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Geochemical and Grain-size Analysis of Salt-bearing Sediments from Nasarawa Area of North-central Nigeria

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Abstract
Sediments belonging to the Keana Formation outcropping at Keana, Ribi and Azara areas of Nasarawa State, North-central Nigeria were mapped and sampled for granulometric and petrographic studies. This is necessary considering the domestic and industrial application of halide. The particle size distribution curves of the locations show that the area is dominated by fine to medium grained sand and this implies deposition in low to medium energy environment. Sediments range from poorly sorted to moderately sorted. This histogram plot of the percentage mass of sediments retained showed unimodal distribution pattern indicating deposition in fluvial environment. Petrographic studies on the sandstone show that the dominant mineral in the salt-rich sediment are sodium and chlorine thereby indicating marine flooding of the environment. Chemical analysis of the sediments also revealed an appreciable mean concentration of 235.0 mg/l and 226.0 mg/l for chlorine and sodium respectively. The total organic carbon (TOC) ranges from 0.64 to 1.02 corresponding to fair to good, which suggests that the Keana, Ribi and Azara shales are good source rocks and have good potential for hydrocarbon generation upon thermal maturity. The pH values vary from 4.5 to 4.8 signifying an acidic environment while the temperature ranged between 26.0oC and 28.0oC. The Na/Cl ratio indicates no negative effect for agricultural purposes.

Keywords: Geochemistry, Grain-size Analysis, Salt-bearing Sediments, Nasarawa, North-central Nigeria

INTRODUCTION

Salt-bearing Sediments are of great economic importance as it is the best and cheapest source of NaCl, which are useful domestically and industrially. The Benue trough is a unique rift feature on the Africa continent which occupies an intra-continental position and has a thick compressionally folded cretaceous supracrustal fill (Grant 1971; Wright, 1976). The recent comparison of the Benue trough with an aulacogen by Olade, (1975) has furnished the most appropriate model so far to explain its origin and tectonic evolution. Located at a major reentrant in the West African continental margin, the Benue Trough is bordered to the southwest by the Cenozoic Niger delta mega-synclinal embankment (Agumanu, 1993). Although it extends transversely northeast ward through the Nigerian shield and seems to die out around the Zambrik basement ridge, its main negative Bonguer anomaly trend continues underneath the Bornu basin (Cratchley and Jones 1965, Ajakaiye and Burke, 1973). The margins of the Benue Trough are collinear with both the Charcot and chain fracture zones of the equatorial Atlantic (Emery *et al*., 1975) and confine over 5,000 m cretaceous sediments.

Hoffman *et al*., (1974) expanded an earlier hypothesis of Grant, (1971) that the Benue Trough is an abandoned arm of a triple radial rift system. Using the Athapuscow aulacogen of the Canadian Shield as an example, they traced the tectonic development of aulacogen from the initial graben stage through the transitional, down warping and compressional stages to the final postgeosynclinal stage which takes place after the abutting geosynclines is involved in collision orogeny. Since the continental margin of West Africa and the Niger delta miogeocline evolution, the Benue aulacogen correspondingly has not advanced beyond the compressional stage, hence it is thought to be a juvenile aulacogen (Hoffman *et al*., 1974). The aulacogen model explains some of the characteristics of the Benue Trough such as a broad down warping involving the basement overlapping with sediments, and the general absence of clearly defined marginal faults at the basement/sediment contact.

Study Area Description.

The areas studied include Keana, Ribi and Azara located at about 64 km, 95 km and 106 km respectively away from Lafia, Nasarawa State Capital (Fig.1). The study area is characterized by tropical sub-humid climate with two distinct seasons: the wet season (May to October) and dry season (November to April). The mean annual rainfall and temperature in the area are 1550 mm and 27^{o}C respectively. The studied area falls within Southern Guinea Savannah Zone. However, clearance of vegetation for farming, fuel wood extraction for domestic and cottage industrial uses as well as saw-milling has led to the development of re-growth vegetation.

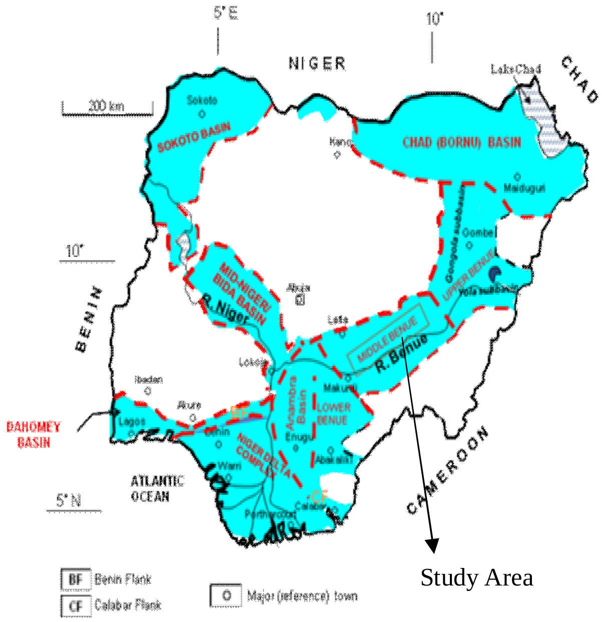

Fig. 1: Map of Nigeria showing the study area (Modified from NGSA, 2004)

GeoHistory and Structure of Halide

Halide is from the Greek word halos meaning "salt". According to dictionary of Geology, Halide is defined as a colourless or white mineral occurring as cubic crystals. Halide is found in dried lake beds in arid climates and is used as table salt. Halide forms isometric crystals, but in thin section is isotropic (as it is cubic). It usually shows strong cleavage and fracture planes and possesses fluid inclusion. Halite is a major component of large evaporite basin fills and it is the main evaporite mineral of modern salt lakes and saline pans.

There is much variation in the textural and bedding features of halite, depending largely on the environment of deposition whether it formed sub aqueous in a near permanent water body, or in a saline pan subjected to perpetrated flooding desiccation cycles. Halite deposited in relatively deep water (below-wall-base) is typically well bedded and laminated. This may simply be bedding on the scale of 5–10cm as a result of slight colour changes through variations in the clay content. Such bedded halite dominates the Triassic salt deposits of Western Europe. A more particular type of laminated halite consists of beds up to several centimeters thick alternating with lamineae of anhydrite a few millimeters thick. This faces occurs in some cycles of the Permian Zecheslein of Northern Europe. In the Devenonian pruivle formation of western Canada and in the Permian salado formation of the Delaware basin, Texas, bedded halite also occurs in the Permian San Andreas formation of Texas (Hovoria, 1987). Halide precipitation in modern saline pans and saline lakes has been studied by Lowenstein and Hardie, (1983) while Sochubel and Lowenstein, (1997) have recognized three stages to the saline pan cycle: flooding, evaporite concentration and desiccation. Flooding planes of the irregular surface of the halite crust of the previous cycle dissolves halite to form vugs and pipes and deposits a layer of mud over the pan surfaces. Evaporation of the shallow water leads to the formation of thin halite raft on the water surface and bottom nucleation of halite crystals on the settled-out rafts. Complete desiccation of the pan causes the halite crust to break up into polygons and tepees (Folk and Ward, 1957).

Halite for most halide deposit is derived from the evaporation of seawater, which of course contains a vast reserve of halite (NaCl). It also can be concentrated from fresh-water continental waters as in many salt lakes or derived from the dissolution and recycling of older evaporates. Halide group includes halides with the structure of halite. In halite, the Na^+ ion is so large that it must be surrounded by six Cl^-, to shield it from other positive ions, each having one charge. The resulting structure is cubic, with identical atoms at the corners of a cube and at a the centres of all six faces in all three axial directions there are rows of alternating Na^+ and k^+ are very ionic in character and are soluble in water, while the halides of Ag^+ (Silver) are considerable more covalent and are insoluble in nature (Friedmen, 1979). Halide also exhibits a variety of forms, depending on the environment. If it is formed in evaporated lakes, it can show desiccation structure such as cracks, polygons and tepees (fold-like structure resembling tepee tents). Trace levels of bromine substituted for the chlorine in halite can indicate the source and environmental condition during formation. Marine halite with increasing bromine reflects a salinity increase and indicates little influx of sea water and no loss of brine. Whereas a decrease in bromine contains indicates that there has been a significant influx of sea water or that the magnesium salts (with high levels of bromine) have been removed. Because of their buoyancy, halite beds may however deformed or rise and drag surrounding rock, producing salt domes or act as fill or lubrication in geological faults

An Overview of Global Occurrences of Salt Deposits

Halite occurs in vast beds of sedimentary evaporite minerals that result from the drying up of enclosed lakes, plagas and seas. Salt beds may be hundreds of meters thick and underline broad areas in the United States and Canada, extensive underground beds extends from the Appalachan basin of western New York through parts of Ontario and under much of Michigan basin, other deposit are in Ohio, Kansas, New Mexico, Nova Scotia and Saskatchewan. The

Khewra salt mine is massive deposit of rock salt near Islamabad, Pakistan. In the United Kingdom there are three mines, the largest of these is at Winsford in Cheshire producing half a million tons in six months.

Unusual purple, fibrous vein filling halite is found in France and a few other localities. Halide crystals termed hopper crystals appear to be “skeletons” of the typical cubes with the edges present and stair step depressions on or rather in each crystal face (Bratish, 1971). In a rapidly crystallizing environment the edges of the cubes simply grow faster than the centres. Halide crystals form very quickly in some rapidly evaporating lakes resulting in modern artifacts with a coating of encrustation of halide crystals, halide flowers are rare stalactites of curling fibres of halite that are found in certain arid lakes of Australia’s Nullurbor plain, halite stalactites and encrustation are also reported in raunchy native copper mine of Hancock, Michigan (Chales, 1985).

Brine Fields/Salt Deposits in Middle Benue Trough

The occurrence brine springs the springs in the Benue valley has attracted considerable attention (Kalu, 1997). The most important seepages are found in the Abakaliki, Keana and Mutum Daya areas of lower, middle and upper Benue Trough respectively. Towns and villages around these localities have maintained a locally viable age, old trade, based on salt produced from the native salt refineries (Oladele, 1975). The socio-economic importance of the mineral in a country that imports more than 90% of its common salt and allied chemicals cannot be over-emphasized. This situation has led to the intensification of the search for rock salt. The origin of the brines is thought to relate to evaporates, possibly occurring in continental, premarine Albian rocks or in the transitional beds of the upper Albian-lower Cenomanian Awe formation (Offodile,1976).Some interesting field evidence points to the probability of the occurrence of dome structure in the brine bearing sediments.

Most of the Benue brine-fields are underlain by formations of cretaceous age. The tectonic set up in the three main fields (Abakaliki, Keana-Awe and Mutum-Daya) is also similar. The Abakaliki, Keana and Lamurde anticlinoria. In each locality brine-springs are closely associated with these structures and are seen to issue from the flanks of the anticloria. The environments of deposition of the saline sediments of the Benue Trough are different from those of the South Atlantic basin in the Gabon and Congo basins there is evidence of restricted access to the sea which allowed only an intermittent but regular, supply of marine in to the basin, mainly in the Aptian to Albian, a condition favorable for the accumulation of evaporates. On the other hand, there is evidence of the existence of a positive basement barrier beneath the mouth of the present Niger Delta. It is not clear whether this feature could have restricted the movement of the sea both in and out of the valley, as in the South-west African basins.

The indication is that the Benue sea-way maintained an open communication with the Atlantic throughout the Cretaceous. The parallel to sub-parallel folds are almost at right angles to the coast and these could not also have impeded the inflow of sea water during this time. However, the marine transgressive and regressive episodes were controlled ,essentially, by tectonic and or eustatic factors and evaporitic conditions appear to have developed ,during the regressive phases when parts of sea were cut off, with shoals and lakes forming in isolated areas under dry continental conditions (Offodile 1976). The occurrence of the brines are form springs, dug-holes and salt ponds(see bellow pictures for details) which had been used for ages as the main raw materials for local salt production within the associated communities had mystified the occurrence of these brines(saline ground water)with some traditional restrictions and rituals in most cases. In most of the communities it is only women folk that have access to the saline waters while non-indigenes or men are either totally or not allowed or allowed only and after an initial traditional ritual. By and large, salt-making venture is generally a women-folk affair and had been, over the years a source of income for greater proportion of these rural women, through at a subsistence level (Nwajide and Olugbemiro, 1997).

In terms of the occurrence, the brines in the Benue Trough are primarily confined to the predominantly shally marine and parallic sequence of the Asu-river group (Albian-Cenomanian) and the Eze-aku as well as the Awgu formation (Tronianian-Coniacian). However, the variation in the local lithology at the outcrop sites from predominantly Shale in lower region to sandstones and intercalation of shale/limestone units in the middle region suggests that the brines are not litho logic controlled. Furthermore, the occurrence in form of springs, ponds and dug-holes are rather closely associated with the fracture systems within the trough .Hence, irrespective of the mode of occurrence, it quite clear that the seepages movements or inflows of the brines are mostly controlled by fracture systems within the trough. Hydro chemical evaluation as presented in Tijani *et al.,* (1997) pointed out that the evolution of the brines in the Benue Trough through the processes of evaporates formation and / or dissolution are less favored, while the source of the primary solution was said to be strongly linked to modified marine fossil seawater or formation water (Simeon and Kenneth, 2001). However, the inter play of water-rock interactions (dolomitization and ion exchange processes), dilution/mixing processes as well as leaching/dissolution of possible disseminated intergranular marine salts or pore fluids regarded as controlling processes for the observed differences in chemical characters compared to that of seawater. Due to the usefulness of halide man, the need to determine the quality and quantity of halide from Keana, Ridi and Azara area of Nasarawa, through geochemical and sieve analysis cannot be overemphasized.

MATERIALS AND METHODS

Sieve Analysis

In order to determine the textural characteristics of the sediments, the samples were subjected to both sieve analysis. About 500g of each of the samples was weighed on a balanced and poured into an aluminum bowl. It was washed with distilled water to remove cementing materials. After washing, the sample was transferred into an oven and oven dried for about 24 hours. It was thereafter removed from the oven and allowed to cool for about 30 minutes, and then poured in the upper test sieve, which is then shaked for a minimum of 20 minutes. Finally, each sieve in which soil is retained is weighed and recorded.

Laboratory Analysis

The sediments were digested in a mixture of concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl) and 27.5% hydrogen peroxide (H_20_2) according to the USEPA method 3050B for the analysis of heavy metals (USEPA, 1996). The extracts were analyzed by atomic absorption spectrophotometer (Perkin Elmer, Model No.2380). Prior to the laboratory analysis, the pH and temperature of the extract were determined on the field using a calibrated pH meter and mercury thermometer respectively.

RESULTS

The geochemical analysis results are summarized in Table 1 while the particle size distribution curves for Ribi, Keana and Azara are illustrated in figures 2 to 4 respectively. The percentage of sediments from Ribi, Keana and Azara that were retained after performing sieve analysis was plotted in histogram (Figures 5 to 7), while the photomicrography of sandstone in the area are contained in figure 8.

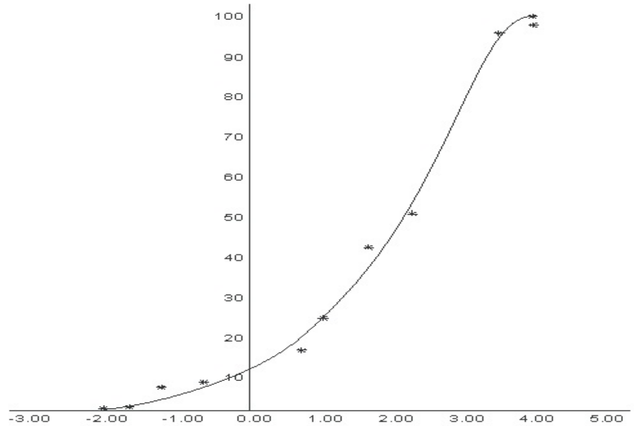

Fig. 2: Particle Size Distribution Curve for Ridi sediment

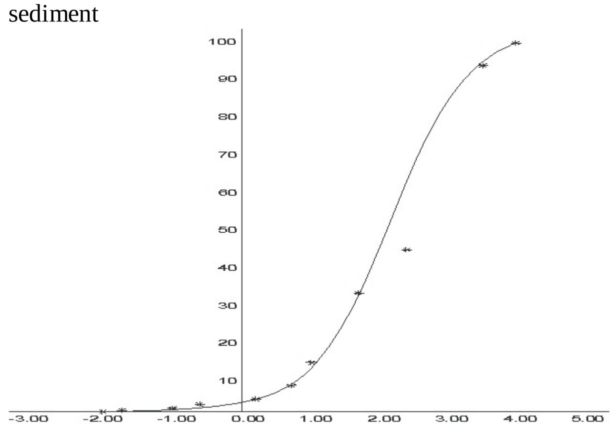

Fig. 3: Particle Size Distribution Curve for Keana sediment

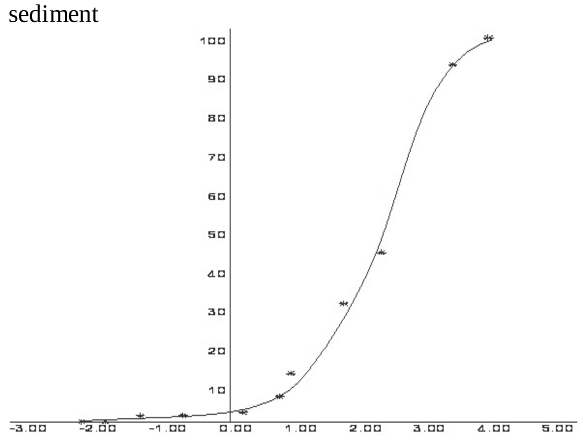

Fig. 4: Particle Size Distribution Curve for Azara sediment

Table 1: Statistical Summary of Geochemical Analysis of Sediments from Ribi, Keana and Azara area of Nasarawa State

Location	TOC Value	Quality	Cl (mg/g	Na (mg/g	pH	Temp. °C	Pond Depth (m)	Pond Diameter (m)
Ribi	1.02	Good	216	119	4.5	26	1.12	28 x 40
Keana	0.64	Fair	248	132	4.7	27	1.05	29 x 40
Azara	0.80	Fair	242	126	4.8	28	1.15	30 x 40

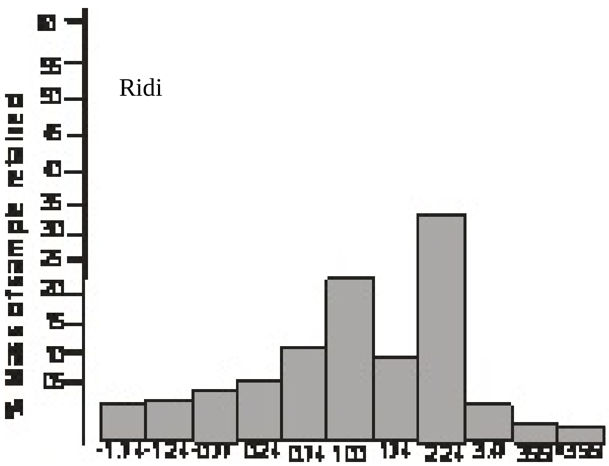

Fig. 5: Histogram showing % of sediment retained at Ridi area

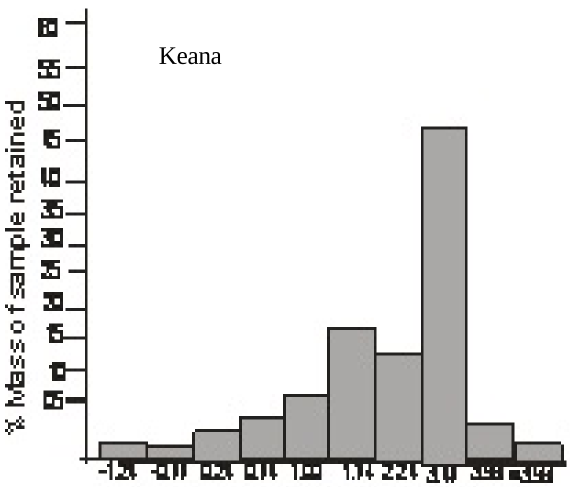

Fig. 6: Histogram showing % of sediment retained at Keana area

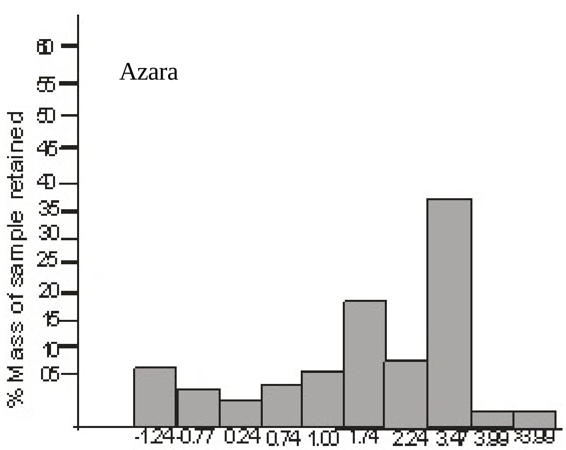

Fig. 7: Histograms showing % of sediment retained the Azara area

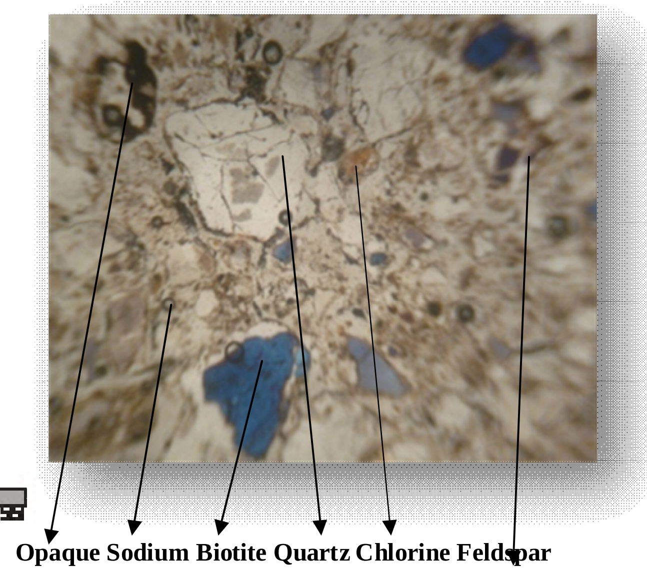

Fig. 8: Photomicrography of Sandstone from the area

DISCUSSION

Grain Size Analysis

Grain size analysis of the samples shows that 40% are medium grained while 60% are coarse grained; 65% are moderately sorted while 35% are poorly sorted; 55% were leptokurtic while 45% are mesokurtic; 75% are fine skewed and 25% are coarse skewed. A short period of transportation from the source area and textural immaturity could be responsible for the poor sorting of the samples. The samples are fine skewed, indicating the dominance of fine grained materials. Leptokurtic samples (excessively peaked) imply better sorting at the centre of the curves and mesokurtic nearly even sorting. The mean ratio of traction, siltation and suspension population are 2:3:1. The ratio for the matrix supported conglomerate and the massive conglomeratic sandstone is 1:3 which indicates that most of the grains are transported by siltation. Also, the ratio of silty-clay and silty-sand is 3:2 and this highlights the fact that little or no particles were transported by traction but rather, siltation and suspension hence the predominance of fine grained particles. All the histograms are unimodal meaning a single source and the environment of deposition fluvial in a low to medium energy current.

Thin Section

The thin sections prepared were viewed under a petrological microscope in order to identify the dominant minerals in the lithology. Sodium and chlorine, quartz, biotite, feldspar and opaque minerals were identified and counted to estimate their relative abundance. The thin section gives a clue on the mineralogical composition and the provenance of the samples.

Chemical Analysis

Total Organic Carbon (TOC) concentration ranges from 0.64 wt% to 1.0w wt% which is greater than the minimum value of 0.5 wt% required for a sedimentary rock for hydrocarbon generation (Tissot and Welte, 1978). This suggests that sediments from the locations (Ridi, Keana and Azara) studied have good potential for generating hydrocarbon and are classified as good source rock based on their TOC values. The temperature values vary from 26.0^{o}C to 28.0^{o}C with a mean value of 27.0^{o}C. The pH concentrations (4.5-4.8) indicate an acidic environment while the sodium and potassium concentrations are within the maximum permissible limits postulated by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). High sodium in soil can decrease plant available water and cause plant stress. The current sodium concentration in the area is within tolerable state and will not affect agricultural activities negatively.

CONCLUSION

The present work was executed through chemical analysis, petrographic studies and sieve analysis. Results of the particle size distribution curves revealed that 40% of the samples are fine-medium grained while 60% are coarse grained. Also 65% of the sediments are moderately sorted while 35% poorly sorted. Sodium and chlorine, quartz, biotite, feldspar and opaque minerals were identified from the photomicrography of sandstone samples prepared. Total Organic Carbon (TOC) concentration ranges from 0.64 wt% to 1.0w wt% and these values are higher than the minimum value of 0.5 wt% required for a sedimentary rock for hydrocarbon generation. The pH values were low suggesting a slightly acid-rich environment. The sodium and chlorine values were below the maximum allowable limit and it does not pose any danger for agricultural activities.

REFERENCES

Agumanu, A. E., (1993). Sedimentology of Owelli Sandstone(Campanian- Maatrichtian) Southern Benue Trough, Nigeria. Journal of Mining and geology, **29**(2), pp 21-34.

Bratish, O. (1971). Salt Deposit: Its Origin and Composition. Springer Verlang Berlin 297 pp.

Chales. A. S., (1985). A field Guild and Introduction to the Geology and Chemistry of Rocks and Mineral. 145 pp.

Folk, R. L. and Ward, W., (1957). A Study in the Significance of Grain size Parameters Journal of the Sedimentary Petrology, **27**, pp 3-26.

Friedmen, G. M., (1979). Differences in size distribution of Population of Particles among Sand of various Origin Sedimentology, Journal of sedimentology, **26**, pp 3-32.

Grant, N.K., (1971). The South Atlantic Benue Trough and Gulf of Guinea Cretaceous Triple Junction Geolosoi Annual Bulletin **82**: pp 295-298.

Kalu, U. M., (1997). The Brine fields of the Benue Trough, Nigeria: a Comparative Study of Geomorphic, Tectonic and Hydrochemical Properties. Journal of Mining and geology, **25**, pp 12-15.

Kogbe, L. A., (1975) **.** Paleogeographic History of Nigeria from Albian times of Geology Of Nigeria. Journal of Mining and geology, **23** (1), pp 5-10.

Laren, M. C. and Kogbe, L. A., (1981). An Interpretation of Trends in Grain size measure, Sedimentary Petrology, **51**(2), pp 611-624.

Nwajide, C. S. and Olugbemiro, R., (1997). Grain size distribution and Particle morphogenesis as signature of Depositional environment of cretaceous/non Ferruginous) facies in the Bida Basin, Nigeria. Journal of Mining and geology, **25**(1), Pp 89-107.

Ofodile, M. E., (1976)**.** The Geology of the Middle Benue Nigeria, Palaco Inst, Uni: Uppsala, Special, **4**, pp 8-14.

Ofoegbu, C.O., (1984). Hydrocarbon in the Middle Benue Trough, A Model for Tectonic Evolution of the Benue Trough of Nigeria. Earth Evolution Science, Viewing, Germany, pp 45-47.

Oladele, M. A. (1975). Geologic Origin of Middle Benue Trough. Evolution of Nigeria (Aulacogen): a Tectonic Model. Journal of Mining and geology, **18**, pp 8-16.

Simeon, J. B. and Kenneth, P., (2001). Grain size distribution and statistical package for the analysis of unconsolidated sediments: Earth surface process and landforms **26**, pp 1237-1248.

Wright, J.B., (1976)**.** Origin of the Benue Trough**-**a critical review in Geology of Nigeria, C.A. Kogbe (ed.), Eliz. Pub.Co. pp 309-318.