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Provenance and Paleoclimatic assessment of the shales penetrated by Erekiti borehole in the Dahomey basin, Nigeria

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Abstract

The shales from the Araromi Formation penetrated by the Erekiti borehole in the Dahomey basin were analyzed for their source area and paleo weathering conditions. Ten (10) samples were subjected to X-ray fluorescence (XRF) and X-ray diffraction (XRD) analyses. The major oxide revealed an abundance of SiO_2 and Al_2O_3 (average 32.81 wt.% and 13.11 wt.% respectively) and depletion of TiO_2, Fe_2O_3, CaO, MgO, and MnO, while the trace elements present includes an abundance of V, Cr, Zr, Sr, Zn, Ba and depletion of Sc, Co, Ni, Cu, As, Rb, Sr, Y, Nb, Mo, Pb, Th, and U. The results shows that the shales are associated to intermediate to felsic igneous origin under a very low weathering intensity. The mineralogical composition reveals quartz, gypsum, and calcite as the most abundant and the presence of other accessory minerals such as Kaolinite, K-feldspar, and plagioclase. The high percentage of quartz and gypsum confirmed the low weathering condition.

Keywords- Cretaceous, Felsic, Ise formation and Provenance

1. Introduction

Dahomey basin is one of the sedimentary basins in the continental Gulf of Guinea, extending from Southeastern Ghana through Togo to Benin Republic down to southwestern Nigeria (Figure 1). It is characterized by both inland and offshore sedimentary sequences covering from lower Cretaceous to recent and covered with about 6000m of thick siliciclastic sequence of sedimentary facies (Omatsola & Adegoke, 1981). The stratigraphic buildup of sediments in the basin happens simultaneously with the accumulation of organic matter and bio-contents, especially in marine settings (Saadu *et al*., 2022). The development of the basin included the fragmentation of the basement, faulting of blocks, and the subsidence of the Jurassic basement complex, accompanied by the lateral movement of these basement blocks due to wrenching actions.(Arthur *et al*., 2003; Darros de Matos, 2000).

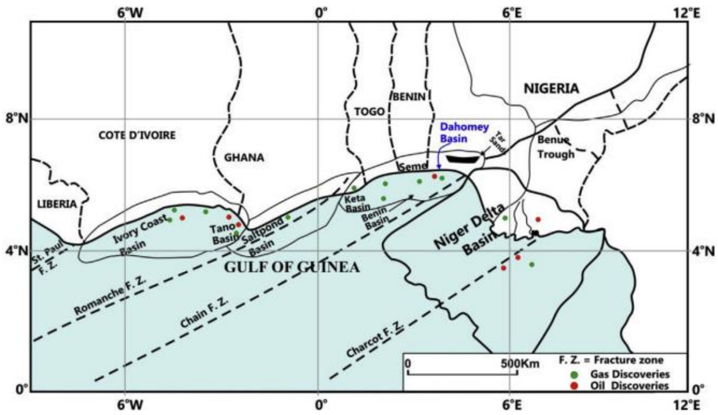

Fig. 1. Major features of the Gulf of Guinea Province, West Africa: Dahomey, Keta, Saltpond, Tano, and Ivory Coast basin from the east to the west (After (Brownfield & Charpentier, 2006)

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The detailed analysis of the geological layers in the Dahomey Basin has been extensively documented by various authors: (Idowu *et al*., 1993; Okosun, 1990; Omatsola & Adegoke, 1981). These researchers have identified and described five distinct lithostratigraphic formations spanning from the Cretaceous to the Tertiary periods. These formations, listed from oldest to youngest, consist of the Abeokuta Group, which comprises the Ise, Afowo, and Araromi formations (Cretaceous), followed by the Ewekoro Formation (Paleocene), the Akimbo Formation (Late Paleocene-Early Eocene), the Oshosun Formation (Eocene), and finally, the Ilaro Formation (Middle-Late Eocene). Previous authors like, (Adekeye *et al*., 2019) reported that the Campanian Araromi shale is immature in terms of organic matter for the generation of hydrocarbon. However, the palaeotectonic and provenance using geochemical proxies has not been well represented for the Campanian- Maastrichtian Araromi shale.

In view of this, the present research aimed at using geochemical proxies such as major oxide and trace elements to determine the palaeotectonic settings and provenance of the shales of the Araromi formation that was penetrated by Erekiti well. Analysing the composition of major oxides and trace elements in geological samples serves as valuable means in exploration activities. These assessments aid in understanding the past environments, palaeotectonic settings, origins, diagenesis, redox conditions, and climatic patterns of sedimentary rock formations (Vine & Tourtelot, 1970). Also, the presence and quantity of trace elements and oxides in sediments are influenced by various factors such as the rate of sedimentation, the influx of terrestrial and biogenic materials, input from hydrothermal sources, diagenetic processes, and, ultimately, weathering processes. These factors collectively regulate the relative abundance of these elements within sedimentary deposits. (Leventhal, 1998). Combination of TiO_2 with trace elements such as Y, Th, Zr, Cr and Sc are effective for unravelling the tectonic setting and provenance of clastic sediments because of their low mobility during sedimentation (Mclennan, 1993). Research conducted earlier has indicated that sedimentary rocks originating predominantly from Precambrian terrains might exhibit variations owing to disparities in their parent materials.(Armstrong-Altirin & Verma, 2005). Additionally, it pointed out by (Karadag, 2014) that various tectonic settings display unique provenance characteristics, which are distinguished by the physicochemical indicators derived from sedimentary processes.

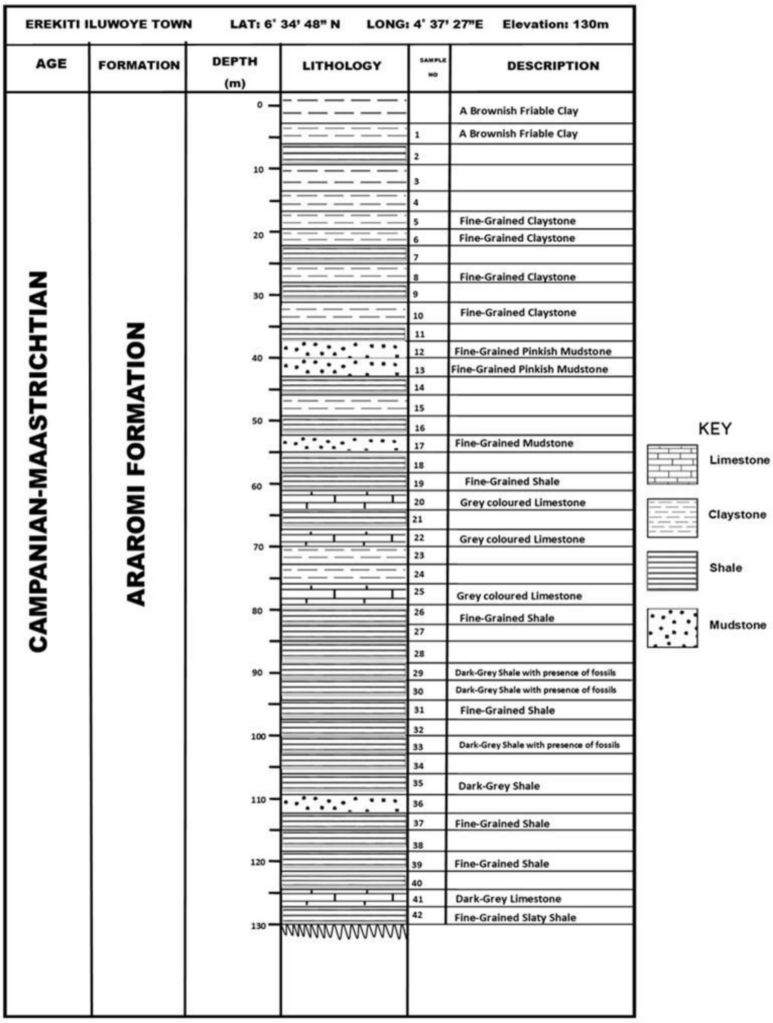

Fig 2: Lithostratigraphic section of Erekiti Borehole, Dahomey basin.

2. Methods and Materials of Study

The studied borehole is located in Erekiti, Luwoye town in Okitipupa area of Ondo state Nigeria, within longitude 4°37'27" and latitude 6°34'48". The Samples were collected from Nigeria's bitumen development project, Akure. The samples were identified, and the borehole was logged according to their depth. The borehole reached a total depth of about 130m with four different lithologies, including shale, mudstone, claystone, and limestone lithologies. The composite lithologic section is presented and described in Figure 2. Ten (10) selected shale samples were pulverized and analyzed for their Elemental and mineralogical composition through X-ray refraction spectrometry (XRF), and X-ray diffraction analysis (XRD), respectively. For the major oxides, all analyses were conducted on a fused bead, while the analysis for Na_2O was performed on a pressed pellet. The WD-XRF utilized in this process is a Rigaku-Primus IV equipped with a Rh tube, operated using ZXS software. The samples underwent milling using an iron mill. To ascertain loss on ignition (LOI), the samples were heated to 950°C, and for the trace elements, the sample was were milled with in an iron mill. A pressed pellet was made using Hoechst wax. The WD-XRF is a Rigaku-Primus IV, with a Rh tube; software for this machine is ZXS. The obtained results are quantitative in nature. XRD analysis was conducted utilizing a Panalytical Empyrean instrument equipped with a Cu-anode X-ray tube. Interpretation of the data was facilitated by employing Highscore in conjunction with the ICDD-PDF2 2021 database.

3. Result and Discussion

Provenance

Geochemical data is essential and useful in provenance study because major oxides and trace elements are pathfinders to the product of weathering. Table 1 shows the major oxides and trace element concentrations obtained from shale samples of Araromi formation, penetrated by the Erekiti borehole. The Erekiti borehole shale exhibits a higher concentration of SiO_2 but lower levels of CaO, K_2O, P_2O_5, MgO, and TiO_2. According to (Hayashi *et al*., 1997) , sediments with an Al_2O_3/TiO_2 ratio of 3 to 8 are mafic igneous rock, while 8 to 21 is intermediate rock, while 21 to 70 is felsic igneous rock. The Al_2O_3/TiO_2 values of Erekiti shale samples range from 18 to 40, indicating that the source rock ranges from intermediate to felsic igneous rock origin. This was supported by the bivariate plot of Cr/V against Y/Ni after (Floyd *et al*., 1991)and, TiO_2 against Al_2O_3 after (Amajor, 1987) (Fig 3 A & B), which shows that the coordinates of Erekiti-Luwoye borehole falls within the intermediate origin and Granite and Granite+Basalt respectively. Also, the plot of Na_2O_3-K_2O which shows that the Erekiti shale sample is quartz–rich (Fig 4A), indicating that they are of felsic origin. The discriminant function diagram suggests an intermediate to felsic origin for these sediments. (Fig 4 B).

Table 1: Major (wt%) and Trace (ppm) elements concentrations of shale samples of Erekiti borehole

SN	**ER23**	**ER24**	**ER25**	**ER28**	**ER30**	**ER32**	**ER35**	**ER38**	**ER40**	**ER42**	**Average**	**UCC**
SiO2	44.67	38.55	41.33	13.85	14.19	14.96	34.28	30.84	45.91	49.56	32.81	65.89
TiO2	0.93	0.83	1.01	0.25	0.17	0.22	0.60	0.55	0.71	0.68	0.60	0.5
Al2O3	18.27	15.24	17.44	5.77	6.95	5.78	10.80	12.54	19.26	19.03	13.11	15.17
Fe2O3	8.26	6.16	7.34	4.95	3.23	2.28	4.57	5.57	7.15	6.24	5.58	5
MgO	2.30	2.74	1.98	12.21	1.04	0.51	0.58	0.54	2.48	1.25	2.56	2.2
MnO	0.04	0.06	0.02	0.08	0.01	0.03	0.02	0.02	0.02	0.03	0.03	0.07
CaO	6.81	12.46	6.84	25.61	40.19	41.07	24.49	22.78	4.58	5.84	19.07	4.19
Na2O	0.04	0.06	0.03	0.02	0.03	0.04	0.04	0.07	0.04	0.06	0.04	3.9
K2O	1.34	1.05	1.15	0.39	0.53	0.46	0.66	0.60	2.11	1.78	1.01	3.39
P2O5	0.54	4.34	0.13	0.06	1.91	0.58	1.10	5.64	0.28	0.62	1.52	-
LOI	18.45	19.90	22.49	37.03	31.58	32.73	23.09	19.17	17.99	16.22	23.87	-
Sc	17	20	17	1.5	1.5	1.5	11	12	18	17	11.65	13.6
~~V~~	~~218~~	~~142~~	~~174~~	~~53~~	~~59~~	~~34~~	~~70~~	~~78~~	~~179~~	~~174~~	~~118.10~~	~~107~~
Cr	107	93	117	71	132	130	185	203	130	139	130.70	85
Co	31	21	28	4	1	1	2	6	28	24	14.60	17
Ni	55	60	48	22	33	21	41	63	56	51	45.00	20
Cu	11	13	12	1	4	3	10	16	18	11	9.90	25
Zn	108	113	122	45	110	69	126	255	148	135	123.10	71
As	18	19	27	6	77	21	20	28	12	20	24.80	
Rb	75	58	65	21	22	24	33	24	130	88	54.00	112.2
Sr	272	465	290	308	363	329	437	722	198	303	368.70	350
Y	34	235	19	11	38	20	34	126	26	29	57.20	22
Zr	238	147	193	72	55	74	235	150	161	145	147.00	190
Nb	31	27	23	8	3	6	12	12	12	16	15.00	12
Mo	5	0.5	21	3	15	7	12	0.5	14	4	8.20	1.5
Ba	154	174	157	54	32	52	85	128	176	168	118.00	550
Pb	2	2	2	2	2	2	2	2	4	7	2.70	17
Th	16	13	17	8	25	12	15	31	11	15	16.30	10.7
U	2	3	2	0	27	3	6	15	4	3	6.50	2.8

UCC: Upper Continental Crust (Taylor & Mclennan, 1985)

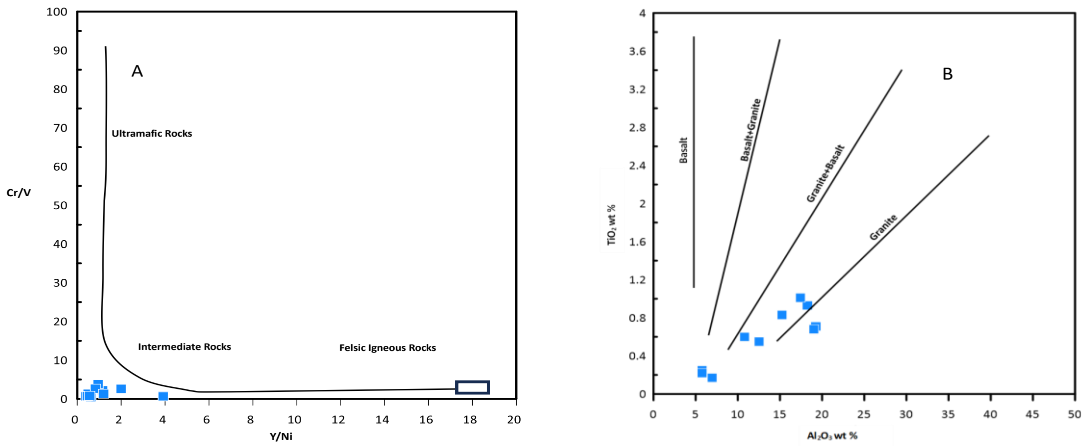

Fig 3. Bivariate provenance plots (a)Plot of Cr/V against Y/Ni after Floyd *et al*. (1990) (b) TiO2 wt % against Al2O3 wt % binary plot of Araromi shale after Amajor, 1987

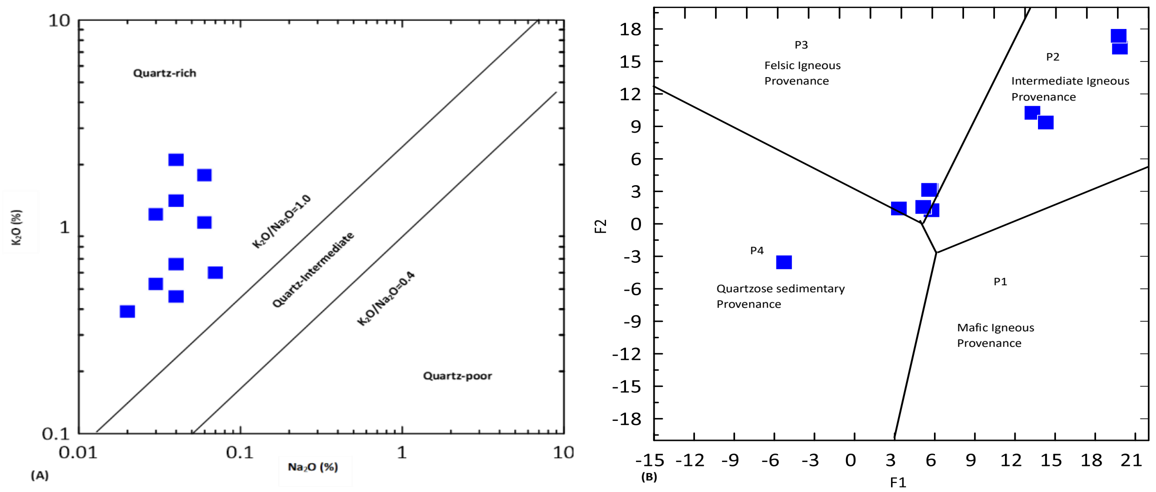

Fig 4: (A) Bivariate plot of Na2O versus K2O of studied sediments showing quartz content (after crook, 1974) (B) Discriminant function diagram using major elements for provenance. (after Roser & Korsch, 1988).

The XRD analysis revealed minerals like Quartz, Gypsum, calcite and Kaolinite in moderate proportions and a minor occurrence of K-feldspar and plagioclase. (Table 2) This result indicates that the shale sediments are moderate to felsic igneous in origin.

Table 2: Relative Abundance of the mineral phases (%) as determined by XRD Analysis

Sample No	Quartz	Gypsum	Smectite	Calcite	Kaolinite	Mica	Plagioclase	Ankerite	Anatase	Jarosite	Pyrite	Apatite	Sphalerite	Kfeldspar
ER23	12	28	25	10	15	10								
ER24	9	28	22	8	10	8	4	11						
ER25	7	40	18		15	8			6	6				
ER28	7	10	14	6	10			53						
ER30	12	12		58	10						4	4		
ER32	10	12		62	6	6							4	
ER35	37	10		22	9	12					4			6
ER38	22	25		24	16						5	8		
ER40	41	28	5		18	4		4						
ER42	29	31	8	6	19						7			

Paleoclimate and Weathering

The assessment of the extent of chemical weathering or alteration in sediment source rocks could be accomplished by computing the Chemical Index of Alteration (CIA) (Nesbitt & Young, 1982). This can be derived by calculating the Chemical Index of Alteration (CIA), where CIA = molar (Al_2O_3/ [Al_2O_3+CaO+Na_2O+K_2O]). The CIA values for the studied Erekiti shale samples range between 12 % and 74%, and the average is 45%. This value reflects cool or arid conditions for these sediments. (Fedo *et al*., 1995). It suggests these sediments have not undergone a high degree of weathering in their cycle. The Th/U ratio was also used by (Gu *et al*., 2002) to evaluate the weathering history due to the oxidation and loss of uranium during the weathering process. Most of the plots of Erekiti shale samples show a wide trend within the upper crust (fig 3A) suggesting that the sediments are have not undergone so much weathering after deposition. A bivariate plot of SiO_2 Vs Al_2O_3+K_2O+Na_2O after (Suttner & Dutta, 1986) also suggests semi-arid to arid conditions for the shale understudy. The Result of XRD analysis showed a low percentage of K-feldspar and Plagioclase (Table 2) which indicates that the sample under study has partially undergone low weathering.

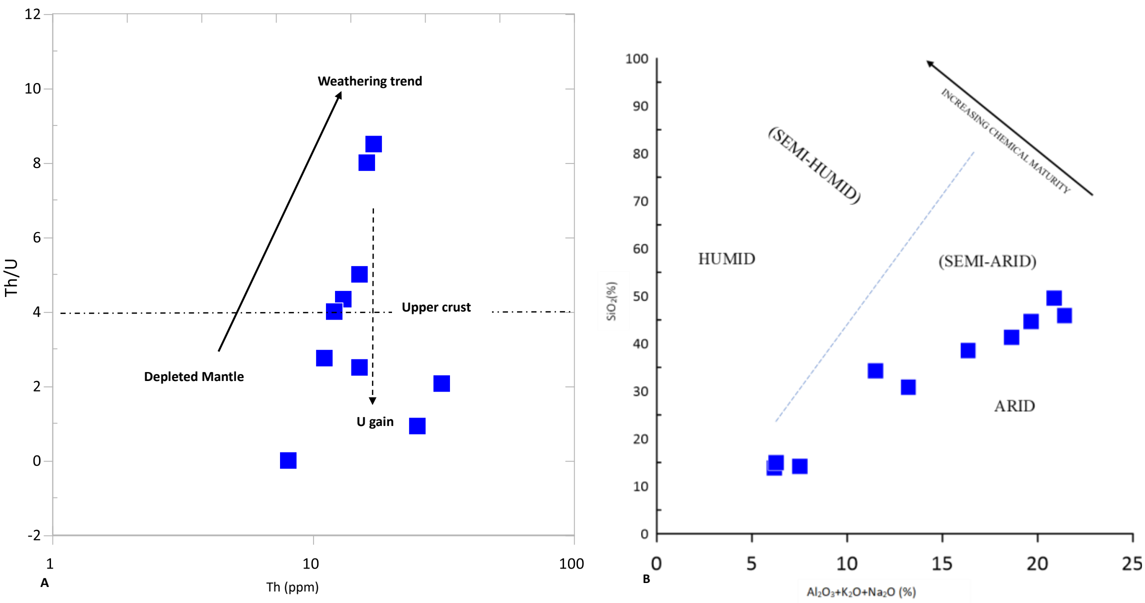

Fig 5: (A)Th/U Vs U plot of Erekiti Shale (after Gu *et al*. 2002) (B) Bivariate plot of SiO_2 Vs Al_2O_3+K_2O+Na_2O showing paleoclimatic condition of Erekiti shale samples (after Suttner & Dutta, 1986)

4. Conclusion

The origin of the shales of Erekiti borehole studied suggests that the shales were derived from range of environment from intermediate to felsic igneous origin with quartz-rich under a semi-arid to arid climatic condition with low weathering.

References

Adekeye, O. A., Akande, S. O., & Adeoye, J. A. (2019). The assessment of potential source rocks of Maastrichtian Araromi formation in Araromi and Gbekebo wells Dahomey Basin, southwestern Nigeria. Heliyon, 5(5). https://doi.org/10.1016/j.heliyon.2019.e01561

Amajor, L. C. (1987). Major and Trace element geochemistry of Albian and Turonian shales from the Southern Benue Trough Nigeria. Jour.Africa Earth Sci, 6, 633–641.

Armstrong-Altirin, J. S., & Verma, S. P. (2005). Critical evaluation of six tectonic setting discrimination diagrams using geochemistry data of Neogene sediments from known tectonic setting. Sedimentary Geology, 177, 115–129.

Arthur, T. J., Macgregor, D. S., & Cameron, N. R. (2003). Petroleum Geology of Africa- New themes and developing technologies. Geological Society London. Special Publication, 207–209.

Brownfield, M. E., & Charpentier, R. R. (2006). Geology and Total Petroleum Systems of the Gulf of Guinea Province of West Africa. U.S Geological Survey Bulletin 2207-C, 32.

Darros de Matos, R. M. (2000). Tectonic evolution of the equatorial South Atlantic (pp. 331–354). https://doi.org/10.1029/GM115p0331

Fedo, C. M., Nesbitt, H. W., & Young, G. M. (1995). "Unravelling the effects of potassium metasomatism in sedimentary rocks and paleosols, with implications for paleo weathering conditions and provenance." Geology, 23, 921–924.

Floyd, P. A., Shail, R., Leveridge, B. E., & Franke, W. (1991). Geochemistry and provenance of Rhenohercynian synorogenic sandstones: implications for tectonic environment discrimination. Geological Society, London, Special Publications, 57(1), 173–188. https://doi.org/10.1144/GSL.SP.1991.057.01.14

Gu, X. X., Liu, J. M., Zheng, M. H., Tang, J. X., & Qi, L. (2002). Provenance and tectonic setting of the Proterozoic turbidites in Hunan, South China: geochemical evidence. J. Sediment. Res. 72(3), 393–407.

Hayashi, K., Fujisawa, H., Holland, H., & Ohmoto, H. (1997). Geochemistry of 1.9 Ga sedimentary rocks from northeastern Labrador, Canada: Geochimica et Cosmochimica, 61(19), 4115–4137.

Idowu, J. O., Ajiboye, S. A., Ilesanmi, M. A., & Tanimola, A. (1993). Origin and significance of organic matter of Oshosun Formation, southwestern Dahomey basin, Nigeria. Journal of Mining and Geology, 29(1), 9–17.

Karadag, M. M. (2014). Geochemistry, provenance, and tectonic setting of the Late Cambrian–Early Ordovician Seydisehir Formation in the Caltepe and Fele areas, SE Turkey. Chemie Der Erde, 74, 205–224.

Leventhal, J. S. (1998). Metal-rich black shales: formation, economic geology, and environmental considerations. In Shales and Mudstones II, J. Schieber, W. Zimmerle, and P. Sethi, (Eds.), Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung. 255-282.

Mclennan, S. M. (1993). Weathering and global denudation. J. Geol, 101(2), 295–303.

Nesbitt, H. W., & Young, G. M. (1982). Early Proterozoic climates and plate motions inferred from major element chemistry of lutites. Nature, 299, 715–717.

Okosun, E. A. (1990). A review of the Cretaceous stratigraphy of the Dahomey Embayment, West Africa. Cretaceous Research, 11(1), 17–27. https://doi.org/10.1016/S0195-6671(05)80040-0

Omatsola, M. E., & Adegoke, O. S. (1981). Tectonic Evolution and Cretaceous stratigraphy of the Dahomey Basin. Journal of Mining and Geology1, 18, 130–137.

Saadu, M. B., Jimoh, A. Y., Adekeye, O. A., & Issa, T. A. (2022). Biostratigraphy and Palaeoecological Studies of the Late Cretaceous-Tertiary Sediments in the Dahomey Basin, Nigeria. European Journal of Environment and Earth Sciences, 3(4), 41–47. https://doi.org/10.24018/ejgeo.2022.3.4.274

Suttner, L. J., & Dutta, P. K. (1986). Alluvial sandstone composition and paleoclimate. I. Framework mineralogy. Journal of Sedimentary Petrology, 56, 329–345.

Taylor, S. R., & Mclennan, S. (1985). The Continental Crust: Its Composition and Evolution. Blackwell, Oxford.

Vine, J. D., & Tourtelot, E. B. (1970). Geochemistry of black shales. A summary report. Econ. Geol. 65, 253–273.