SCIENCE FORUM (JOURNAL OF PURE AND APPLIED SCIENCES) 21 (2021) 606 – 612

http://dx.doi.org/10.5455/sf.140804

Science Forum (Journal of Pure and Applied Sciences)

journal homepage: www.atbuscienceforum.com

Geochemistry and geotechnical characterization of some clay deposits within Bima Sandstone from Girei and Environs Yola sub-basin, Upper Benue Trough, Northeastern Nigeria

Yunis Boga Valdon, Finthan Boniface*, Stephen John Kwagga

Department of Geology, Faculty of Physical Sciences, Modibbo Adama University Yola, Yola, Nigeria

ABSTRACT

This paper presents the geochemistry and geotechnical properties of some clays deposited within sandstones of the Bima Formation in Girei and Environs. The aim is to understand their economic potentials for the national development. The study area falls within latitudes 9°20' N to 9°25' N and Longitudes 12°30' E to 12°34' E with aerial extent of about 60 km2. Field work was carried out systematically in the study area whereby clay samples within the Bima Sandstone were collected for the purpose of laboratory analysis. The X-ray fluorescence and geotechnical analysis carried out on the samples showed the average concentration of silica to be 69.55%, while iron oxide (4.5%) and low water absorption, low plasticity index, respectively. The concentration of the oxides suggests that the clays from the study area are unsuitable for refractory fired clays and production of high-grade ceramic materials; however, they can be used for burnt bricks and traditional ceramics production.

ARTICLE INFO

Article history:
Received 06 December 2021
Received in revised form
20 December 2021
Accepted 20 December 2021
Published 28 December 2021
Available online 28 December 2021

KEYWORDS

Clay
Geochemistry
Geotechnical
Ceramics and Bima Sandstone

1. Introduction

Bima Sandstone unconformably overlies the Precambrian basement complex (Carter et al., 1963), extensive and most exposed amongst the sedimentary successions in the Upper Benue Trough. Claystone is one of the facies units that this formation is composed of Carter et al. (1963). According to Brady and Weil (2009) clay is a sedimentary rock that is 2 μm in size, "clay minerals have a wide range of particle sizes from 10's of angstroms to millimeters [An angstrom (angstrom) is a unit of measure at the scale of atoms]" (Velde, 1995). It is an alumino-silicate mineral that is associated with clay size fraction of sedimentary rock as well as some weathered rocks, and these are products of weathered granites and other silicate rocks probably in an arid to semi-arid climatic setting of the world (Velde, 1995). Claystone are largely characterized by phyllosilicate minerals which is mainly composed of trapped variable quantities of water engineered by mineral structures. The quality of any given clay is largely dependent on the content of its mineral composition (Mukherjee, 2013). Clay facies are composed of both plastic and non-plastics constituents, varieties of clays such as illite, kaolinite, montmorillonite, and vermiculite; however, other minerals like feldspars, iron oxides, micas, quartz, and hydroxides, e.g., hematite, magnetite determine non-plastic nature of any given clay deposit (Mukherjee, 2013). Ceramic materials are usually produce from both traditional single and double firing technology with aid of both plastic and non-plastics clays (Dondi, 2001). Red

* **Corresponding author** Finthan Boniface ✉ finthanboniface@gmail.com ✉ Department of Geology, Faculty of Physical Sciences, Modibbo Adama University Yola, Yola, Nigeria.

shales which are composed of illite + chlorite ± kaolinite ± smectite without carbonates, illite-chlorites clays play a vital role in ceramic factories (Dondi, 2001).

This work is aimed at providing preliminary data on the geochemistry and geotechnical analysis as well as industrial utilization of the claystone deposit within the Bima Sandstone in Girei and Environs.

2. Geologic Setting

The Benue Trough is 1,000 km long and 50 to 150 km wide. The basin is trending in NE–SW direction, infilled by continental and marine sedimentary deposits, with total thickness of 6,000 m (Abubakar, 2014). The evolution of the basin is attributed to different postulated tectonic models for mega intracontinental structure. King (1950) proposed the evolution of the Benue Trough to be attributed to rifting. The principal forces associated with the rifting episode was due to tensional movement and was supported by gravity data acquired from the basin. Grant (1971), on the other hand, proposed a drifting model of the continental plate during late Jurassic to Early Cretaceous. The third evolutionary concept of the Benue Trough has been linked to sinistral wrenching in Early Cretaceous by Benkhelil and Robineau (1989); Benkhelil (1983); Mourin et al. (1985), and Popoff (1990). The phenomenon is a process attributed to movement along a NE–SW transcurrent fault derived from the Atlantic Ocean.

The Upper Benue Trough (Fig. 1) reflects a sort of Y-shape structure bounded in the northeast by Hawal massif and to the south by Adamawa Massif. The basin is sub-divided into E–W trending Yola and N–S trending Gongola arms (Fig. 1). The Yola Arm is stratigraphically composed of continental, transitional, and marine sedimentary successions (see Fig. 2) (Carter et al., 1963).

3. Location and Methodology

The study area falls within latitude 9°17' to 9°23'N and longitude 12°29' to 12°35' E (Fig. 1). The area covers a land mass of about 122 km2. It can be accessed through Yola-Mubi trunk “A” road. Field work was carried out in order to determine the occurrence and distribution of the clay within the Bima Sandstone. Samples were taken in stratigraphic succession for the purpose of laboratory analysis. The samples were oven dried at 60°C temperature and pulverized to 100 µm. The major oxides of the claystones were analyzed through X-ray fluorescence (XRF). The geotechnical properties, such as bulk density, linear shrinkage, liquid limit, plasticity index, plastic limit, specific gravity, water content, and water absorption, were also analyzed in the Department of Civil Engineering, Federal Polytechnic Mubi.

4. Results

4.1. Composite lithostratigraphic section from Girei

The composite section of the Bima Sandstone from Girei and Environs (Fig. 3) present a local cycle of deposition that is composed of 2.2 m thick coarse to very coarse grained planar cross-bedded sandstone facies overlain by 1.8 m medium to coarse grained planar cross-bedded sandstone facies. A dark grey mudstone of 90 cm thick overlies the planar cross-bedded sandstone facies (Figs. 3 and 4), this is built up into another local cycle that is composed of coarse grained small scale trough cross-bedded sandstone facies that is associated with medium to coarse grained planar cross-bedded sandstone facies, ripple cross laminated sandstone facies and thin bed of grey mudstone that marked the end of the cycle (Plate XII b), similar repetition of such localized cycles continue toward the top as the mudstone facies depreciate and iron concretion appreciate within the amalgamated planar cross-bedded sandstone facies. The coset of this section varies between 1.3 and 3.6 m, while the foreset range from 1 to 2 cm; however, the section has total thickness of about 26 m, and it is generally fining and thinning upward.

4.2. Geochemistry

4.2.1. XRF result

The XRF analysis was carried out in Geochemistry Laboratory of Gombe State University, and the detected major oxides are presented in Table 1, clearly showing the respective concentration range and average value of the major oxide.

4.3. Geotecnical analysis

The results for the geotechnical properties such as water content, liquid limit, plastic limit, plasticity index, linear shrinkage, specific gravity, bulk density, and water absorption as analyzed in the Laboratory of Department of Civil Engineering, Federal Polytechnic Mubi, Adamawa State are presented in Table 2.

5. Discussion

5.1. Geochemical

The results from the samples analyzed show that the average concentration of silica is (69.55%), while

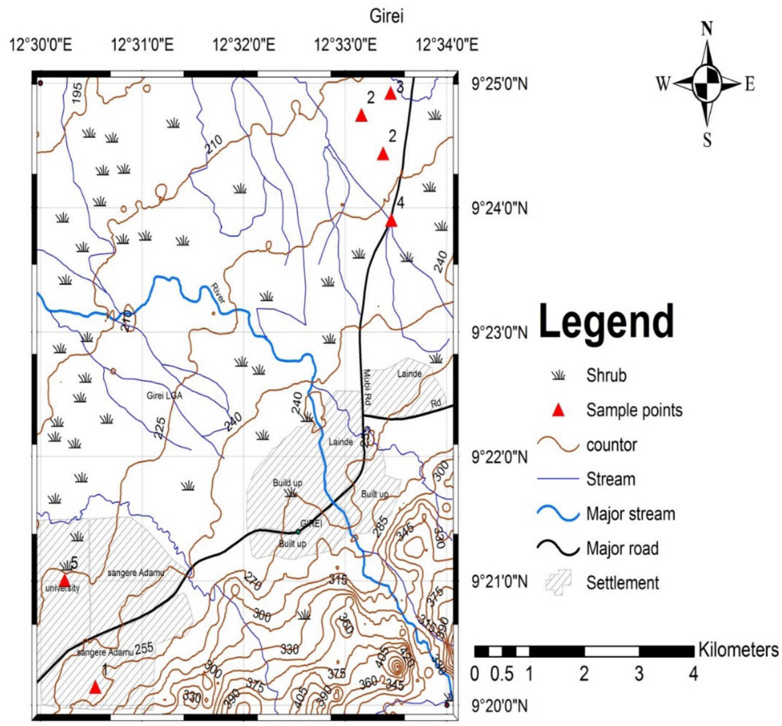

Figure 1. Topographical map of the study area (modified after GNS 2021).

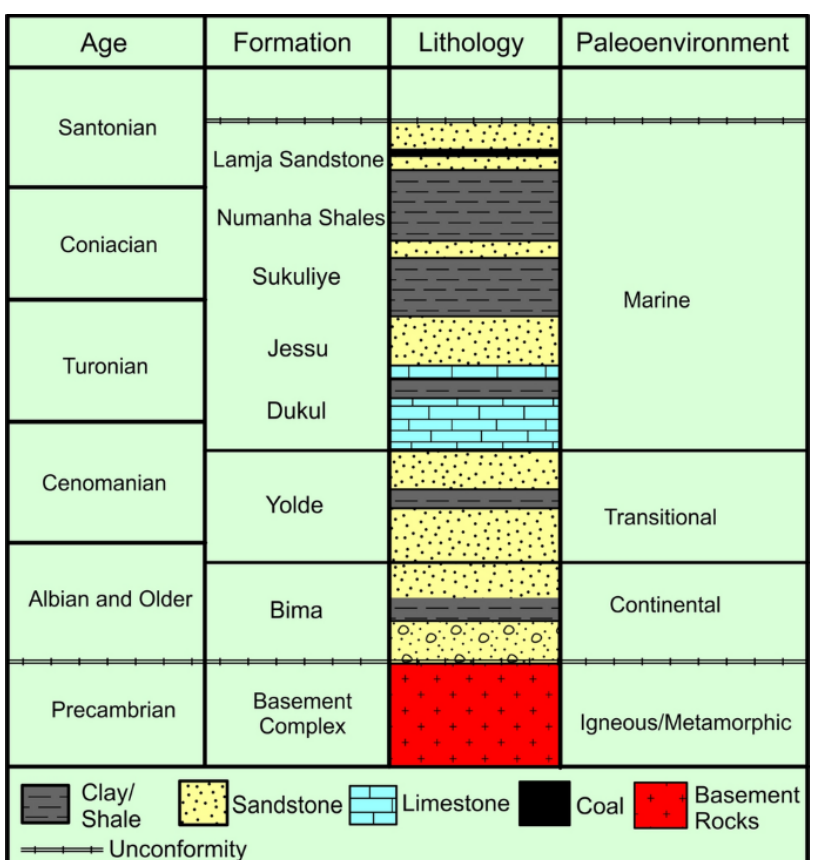

Figure 2. Stratigraphic succession of the Yola Arm of the Upper Benue Trough, (Modified after Zaborski et al., 1997).

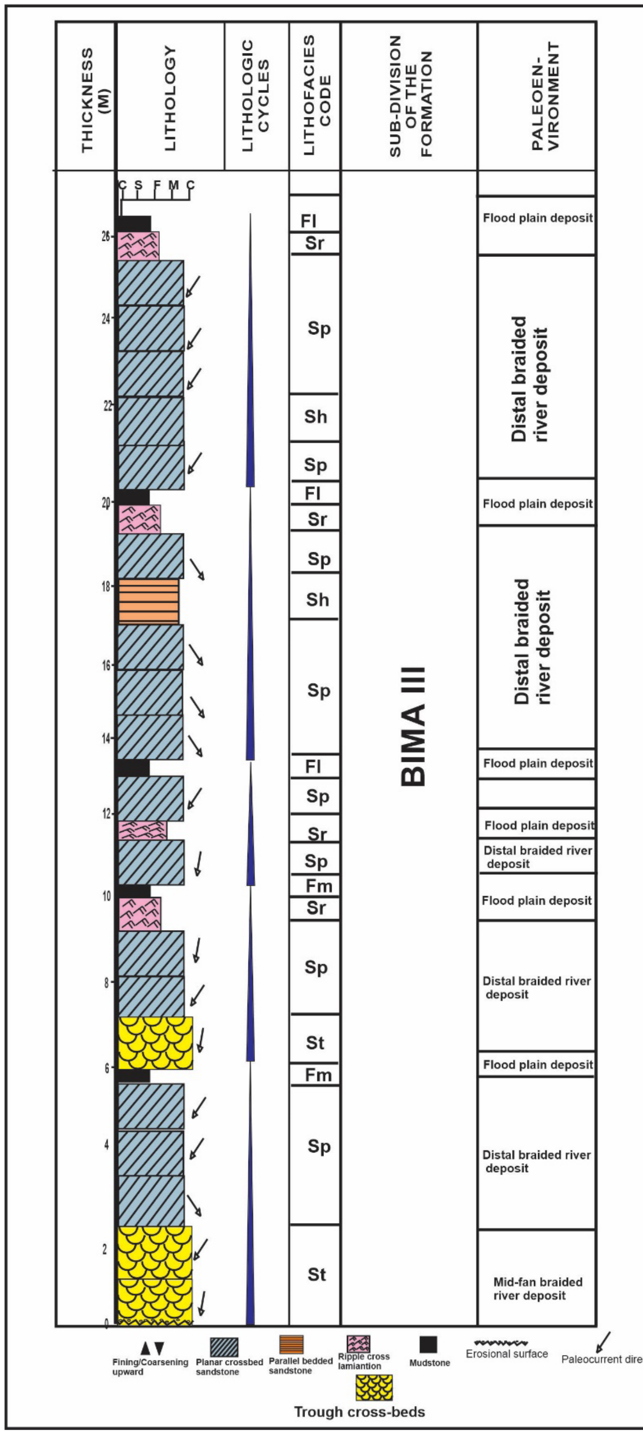

Figure 3. The composite stratigraphic section of the Bima Sandstone showing various facies within stacked braided river deposit.

iron oxide (4.5%) with low concentration of alumina (20.75%); however, other oxides such as CaO, MgO, , MnO, TiO_2, Cr_2O_3, K_2O, P_2O_5, and ZrO were detected in the studied samples (Table 2). Alkalis and Magnesia are generally known to be low in claystone. The presence of silica in the claystone suggests the reason why the clay from Girei and Environs exhibits gritty texture. The claystone from Girei and Environs have high concentration of more than 1% and low concentration of Alumina less than 30%, according to Murray (2007) such clay are poor raw materials for high grade ceramic production. However, Murray (2007) went on

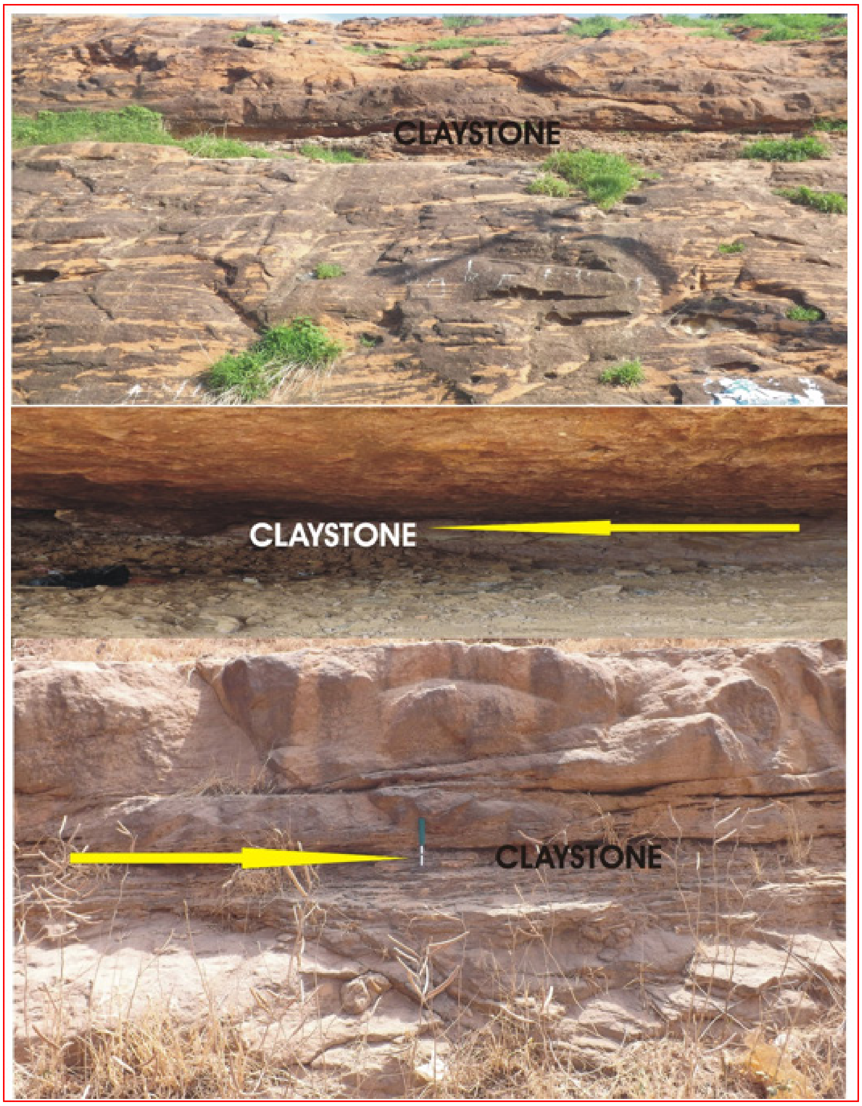

Figure 4. Representative outcrop section from the study area.

Table 1. XRF results of the claystone from the Bima Sandstone (SG1-SG6) represent sample IDs.

Elements (oxides)	SG1	SG2	SG3	SG4	SG5	S G6	Range	Average
Al_2O_3	24.8	17.5	17.9	23.9	17.4	16.7	16.7–24.8	20.75
SiO_2	66.9	70.1	70.8	65.8	73.3	70.8	65.8–73.3	69.55
Fe_2O_3	4.72	5.20	5.23	5.22	3.89	4.47	3.89–5.23	4.56
K_2O	1.23	1.69	1.64	1.44	2.65	2.96	1.23–2.96	2.095
MgO	0.394	0.851	0.854	0.66	0.293	0.795	0.293–0.854	0.5735
Na_2O	-	0.312	0.319	0.127	0.166	1.12	0.12–0.319	0.218
P_2O_5	0.079	0.0667	0.063	0.090	0.089	0.080	0.062–0.0902	0.07645
MnO	0.037	0.168	0.174	0.092	0.071	0.224	0.037–0.224	0.1305
CaO	0.394	1.28	1.37	1.12	0.429	1.53	0.394–1.53	0.967
Cr_2O_3	0.020	0.0177	0.011	0.019	0.012	0.017	0.011–0.0204	0.0158
TiO_3	1.21	1.33	1.30	1.19	1.43	1.04	1.04–1.43	1.235

Table 2. The results of the geotechnical properties for the Bima Sandstone.

Samples	Water content (%)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	Linear shrinkage (cm)	Specific gravity	Water absorption (%)
G1	9.37	30.00	20.50	9.50	8.22	2.4	0.08
G3	12.71	34.50	22.55	11.95	9.65	2.5	0.07
G5	10.62	34.0	20.50	13.50	12.0	2.5	0.08
Range	9.37–12.71	30.0–34.5	20.50–22.55	9.50–13.50	8.22–12.0	2.4–2.5	0.07–0.08
Average	11.04	32.25	21.53	11.50	10.11	2.45	0.075

to point out that such clay with 5% iron oxide concentration may be good for the production of red firing clays.

5.2. Geotechnical

The results from the geotechnical analysis show that the physical parameters, e.g., linear shrinkage, plasticity index, water contents for sample G1 are generally characterized by low water absorption. The low water absorption suggests the high concentration of silica in the claystone. The linear shrinkage values of sample G1 and G5 is 8.22% and 9.65%, respectively, and this falls within the range of the international standard value which ranges between 7% and 10% designated to alumino-silicates, kaolin, and fire clays (Zubeiru, 1997). According to Ozkan and Yalya (2015), whatever value of plasticity index below 10% is technically unsuitable for the production of ceramic materials and this is attributed to fact that the product will be highly susceptible to cracking in the course of extrusion, this criterion favors samples G3 and G5 as their plasticity index values of 11.95 and 13.8 and falls a bit high above the international set average standard value.

6. The Utilization of Clay

The chemical, mineralogical, and physical compositions are the key parameters that determines the quality and specification for clay deposits in the light of industrial application. The geochemical analysis show that the clay is composed of iron oxide with 4.5% which is higher than 1%, required concentration for the iron oxide in clay deposit, the concentration of the alumina is 20.75% and is below 30%. These values suggest that the clay deposits are unsuitable for refractory fired clays and may be bad for the production of high-grade ceramic, e.g., glossy papers, white porcelain, etc. According to Murray (2007), 5% concentration of iron oxide in clays are utilized as red firing clays. Physical properties such as plasticity index plays a vital role in ceramic production as it enhances easy workability of the clays, sample G3 and G5 have suitable values of plasticity of 11.95% and 13.50%, respectively, which indicates low content of silica and it can serve as raw material for refractory fired clays and production of high-grade ceramic. The plasticity value below 10% can result to cracking during the extrusion process (Ozkan and Yalya, 2015). The samples G1 and G2 analyzed for Linear Shrinkage have 8.22% and 9.65% fall within the internationally set standards with 7% to 10% values and this qualifies it to be suitable for fired clay (Zubeiru, 1997). Generally, the clay deposits from the study area are not suitable for the purpose of high grade standard ceramic production.

7. Conclusion

The evaluation of the clay from the study area shows that clays are not suitable for the production of high-grade ceramics material such as glossy papers and white porcelain; however, the clays can be used in the production of burnt bricks and other traditional ceramics.

Acknowledgment

The authors wish to express their gratitude to the anonymous reviewers for their constructive and valuable comments.

References

Abubakar MB. Petroleum potentials of the Nigerian Benue Trough and Anambra Basin: a regional synthesis. Nat Resour 2014; 05(01):25–58; doi:10.4236/nr.2014.51005

Benkhelil MJ. Is the Benue Trough a ridge? Bull Centre Rech Expl Prod Elf Aquataine 1983; 7:315–21.

Benkhelil J, Robineau B. Le Fossé de la Bénoué Est-il un rift? In: Benkhelil J, Guiraud M, Posard JF, Saugy L (eds.). The Bornu—Benue Trough, the Niger Delta and its offshore: tectono-sedimentary reconstruction during the cretaceous and tertiary from geophysical data and geology; In: Kogbe CA (ed.). 2nd edition, Geology of Nigeria, Rock View Nigeria Limited. Jos, Nigeria, pp 277–309, 1989.

Brady NC, Weil RR. The nature and properties of soils. 15th edition, Prentice Hall, Upper Saddle River, NJ, 2009.

Carter JD, Barber W, Tait EA, Jones GP. The geology of part of Adamawa, Bauchi and Borno Provinces in Northeastern Nigeria. Bull Geol Survey Niger, 1963; 30:109.

Dondi M. (2001) "Technological and compositional requirements of clay materials for ceramic tiles", in Domínguez E.A., Mas G.R., Cravero F. (eds) Proceedings of the 12th International Clay Conference Bahía Blanca, Argentina, July 22-28,2001, Elsevier, 23–30.

Grant NK. The south Atlantic, Benue Trough and Gulf of Guinea Cretaceous triple junction. Soc Am Bull 1971; 82:2295–98.

King, L.C., (1950), Outline land disruption of Gwanduanaland. Geol. Mag. 87:353–359.

Mourine, J.C., Benkhelil J., Robineau B., (1985), Fault rocks of the kaltungo lineament (N.E. Nigeria) and their relationships with the Benue Trough. Jour. Geol. Soc. London, 140:587–599.

Mukherjee S. (2013) "The Science of Clays - Applications in Industry", Engineering and Environment, Springer, Dordrecht, The Netherlands, p.335.

Murray HH. Applied clay mineralogy, occurrence, processing and application of Kaolin, Bentonitepalygorskite-sepiolite and common clays. Elsevier's Science & Technology Right Department in Oxford, UK, Amsterdam, Netherlands, pp 210–7, 2007.

Nigeria Geological Survey Agency. Topographic map showing the study area, Abuja FCT, Nigeria. 2021.

Ozkan I, Yalya Z. Investigation of Doğanhisar clay in floor-tile manufacture. J Aust Ceram Soc 2015; 51(1):116–9.

Popoff M. Les gres de Bima (Alba-Aptien) dans la region de Mayo Lope N.E. Nigeria. In Res. 5e Congress European de sedimentalogie, Marseille, France, pp 363–4, 1990.

Velde B. Composition and mineralogy of clay minerals. In: Velde B (ed.). Origin and mineralogy of clays, Springerverlag, New York, NY, pp 8–42, 1995.

Zaborski PM, Ugodunlunwa F, Idornigie A, Nnabo P, Ibe K. Stratigraphy and structure of the cretaceous Gongola Basin (N.E. Nigeria). Bull Centre Rech Explor Prod Elf Aquitaine 1997; 21(1):153–77.

Zubeiru SE. Investigation on refractory clays for application in Nigerian industries. BE Thesis, Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria, H102, Vol. 12, pp 14–20, 1997.