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Geochemical Evaluation of Kaolin at Garin Papa and Environs in Darazo Local Government Area, Bauchi State.

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Abstract
This work involves detailed geological mapping of the Garin Papa area to evaluate kaolin mineralization and assess the physical and chemical properties of the kaolin for economic purpose. Scout pitting was carried out followed by close grid pitting of an area measuring 250 x 250m square. Samples collected were subjected to geochemical analysis. The geological mapping revealed that the area is underlain by reddish sandstones and the lateritic horizons of the Kerri-Kerri Formation. Three kaolin horizons, the whitish; the pinkish and the reddish varieties were encountered. Major geochemical analysis shows that the silica and aluminium are enriched with average values of 43.69% and 38.2% respectively while other oxides are depleted (Soda = 0.15%, potash = 0.07%, lime = 0.42%, magnesia = 0.08%, iron = 0.75% and titanium oxide = 1.05%). The enrichment of silica and alumina coupled with depletion of other oxides indicated that the kaolin is of good quality which met the required standard outline by American element and can be utilized by manufacturing industries such as agriculture, pharmaceutical, chemical and metallurgical companies.
Keywords: *Kaolin, Garin Papa, Kerri-Kerri, Darazo, mineralization.*

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I. Introduction

Mineral resources play an essential part in the economy of any nation, especially in a developing country like Nigeria. Kaolin is almost a part of everyday life because it is used in various aspects of agriculture, pharmaceutical, construction, chemical and metallurgical studies; hence, it plays a vital role in the well-being of mankind (Bu et al., 2017). Kaolin has been of economic importance in the family of industrial minerals it plays an important role in the economic development of any industrialized nation.The industrialized nations account for large-scale production of kaolin in the world and are the large consumer of kaolin. The demand for raw materials such as kaolin has increase due to increase in population;there are high demands of kaolin in the industries.

Kaolin is a white non-swelling clay which has been formed typically by intense weathering which leached the cations of the source rock into predominantly relatively pure white kaolinite (Kaolin, 2005).The group includes kaolinite, dickite, nacrite and halloysite with Hardness: 2-2.5 ranges (Mohs scale). Particles Size;generally, below 10 microns are for coating clays generally 90% below 2 microns. Particle Shape; Pseudo-hexagonal crystal plates, which may be stacked or vermicular shape. Chemistry: Approximated formula: $2H_20A1_20_32Si0_2$. Chemical composition: Approximately Alumina 39% Silica 46% formula water 14%. Reactivity: Inert. Good stability over pH 3-9 (Kaolin, 2005).Kaolin$\{Al_2Si_2O_5(OH)_4\}$ was firstly mined in China.Its name was adapted from the word Kau Ling,which implies high ridge,the name of a hill near Jau-chau fu in China.It is sometimes referred to as China clay (2005; Bu *et al.*,2017). Comparatively kaolin is pure clay predominantly consisting of about 85-95% kaolinite ($Al_2O_3.2SiO_2.2H_2O$). Other constituents usually found in kaolin in addition to kaolinite include, quartz and mica and also,less often include feldspar,illite,montmorillonite,ilmenite,anastase,haematite,bauxite,zircon,rutile,kyanite,silliminate,graphite,attapulgite,and halloysite(Bu *et al*.,2017). Kaolin is a product of natural hydrated aluminium silicate which has undergone refinement.It is usually in powder form and is whitish in colour.It is a soft sedimentary rock which has light weight and a chalk-like appearance(Varga,2007). The SiO_2/Al_2O_3 percentage shows that it is good for geology,engineering,agriculture,processing industries and environmental application(Bu *et al.*,2017).It is of economic importance for most industries owing to its properties such as high brightness,very fine particles size,inertness and non-toxicity thus giving it versatility and wide spread applications(Bu *et al*.,2017). Kaolin can be found commercially as sedimentary deposits where weathering of rocks containing high composition of alumina-silicate minerals is located.It is classified as clay mineral containing atom of silicon; aluminium,oxygen,iron, and hydroxyl groups as the main elements. It also contains other elements such as calcium, potassium, phosphorus, sodium, and magnesium in very minute quantities.The members of the kaolin family include dickite, nacrite, allophone, and hallosite (Badmus and Olatinsu,2009).The colour of each type of kaolin is determined from its iron content,but the pure one is mostly white in appearance.Impurities in the kaolin material can change the colour to purple or pale brown.

Deposits of kaolin are wide spread throughout Nigeria with each state having at least one known deposit(Badmus and Olatinsu, 2009).For instance,the Ozubulu deposit in Anambra state; Darazo deposit in Bauchi; AkpeneQbom deposit in Cross-Rivers state and the Kankaradeposit in Katsina state,just to mention a few (Badmus and Olatinsu,2009). David *et al.* (2017)explains that kaolinite has a tetrahedral structure of silica sheet alternating with an octahedral structure of alumina sheet. The arrangement of the sheet is such that the tips of silica tetrahedrons and the adjacent layers of the alumina octahedral sheet form a common layer. Two thirds of the oxygen atoms found in the common layer of the tetrahedral groups and the octahedral groups are shared by aluminium and silicon. They therefore become O instead of OH and the charges within the structural unit are balanced. Analyses of many samples kaolinites have shown that there is very little substitution in the lattice (Adamis and Williams,2005).

Though it is being mined locally in Darazo Local Government area of Bauchi State for over a decade, there are no systematic studies of its occurrence and quality. Therefore, this research work intends to analyze the deposits to determine the nature of occurrence and quality of the deposit.

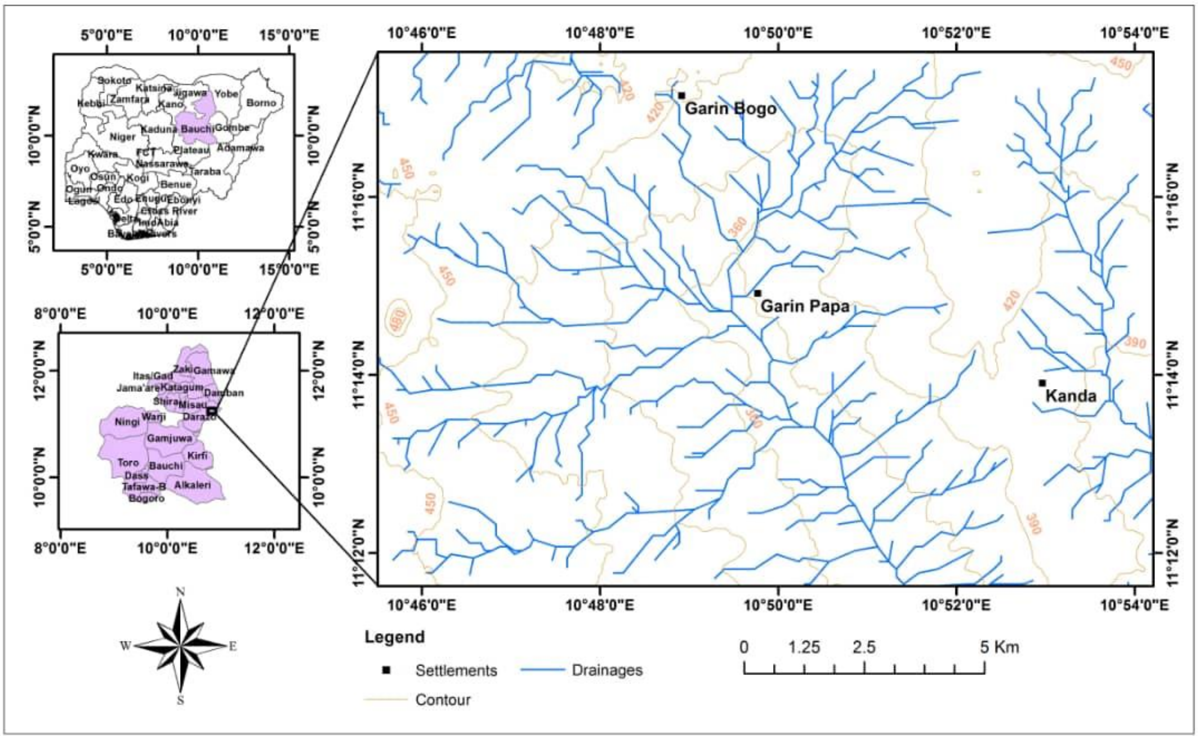

Figure 1. Location map of the study area.

Plate.1Topography of the Garin Papa

II. Geological Setting

The study area is located in within Garin Papa and environs (Fig. 1) in Darazo Local Government Area of Bauchi State. It geologically belongs to the Nigerian sector of the Chad Basin. The Nigerian sector of the Chad Basin corresponds to the South-western part larger Chad basin, which is recently referred to as Bornu Basin (Dike, 2002) and it is located in the North Western part of Nigeria. The Nigerian Chad is one tenth of the total aerial extent of the larger Chad Basin.

III. Stratigraphy Of The Chad Basin

Garin Papa is located within the South-western part of the Nigerian sector of the Chad Basin. Many authors (Okosun, 1995; Olugbemiro 1997; Obaje 1999; Nur, 2000; Shetima*et al.*, 2007) have described the geology of the area. Six stratigraphic units namely Bima sandstone, Gongila Formation, Fika Shale, Gombe Sandstone, Kerri Kerri and Chad Formations were recognized to overlay the Basement Complex in the Chad Basin. The stratigraphic succession of the Chad Basin in Nigeria is presented in (Table 1).

Age	Formation	Lithology	Paleoenvironment
Pliestocene	Chad		Continental
Paleocene	Kerri Kerri		Continental
Maastrichtian	Gombe Sandstone		Transitional
Companian			
Santonian			
Coniacian	Fika Shales		Marine
Turonian	Gongila		Marine
Cenomanian			
Albian-Aptian	Bima Sandstone		Continental
Precambrian	Basement Complex		Igneous/Metamorphic

Sandstone Fanglomerate Claystone Shale Limestone
Coal Granite/Gneiss/Migmatite/Schist = = = = Unconformity

Table 1: Stratigraphic succession of the Bornu Basin (Shettima *et a1.*, 2011)

3.1 BIMA SANDSTONE

Bima sandstone is the oldest stratigraphic unit in the Chad Basindeposited under continental environments (Carter *et a1.,* 1963).

The Formation consists of thin to thick beds of fine to coarse grained sandstone of variable colour from brown, reddish to grey. Thin bands of clay and siltstone occur as intercalation with the sandstone (Okosun, 1995). The thin limestone, calcareous sandstone and substantial shale intervals occurs according to Olugbemiro (1997). The Formation is feldspathic, poorly sorted with current bedding as some of the important features.The bedding is planar, tabular or wedged shaped varieties and the sediments thickness varies from 100-3000m (Okosun, 1995). The variation in the thickness is due to the irregular relief of the crystalline floor and/ or variable degree of deposition. The Formation is diachronous and probably of Albian to Turonian age (Carter *et al.,* 1963). Okosun (1995) and Olugbemiro (1997) respectively suggested Albian to Turonian and Albian to Cenomanian age for the Bima Formation.

Gongila Formation is a transitional sequence between continental BimaSandstone and marine FikaShale. The Gongila was name by (Carter *et al.,* l963) to differentiate it from the almost similar PindigaFormation on the Zambuk ridge). The type section of the Formation is near Gongila Village (Carter *et al.,*1963).The Formation is regarded as transitional facies (Avbovbo*et a1.*,1986) or passage beds (Carter *et a1.*, 1963). The Formation overlies the Bima Sandstone and consists of moderately thick interbeds of shale, silty sandstone and sandstone. The shale is grey to dark grey while the sandstone is of variable colour. The sandstone texture is fine to coarse grained. It has a maximum thickness of nearly 500m. The base of the formation is defined by the appearance of marine limestone above the Bima Sandstone. This basal limestone of about 3m in thickness consists of both non-fossiliferous and shalyvarieties (Carter *et al.*, 1963; Okosun, 1995;Olugbemiro, 1997). Taking into account both the Paleontological and sedimentological data, the lower part of the Gongila Formation have been deposited in shallow water in a carbonate platform environment (Rebelle, 1990) but for Obi (1998) the Gongila formation was deposited under upper shore face environment by storm and wave.Carter *et al.* (1963) reported the presence of numerous Cenomianian-lower Turonian ammonites limit the basal limestone facies in the outcrops of the Gongila Formation. Okosun (1995) and Olugbemiro (1997) have no recorded basal limestone facies as was recorded in the borehole samples (Carter *et a1.*,1963).

The Formation has a maximum thickness of nearly 500m, while the two authors Okosun (1995) and Olugbemiro (1997) recorded maximum thickness of the formation as 1410m and 1245m thick from Kinasar-l borehole. Matheis (1976) gave the age of the Formation as Cenomanian Turonian. Petter (1981) is of the view that the Formation comprises of diverse assemblage of marineplanktonic and benthonic forams of Turonian-Coniacian age. Wozony and Kogbe (1983) re-interpreted the lower Turonian Vascoreratids as partly Upper Cenomanian and dated the Gongila Formation as late Cenomanian to Turonian. Okosun, (1995) and Olugbemiro, (1997) suggested a lower Turonian and Turonian age for the Gongila Formation.

The FikaShale overlies the Gongila Formation. The formation is a marine transgression sequence. The FikaShale consists of blue-black shales, occasionally gypsiferous with thin limestone intercalations (Carter *et al.,*1963; El-Nafaty and El-Nafaty, 2000). The FikaShale hosts the gypsum mineralization. The blue black shale were deposited during the middle Cretaceous worldwide transgression in both the Benue and the Chad Basin (Petters, 1978;Okosun, 1995; Olugbemiro, 1997) the shale is locally gypsiferous with volcanic intrusive and occur as diorite sills numerous horizons in wildcat wells the Kanadi I, Sa l and Wadi -1 Wildcats Lactostratotype of 890m that was proposed by Okosun(1995) from kanadi 1 well and Olugbemiro (1997) though assign thickness of 453m.

The emplacement of the volcanoes has thermally degraded the adjacent shells that has turned buried bristled and salt. Fish and reptiles remains have been obtained and suggest a Turonian to Maastrichtian age (Carter *et al.,*1963). Lawal and Moullade (1986) suggested a Santonian to Companian age. LaterOkosun (1995) and Olugbemiro (1997) from arenaceous Foraminifera fauna and planktonic forams assigned Turonian to Santonian age respectively for the FikaShale.

The Gombe Sandstone overlies the Gongila Formation and represents the youngest Cretaceous sediments in the Chad Basin. Gombe Sandstone is a sequence of estuarine and detail sandstones, shales,siltstone, and ironstone that overlies Fika Shale Formation. Dike and Onumara (1999) and Dike (2002) suggested that the lower Gombe Sandstone contains open or central lake and mudstone passing upward to prodetail shales with thin ferruginised siltstones, then to fine and very fine grained subarkose sand. The sequence represents a prograded mouth bar. Dike (1993) reported local occurrence of coal horizon in the upper part of Gombe Sandstone. Traces of fossil and sedimentary structure suggest lower Gombe Sandstone in most place marine (Zarborki*et al.*, 1997; Zarborki, 2003). An unconformity exists between the Gombe Sandstone and the overlying Kerri Kerri Formation. A late Maastrichtian age by (Carter *et a1.*, 1963) has been confirmed by Lawal (1982).

The Kerri Kerri Formation represents the record of Early Tertiary sedimentation in northeastern Nigeria, and overlies the Cretaceous Gombe Sandstones unconformably in the Chad Basin. The Formation is essentially flat lying to gentle dipping of about 5^o (Carter *et al*., 1963 and Dike, 1993). It consists predominantly of grits and ferruginous sandstones, siltstones and claystone which is often kaolinitized.

The maximum thickness for the Kerri Kerri Formation varies from 300 meters to over 320 meters (Dessauvagie, 1975; Dike, 1993).This sequence is deposited in a wide range of environments including fluoviatile, deltaic and marginal lacustrine. Dike (1992) recognized alluvial fan, fan delta, braided stream and marginal lacustrine environments of deposition for the formation.Based on palynological data of a coaliferous horizon, the Shell-BF PetroleumDevelopment Company palynologists suggested a tentative Palaeocene age, which was confirmed by Adegoke *et al.* (1978).

The Chad Formation is a variable sequence that includes all Quaternary sediment of lacustrine origin underlying the surface deposits over a vast area (about 15,000 Km^2).The Chad Formation is the youngest stratigraphic unit in the Chad Basin. The Formation consists of sand and clay. The sand is uncemented with angular and sub angular quartz grains. It is fine to coarse grained and of variable colour from yellow brown, white to grey. The clay is massive and locally gritty in texture due to the presence of angular to sub angular quartz grains. Three separate sand bodies with thin interbeds of clay, clayey sand and sandy clay are present in the Formation. Thick sequences of clay separate the sand bodies from each other. According to Barber and Jones (1960), these sand bodies correspond to the Upper, Middle and Lower aquifers in the Chad Formation. A maximum thickness 925m were recorded from Kinasar l bore hole. Based on vertebrate fossils Barber and Jones, (1960) suggest a Lower Pleistocene age. Carter*et a1.* (1963) also suggest a Pleistocene age and Barber (1965) suggest a Pliocene age for the Chad Formation.

III. Methodology

The study involves field mapping, sampling and pitting of the kaolin layer. The fieldwork was carried out before the commencement of the rains, which tends to make the roads inaccessible due to the nature of the soil (muddy). After the fieldwork, analytical work was done and used the X- ray Fluorescence (XRF) at the Chemical and Physical Laboratories, Nigerian Mining Corporation Jos and Geochemical Laboratory University of Maiduguri for the determination of major element composition. A representative sample weighing 10g was ignited at 1100°c for 1 hour in a furnace. The different between the initial weight and the final weight was calculated to percentage for all the samples in the two locations.

3.1GEOLOGICAL MAPPING

The geologic field mapping of the areas was conducted during the dry season between the months of March-April. The field mapping was carried out after marking out the Garin Papa mining sites on the topographic map at scale of 1:25,000. Mapping was carried out along traverses and samples were collected at specific spots where outcrops are exposed and in mining pits. Materials used in the mapping exercise include; Compass Clinometers, Topographic maps, Geological Hammer, Masking tape, Pencils, Field notebook, Global Positioning System (GPS) and measuring tape. Samples were collected from the kaolin strata encountered in each pit. Sampling of the kaolin involved collection by hand sorting of the kaolin from material associated with each stratum encountered in the pits. The kaolin samples thereafter were bagged in polythene bags and labelled after its pits and stratum level. Twenty (20) representative samples of kaolin were selected for geochemical analysis

3.2 PITTING

The local mining involves the use of shovel, digger and a rubber jar with a rope tied on it to some length. The shovels used in removing overburden to the surface, while diggers used for digging, to deeper part of the pit. A rope tied with a jar used to off load the cuttings from the pits continuously until kaolin bedsare reached. Pitting was used to get access to the kaolin mineralization at depth. The pitting was carried out at two stages, the first stage comprising of scout pitting which was done in conjunction with geological mapping, to assist in search for detailed evaluation while the second stage was carried out to select prospective areas. The scout pitting was carried out as reconnaissance survey of the geological mapping. Total depth of the pits was measured and the kaolin horizon where, the close grid pits was guided by the results of the scout pitting. The areas measuring 250m x 250m each, comprising Garin Papa, Kanda, and Garin Bogo where selected for close grid pitting on a 50m square. Twenty-three pits (23) wereselected in each area with cumulative depth and maximum depth of 311.04 metres and 8 meter respectively. The pits were measured and any kaolin horizon encountered sampled.

Figure 3.2: Pitting and sampling in Kanda Area.

3.4 GEOCHEMICAL ANALYSIS

The samples are prepared for geochemical analysis, which involves the removalof impurities and thenthe dried samples were then crushed and milled to obtain fine powder. The fine powdered samples were then weighed and subjected to geochemical analysis using x-ray fluorescence analytical techniques for the determination of major elements composition,to assess the quality of the kaolin.

The procedure involved, powdered samples were loaded on the stage and concentrations were measured in percentage using minipal software programme. The stages of analysis include setting up an application by naming it as appropriate and specifying the sample type, characteristics and elements to be measured. Measuring time of 10 seconds and percentage as the unit of measurement were selected in the course of this work. The elements to be analysed are then selected from the periodic table window and saved.

The condition set window enables for selection KV value between 4 and 10 was selected together with a milliamp value between 100 and 500. Line overlap mam x was then calculated and pure specimen measured. By entering the standard and their concentrations, their measurements were effected and alphas were calculated. From the navigation control of the standardapplication window, regression analysis was conducted.Standard spectra and graph for each element was viewed. A measure window from the tool navigation bar was opened. The identity of each sample is entered and measure bottom pressed to effect the measurement of the sample. After 10 second the measurements were completed, the loading page ruled forward. Alter pressing the results bottom from the lower navigation tool, the results were viewed.

IV. Result

4.1Geology of Garin Papa

The Garin Papa area is completely underlain by Kerri Kerri Formation (Fig. 4). It comprises of grits and sandstones with well-developed cross-bedding and in some places the bedding is typically trough stratified whereas in other places it is normally bedded. Many small flat-lying and mildly undulating outcrops of the Kerri Kerri Formation dominate the Garin Papa area. The sandstone is characteristically reddish and often capped by lateritic horizons in many places. The laterites are either oolitic or pisolitic and are locally associated with kaolin mineralization which is being mined. The deposit of the kaolin where located in three different places at Garin Papa, Garin Bogo and Kanda in the central, northern and eastern part of the mapped area respectively. The mode of mineralization was observed as residual concentration type where the unwanted material was leached leaving behind the valuable material to concentrate insitu forming workable deposit which is conformable with the view of Gilbert and Park (1986).

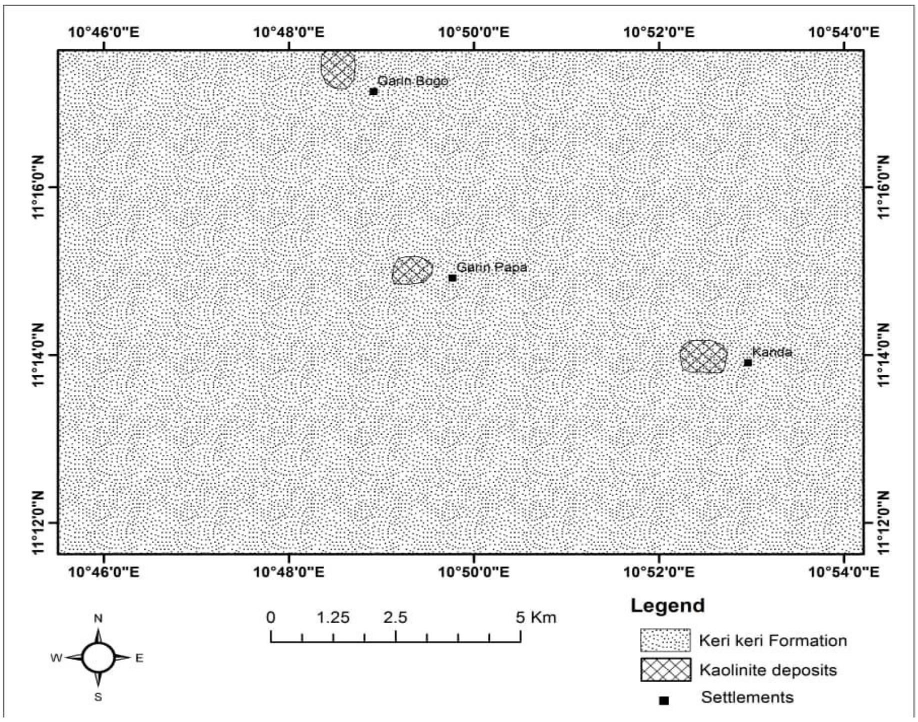

Figure 4. Geological map of the Garin Papa and environs

The mode of mining in all the mineralization area is pitting.The pits range from 3.00m to 13.25m deep. The mineralization of the kaolin is continuous andthe continuity suggests a uniform depositional environment over a wide area. Based on field observation the kaolin samples are of three different formsand the contrasting feature is basically colour which are; pinkish, reddish, and whitish varieties(Fig. 5).

Figure 5 Typical deposit of kaolin

4.2 GEOCHEMISTRY

Geochemical analysis for major element contents was carried out on the kaolin samples. A total of ten (10) samples of the kaolin was analyzed geochemically and the result is presented in Table 1.

Table 1. Major elements abundance of Kaolin in Garin Papa and environs

Oxide (wt%)	L1	L2	L5	L6	L7	L29	L30	L36	L37	L38	Average
SiO_2	43.6	42.6	43.8	44.7	44.4	42.6	41.9	45.7	44.0	43.6	43.69
Al_2O_3	39.5	38.8	37.8	38.3	38.1	39.0	36.7	37.9	38.4	38.0	38.20
Na_2O	0.16	0.18	0.09	0.11	0.16	0.17	0.19	0.16	0.08	0.20	0.15
K_2O	0.07	0.06	0.08	0.04	0.10	0.08	0.09	0.05	0.07	0.06	0.07
CaO	0.40	0.38	0.40	0.44	0.38	0.41	0.50	0.40	0.44	0.46	0.42
MgO	0.09	0.08	0.07	0.09	0.07	0.07	0.06	0.10	0.11	0.08	0.08

Fe_2O_3	0.76	0.75	0.73	0.70	0.80	0.74	0.77	0.69	0.75	0.78	0.75
TiO_2	1.05	1.10	1.07	1.08	1.06	1.06	1.10	1.00	0.89	1.06	1.05
LOI	**12.64**	**12.70**	**11.72**	**12.67**	**13.06**	**13.66**	**12.48**	**12.93**	**12.52**	**12.80**	**12.72**

The silica (SiO_2) content of the Garin Papa kaolin ranges from 41.9 % to 45.7 % with an average value of 43.69 %. The Kutigi kaolin has average silica value of 50.94% (Akhirevbulu*et al*., 2010) and the Ukpor and Ahoko Kaolin has average silica content of 57.85% (Eterigho and Olutoye, 2007) indicating that the Garin Papa kaolin has lower silica content compared to the Kutigi, Ukpor and Ahoko kaolin. It is also less than the standard average value given by American Elements (2014) as 52 ± 2.0.

Alumina (Al_2O_3) content in Garin Papa kaolin varies from 36.7 % to 39.5 % with an average value of 38.2 %. The Kutigi kaolin gave average alumina content of 32.93% (Akhirevbulu*et al*., 2010) while the Ukpor and Ahoko kaolin gave average alumina value of 28.15% (Eterighoand Olutoye, 2007). These suggest that the Garin Papa kaolin has higher alumina compared to both Kutigi, Ukpor and Ahoko kaolin and also less than the standard average value given by American Elements(2014) as 45 ± 2.0.

Soda (Na_2O) values of the Garin Papa kaolinranges from 0.08 % to 0.20 % with an average of 0.15 % whereas that of Xuzhou (China) has an average value of 0.37% (Bu *et al*., 2017) and that of Marand (Iran) has average value of 0.80 (Hosseni*et al*., 2011) indicating that the Garin Papa kaolin has lower content of soda compared to the Xuzhou and Marand kaolin. It agrees with the standard average value given by American Elements (2014) as < 0.2.

The potash (K_2O) content in the Garin Papa kaolinranges from 0.04 % to 0.10 % with an average of 0.07%. The Xuzhou kaolin has average potash content of 1.80% while the Riyadh (Saudi Arabia) kaolin has average potash content of 0.17%. These indicate that the Garin Papa kaolin has lower content of potash in comparison with those of Xuzhou and Riyadh and itfalls within the standard average value given by American Elements (2014) as <0.1.

Lime (CaO)composition in the Garin Papa kaolin varies from 0.38% to 0.50% with an average value of 0.42°/o. However, in the Kutigi, Ukpor and Ahoko areas the lime averages 0.23%and 0.4% respectively indicating higher lime content in the Garin Papa kaolin compared with the Kutigi kaolin but lower lime content in Garin Papa kaolin compared with the Ukpor and Ahoko area whileit is conformable with the standard average value by American Elements (2014) as < 0.5.

The magnesia (MgO)concentration in theGarin Papa kaolin ranges from 0.06% to 0.11% with an average value of 0.08%. The Xuzhou kaolin has average value of magnesia as 0.32% while the Marand kaolin has magnesia content of 0.60% suggesting that the Garin Papa kaolin has lower magnesia in comparison with both Xuzhou and Marand kaolin and also is slightly above the standard average value given by American Elements (2014) as < 0.03.

Total iron (Fe_2O_3) content in the Garin Papa kaolin ranges from 0.69% to 0.80% with an average value of 0.75% while the Kutigi, Ukpor and Ahoko kaolin has average values of total iron as 1.78% and 2.91% respectively. This indicate that the Garin Papa kaolin has lower total iron compared to the both Kutigi, Ukpor and Ahoko kaolin and it is slightly above the standard average value given by American Elements (2014) as ≤ 0.5.

TiO_2concentration in the Garin Papa kaolin varies from 0.89 % to 1.10 % with an average value of 1.05 % while the Kutigi kaolin has average TiO_2content of 0.03% indicating that the Garin Papa kaolin has higher TiO_2 compared to those of Kutigi area andit is conformable with the standard average value given by American Elements (2014) as ≤ 1.5.

V. Discussion

5.1 Geology of the Garin Papa

Geological mapping of the Garin Papa area was conducted and the geological map was produced (Fig. 4). The field mapping exercise revealed that the area is wholly underlain by Kerri-Kerri Formation typified by reddish sandstone which is occasionally capped with lateritic blanket that is either oolitic or pisolitic. Three kaolin mineralization areas were located, sampled and investigated. The kaolin is divided into three type on account of field observation as: the pinkish variety, the reddish variety and the whitish variety but all are geochemically similar. The variation in colour is attributable to impurities present in varying proportions in the samples (Adamis and Williams, 2005; Bu *et al*., 2017).

The Garin Papa Kaolin has average (n=10) concentrations of the major oxides as follows: 43.69% SiO_2, 38.2% Al_2O_3, 0.15 Na_2O, 0.07% K_2O, 0.42% CaO, 0.08% MgO, 0.75% Fe_2O_3, 1.05% TiO_2. These indicate that the kaolin has $Al_4Si_4O10(OH)_8$ value of over 75% this met the standard value reported by the American element (2004) and also the alumina-silicate content is comparable with those reported by Bu et al. (2017); Varga (2007); Zahrani and Abdul-Majid (2009) indicating good quality kaolin that can be utilized in the manufacture of agricultural chemicals, pharmaceutical purposes, construction materials, chemical and metallurgical applications.

Zahrani and Abdul-Majid (2009) worked on kaolin from Riyadh area of Saudia Arabia, the chemical compositions of the kaolinitic clay are SiO_2 47.25% and Al_2O_3 having 29.4%.The sample is found to be rich in silica and alumina but poor in Fe_2O_3 (2.87%) and TiO_2 (1.17%). Other components present such as CaO, MgO and MnO are in negligible amounts. This is closely related to the work of Varga (2007) who studied the chemical composition of kaolin and found the clay to be rich in SiO_2 (46.3%) and alumina (39.8%). Bu *et al*, (2017) investigated the removal of fine quartz from coal-series kaolin sourced from Xuzhou, Jiangsu province of Eastern China. The X-ray fluorescence analysis showed the silica and alumina content to be 56.72% and 21.67% respectively. Other constituents such as CaO,MgO,Fe_2O_3 and TiO_2 are present in trace amounts. However, this chemical characteristic is similar to the kaolin of Garin Papa and environs.

The loss on ignition (L.O.I) value gives information about the organic matter content in a sample. It calculates the percentage organic matter by comparing the weights of a sample before and after the sample have been ignited. The L.O.I value for the Garin Papakaolin has average value of 14.85% this was found to be closely related to that obtained by Bu et al. (2017) which was 14.13%. Although these were a little higher than the value reported by Hosseniet al., (2011) and lower than that reported by Zahrani and Abdul-Majid (2009) which were 10% and 16.02% respectively. This is an indication that there is low organic matter present in these clay materials suggesting high quality.

VI. Conclusion

The following are the main conclusions drawn from this study; Geochemical analysis of theGarin Papa kaolin samples indicates that it contained over 75% $2H_2OA1_2O_32SiO_2$indicating good quality kaolin suitable for agriculture, pharmaceutical, construction, chemical and metallurgical industries. The mineralization of the kaolin is of residual concentration type which is been mined for many industrial utilizations.

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