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Trace Elements and Major Oxides Characteristic of the Geochemistry of Ajali Sandstone, South West, Anambra Basin, Nigeria

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ABSTRACT

The study aimed at characterizing the geochemical compositions of the Maastritchtian sandstones of Ajali formation, Anambra Basin, in Fugar, Ayoguri, Auchi and Uzebba area of Edo State Nigeria. X-Ray Fluorescence (XRF) and Induced Coupled Plasma-Mass Spectrometry (ICP-MS) analyses were used to determine the sandstone composition. A total of 51 samples were collected at an interval of 0.6 m in 5 different locations within the Ajali formation in the Benin flank. The geochemistry of the major oxides revealed that SiO_2 averaged 98.24%, Al_2O_3 averaged 0.79%, Fe_2O_3 averaged 0.47% and TiO_2 averaged 0.31%. The Maastritchtian sandstones are rich in SiO_2 but are depleted in all other major elements. The observed depletion in Al_2O_3, Fe_2O_3 and TiO_2 is not only likely due to quartz dilution but also indicates that the studied sediments have suffered from intense weathering and recycling. Generally, low concentrations of Fe_2O_3 and TiO_2 in all sandstones reflect low abundances of Ti-bearing minerals (biotite, ilmenite, titanite and titaniferous magnetite) in the analyzed samples. The SiO_2/Al_2O_3 ratio averaged 180.24. This high value indicates mineralogical mature sediments. The mean Al_2O_3/TiO_2 ratio of 3.25, indicates that the sediments were likely sourced from igneous rocks. The concentrations of chromium (Cr), which averages 142 mg/L and the low concentration of iron (Fe) at 15.90 mg/L both confirm a felsic source.

1. INTRODUCTION

The use of geochemical composition of siliciclastic sedimentary rocks is a vital tool to assessing the nature of source rocks (Ajayi *et al.*, 2006; Ma, *et al.*, 2012; Li, *et al.,* 2016), weathering and erosion dynamics, the tectonic setting of the depositional basins (Ge, *et al.*, 2014; Ge *et al.*, 2019) and post-depositional changes (Lucas *et al.*, 2016; Ighodaro *et al.,* 2018). Utilization of geochemical data from sediments to understand such sedimentary processes is a growing trend in the literature due to the sensitive nature of some key trace elements in identifying minor components that are not easily recognized petrographically (Garver *et al.,* 1996; Gallala *et al.,* 2009; Abd El-Rahman *et al.,* 2010).

The Anambra Basin is a major inland sedimentary Basin in Nigeria. Its evolution was based on the theory of the separation of the African and South American Plates during the Middle Mesozoic period (Nwajide *et al*., 2013). The theory ascertains that the Anambra Basin contains Albian Santonian sediments in the eastern half referred to as Abakaliki depression while the other half proto-Anambra was a platform consisting of post Santonian sediments (Ejeh *et al*., 2016; Haruna *et al.,* 2019; Gao *et al*., 2020; Obi, 2000). Past research works showed that the northern and western parts of the Anambra Basin mainly consist of post Santonian sediments. However, it has been proven otherwise that the northern and the western parts of the basin in Onitsha and Edo state respectively, contain Middle Cretaceous to late tertiary sediments (Ola-Buraimo and Akaegbobi, 2012; Ola-Buraimo 2013a, 2013b; Ola-Buraimo and Akaegbobi, 2013).

In the aspect of deciphering the characteristics of the Geochemistry of the sandstone, so much has been done in the eastern part of the Ajali formation, Anambra basin (Ibe *et al*., 2010; Chiaghanam *et al.,* 2012; Odedede and Adaikpoh, 2013; Edirin and Etu –Efeotor, 2013; Gideon *et al*., 2014), but not much work has been carried out in the South – western Ajali formation. Thus, this study, focuses on using geochemical tools to ascertain the sandstone composition, provenance and ancient weathering condition which prevailed during sedimentation, South west, Ajali formation of the Anambra basin.

2. MATERIALS AND METHODS

2.1. Location of Study Area

The study area and its environs are situated in Fugar, Ayogwuiri, Auchi and Uzebba all enclosed within the Ajali formation. The area is highly accessible with major and minor roads, together with other adjoining roots. The location map (Figure 1) was generated using the GPS coordinates obtained from the field studies.

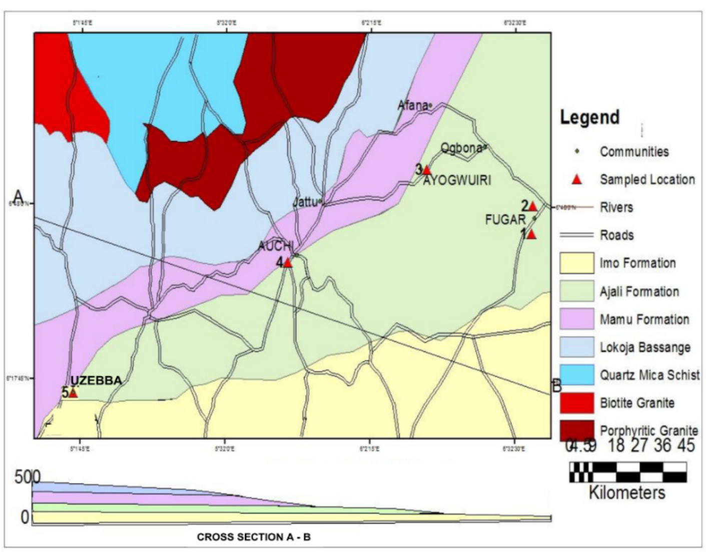

Figure 1: Geologic map of study area

2.2. Sample Collection

A total of 51 samples were collected at an interval of 0.6 m from the bottom to top of the exposure, using a sledge hammer to disaggregate the consolidated sandstone in 5 different locations (Fugar, Fugar II, Ayowuiri, Auchi and Uzebba) within the Ajali formation in the Benin flank, Anambra Basin, Edo State Nigeria.

2.3. XRF Analysis for Metallic Oxides

A total of 15 samples was analysed for XRF analysis while 19 samples was analysed for trace elements. The samples were analysed for major oxides using the fused beads techniques of XRF spectrometer by method described in Busaltic *et al*. (2009).

2.4. ICP Analysis for Trace Elements

The sample were analysed for trace elements using Philips 45 channel inductively coupled plasma (ICP) mass spectrometer by method described in Ge, *et al*., (2019). A total of 7 trace elements were analyesd (Zn, Cu, Se, Cr, Fe, Mo, Zr) from 10 samples selected at random across study location.

3. RESULTS AND DISCUSSION

The results of the geochemical analyses are presented in Tables 1 and 2.

Table 1: Major oxide components (wt%) of the Ajali Sandstone and their weathering indices

Oxides	FG2	FG7	FG16	FGB3	FGB7	FGB12	AY1	AY5	AY9	AU1	AU4	AU6	UZ1	UZ3	UZ5
Al_2O_3	0.50	0.60	0.90	1.00	0.53	0.30	0.50	0.68	3.00	0.90	0.40	0.20	1.00	0.8	0.80
Fe_2O_3	0.40	0.80	0.83	0.20	0.82	0.80	0.40	0.38	0.50	0.40	0.40	0.50	0.30	0.3	0.20
SiO_2	98.80	98.27	97.8	98.30	98.30	98.90	99.10	98.60	95.91	98.20	99.10	99.30	97.60	98.3	98.0
TiO_2	0.20	0.200	0.10	0.50	0.30	<0.10	0.20	0.20	0.40	0.30	0.10	<0.10	0.80	0.4	0.90
LOI	0.10	0.13	0.37	<0.01	0.05	<0.01	<0.01	0.14	0.91	0.20	<0.01	<0.01	0.30	0.20	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.0	100.00
$SiO_2/A1_2O_3$	197.60	163.50	108.70	98.30	196.60	329.70	198.20	164.3	31.70	109.10	248.00	497.50	97.60	122.8	140.00
Al_2O_3/TiO_2	2.50	3.00	9.00	2.00	1.70	-	2.50	3.00	7.50	3.00	4.00	-	1.25	2.00	0.80
Log SiO_2/Al_2O_3	2.30	2.21	2.04	1.99	2.29	2.52	2.30	2.22	1.50	2.40	2.40	2.70	1.99	2.09	2.15

FG, FGB, AY, AU and UZ correspond to Fugar, Fugar II, Ayogwuiri, Auchi and Uzebba respectively

Table 2: Mean of trace elements in the study locations

Sample ID	Mean metal concentration (mg/L)						
	Zn	Cu	Se	Cr	Fe	Mo	Zr
FG6	176.50	175.00	3.05	155.00	28.50	12.00	0.75
FG15	164.00	121.50	4.25	185.00	3.50	31.00	0.60
FGB6	178.00	90.00	3.00	185.00	11.50	37.6	0.75
FGB11	171.50	138.50	2.95	121.00	10.50	41.50	0.30
AY1	156.20	128.50	1.10	177.00	9.00	11.40	0.40
AY7	222.00	96.00	1.50	177.00	22.50	41.65	0.65
AU6	152.50	124.00	1.50	129.00	27.50	8.60	0.65
AU7	128.50	130.00	1.30	172.00	32.50	42.00	0.70
UZ2	162.80	118.50	1.50	161.50	10.50	11.55	1.20
UZ5	114.00	130.00	2.70	130.50	3.00	7.40	0.70
Average	162.60	125.20	2.29	141.60	15.90	24.47	0.67
Analyte Std.	213.86	324.75	196.03	357.87	213.86	313.26	360.12

Key: Zn – Zinc; Cu – Copper; Se – Selenium; Cr – Chromium; Fe – Iron; Mo – Molybdenum; Zr – Zircon

The samples were dominated by SiO_2, Al_2O_3, Fe_2O_3 and TiO_2, with percent weight composition in the range (95.91 – 99.10), (0.2 -0.9), (0.2 -0.83), and (0.1 – 0.9) respectively, (Table 1). The low concentration of Fe_2O_3, Al_2O_3 and TiO_2 could be due to chemical disintegration under oxidizing conditions during weathering and diagenesis. The Maastrichtian sandstones are enriched in SiO_2 but, are depleted in all other major elements. The observed depletion in Al_2O_3, Fe_2O_3 and TiO_2 is not only likely due to quartz dilution but also indicates that the studied sediments have been suffered from intense weathering and recycling (Joo *et al.*, 2005; Jin *et al.*, 2006). From Table 1, the aluminium oxide (Al_2O_3) concentration at Fugar is approximately the same as the sandstone at Ayogwuiri (AY), Auchi (AU) and Uzebba (UZ). The iron oxide (Fe_2O_3) and Titanium Oxide (TiO_2) concentration of the sandstone within the study location were extremely low concentration. Generally, low concentrations of Fe_2O_3 and TiO_2 in all sandstones reflect low abundances of Ti-bearing minerals (biotite, ilmenite, titanite and titaniferous magnetite) in the analyzed samples (Armstrong-Altrin *et al.,* 2004). The SiO_2/Al_2O_3 ratio from the weathering indices (Table 1) was 180.24, indicating mineralogical mature sediments. Thus, the quartz survived the weathering process in comparison to the feldspar. This is in consonance with the findings of Ilevbare and Imasuen, (2020), he opined that SiO_2/Al_2O_3 ratios of clastic rocks are sensitive to sediment recycling and weathering process and can be used as an indicator of sediment maturity. Hayashi *et al*., (1997), pointed out that Al_2O_3/TiO_2 increases from 3 to 8 for igneous – metamorphic rocks, 8-21 for intermediate rocks and 21-70 for felsic igneous rocks. The values of Al_2O_3/TiO_2 in the study were very low, an average of 3.25 (Table 1), thus it follows that sediments were likely sourced from igneous source rocks.

The seven trace elements analysed (Table 2), in the Ajali sediments are grouped as grouped as compactible and incompactible trace elements. The compactible trace elements include Zn, Cu, Cr and Iron. The remaining elements Se, Mo and Zr are incompatible. Compactibility is a term used by geochemists to describe how elements partition themselves in the solid and melt within Earth' mantle. In geochemistry it is the measure of how readily a particular trace element substitutes for a major element within a mineral. By constrast, an incompactible element is one that is least stable within its crystal structure. When an element is compactible without mentioning what rock it is, the mantle is implied (Heinnonem et al., 2020). Thus, incompactible elements are those that are enriched in continental crust and depleted in the mantle. The mean values of the compatible trace elements (Zn, Cu, Cr, Fe) were 162.2 mg/L, 125.2 mg/L, 159.3 mg/L and 15.9 mg/L respectively, with Fe having the least concentration while Zn had the highest concentration. The mean of the incompactible elements (Se, Mo, Zr) were 2.29 mg/L, 24.47 mg/L and 0.67 mg/L respectively, with Mo having the highest concentration and Zr with the least concentration.

According to Ma *et al.* (2019), Cai *et al.* (2018) and Uchida *et al.* (2017), elements such as Zr, Cr, Fe and Mo are appropriate for provenance and tectonic setting determination because of their relatively low mobility during sedimentary processes, and their short times in seawater (Ge et al., 2014). These elements are transported quantitatively into clastic sediments during weathering and transport, and hence reflect the signature of the parent material. Garver *et al.*, (1996) and Amstrong-Altrin et al. (2004) suggested that when Cr is greater than 150 mg/L and Fe greater than 100 mg/L in abundance, it is an indication of mafic or ultramafic provenance. Interestingly, Cr (142 mg/l) and Fe (15.90) have low concentrations relative to the conditions above thus, confirming a felsic source.

4. CONCLUSION

A comprehensive analysis based on geochemistry (major and trace elements) were performed on the sandstones of the Ajali formation from Anambra basin to deduce the ancient weathering conditions, source rock and provenance. The observed depletion in Al_2O_3, Fe_2O_3 and TiO_2 is not attributed to quartz dilution but indicates that the sediments have undergone intense weathering and recycling. The SiO_2/Al_2O_3 weathering indices of 180.24, indicates mineralogical mature sediments. The Al_2O_3/TiO_2 of 3.25, indicating that the sediments were likely sourced from igneous source rocks. The Cr (142 mg/L) and Fe (15.90 mg/L) concentrations are also consistent with a felsic source.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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