Open Journal of Geology, 2024, 14, 617-628
https://www.scirp.org/journal/ojg
ISSN Online: 2161-7589
ISSN Print: 2161-7570

Exoscopy of Detrital Zircons from Niamey Neoproterozoic Sandstones (Eastern Edge of the West African Craton, Southwestern Niger): Interpretation of Detrital Sediments Provenance

Hassan Ibrahim Maharou[1*], Karimou Laouali Idi[2], Diafarou Alzouma Amadou[1], Salissou Abdoul Ganiou Amadou[1], Gnissa Sidibé[1], Moussa Konaté[1]

[1]Department of Geology, Faculty of Science and Techniques, Abdou Moumouni University, Niamey, Niger
[2]Department of Life and Earth Sciences, Ecole Normale Supérieure (ENS), Abdou Moumouni University, Niamey, Niger
Email: *maharou86@gmail.com

How to cite this paper: Maharou, H.I., Idi Karimou, L., Amadou, D.A., Amadou, S.A.G., Sidibé, G. and Konaté, M. (2024) Exoscopy of Detrital Zircons from Niamey Neoproterozoic Sandstones (Eastern Edge of the West African Craton, Southwestern Niger): Interpretation of Detrital Sediments Provenance. *Open Journal of Geology*, **14**, 617-628.
https://doi.org/10.4236/ojg.2024.145026

Received: April 3, 2024
Accepted: May 25, 2024
Published: May 28, 2024

Abstract

This study focuses on exoscopic analyses of detrital zircon grains of Archean and Paleoproterozoic age, contained in the sediments from the Niamey Neoproterozoic sandstones (Niamey region), with a view to confirming the sediments sources already proposed (Kénéma-Man domain for Archean-age zircons and Baoulé Mossi domain for Paleoproterozoic-age zircons). Exoscopic analysis reveals that Archean zircon grains are more corroded, with rounded to sub-rounded shapes, while Paleoproterozoic zircon grains are less corroded and mostly angular in shape. The strong corrosion of Archean zircon grains, implying long-distance transport, is consistent with the remoteness of the Kenema-Man domain which are the source these sediments. The fact that the Paleoproterozoic zircon grains show little or no wear implies a proximal source of sediments, corresponding to the Baoulé Mossi domain.

Keywords

Exoscopic Analysis, Detrial Zircon Grains, U-Pb Ages, Niamey Neoproterozoic Sandstones, Niamey Region

1. Introduction

In Niger, Niamey sandstones overlie unconformably the Paleoproterozoic terrains (Birimian schists and granites) of the southeastern edge of the West African Craton (WAC) [1] [2]. Classically, due to their stratigraphic position, they have been considered as equivalent to the sediments of the neighboring Taoudenni and Gourma basins to the north [3] [4] [5], and of the Volta basin to the south [6]. However, few studies have been carried out on Niamey sandstones, so that their age and origin are still debated.

Radiometric data obtained in these sandstones indicate the presence of two classes of detrital zircons: on the one hand, Archean-age zircons (2588 ± 10 to 3392 ± 9 Ma) and, on the other, Paleoproterozoic zircons, with ages ranging from 1822 ± 9 to 2436 ± 17 Ma [7]. Correlations of these ages from the Niamey region with those terrains form other regions of the West African Craton indicate that the Archean Kénéma-Man and Paleoproterozoic Baoulé Mossi domains represent the sources, respectively, of Archean and Paleoproterozoic zircons from the Niamey sandstones [7] (**Figure 1**). However, Scanning Electron Microscope (SEM) shape analysis of these zircon grains has not been performed to verify these sediments sources.

The aim of this study is to confirm the sediments sources, already proposed (Kénéma-Man and Baoulé Mossi domains), that make up the Niamey sandstones, by analyzing zircon grains. Specifically, the aim is to:

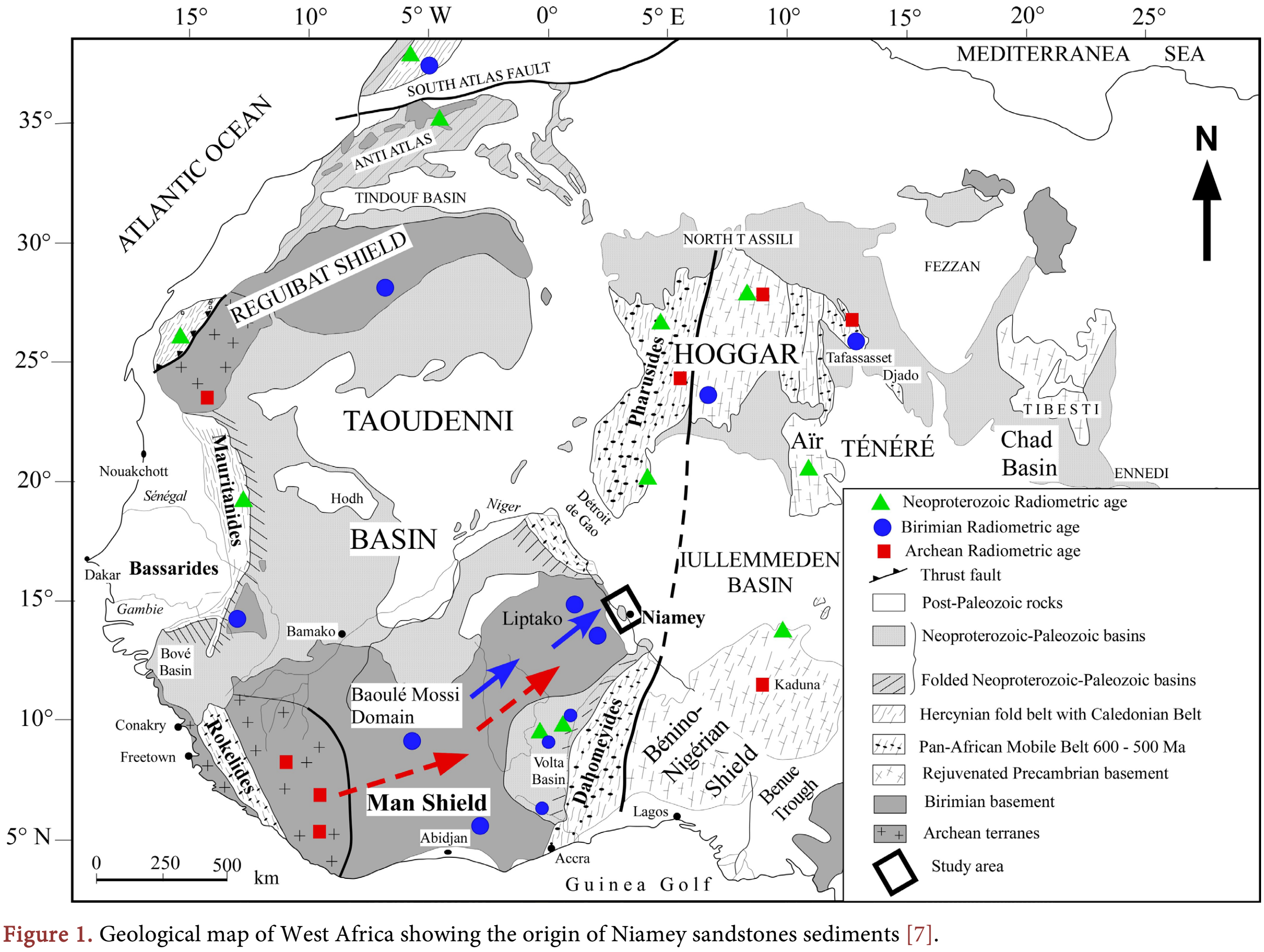

Figure 1. Geological map of West Africa showing the origin of Niamey sandstones sediments [7].

- Analyze the shape and surface appearance of: Archean-age zircon grains on the one hand and Paleoproterozoic-age zircon grains, on the other;
- Match the results of these analyses with the proposed sediments sources (Kénéma-Man and Baoulé Mossi domains).

2. Location of the Niamey Neoproterozoic Sandstones

Niamey Neoproterozoic Sandstones, the subject of this study, are located in Southwestern Niger, between parallels 13˚28' and 13˚35' North latitude and meridians 02˚03' and 02˚12' East longitude (**Figure 2**). They are part of a set of Neoproterozoic deposits that outcrop discontinuously along the Eastern edge of the West African Craton and follow the Niger River valley [2] [7] [8] [9] [10].

These Neoproterozoic deposits outcrop, from North to South, in the regions of: Firgoun (Firgoun sandstones), Gassa (Gassa sandstones), Niamey (Niamey sandstones) and Kirtachi-Tamou (Kirtachi sandstones) (**Figure 2**).

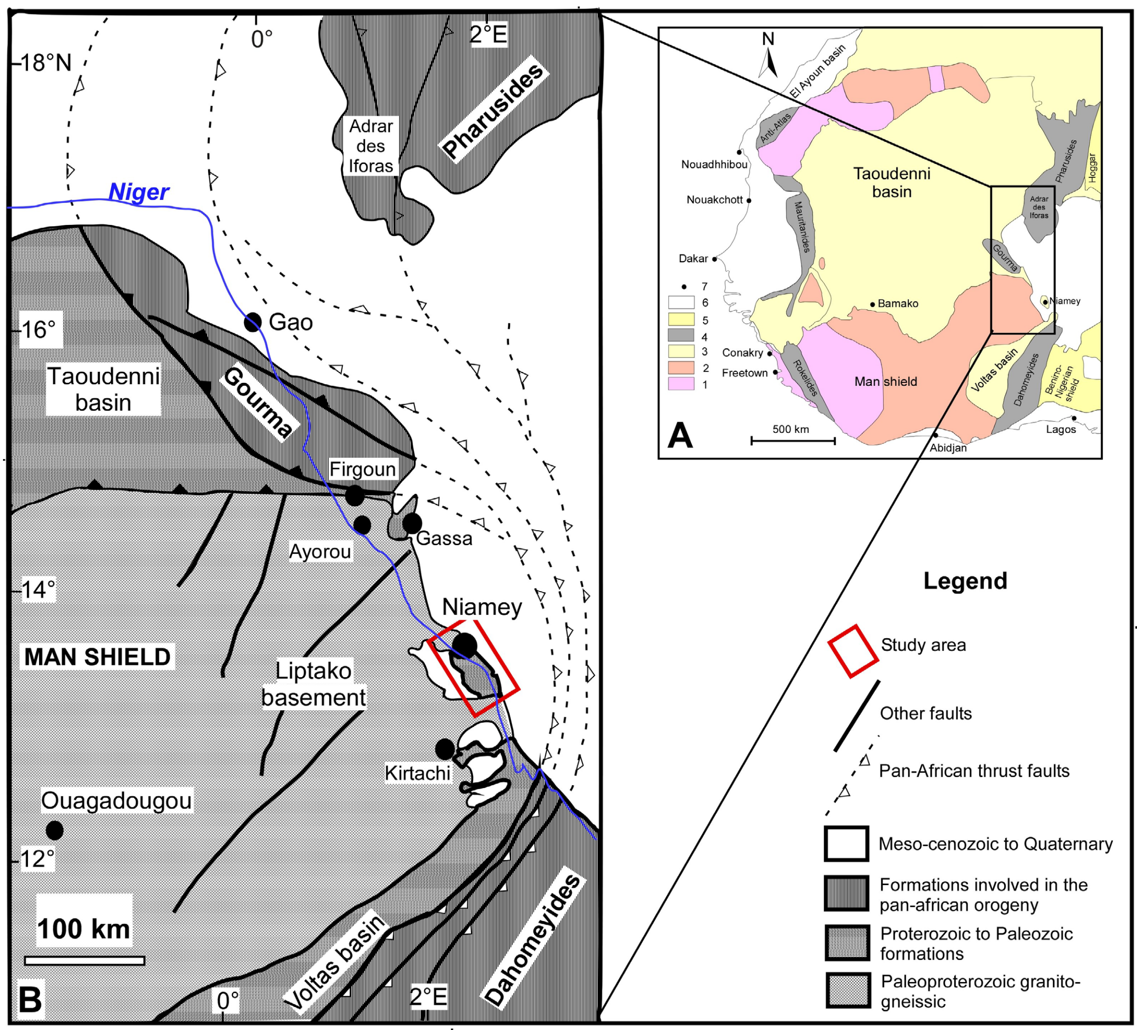

Figure 2. A: Geological map of West Africa [11]. 1: Archean; 2: Birimian (Paleoproterozoic); 3: Paleozoic basins locally encompassing Upper Precambrian; 4: Mobile zones; 5: Post-Neoproterozoic terranes; 6: Post-Paleozoic terranes; 7: Cities. B: Location of the study area in the Liptako structural context [12].

The Niamey Neoproterozoic Sandstones outcrop in two areas on either side of the Niger River [2]: Tondibia area (on the left bank of the Niger River) and Karey Gorou area (on the right bank of the Niger River) (**Figure 3**).

3. Geological Setting

Geologically, the Niamey region is part of the Niger Liptako province, which corresponds to the Northeastern edge of the Man Shield (Birimian domain of the Man Shield) [2] [8] [12] [13] [14]. The Liptako is bounded to the east by the Iullemmenden basin, to the north by the Gourma basin and to the southeast by the Volta basin (**Figure 4**). Two major geological units have been distinguished in the Niger Liptako province:

1) The Paleoproterozoic (Birimian) basement (2300 to 2000 Ma [15]), outcropping over 2/3 of the region [8] [16]-[21];

2) A sedimentary cover comprising Neoproterozoic (Niamey sandstones), Oligocene (Continental terminal 3 (Ct^3)) and Quaternary deposits [1] [2] [8] [9] [10] [12] [14].

3.1. Paleoproterozoic Basement Deposits of the Niger Liptako Province

The Paleoproterozoic basement of the Niger Liptako province consists of alternating greenstone belts and granitoid plutons (granitic massifs) [8] [15] [19]-[25] (**Figure 4**). The greenstone belts consist of metabasalts, amphibolites, ultramafic to mafic granitic rocks, often transformed into talcchists and chloritoschists,

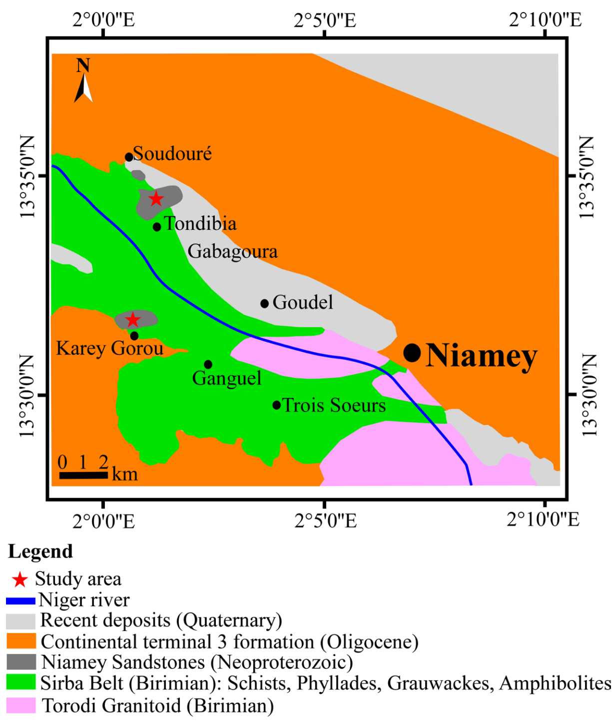

Figure 3. Location of sectors study on an extract of simplified geological map of Liptako (extract from [8]).

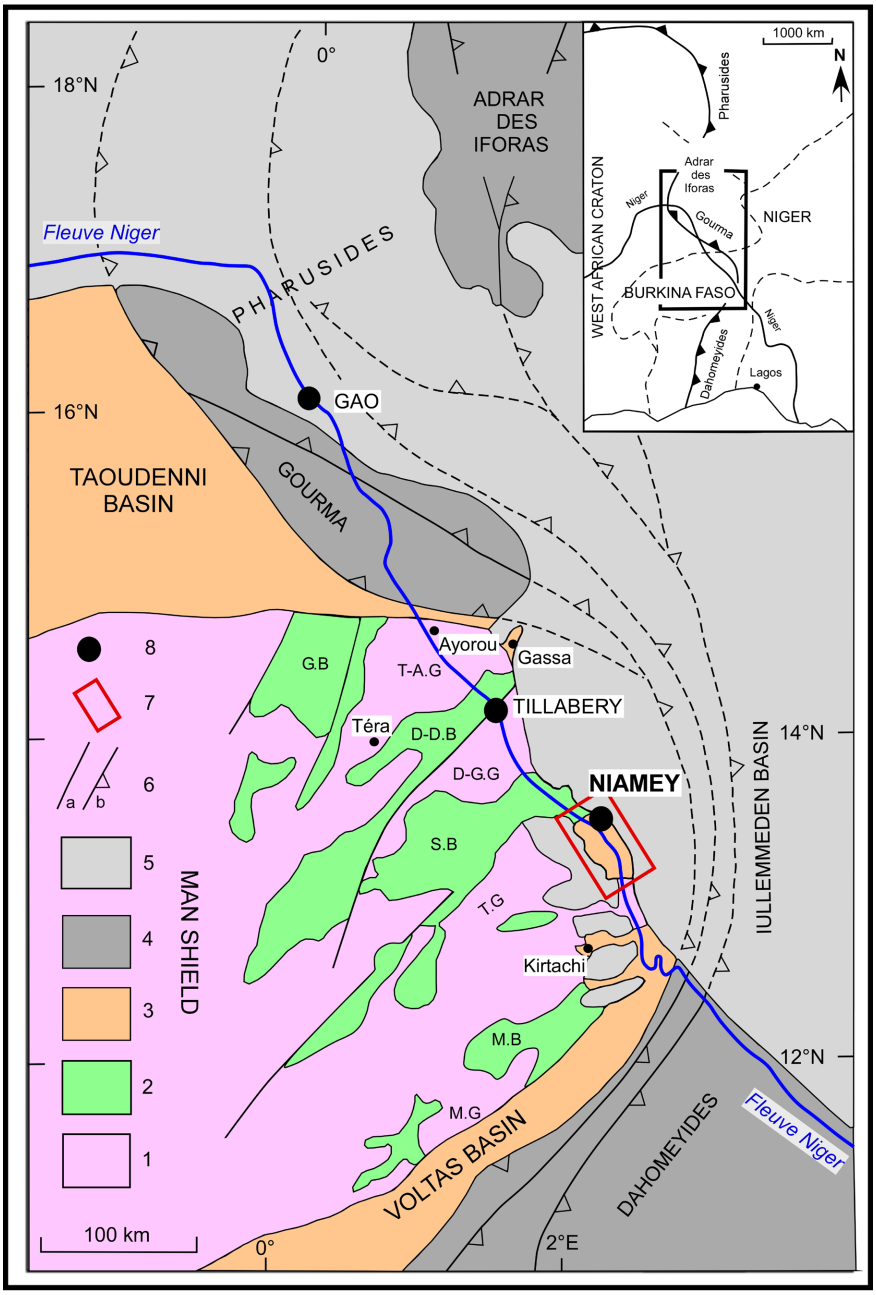

Figure 4. Location of the Niamey region within the Liptako structural framework ([12] modified). (1) Paleoproterozoic granite-gneissic massifs. (2) Paleoproterozoic schist belts. (3) Neoproterozoic and Paleozoic formations of the Taoudenni and Volta basins. (4) Formations involved in the Pan-African orogeny (600 Ma). (5) Mesocenozoic to Quaternary formations of the Iullemmeden basin. (6) Faults (a) and thrust planes of the Pan-African nappes (b). (7) Eastern and western branches of the Green Belt. (8) Niger River, (9) Cities. G.B: Gorouol Belt; T-A.G: Téra Ayorou Granitoid; D-D.B: Diagourou Darbani Belt; D-G.G: Dargol Gotheye Granitoid; S.B: Sirba Belt; T.G: Torodi Granitoid; M.B: Makalondi Belt; Mossipaga Granitoid.

sediments and metamorphosed volcano-sediments in the greenschist to amphibolite facies [8] [15] [20] [21] [23] [24] [25]. Granitoid plutons are composed mainly of granites, TTG (Tonalite-Trondhjemite-Granodiorite), diorites and quartz diorites, monzonite and locally syenite [8] [15] [16] [20] [21] [24].

3.2. Neoproterozoic Deposits of the Niamey Sandstones

The lithostratigraphic column established in the Niamey sandstones comprises three lithofacies which are, from bottom to top: quartzite sandstones with hummocky cross stratification (HCS) structures, glauconitic quartzite sandstones and diamictites with faceted pebbles [1] [2].

3.3. Oligocene Deposits of the Terminal Continental 3

The Terminal Continental deposits represent the upper terms of the Iullemmeden Basin [26]. This author defined three groups within this formation. These are, from bottom to top, the:

- Siderolithic of Ader Doutchi (Continental terminal 1 (Ct^1));
- Sandy-clay with lignites (Continental terminal 2 (Ct^2));
- Middle Niger sandstones clay (Continental terminal 3 (Ct^3)).

Continental terminal 3, the only Continental terminal unit to outcrop in the Niger Liptako [14] [27] [28], is an Oligocene-age formation [29] essentially consisting of alternating clayey sandstones and ferruginous oolitic sandstones with indurated levels, more or less associated with termite tubules [14] [27] [28]. The Ct^3 rests in gully unconformity on the Infracambrian deposits and/or in major unconformity on the Paleoproterozoic basement [2] [14] [27] [28].

Quaternary deposits consist of alluvium, more or less reworked ferruginous lateritic deposits and dunes overlying Terminal Continental 3 or Paleoproterozoic basement [14] [26] [27] [28] [30].

4. Methodology

The methodology implemented is based on Scanning Electron Microscope (Electron High Tension (EHT) = 20 kv; Work Distance (WD) = 14 mm; Signal = SE1; Magnification (Mag) = 550 X) shape and surface analyses of Archean (2588 ± 10 to 3392 ± 9 Ma [7]) and Paleoproterozoic (1822 ± 9 to 2436 ± 17 Ma [7]) detrital zircons from two samples (N1 and N2) of the Niamey sandstones (**Figure 2**). These detrital zircons were dated by the U-Pb method via the LA-ICP-MS (Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry) technique [7]. Radiometric dating was carried out at the "GeoPlasmaLab" laboratory of the Senckenberg Naturhistorische Sammlungen, Dresden (Germany) [7]. It should be noted that the LA-ICP-MS technique has great potential in the field of geochronology, notably due to its high sensitivities and high yields [31] [32].

5. Results

5.1. Exoscopic Analysis of Archean-Age Zircons from the Niamey Sandstones

Observed under the Scanning Electron Microscope, Archean-age zircon grains from Niamey sandstones are bluntly shiny, with rounded (**Figure 5 (A)**, **Figure**

5 (C), Figure 5 (E)) to subrounded (Figure 5(B), Figure 5(D), Figure 5(F)) shapes, according to the morphoscopic classification established by [33]. According to [34], roundness is the smoothing of crystal edges caused by abrasion. It is therefore an important parameter for estimating transport distance [33]. These morphoscopic features imply that Archean-age zircons from Niamey sandstones are of distant origin.

5.2. Exoscopic Analysis of Paleoproterozoic-Age Zircons from the Niamey Sandstones

Exoscopic analysis of Paleoproterozoic-age zircon grains from Niamey sandstones shows the predominance of angular shapes (Figures 6(A)-(F)). These features indicate a transport process involving proximity to the material source.

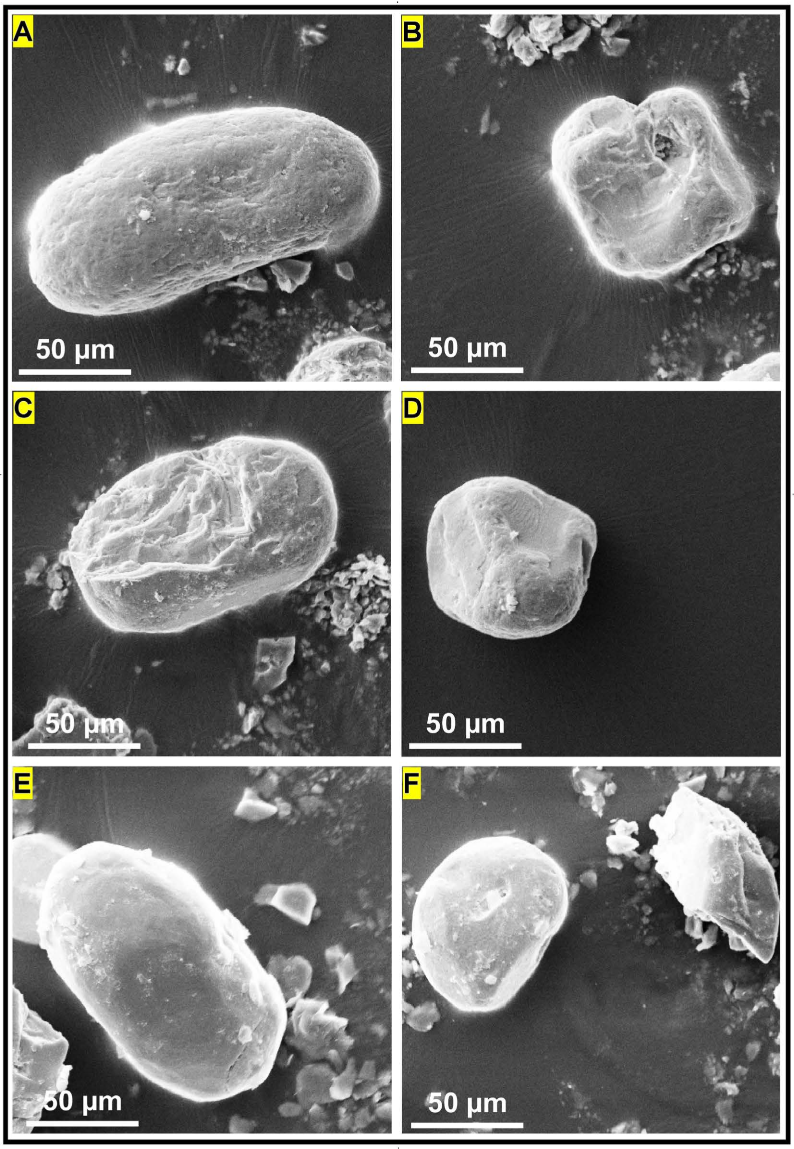

Figure 5. Scanning Electron Microscope view of Archean-age zircons from Niamey sandstones.

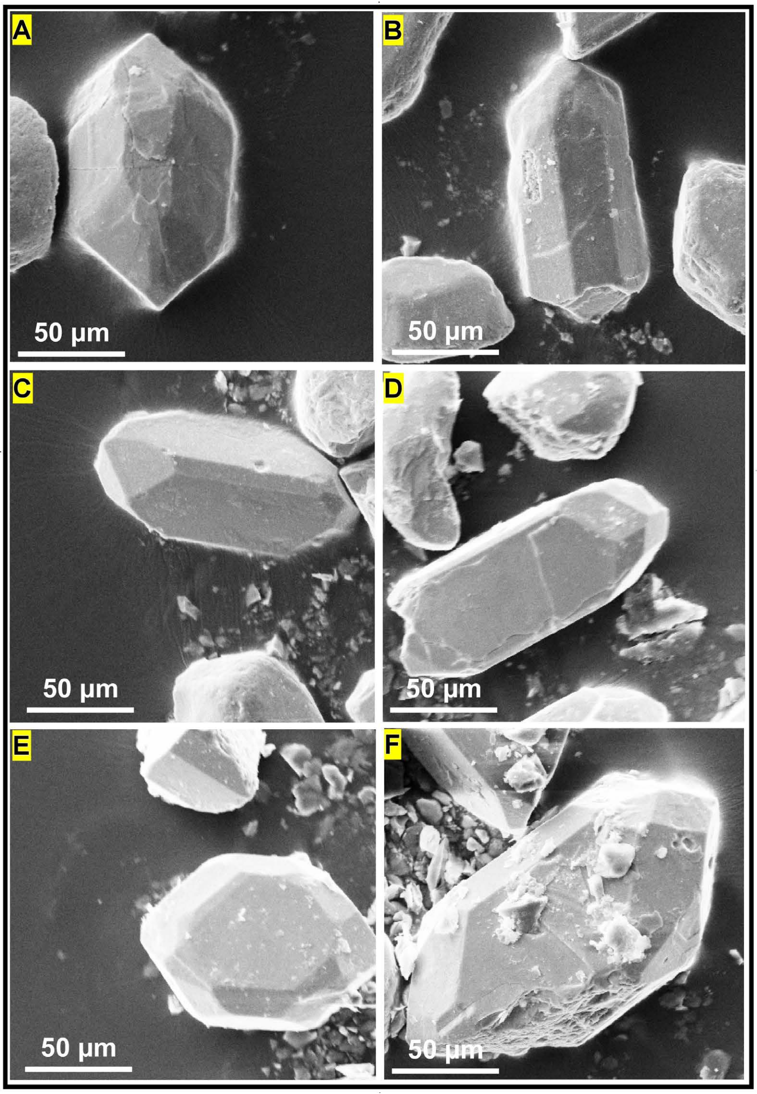

Figure 6. Scanning Electron Microscope view of Paleoproterozoic-age zircons from Niamey sandstones.

6. Discussion

Detrital zircon analysis is therefore a powerful tool for determining the likely sources of sediments deposited in sedimentary basins [35] [36] [37] [38]. Morphoscopic analysis of zircon grains from Niamey sandstones has enabled them to be classified into two categories:

1) corroded, rounded to subrounded, Archean-age zircon grains (between 2588 ± 10 and 3392 ± 9 Ma [7]);

2) lightly corroded, mostly angular, Paleoproterozoic-age zircon grains (between 1822 ± 9 and 2436 ± 17 Ma [7]).

The strong corrosion of zircon grains in the first category, (predominantly rounded shapes), implies long-distance transport [33] [34] [38]. Indeed, according to [39], the distribution of roundness gives a general idea about the distance of transport.

This result is consistent with the sediments source, the Kénéma-Man domain, proposed by [7]. According to these authors, these sediments originate from the very ancient Archean rocks of the Kénéma-Man domain, notably those of Ivory Coast and Guinea.

The fact that the zircon grains in the second category are little or not worn, due to their proximity to the material source [33] [34] [38] [39], is also in agreement with the sediments source, the Liptako birimian terrains (Baoulé Mossi domain), proposed by [7]. Indeed, the Paleoproterozoic terrains are contiguous with the Niamey sandstones, for which they form the bedrock.

7. Conclusions

The exoscopic study of detrital zircons from Niamey sandstones enabled them to be classified into two categories:

- Archean-age zircon grains, rounded to subrounded in shape (corroded zircon grains);

- Paleoproterozoic-age zircon grains, mostly angular in shape (slightly corroded zircon grains).

Zircon grains in the first category (rounded shape) imply long-distance transport. This is consistent with the distant source of the sediments proposed (Archean domain of Kénéma-Man) in previous work.

Similarly, the shape of the Paleoproterozoic zircon grains (angular form) is in line with the proximal source of the sediments also proposed (Paleoproterozoic domain of Baoulé Mossi). In fact, the Paleoproterozoic terrains are contiguous with the Niamey sandstones, for which they form the bedrock.

Acknowledgements

The authors are deeply grateful to the anonymous reviewers for their constructive comments. The first author thanks the "PhD Geology UAM" for the collaboration.

Conflicts of Interest

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

References

[1] Ibrahim Maharou, H. and Konaté, M. (2018) Depositional Environments of Niamey Area Proterozoic Deposits (Western Niger). *International Journal of Science and Research* (*IJSR*), **7**, 1126-1131.

[2] Ibrahim Maharou, H. (2020) Dynamique sédimentaire des grès de Niamey (Niger Occidental): Indices de glaciation et déformations associées. Thèse de Doctorat, Université Abdou Moumouni, Niamey, 136 p.

[3] Reichelt, R. (1972) Géologie du Gourma (Afrique occidentale), un «seuil» et un bassin du Précambrien supérieur. Mem. Bur. Rech. Geol. Min. Paris 53, 213.

[4] Bertrand-Sarfati, J., Moussine-Pouchkine, A., Affaton, P., Trompette, R. and Bellier,

Y. (1991) Cover Sequences of the West African Craton. In: Dallmeyer, R.D. and Lécorché, J.P., Eds., *The West African Orogens and Circum-Atlantic Correlatives*, Springer-Verlag, Berlin, 65-82. https://doi.org/10.1007/978-3-642-84153-8_4

[5] Miningou, M.Y.W., Affaton, P., Meunier, J.D., Blot, A. and Nebie, A.G. (2017) Establishment of a Lithostratigraphic Column in the Béli Area (North-Eastern Burkina Faso, West Africa) Based on the Occurrence of a Glacial Triad and a Molassic Sequences in Neoproterozoic Sedimentary Formations. Implications for the Pan-African Orogeny. *Journal of African Earth Sciences*, **131**, 80-97. https://doi.org/10.1016/j.jafrearsci.2017.03.016

[6] Affaton, P. (1990) Le bassin des Volta (Afrique de l'Ouest): Une marge passive, d'âge Protérozoïque supérieur, tectonisée au Panafricain (600_50 Ma). Collect. Thèses et Documents, Editions de l'Orstom, Paris.

[7] Konaté, M., Ahmed, Y., Gärtner, A., Alzouma Amadou, D., Ibrahim Maharou, H., Tourba, K., Hofmann, M., Zieger, J. and Linnemann, U. (2018) U-Pb Detrital Zircon Ages of Sediments from the Firgoun and Niamey Areas (Eastern Border of West African Craton, West Niger). *Comptes Rendus Geoscience*, **350**, 267-278. https://doi.org/10.1016/j.crte.2018.06.005

[8] Machens, E. (1973) Contribution à l'étude des formations du socle cristallin et de la couverture sédimentaire de l'Ouest de la republique du Niger. Editions BRGM (No. 82), 167 p.

[9] Alzouma Amadou, D., Konaté, M. and Ahmed, Y. (2020) Geodynamic Context of the Proterozoïc Deposits of the Firgoun Region (Eastern Border of the West African Craton, West Niger). *Geological Society, London, Special Publications*, **502**, 215-236. https://doi.org/10.1144/SP502-2019-115

[10] Azouma Amadou, D. (2022) Environnements de dépôt des formations néoprotérozoïques de la région de Firgoun (Ouest Niger): Glaciations, Déformations et minéralisations en cuivre. Thèse de Doctorat, Université Abdou Moumouni, Niamey, 188 p.

[11] Trompette, R. (1973) Le Précambrien supérieur et le Paléozoïque inférieur de l'Adrar des Mauritanie (bordure occidentale du bassin de Taoudeni, Afrique de l'Ouest). Un exemple de sédimentation de craton. Etude stratigraphique et sédimentologique. Trav. Lab. Sci. Terre, Marseille (St-Jérome), 1 et 2, 573 p.

[12] Affaton, P., Gaviglio, P. and Pharisat, A. (2000) Réactivation du Craton ouest-Africain au Panafricain: paléocontraintes déduites de la fracturation des grès néoprotérozoïques de Karey Gorou (Niger, Afrique de l'Ouest). *Comptes Rendus de l'Académie des Sciences Paris, Sciences de la Terre et des planètes/Earth and Planetary Sciences*, **331**, 609-614. https://doi.org/10.1016/S1251-8050(00)01445-2

[13] Bessoles, B. (1977) Géologie de l'Afrique: Le Craton Ouest Africain. Mém. BRGM, 88, 402 p.

[14] Ousmane, H., Dia Hantchi, K., Boubacar Hamidou, L., Abdou Ali, I. and Konaté, M. (2020) Caractérisation de la déformation des dépôts oligocènes du Continental terminal 3 (Ct3) dans la région de Niamey (Bordure Orientale du Craton Ouest Africain, Bassin des Iullemmeden). *ESJ Natural/Life/Medical Sciences*, **16**, 418. https://doi.org/10.19044/esj.2020.v16n15p418

[15] Soumaila, A. (2000) Etude structurale, pétrographique et géochimique de la ceinture de Diagorou-Darbani, Liptako, Niger Occidental (Afrique de l'Ouest). Thèse de Doctorat,, Université de Franche-Comté, Besançon, 203 p.

[16] Soumaila, A. and Konaté, M. (2005) Caractérisation de la déformation dans la ceinture birimienne (paléoprotérozoïque) de Diagorou-Darbani (Liptako nigérien,

Afrique de l'Ouest). *African Geographical Review*, **13**, 161-178.

[17] Soumaila, A. and Garba, Z. (2006) Le métamorphisme des formations de la ceinture de roches vertes birimienne (paléoprotérozoique) de Diagorou-Darbani (Liptako, Niger, Afrique de l'Ouest). *Africa Geoscience Review*, **13**, 107-128.

[18] Soumaila, A., Henry, P., Garba, Z. and Rossi, M. (2008) REE Patterns, Nd-Sm and U-Pb Ages of the Metamorphic Rocks of the Diagorou-Darbani Greenstone Belt (Liptako, SW Niger): Implication for Birimian (Paleoproterozoic) Crustal Genesis. *Geological Society*, *London*, *Special Publications*, **297**, 19-32. https://doi.org/10.1144/SP297.2

[19] Hallarou, M.M., Konaté, M., Olatunji, A.S., Ahmed, Y., Ajayi, F.F. and Abdul, R.M. (2020) Re-Os Ages for the Kourki Porphyry Cu-Mo Deposits, North West Niger (West Africa): Geodynamic Implications. *European Journal of Environment and Earth Sciences*, **1**, 1-13. https://doi.org/10.24018/ejgeo.2020.1.4.43

[20] Mallam Mamane, H. (2021) Contexte de mise en place des minéralisations en cuivre et molybdène des formations birimiennes de la région de Kourki (Liptako, Ouest Niger): Genèse et évolution magmatique. Thèse de l'Université Abdou Moumouni de Niamey, Niamey, 162 p.

[21] Garba Saley, H. (2022) Contextede mise en place des minéralisations en chrome et en cuivre des formations birimiennes de la région de Makalondi (Liptako, Ouest Niger): Implication géodynamique. Thèse de Doctorat, Université Abdou Moumouni, Niamey, 171 p.

[22] Dupuis, D., Pons, J. and Prost, A.E. (1991) Mise en place de plutons et caractérisation de la déformation birimienne au Niger occidental. *Comptes Rendus de l'Académie des Sciences Paris*, **312**, 769-776.

[23] Ama-Salah, I., Liegeois, J.P. and Pouclet, A. (1996) Évolution d'un arc insulaire océanique birimien précoce au Liptako nigérien (Sirba): Géologie, géochronologie et géochimie. *Journal of African Sciences*, **22**, 235-254. https://doi.org/10.1016/0899-5362(96)00016-4

[24] Abdou, A., Bonnot, H., Bory Kadey, D., Chalamet, D., Saint Martin, M. and Younfa, I. (1998) Notice explicative des cartes géologiques du iptako à 1/100 000 et 1/200 000. Ministère des Mines et de la géologie, Rép. Niger, 64 p.

[25] Garba Saley, H., Konaté, M., Ahmed, Y. and Soumaïla, A. (2017) Les minéralisations de manganèse du Nord Téra (Liptako, Ouest Niger): Origine et conditions de mise en place. *Revue RAMReS*, **5**, 18-28.

[26] Greigert, J. (1966) Description des formations Crétacées et Tertiaires du basin des Iullemmeden (Afrique occidentale). Pub. Direct. Min. et Géol. Niger n° 2. Mem. BRGM. n° 32, 234 p.

[27] Hamza Mayaki, I., Souley, H. and Konaté, M. (2017) Caractéristiques géologiques et géotechniques de deux géomatériaux exploités en carrière dans la région de Niamey: Les grès oolithiques ferrugineux et les granitoïdes birimiens. *Journal des Sciences*, 7-26.

[28] Ousmane, H. (2022) Environnements de dépôt de la formation du Continental terminal (Ct^3) de la région de Niamey et déformations associées. Thèse de Doctorat, Université Abdou Moumouni, Niamey, 182 p.

[29] Beauvais, A., Ruffet, G., Henocque, O. and Colin, F. (2008) Chemical and Physical Erosion Rhythms of the West African Cenozoic Morphogenesis: The 39Ar-40Ar Dating of Supergene K-Mn Oxides. *Journal of Géophysical Research*, **113**, F04007. https://doi.org/10.1029/2008JF000996

[30] Dubois, D. (1979) Etude des formations ferrugineuses du bassin des Iullemmeden (Niger). Thèse de Doctorat, Université d'Orléans, Niamey, 123 p.

[31] Bruguier, O. (2009) Géochronologie U-Pb par ablation laser et ICP-MS (LA-ICP-MS): Principes, Complexités et Perspectives. Mém. Bureau de Recherches, Université de Montpellier II, Montpellier, 150 p.

[32] Didier, A. (2013) Comportement géochimique du chronomètre U-Th-Pb dans la monazite: Approche par analyses in-situ au LA-ICP-MS. Thèse, Université Blaise Pascal, Clermont-Ferrand, 346 p.

[33] Gärtner, A., Linnemann, U., Sagawe, A., Hofmann, M., Ullrich, B. and Kleber, A. (2013) Morphology of Zircon Crystal Grains in Sediments—Characteristics, Classifications, Definitions Morphologie von Zirkonen in Sedimenten—Merkmale, Klassifikationen, Definitionen. *Journal of Central European Geology*, **59**, 65-73.

[34] Murawsky, H. and Meyer, W. (2010) Geologisches Wörterbuch. Heidelberg (Spektrum).

[35] Bossière, G., Bonkoungou, I., Peucat, J.J. and Pupin, J.P. (1996) Origin and Age of Palaeoproterozoic Conglomerates and Sandstones of the Tarkwaian Group in Burkina Faso, West Africa. *Precambrian Research*, **80**, 153-172. https://doi.org/10.1016/S0301-9268(96)00014-9

[36] Hirdes, W. and Davis, D.W. (2002) U/Pb Geochronology of Paleoproterozoic Rocks in the Southern Part of the Kedougou-Kéniéba Inlier, Senegal, West Africa: Evidence for Diachronous Accretionary Development of the Eburnean Province. *Precambrian Research*, **118**, 83-99. https://doi.org/10.1016/S0301-9268(02)00080-3

[37] Pereira, M.F., Ribeiro, C., Gama, C., Drost, K., Chichorro, M., Vilallonga, F., Hofmann, M. and Linnemann, U. (2017) Provenance of Upper Triassic Sandstone, Southwest Iberia (Alentejo and Algarve Basins): Tracing Variability in the Sources. *International Journal of Earth Sciences*, **106**, 43-57. https://doi.org/10.1007/s00531-016-1295-2

[38] Gärtner, A., Youbi, N., Villeneuve, M., Linnemann, U., Sagawe, A., Hofmann, M., Zieger, J., Mahmoudi, A. and Boumehdi, M.A. (2018) Provenance of Detrital Zircon from Siliciclastic Rocks of the Sebkha Gezmayet, Unit of the Adrar Souttouf Massif (Moroccan Sahara)—Paleogeographic Implications. *Comptes Rendus Geoscience*, **350**, 255-266. https://doi.org/10.1016/j.crte.2018.06.004

[39] Pupin, J.-P. (1980) Zircon and Granite Petrology. *Contributions to Mineralogy and Petrology*, **73**, 207-220. https://doi.org/10.1007/BF00381441