RESERVE ESTIMATIONS AND ECONOMIC POTENTIALS OF EXPOSED KAOLIN OUTCROPS IN PARTS OF SOUTH- EASTERNANAMBRA BASIN, ANAMBRA STATE, NIGERIA

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ABSTRACT:
The study area covers parts of Ukpor, Okija, Ozubulu, Orsumoghu, Lilu, Ihiala and environs. The area is located in the Southeastern Anambra Basin and underlain by the Coastal Plain Sands (Miocene to Pleistocene), Ameki Formation (Eocene), and Ogwashi Asaba Formation (Oligocene to Miocene). In this research, the reserve estimations and economic potentials of the exposed kaolin deposits in parts of Southeastern Anambra Basin in Anambra State of Nigeria with that of Nothern Benue Trough kaolin deposits used for comparison were studied. All the Kaolin deposits in the study area, were hosted in Ogwashi-Asaba Formation. The Kaolin samples were collected from the exposed outcrops in the study area. They were using Atomic Absorption Spectroscopy. The oxides detected from the analysis include: SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O, MnO, CuO, ZnO, Cr_2O_5, V_20_5 and the major oxides of Kaolins from the study areas shows that $Si0_2$ (50.74% to 58.24%) and Al_20_3 (23.48% to 32.21%) constitute over 75% of the bulk chemical compositions. The high content of $Si0_2$ shows that the source rocks are silica rich minerals resulting in the grittiness of the kaolin, while other oxides are present in relatively very small amounts. The occurrence of Ca0, Na0 and K_20 which are the major components of feldspars in clay suggest the kaolin to be of granitic origin, possibly from Oban massif, east of the Anambra Basin. The more siliceous and aluminous materials confirm a high degree of weathering activities during the lower to middle Jurassic time when the weathering processes were on the peak within the Oban massif. Results of laboratory analysis, physical tests and literature on previous works in the area indicate that the kaolin deposits are good for the manufacture of fertilizer, bricks, ceramics, fiber, glass, plastic, pottery, among others. The total reserve evaluate of the exposed kaolin deposits in the study area is approximately sixty-six (66) million metric tons.

Keyword: kaolin, Anambra Basin, Reservior Estimation, Economic Potential, Nothern Benue Trough

1. INTRODUCTION

The Geological field study was carried out in the areas of Ukpor, Ozubulu, Orsumoghu, Lilu ,Okija and Ihiala environs on Kaolin deposits exposures within some parts of Southeastern, Anambra Basin, Anambra State, Nigeria, and they were studied in details; and the Formations encountered were noted. The study areas consist of mainly Kaolin, Clays, Kaolinites, Lateritic Sands with little Sandstones, Siltstones, Mudstones and Ironstones. They were logged and their textural descriptions noted. Samples were collected from different exposed outcrop locations for geochemical analysis. The study areas were characterized by sedimentary aggregates of Coastal plain sands, Ameki and Ogwashi-Asaba Formations. They lie in Anambra Basin which is one of the intracratonic Inland Basin in Nigeria. Kaolin is a versatile industrial raw material because of its enormous economic valuability and industrial applications. The search for its deposits is very timely and welcome, given the facts that solid minerals development is a much needed alternative to economic recovery hence the choice for this research topic by the researcher.

The main objectives of this study is to determine the quality of the Kaolin found in the studied areas through geochemical analysis and to estimate it's reserves, and economic potentials .

Again, to compare the Kaolins from the study areas with those Kaolins from Pindiga and Alkaleri of Northern Benue Trough in terms of their elemental compositions, brightness in color and light on ignition (LOI) characteristics.

2. THE GEOLOGICAL SETTING

The Anambra Basin is located in the southeastern part of Nigeria; and is bounded to the North by Bida Basin and to the East by Benue Trough to the west by West African Massif and to the south by Niger Delta complex (Obaje, 2009). The Basin is a Cretaceous Basin, structural synclinal depression and one of the intracratonic Basins in Nigeria, having almost a roughly triangular shape with a total sediment thickness of about 9km; which covers an area of about 40,000sq.km (Reyment, 1965), characterized by enormous lithologic heterogeneity in both lateral and vertical extensions derived from a range of paleoenvironmental settings (Nwajide and Reigers, 1998). Volcanic activity occurred at different times and places throughout the cretaceous history of the Benue trough, but minor intrusive are mainly confined to Albian sediments (Olade, 1978). Overlying these sediments are the late Upper Albian sediments of Awi Formation, Abakaliki Shale,Ngbo Formation (Petters and Ekweozor, 1982). In the Lower Benue Trough, these rocks form the Asu River Group which were affected by the localized Cenomanian folding (Nwachukwu, 1972), succeeding the Asu River Group is the sequence of sediments which include Agila Sandstone, Ibir Sandstone, Odukpani Formation all aged Cenomanian; Makurdi Sandstone, Ezeaku Shales, Agu-Ojo Sandstone and Amaseri Sandstone all aged Turonian. The Coniacian Awgu Shale which is bluish, well bedded shale with occasional intercalation of fine grain, pale yellow, calcareous sandstone and shale limestone overlie the Cenomanian sediments (Reyment, 1965).

The extensive Campano-Maastrichtian transgression initiated sedimentation in the Anambra basin. The stratigraphy indicates that the Campanian Nkporo Shale from the base which is separated from the pre-Campanian strata by a type-1 sequence boundary (Nwajide and Reigers, 1998). The Nkporo Shale passes laterally into Owelli Sandstone in the Awgu area and Enugu Shale in the Enugu area. The Owelli Sandstone is a cross stratified fluvial deltaic sandstone while the Enugu Shale is composed of marginal marine-shallow marine carbonaceous mudstone and fine grain sandstone containing thin coal seam (Obi et al, 2000). These three Formations form the Nkporo Group. Succeeding the Nkporo Group is the Mamu Formation or the Lower Coal Measure (Simpson, 1955). It is aged Maastrichtian and characterized by carbonaceous fossil shale and mudstone deposited in a shallow shore face environment. Overlying the Mamu Formation is the Ajali Sandstone which is profusely cross bedded tidal channel/fluvial channel deposit and aged late Maastrichtia (Ladipo, 1986). Capping the Campano-Maastrichtian succession is the Nsukka Formation characterized by carbonaceous mudstone and sandstone similar to Mamu Formation. It is also called the lower coal measure. A short Paleocene transgression deposited the Imo Shale. It is typically of high energy shore face (Arua, 1980). Marine environment. The Imo Shaleis dark grey to bluish shale with thick sandstone bands as well as iron stone. It is fine textured, it is sandy and heterolithic upward (Whiteman, 1982). The regressive Eocene Ameki Group forms the last succession in the Anambra Basin. This consists of the Nanka Sand and the Nsugbe Sandstone. The Table 1 shows the stratigraphic succession and lithostratigraphic units respectively described.

3. THE STUDY AREA

The study areas include Ukpor town in Nnewi L.G.A., Orsumoghu, Lilu, Okija and Ihiala in Ihiala L.G.A., and Ozubulu in Ekwusigo L.G.A., Anambra State, and Southeastern Anambra Basin, one of the intracratonic Basins in Nigeria. Geological the study areas lie between Latitudes $05^0 50$ AND- 06^0 00'N and Longitudes 06^0 50' E – 07 ^{0}00'E; covering an area of approximately 185.15km^2 (fig.1). Topographically, the study area is undulating and mostly covers by Clayey as overburden, Laterites with intercalation of Mudstones, Siltstones and Pebbles in some areas. The study areas are within the Coastal plain sands (Miocene- Pleistocene), Ameki Formation (Eocene), and Ogwashi-Asaba Formation (Oligocene- Miocene). The Ogwashi-Asaba Formation host all the Kaolin deposits in the study areas.

Table 1a: Stratigraphic succession in the Anambra and the Niger Delta Basins (based on Reyment, 1965; short and stauble, 1967; Maron, 1969)

Age	Basin	Stratigraphic Units						
Thanetian	Niger Delta	Imo Formation						
Danian								
Maastrichtan	Anambra Basin	Coal Measures	Nsukka Fm					
			Ajalli Fm					
			Mamu Fm					
Campanian		Nkporo Fm GP	Nkporo Shale	Enugu Fm	Owelli Ss	Afikpo Ss	Otobi Ss	Lafia Ss
Santonian	Southern Benue Trough	Awgu Fm						

4. METHODOLGY AND MATERIALS

Kaolin samples collections from the field of the study areas in southeastern Anambra Basin, Anambra State with Pindiga and Alkaleri samples from Northern Benue Trough for comparison were carried out. The sampled locations coordinates were taken with Global Positioning System, while the lateral and thickness of the Kaolin deposits exposures were measured with measuring tape and their photographs were taken with digital camera. The samples were collected from top, middle and basal portions of the Kaolin deposits at its outcropped locations with geological hammer and grinded with mortar and pestle, weighed in grams with weighing balance. They were carefully labeled with marker and taken to the Nigeria Geological Survey Agency laboratory for Geochemical analysis. The equipment/ apparatus involved during the course of this laboratory studies include: AAS, UV, Reagents, and result sheet.

5. RESULTS

The results obtained from the geochemical analysis from the study areas of Anambra Basin and Benue Trough of Nigeria were shown below in tables 2 and 3 respectively. From the results, the values of the major oxides; SiO_2 and Al_2O_3 of Kaolin from the study areas in Anambra Basin ranges from 50.74 to 58.24 and 23.48 to 32.21 respectively. While Kaolin from Northern Benue Trough ranges from 44.98 to 45.62 and 32.91 to 35.20 respectively. Also, the values of CaO, MgO and Na_2O of Kaolin from Anambra Basin ranges from 0.11 to 0.74, 0.26 to 2.50 and 0.07 to 2.59 respectively. While Northern Benue Trough values ranges from 0.31 to 0.52, 0.43 to 0.94

and 0.01 respectively. The light on ignition (LOI) and brightness values of Kaolin from the study areas in Anambra Basin ranges from 6.93 to 12.29 and 79.60 to 84.10 respectively, while that of Northern Benue Trough ranges from 14.69 to 15.04 and 86.40 to 88.70 respectively. The results infers that the Kaolin from the study area in Anambra Basin contains more impurities, burns lesser and milky in color while that of Northern Benue Trough contains lesser impurities, burns faster and brighter in color, which classified it to be a good raw materials for paints, drugs manufacturing industries, and it's counterpart a good raw materials for pottery, ceramic and Agricultural manufacturing industries .The reserves of the kaolin were also estimated to be approximately 66million metric tons,worth to be exploit; (Tab.4) shows that Ukpor areas have over 31mmt, followed by Okija= 11mmt, Ozubulu =9mmt, Lilu=8mmt and Orsumuoghu =7mmt. Therefore, this essential industrial raw materials were found in commercial quantities in the studied areas. The state and federal government should follow up its exploitation exercise in order to boast the economy of the state and nation in general.

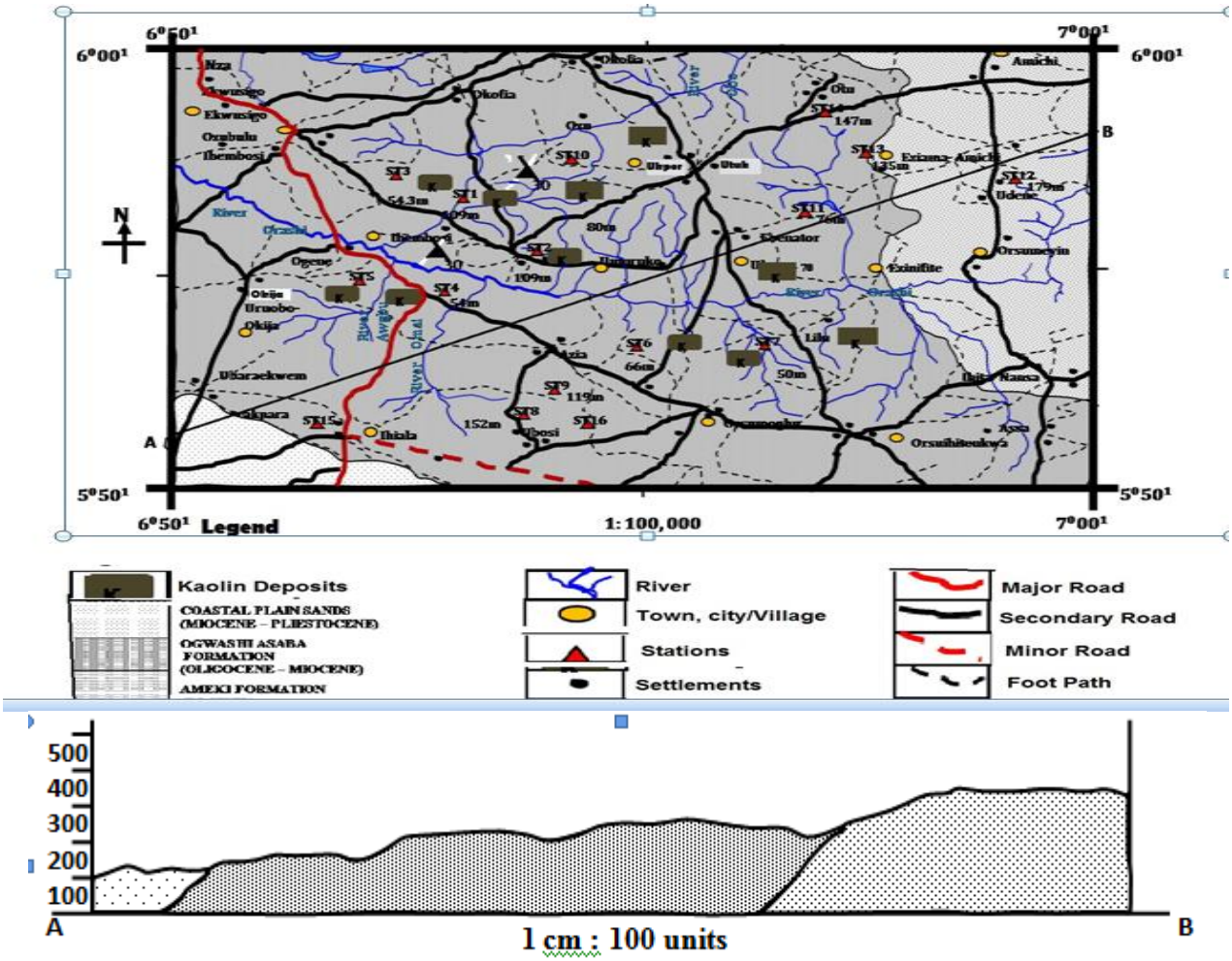

Fig. 1: The Geologic map of the studied areas showing the locations of the exposed kaolin deposits with cross sectional profile (Obinegbu, 2016)

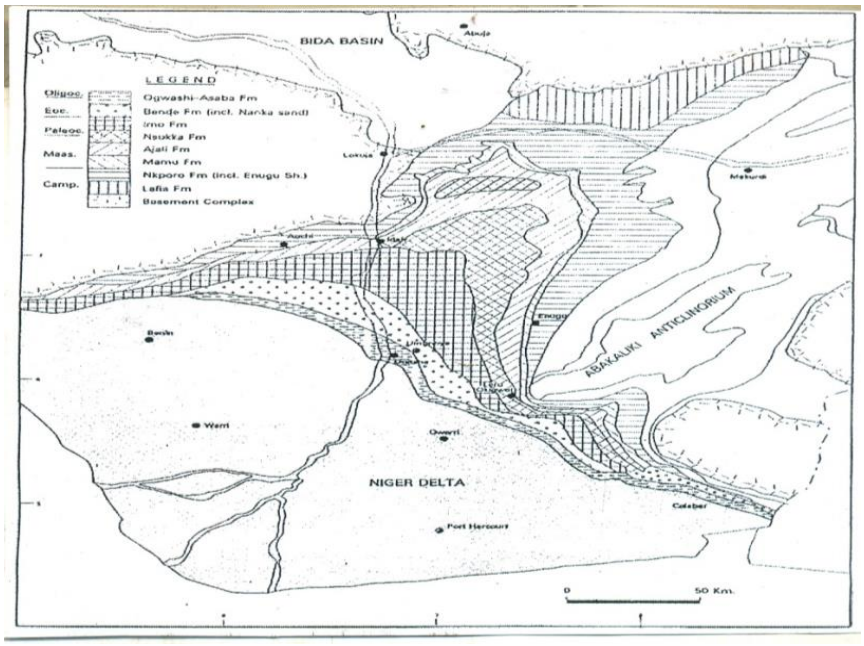

Fig.2: **Geological sketch map of the Anambra Basin (Obaje, 2009)**

Table 2: Chemical analysis results of the kaolin samples from the study areas (%)

Oxid%	Orsum 05	Lilu- 06	EOkij 04	OFmaOzub3	MpUkpor-02	AmUkp:01
SiO_2	58.24	56.01	55.39	57.61	54.34	50.74
Al_2O_3	27.53	27.24	28.34	23.48	25.98	32.21
Fe_2O_3	1.09	1.68	2.07	3.12	3.02	2.44
TiO_2	0.68	0.96	0.67	0.82	0.88	0.13
CaO	0.18	0.56	0.59	0.74	0.17	0.11
MgO	1.63	0.98	0.43	2.33	2.50	0.26
Na_2O	1.07	2.59	0.52	0.46	2.18	0.07
K_2O	2.5	1.06	0.59	1.51	2.47	1.58
MnO	<0.01	0.02		0.01	0.02	0.01
CuO	0.01	0.03	0.01	<0.01	0.01	0.02
ZnO	<0.01	0.01				
Cr_2O_5	0.01	0.02	0.04		0.04	0.03
V_2O_5	0.13	0.01	<0.01	0.01	<0.01	0.11
LOl	6.93	8.80	11.35	9.91	8.39	12.29
Brightness	84.1	76.92	81.2	79.6	79.6	80.13

Table 3: Chemical Analysis results of Kaolin Samples from Benue Trough (%)

Oxide %	Pindiga BT	Alkaleri BT
SiO_2	45.62	44.98
Al_2O_3	32.91	35.2
Fe_2O_3	3.58	3.31
TiO_2	0.16	0.14
CaO	0.31	0.52
MgO	0.94	0.43

Na_2O	**0.54**	**0.38**
K_2O	**0.75**	**0.45**
MnO	**0.01**	
CuO	**0.01**	**0.02**
ZnO	**<0.01**	**<0.01**
Cr_2O_5	**0.02**	**0.03**
V_2O_5	**0.11**	**0.03**
LOl	**15.04**	**14.69**
Brightness	**86.4**	**88.7**

Table.4: The Reserve evaluation of the exposed kaolin outcrops in the study areas

Loc name	Lm	Wm	Area Expo(m^2)	Thickness(m)	Volume (m^3)	Grad%	Res (mm tons)	Appro.mmt
A,Ukpor	20	6	120	2.5	300	32.21	19,326	19
MkP,Ukpr	10	9	90	2.0	180	25.98	12,158	12
OfAmOzu	10	6	60	1.5	90	23.34	9,102,600	9
Ezie,Okija	20	5	100	1.5	150	28.34	11,052	11
Orsum	15	5	75	2.5	187.5	27.53	6,817	7
Lilu	20	6	120	2.25	420	27.24	8,498	8

Total =66

Note: An average specific gravity of 2.6 for kaolin 'clay'was used to calculate the Reserve Evaluations (Read,1962, Peters,1978) for the exposed outcrops only.

Therefore, from the calculated reserve evaluations shown in Table 4 above, the total reserve evaluation of the exposedkaolin outcrops in the studied areas is approximately sixty-six (66) million metric tons

$$L \times W = A \quad (1)$$

$$A \times T = V \quad (2)$$

$$Grade\ (\%) \times Specific\ Gravity = Reserve\ Estimate \quad (3)$$

where L is the length of the exposed Kaolin deposits in m, W is the average of the Kaolin deposits in m^2, A is the aeral exposure of the Kaolin deposits inm^2, T is the Kaolin deposits exposure, V is the volume of the Kaolin deposits in m^3.

Historically, kaolin was first used in ceramic and this is perhaps still the best known application, even though, the total tonnage sold for this use is small compared with that marketed for paper, paint and rubber manufacturing. It is used in the manufacture of white wares, wall tile, insulators, refractive and in some face bricks when a white color is desired. Kaolin is used in insulators, because of its properties of low conductively, high electric constant, low power loss, plasticity and fired strength. Kaolin is used in casting operations and in porcelain because of its excellent flow ability, excellent suspension properties characteristics, water release and good color.

The use of kaolin by the pharmaceutical and Agricultural industries in manufacturing of medicines and fertilizers respectively would not be excluded. Finally, kaolin has other important industrial application because of various characteristics it possessed. The other products that can be obtained from this industrial mineral include: Ink, adhesives, insecticides, food additives, catalyst, preparations, bleaching adsorbents, plasters, filters aids, cosmetics chemical, crayons, pencils detergent paste, roofing granules, sizing form dries Linoleum, textiles to maintain but a few. (Fig.3) above is a chart illustrating obtainable products from kaolin especially those from the studied area of southeastern Anambra Basin.

6 SUMMARY AND CONCLUSION

The study area is underlain by the Coastal Plain Sands, Ameki Formation , and Ogwashi Asaba Formation, but all the kaolin deposits in the study area are hosted in the Ogwashi Asaba Formation. The study revealed that the kaolin is a sedimentary deposit which originated from the weathering and transportation of hydrothermal altered feldspars of granitic rocks from Oban Massif, during the lower to middle Jurassic times (Allege et al, 2013). Thus; the deposits underwent long transportation, resulting in well sorted deposits consisting of mainly sands, clays and silts. This usually help to beneficiate the materials into industrial quality.

The various tests and analyses in this research work prove that the kaolins in the study area are very good refractory material particularly for the non-ferrous foundry and the ceramic industry as well. It is also good for fertilizers production, while kaolins from Pindiga and Alkeleri of upper Benue Trough would be better raw materials for drugs and paints industries because brightness is highly needed in such industries. Importantly, its economic potentials and industrial applications if properly harnessed and utilized, would create employment opportunity for many job seekers and increase internal generated revenue (IGR) to the State Government. Also, the effort to improve the quality and production of this material for our local industries will further reduce our over dependence on foreign raw materials and save our Government a lot of foreign exchange. Impurities so far discovered which are quartz and little iron components, could be easily processed to produce industrial quality for our manufacturing industries. The evaluated reserve of the exposed kaolin outcrops in the studied area is approximately sixty-six million metric tons (66 million metric tons).

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