://doi.org/10.1016/j.precamres.2011.08.010

[23] Metelka, V., Baratoux, L., Naba, S. and Jessell, W.M. (2011) A Geophysically Constrained Litho-Structural Analysis of the Eburnean Greenstone Belts and Associated Granitoid Domains, Western Burkina-Faso. *Precambrian Research*, **190**, 48-69. https://doi.org/10.1016/j.precamres.2011.08.002

[24] Perrouty, S., Ailleres, L., Jessell, M.W., Baratoux, L., Bourassa, Y. and Crawford, B. (2012) Revised Eburnean Geodynamic Evolution of the Gold-Rich Southern Ashanti Belt, Ghana, with New Field and Geophysical Evidence of Pre-Tarkwaian Deformations. *Precambrian Research*, **204-205**, 12-39. https://doi.org/10.1016/j.precamres.2012.01.003

[25] Block, S., Jessell, M., Ailleres, L., Baratoux, L., Bruguier, O., Zeh, A., Bosch, D., Caby, R. and Mensah, E. (2016) Lower Crust Exhumation during Paleoproterozoic (Eburnean) Orogeny, NW Ghana, West African Craton: Interplay of Coeval Contractional Deformation and Extensional Gravitational Collapse. *Precambrian Research*, **274**, 82-109. https://doi.org/10.1016/j.precamres.2015.10.014

[26] McFarlane, H.B., Ailleres, L., Betts, P., Ganne, J., Baratoux, L., Jessell, M.W. and Block, S. (2019) Episodic Collisional Orogenesis and Lower Crust Exhumation during the Paleoproterozoic Eburnean Orogeny: Evidence from the Sefwi Greenstone Belt, West African Craton. *Precambrian Research*, **325**, 88-110. https://doi.org/10.1016/j.precamres.2019.02.012

[27] Nunoo, S., Hofmann, A. and Kramers, J. (2022) Geology, Zircon U-Pb Dating and εHf Data for the Julie Greenstone Belt and Associated Rocks in NW Ghana: Implications for Birimian-to-Tarkwaian Correlation and Crustal Evolution. *Journal of African Earth Sciences*, **186**, Article ID: 104444. https://doi.org/10.1016/j.jafrearsci.2021.104444