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Paleo Environmental Studies for Stream Sediments around Awe-Obi Area North Central Nigeria

Gajere JN[1]*, Abaa SI[2] and Kana JE[1]

[1]*Department of Natural Sciences, Nasarawa State Polytechnic, P.M. B. 109 Lafia, Nasarawa State, Nigeria*
[2]*Department of Geology and Mining, Nasarawa State University, P.M.B. 1022 Keffi, Nasarawa State, Nigeria*

Abstract

A stream's sediment load is typically deposited, eroded, and redeposited many times in a stream channel, especially during climatic variations such as flooding. During this process of deposition, erosion and redeposition the chemistry of stream sediments changes. Understanding the past environmental conditions under which these sediments have been subjected to are of great significance to geologist interested in exploring for mineral and petroleum resources. Paleo Environmental studies conducted on 17 stream sediment samples in parts of Awe-Obi area using chemical index of alteration (CIA) and chemical index of weathering (CIW) revealed that the area is intense to extremely weathered with calculated values between 67 and 99. The mineralogical index of alteration (MIA) was studied to evaluate the degree of mineralogical weathering. The calculated values revealed that Awe-Obi is intermediate, intense-extremely weathered. Index of compositional variability (ICV) was used in this study as measure of sediment maturity. The calculated ICV values showed all the samples as immature except sample SSB8 which has a value of 0.765515. Paleo-Oxygenation condition of the study area was conducted using Ni/Co ratio. This revealed that all the samples were deposited in an oxygenated condition.

Keywords: Paleo-environment; Stream sediments; Awe-Obi

Introduction

Stream sediments are composites of rock and soil material eroded upstream in a catchment area. A stream's sediment load is typically deposited, eroded, and redeposited many times in a stream channel, especially during climatic variations such as flooding. During this process of deposition, erosion and redeposition the chemistry of stream sediments changes. Understanding the past environmental conditions under which these sediments have been subjected to are of great significance to geologist interested in exploring for mineral and petroleum resources. Various geochemical proxies have been proposed to estimate the intensity of chemical weathering in continents.

Geochemical weathering proxies make use of the changes of bulk rock geochemical composition caused by chemical alteration. A very simple proxy is the Ruxton Ratio R [1] given by the SiO_2/Al_2O_3 ratio. The ratio assumes that Al_2O_3 remains immobile during weathering so that changes in R reflect silica loss as a proxy for total element loss. Although Ruxton Ratio may be useful when weathering profiles on rocks of felsic and intermediate composition are considered, it was found to be poorly correlated to the actual weathering grade of a silicate rock [2]. As in hydrolytical weathering, i.e. the transformation of feldspar to clay minerals and the coincident mobility of the main cations is a major process of chemical, Parker [3] considered it more useful to mirror changes in Na^+, K^+, Ca_2^+ and Mg_2^+ and created a weathering index (WIP, Weathering Index of Parker). Although, WIP is considered the most appropriate for application to weathering profiles on heterogeneous and homogeneous parent rock, some implicit assumptions rendered the index limited in application. The WIP implicitly assumes that all Ca_2^+ in a silicate rock is contained in silicate minerals. More problematic still is the lack of consideration of a relatively immobile reference phase like Al_2O_3 in the formula which would help to monitor relative changes of composition of the relevant mineral components. The disadvantages of the WIP are overcome in the Chemical Index of Alteration (CIA) using whole rock geochemical data of major element oxides [4]. It represents a ratio of predominantly immobile Al_2O_3 to the mobile cations Na^+, K^+ and Ca_2^+ given as oxides.

Geology

The area of study falls within the Middle Benue Trough and stratigraphically it is composed of continental and marine sediments, represented by sandstone, shale and the limestone of the Asu River Group [5,6]. The succession upward is the Awe formation which consists of transitional sandstone, shale, siltstone and limestone and the fluviatile sandstone of the Keana Formation. Major lead-zinc-baryte mineralization is associated with the mineralized hydrothermal vein that is a consequence of the tectonic rifting that led to the emplacement of the Benue Trough which was in part controlled by transcurrent fault activity [7]. These faultings are thought to have been responsible for creating pathways through which hydrothermal veins of possibly magmatic origin [8] or remobilized meteoric waters enriched in Pb, Zn and Na percolated. Two sets of fractures were recognized in the Keana Azara area, the former of which are associated with the Pb-Zn mineralization while the later was associated with the baryte mineralization [5].

Methods

A total of Seventeen (17) samples were collected in the study area (parts of Awe-Obi North-Central Nigeria) (Figure 1). The samples collected were laid out in pre-numbered evaporating dishes to dry and then placed in low temperature oven and maintained at 105°C for 12 hours. Each sample was disaggregated and homogenized by the use of agate pestle and mortar [9]. A 100 mesh screen was used. This is

***Corresponding author:** Gajere JN, Department of Natural Sciences, Nasarawa State Polytechnic, P.M. B. 109 Lafia, Nasarawa State, Nigeria, Tel: +2348052900806; E-mail: jirikog@yahoo.com

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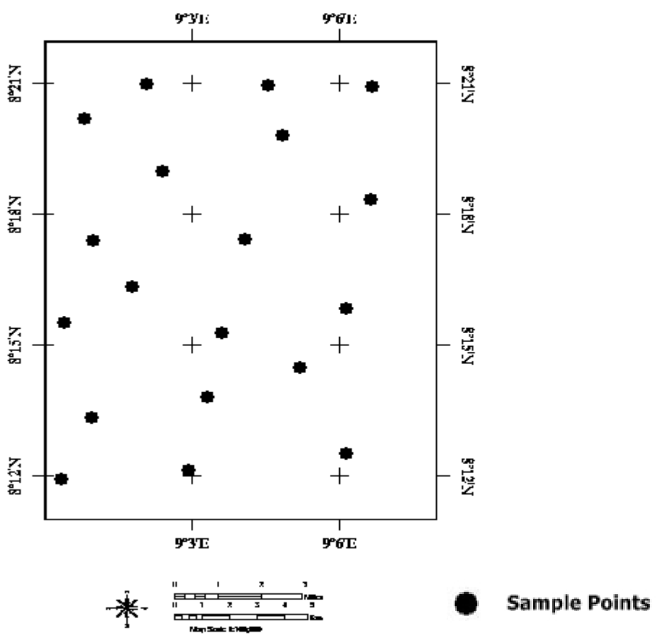

Figure 1: Sample map showing sample points in the study area.

because in environmental research with the purpose of assessment of total elemental concentration, it is necessary to use a broader screen value compared to that needed in mineral exploration [10]. The homogenized samples were passed through 100 mesh nylon screen. This helped extract metals from the <100 mesh fractions which is considered highly adsorptive fraction. The nylon screen was used to avoid contamination. The samples were digested by the use of aqua regia based on standard methods described in Fletcher (1981) [9]. 0.5 g of the screened samples were weighed out and placed in 20 ml beaker. 10 ml of aqua regia was added and stirred and was gently boiled on hot plate to a volume of 25 ml. 10 ml of deionized water was added and gently boiled to the volume of 5 ml. This was kept to cool and there after filtered into 50 ml measuring cylinder. Beaker and filter paper were washed into the cylinder to a level of 12.5 ml. Deionized water was added to make up to 25 ml. The samples were analyzed for major and trace elements using the Inductive Couples Plasma Optical Emission Spectrometer (ICPMS) technique in Acme Laboratory Ltd Vancouver, Canada.

Chemical Index of Alteration

Chemical index of alteration (CIA) was proposed by Nesbitt and Young [4] as a measure of the role played by chemical weathering in the production of clastic sediments. CIA is calculated using this equation: $CIA=(Al_2O_3/Al_2O_3+CaO^*+Na_2O+K_2O) \times 100$. (Where CaO* is calcium in silicates). CaO* was corrected using the formula ($CaO^*=CaO-P_2O_5 \times 10/3$). From this formula, if the resultant CaO* value is less than Na_2O, CaO* is assumed to be equal to CaO.

The above equation yields CIA values between 50 and 60 for incipient weathering, between 60 and 80 for intense weathering and more than 80 for extreme weathering. CIA for different samples within the study area is given in Table 1 (Figure 2).

Chemical Index of Weathering

Chemical index of weathering is an improved measure of the degree of weathering experience by a material relative to its parent rock. The principal difference between CIA and CIW is that the former treats K strictly as mobile component whereas the latter does not. The value of this index increases as the degree of weathering increases, and the difference between CIW index values of the silicate parent rock and soil or sediment reflects the amount of weathering experienced by the weathered material [11]. CIW for stream sediments were calculated using the formula:

$$CIW=(Al_2O_3/Al_2O_3+CaO+Na_2O) \times 100)$$

From this formula, chemical index of weathering, values in the range of 50 to 60 indicate incipient weathering, values between 60 to 80 indicates intermediate weathering, and values above 80 indicate extreme weathering. Calculated values of chemical index of weathering are presented on Table 2 (Figure 3).

Mineralogical Index of Alteration

Because CIA ranges from 50-100 and cannot be directly applied for normative calculations, thus it is necessary to calculate the mineralogical index of alteration given by the formula.

$$MIA=2 \times (CIA-50)$$

The mineralogical index of alteration evaluates the degree of

Samples	CIA value	Remarks
SSB6	70.40066	Intense weathering
SSB7	67.98449	Intense weathering
SSB8	78.44681	Intense weathering
SSB9	73.66754	Intense weathering
JSSA 01	91.52102	Extreme weathering
JSSA 02	86.92504	Extreme weathering
JSSA 03	90.20776	Extreme weathering
JSSA 04	96.02682	Extreme weathering
JSSA 05	97.78803	Extreme weathering
JSS 6	82.41515	Extreme weathering
JSSS 1	78.99933	Intense weathering
JSSS 2	87.24457	Extreme weathering
JSSS 3	83.25819	Extreme weathering
JSSS 4	83.52478	Extreme weathering
JSSS 5	83.34418	Extreme weathering
JSSS 7	84.53855	Extreme weathering
JSSS 8	90.46489	Extreme weathering

Table 1: Chemical index of alteration table showing CIA values across samples in parts of Awe-Obi area.

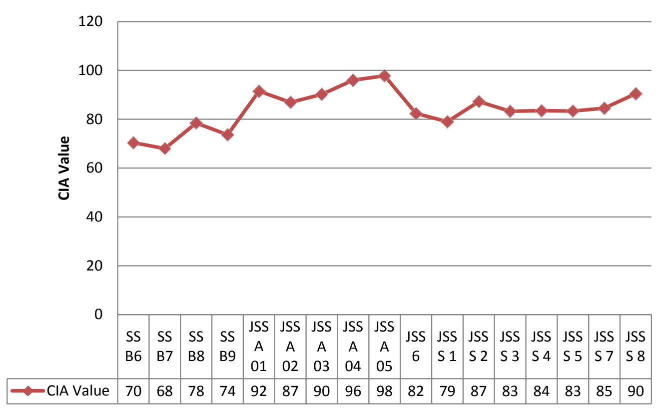

Figure 2: Profiles of CIA value across samples of the study area.

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Samples	CIW	Remarks
SSB 6	89.51964	Extreme
SSB 7	94.46959	Extreme
SSB 8	92.81807	Extreme
SSB 9	85.49214	Extreme
JSSA 01	98.57771	Extreme
JSSA 02	95.79366	Extreme
JSSA 03	95.90149	Extreme
JSSA 04	98.62526	Extreme
JSSA 05	99.64495	Extreme
JSS 6	94.63207	Extreme
JSSS 1	89.1634	Extreme
JSSS 2	95.21836	Extreme
JSSS 3	93.66418	Extreme
JSSS 4	92.393	Extreme
JSSS 5	93.10734	Extreme
JSSS 7	91.99573	Extreme
JSSS 8	94.64388	Extreme

Table 2: CIW values for stream sediments.

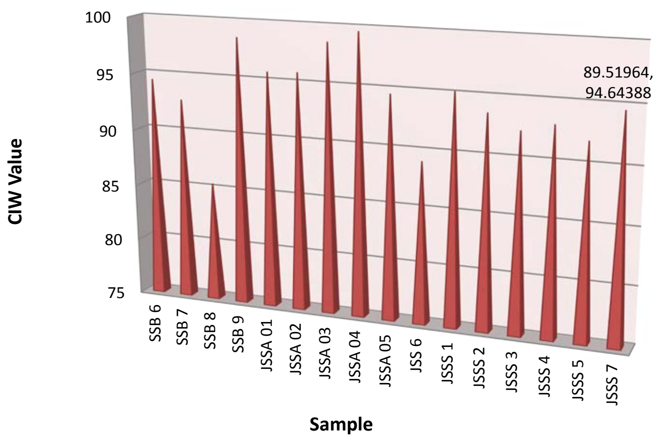

Figure 3: Profiles of CIW value across samples of the study area.

mineralogical weathering, that is, the transformation ratio of a primary mineral into its equivalent alteration mineral. MIA yields value between 0-100, and reflects incipient weathering (MIA<20), intermediate (MIA=20-60) and intense to extreme (MIA>60) mineralogical transformation. The value of 100 means complete transformation. MIA values for different samples within the study area are represented on the Table 3 (Figure 4).

Index of Compositional Variability

Because minerals show resistance to weathering, index of compositional variability can be used as a measure of sediment maturity. This index measures the abundance of alumina relative to other major cations in a rock or mineral. ICV for sediments was calculated using the formula:

$$ICV=(Fe_2O_3+K_2O+Na_2O+MgO+MnO+TiO_2)/Al_2O_3$$

This formula excludes silicates so as to eliminate the problem of quartz dilution. Using this formular, ICV>1 indicates immature sediments, while ICV values <1 indicates matured sediments. Calculated ICV values for samples are presented on Table 4 (Figure 5).

Paleo-oxygenation Conditions

Several trace elemental ratios have been used to discriminate paleo oxygenation conditions for sediments. Kroner et al. [12] used the Ni/Co ratio to discriminate whether sediments were deposited in an oxygenated conditions or a reducing condition. Based on their ratio, Ni/Co ratio <5 suggest an oxidizing condition of deposition while Ni/Co ratio >5 suggest a sub oxidizing to reducing conditions [13]. This ratio was determined for samples (Table 5).

Discussion

Chemical index of alteration for stream sediments in Awe-Obi revealed most sediment have been subjected to extreme weathering. Only a single sample had experience intense weathering. Further evaluation of weathering using chemical index of weathering revealed all samples had undergone extreme weathering. However, evaluation of weathering using the mineralogical index of alteration revealed samples had undergone intermediate weathering and intense to extreme weathering, most samples showed intense to extreme weathering characteristics with five samples showing intermediate weathering characteristics. High CIA, CIW and MIA values are indication that sediments have been subjected to severe alterations

Sample	MIA	Remarks
SSB6	40.80133	Intermediate
SSB7	35.96897	Intermediate
SSB8	56.89361	Intermediate
SSB9	47.33508	Intermediate
JSSA 01	83.04203	Intense to extreme
JSSA 02	73.85008	Intense to extreme
JSSA 03	80.41552	Intense to extreme
JSSA 04	92.05363	Intense to extreme
JSSA 05	95.57606	Intense to extreme
JSS 6	64.83029	Intense to extreme
JSSS 1	57.99866	Intermediate
JSSS 2	74.48914	Intense to extreme
JSSS 3	66.51638	Intense to extreme
JSSS 4	67.04955	Intense to extreme
JSSS 5	70.68835	Intense to extreme
JSSS 7	69.0771	Intense to extreme
JSSS 8	80.92978	Intense to extreme

Table 3: Mineralogical index of alteration showing MIA values across samples in parts of Awe-Obi area.

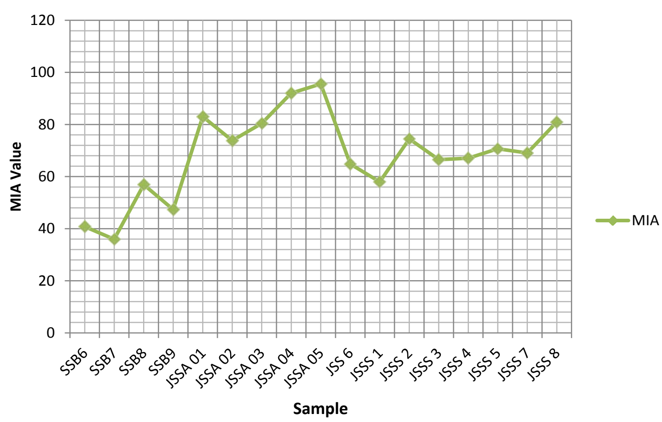

Figure 4: Profiles of MIA value across samples of the study area.

Samples	ICV	Remarks
SSB 6	1.513434	Immature
SSB 7	2.375354	Immature
SSB 8	0.765515	Mature
SSB 9	1.407367	Immature
JSSA 01	2.523827	Immature
JSSA 02	1.931619	Immature
JSSA 03	3.053004	Immature
JSSA 04	3.83714	Immature
JSSA 05	3.148043	Immature
JSS 6	1.80792	Immature
JSSS 1	2.244322	Immature
JSSS 2	3.134128	Immature
JSSS 3	2.195364	Immature
JSSS 4	4.118853	Immature
JSSS 5	3.821462	Immature
JSSS 7	2.88721	Immature
JSSS 8	1.224251	Immature

Table 4: Calculated ICV values for samples in parts of Awe-Obi area.

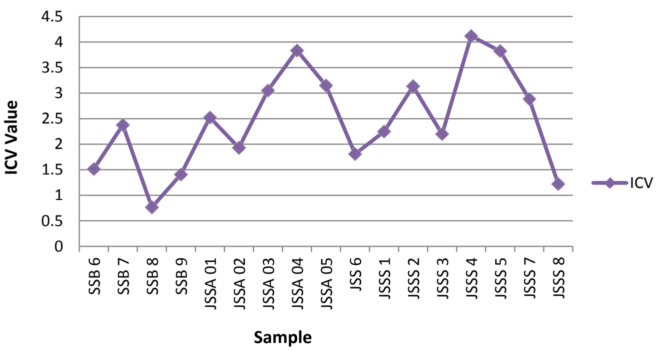

Figure 5: Profiles of ICV value across samples of the study area.

Samples	Ni/Co	Remarks
SSB 6	1.172297	Oxidizing
SSB 7	0.585417	Oxidizing
SSB 8	1.663636	Oxidizing
SSB 9	1.034014	Oxidizing
JSSA 01	2.776579	Oxidizing
JSSA 02	2.138081	Oxidizing
JSSA 03	2.512357	Oxidizing
JSSA 04	3.961965	Oxidizing
JSSA 05	4.472934	Oxidizing
JSS 6	1.39521	Oxidizing
JSSS 1	2.757603	Oxidizing
JSSS 2	3.51325	Oxidizing
JSSS 3	2.271298	Oxidizing
JSSS 4	3.242424	Oxidizing
JSSS 5	2.75134	Oxidizing
JSSS 7	1.963595	Oxidizing
JSSS 8	0.073232	Oxidizing

Table 5: Ni/Co ratio for samples in parts of Awe-Obi area.

under humid climate. Inferences on maturity of these rocks using index of compositional variability (ICV) revealed most samples are immature (ICV values greater than 1). This study also inferred that the paleo-oxygination conditions for sediments using Ni/Co ratio revealed an oxidizing environment of deposition of the samples. It must be made clear here that the application of chemical index of alteration (CIA), chemical weathering index (CIW) and mineralogical index of alteration (MIA) of heterogeneous profiles of Awe-Obi was done with extreme caution, accepting its limitations, because this study too just as previous study, assume aluminium is immobile during the process.

Conclusion

The Chemical Index of Alteration (CIA) [4] is the most widely applied and most indicative of the available weathering indices. From this study, one can conclude that the sediments from the study area have been subjected to varying degree of weathering and were deposited in an oxidizing environment. Furthermore, the ICV values for sediments in the study area suggest most sediments are immature. The high CIA, CIW and MIA values are indications that the sediments have been subjected to severe alteration under humid climatic condition.

References

1. Ruxton BP (1968) Measures of the degree of chemical weathering of rocks. Journal of Geology 76: 518-527.
2. Duzgoren-Aydin NS, Aydin A, Malpas J (2002) Re-assessment of chemical weathering indices: case study of pyroclastic rocks of Hong Kong. Engineering Geology 63: 99-119.
3. Parker A (1970) An index of weathering for silicate rocks. Geological Magazine 107: 501-504.
4. Nesbitt HW, Young GM (1982) Early predictions of some weathering trends of plutonic and volcanic rocks based on thermodynamics and kinetic considerations. Geochimica et Cosmochimica Acta 48: 1523-1534.
5. Offodile ME (1976) The geology of the Middle Benue, Nigeria. Palaentological Institute, University Uppsala, Special Publication, 4: 1-166.
6. Obaje NG, Abaa SI (1996) Potential for coal-derived gaseous hydrocarbons in the Middle Benue Trough of Nigeria. Journal of Petroleum Geology 19: 77-94.
7. Benkhelil JA (1989) The origin and evolution of the cretaceous Benue Trough, Nigeria. Journal of African earth sciences 8: 251-282.
8. Olade MA (1976) On the genesis of lead-zinc deposits in Nigeria's Benue rift (Aulacogen): A re-interpretation. J Min Geol Mag 20: 76-80.
9. Fletcher WK (1981) Analytical Methods in Geochemical Prospecting. Jourl of Geochem Exploration.
10. Okoronkwo NE, Igwe JC, Onwuchekwa EC (2005) Risk and health implication of polluted soils for crops production. Afric Jourl Biotech 4: 1521-1524.
11. McLennan SM, Hemming S, Mac Daniel DK, Hanson GN (1993) Geochemical approaches to sedimentation, provenance and Pectoris. Geol Soc of America 23-35.
12. Kroner A, Cooray PG, Vitanage PW (1991) Lithotectonic subdivision of the Precambrian basement of Sri Lanka. The Crystalline Crust of Sri Lanka - Part 1, Professional paper 5, Geological Survey Department Sri Lanka.
13. Fedo CM, Nesbitt HW, Young GM (1995) Unraveling the effects of potassium metasomatism in sedimentary rocks and paleosols, with implications for paleoweathering conditions and provenance. Geology 23: 921-924.