The Geology and Mineralogy of Clay Occurrences Around Kutigi Central Bida Basin, Nigeria.

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Abstract

This paper reports the geology and mineralogy of the clay occurrences around Kutigi. The methodology of research includes detailed mapping of the area, collection of clay samples and laboratory analysis using X- ray diffraction. Field results show that clays in Kutigi are deposited as alluvial deposit from braided and meandering streams and occur in two locations A and B. The deposits are of varying thicknesses and are capped by thin lateritic soil. The clay varies from white to dirty- white in colour as a result of the decolouration from the laterite overburden. The gritty feel of the clay from hand specimen is attributed to the clay-sand admixture, an indication of proximal overbank environment. The results from X-ray diffractogram show that the clay mineral is predominantly kaolinitic with a percentage abundance of about 43.64%. The high dominance of quartz with a percentage abundance of about 54.55% further confirms the grittiness of the clay. Illite constitutes about 1.18% and occurs in traces amongst other minerals. The above results and an earlier geochemical analysis suggest that it can be utilized in the manufacture of ceramics, refractory bricks, paper, paint and fertilizer.

Introduction

Clay is a common name for a number of fine-grained, earthy materials that become plastic and tenacious when moist, and that becomes permanently hard when baked or fired. According to (Velde, 1995), clay is applied both to materials having a particle size of less than 2 micrometers and to the family of minerals that has similar chemical compositions and common crystal structural characteristics.

Clay is formed either as a product of the chemical weathering of pre-existing granitic rocks and feldspar minerals, particularly in warm tropical and subtropical regions of the world or as a result of the hydrothermal alteration of granitic rocks.

Chemically, clays are hydrous aluminum silicates, ordinarily containing impurities, for example potassium, sodium, calcium, magnesium, or iron, in small amounts, and are characterized by sheet silicate structures of composite layers stacked along the c-axis (Grim, 1968). Clay has a wide variety of physical characteristic such as plasticity, shrinkage under firing and under air-drying, fineness of grain, colour after firing, hardness, cohesion, and capacity of the surface to take decoration.

Clay and clay minerals have been mined since the Stone Age and has been indispensable in architecture, in industry, and agriculture. Today they are among the most important minerals used by manufacturing and environmental studies. Globally, clay has a wide spread occurrence. In Nigeria, clay is widely distributed though not always found in sufficient quantity or suitable quality for modern industrial purposes. More than 80 clay deposits have been reported from all parts of the country. For instance, clay deposits occur in Abak, Akwa Ibom State, Uruove near Ughelli in Delta State, Ifon in Ondo State, Mokola in Oyo State, Sokoto in Sokoto State, Gombe in Gombe State, Dangara in Niger State, Umuahia in Abia State, Onitsha in Anambra State and Kutigi in Niger State. e.t.c. The focus of this work is to investigate the occurrences of clay around Kutigi, as well as to determine its mineralogical properties.

The study Area.

The study area (Kutigi) is situated in Lavun Local Government Area of Niger State, within Bida basin. It lies between longitude 5^{o} 35^{1} E and 5^{o} 39^{1} E and latitude 9^{o} 10^{1} N and 9^{o} 13^{1} N and covers an area of about 39.88km^{2} (Fig. 1). Kutigi is the major town in the area, while the surrounding villages include Kusogi, Shebe, Makufu, Fazhi and Ruga.

The physical landform of Kutigi area is made up of flat-lying to gently rolling plains. The monotony of the landscape is however broken by residual hills, which are either conical or flat-topped. The area is mark by a NW–SE and a NE–SE running ridges that are prominently composed of laterite. The ridges ranges from 15m to 50m in height as observed along the road cutting between Kutigi town and Ruga village. The terrain is mostly covered by laterite and fairly by sandstone as a result of the weathering activities that have depleted the hills and ridges. The area is particularly drained by river Toro which run near Kusogi village and flow in the NE direction of Egbako SW. Many insequent streams that enters river Toro as tributaries are seasonal and forms a dentritic drainage pattern which strongly suggest that the terrain is

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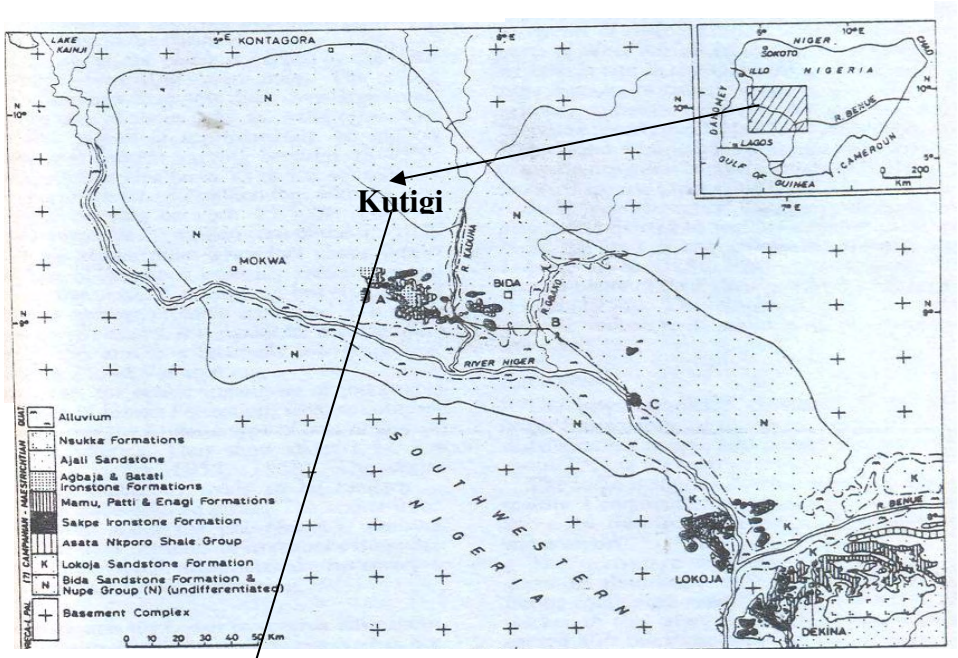
composed of lithological, structural and topographic homogeneity.

Though the rainy season and dry season are the two known climatic seasons, it is worthy to note that the duration of any of these seasons may vary locally from one area to another- this is the case of Kutigi. Its annual rainfall have been determined by the Department of Geography, Federal University of Technology, Minna to amount between 1270mm – 1524mm, spread over the month of April – October with the highest amount received in the month of July. Mean annual temperatures are between 22°C and 33°C although there could also be local climatic changes. The vegetation is characterized by patches of woodlands and long grasses in river valleys and fairly low hills.

(a)



(b)

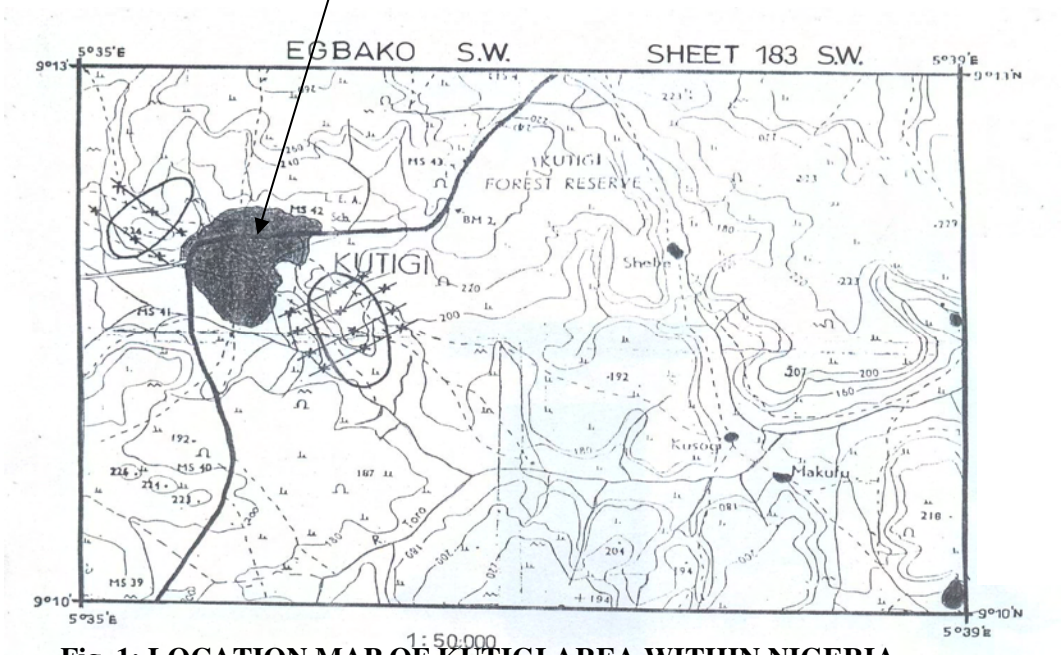


Fig. 1: LOCATION MAP OF KUTIGI AREA WITHIN NIGERIA AND BIDA BASIN

Review of Literature

Adeleye (1971), and Adeleye and Dessauvagie (1972) identified clays in the Middle Niger Basin or the Nupe sandstone now renamed the Nupe Group. They studied the Stratigraphic succession in the area and reported the direct overlying of the basement complex by a coarse conglomerate, clay-sandstone admixture, boulders etc of sedimentary origin. These, according to Adeleye, were themselves overlain by sandstone, and subsidiary claystones, conglomerate and siltstones.

The University of Ife (Adegoke, 1979) and Ahmadu Bello University Consultancy team also studied clays in parts of Bida basin. Adegoke, (1979) worked on the structural properties of these clays at temperatures of 600^{o}C -1000 ^{O}C. All the clay occurrences investigated fall within the Cretaceous Maestrichtian in middle Niger basin (Bida Basin). The two main types of clays in the area are the earthy brownish to red lateritic clays and the grayish ball clays. There are also the whitish and silty kaolinites. The lateritic clay occurs beneath thin to thick covers of laterite on residual hills. The earthy lateritic clays are ubiquitous in occurrence. The grayish ball-clays within the Bida basin occur on alluvial plains of rivers. These are seemingly secondarily derived clays deposited from suspension load in the streams. They are generally plastic in nature. There are other similar clays but those are derived from the feldspar rich basement rocks (Adegoke, 1979).

The first hill visited (which he called location A) is located behind ministry of works north east of Kutigi town. The second hill visited (which he called location B) is located behind Sharia Court, north west of Kutigi town. He explored and estimated the reserve extent of the clay deposits. Geophysical evidence of Alabi, (2005) suggests that the total reserve of the Kutigi clay deposits are estimated to about 672,579 tons, with an aerial extent of about 57,400m^2 of clay bed in location A, and also an area extent of 300m^2 in location B. The results of his physical analysis show medium plasticity index average of 30%, Specific gravity of 2.61 and medium linear shrinkage average of 2.68%. His chemical analysis show the high dominance of SiO_2 66%, Al_2O_3 26.87%, TiO_2 1.45%, Fe_2O_3 0.99 %, while the remaining 4.69% represents other elements in trace amount.

From various tests conducted on Kutigi clay, he reported that Kutigi clay occur as residual clay due to the weathering of feldspar from feldspathic sandstone. The clay was noted to be suitable as raw material to the ceramic, paper, refractory and paint industries respectively.

General Geology of the study area

The area of study falls within Bida Basin, which extends from Kontagora in Niger State to Dekina in Kogi State where it merges with the Anambra Basin. The total length of Bida basin was estimated at 400km with a maximum width of about 160km. The basin is bounded to the North and South by the Precambrian basement rocks. The largest portion of the basin (the central part) occurs in the southern half of Niger State and constitutes the study area (Fig. 1.). The age of the sediment is Maestrichtain as determined by Jan du Chene et al (1978) from pollens in Lokoja formation to the south, which Adeleye (1973, 1975) considered to be laterally equivalent to the Bida sandstones. The origin of the basin is believed to result from the reactivation of mega-shears in the Precambrian basement, which created fault patterns trending northeast-southwest and northwest-southeast (Kogbe, 1981). A rift origin for the basin has been postulated by Kogbe (1981) whilst Whiteman (1982) suggested the basin to have been formed from simple cratonic sag. The sedimentation data presented suggest that the central Bida basin was formed by rifting or by cratonic sagging.

Research Methodology

Detailed field mapping was carried out around Kutigi in order to establish the local geology of the area. The method of investigation involved an intensive fieldwork, which lasted for eight days. For the purpose of this study, a map extract was adopted from a topographical map on sheet 183 of Egbako SW of Niger State at a scale of 1: 12,500. During the fieldwork, accessibility and collection of soil samples in the study area were made possible by walking along roads and footpaths. On the field, the soil exposures were observed and described based on their colour, texture, structural elements and mode of occurrences.

From field observations, all locations within the study area consist of laterite except near Kutigi town, where two hills suspected to contain clay were identified.

To ascertain if the two hills observed near Kutigi town actually contains clay, a

confirmatory test was conducted which involves the addition of small amount of water to powdered sample and the mixture uniformly stirred until a plastic stage is attained. The results of the observed experiments were affirmative. As such, both hills were assigned location A and location B respectively for easy identification. A total of twenty (20) clay samples weighing about 18kg, were randomly taken from both locations with the aid of a geological hammer. All samples were carefully labeled and arranged in sac bags for the laboratory analyses.

Laboratory Analysis

A quantitative determination of the mineralogical property of the clay samples using X-ray diffraction were carried out at National Steel Raw Material Exploration Agency, in Kaduna, Nigeria.

The clay samples were broken down and a representative quarter obtained. With a clean mortar and pestle, the sample was pulverized into powder consisting of a near- infinite number of small crystals in random orientations. The powdered sample was weighed and tested using a PW1800 automated powder diffraction equipped with a Cu -Kα radiation source (30kV, 55mA), inbuilt standards, peak/width and a detector. The diffraction pattern was obtained with the aid of a computer, while the 2θ, d-values and peak intensities yielded by the powder patterns were used to identify the minerals.

Results

Field Observations.

Two hills (location A and location B) were identified and observed to contain deposits of clay within the study area, both which are near, and separate by Kutigi town. Location A measures N 20° W, while location B measures N 39° E of Egbako SW. Other locations within the study area consist typically of laterite.

Description of Location A

Location A was the first hill visited in the study area. It is situated southeast of Kutigi town and lies beside Niger State Ministry of Works, Kutigi. It is a long residual hill with an average height of about 38m and a length of about 138m. The hill is steep and has poor vegetative covers. It consists of a coarse-grained, thin layer of lateritic overburden of about 2.5 – 9m thick that grade finely upward. It varies from red to reddish brown in colour. The overburden was underlain by a bed of poorly exposed deposits of clay, though relatively exposed by an abandoned excavated pit located at the side of the hill. The clay feels gritty to touch from hand specimen and varies from white to dirty white in colour. The clay, which is about 3m – 12m in thickness, thins out towards Kusogi village. At the foot of the hill lies a bed of sandstone of about 1-10m thick.

Exposures of clay in location A occur at five (5) different points on the surface of the hill, with varying heights and distance from each other. The points were assigned location A_1 (loc A_1), location A_2 (loc A_2), location A_3 (loc A_3), location A_4 (loc A_4) and location A_5 (loc A_5) respectively for easy identification.

Description of Location B.

Location B was the second hill visited in the study area. It is situated behind Hillside Hotel/ Niger State Judiciary Upper Sharia Court Northwest of Kutigi town. The hill, which is about 30m high, with a length of about 110m, is a continuous ridge with steepy sides and poor vegetation. The hill consists of an overburden with mixture of laterite and sandstone with a thickness of about 1.5m. Beneath the overburden lies a bed of poorly exposed clay with a thickness of about 6m intercalated with a layer of laterite of about 14m. The clay varies from white to brownish white in colour from hand specimen. The decolouration of the clay was probably as a result of stains from the laterite overburden. Present at the foot of the hill are deposits of coarse-grained sandstone of about 8m in thickness.

Location B contains two (2) points of clay exposure at the surface of the hill with varying heights and distances from each other. Each point was assigned location B_1 (Loc B_1) and location B_2 (Loc B_2) respectively.

Results of mineralogical analysis.

A sample of the results obtained from the X-ray diffraction analysis is presented in fig. 2. below. A summary of the XRD results of the mineralogical analysis are presented in Table 1. Table 2 shows the comparison of the mineralogical composition of the clay with those of other well-known clays.

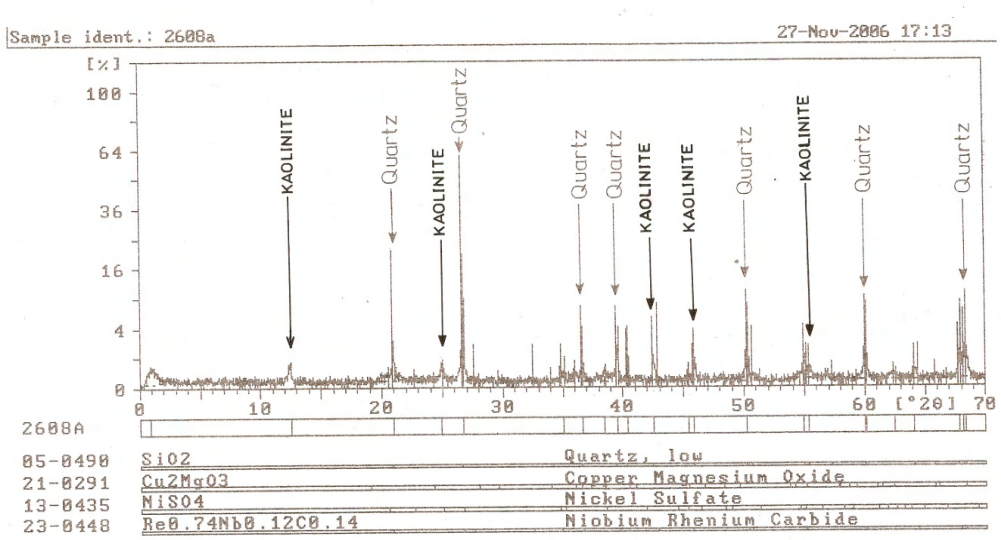


Fig. 2. X -ray diffraction result of Kutigi clay Loc A1/ sample 1.

The XRD results of the mineralogical analysis showed the mineralogical assemblages of the sample. The major minerals present have been indicated against the diagnostic peaks as shown in figure 2.

The results of the mineralogical composition of the clay show that the dominant minerals present are kaolinite and quartz, while illites occur as traces. Of all the mineral presents, kaolinite alone constitutes about 43.64%, quartz constitutes about 54.55% while illite constitute about 1.18% in the unprocessed sample. However, result of the investigated clay deposits differ significantly from those of some well-known kaolin deposits in terms of their mineralogical compositions (Table .2). The Kaolinite content of Kutigi clay (43.64%) is by far lower than that of Ibadan (91%), Oza-Nagogo (86%), Kaduna (96%), China-clay (85%) and NAFCON recommended value (85%). Whereas the quartz content of Kutigi clay (54.55%) is far higher than those of Ibadan (6%), Oza-Nagogo (14%) Kaduna (2%), China-clay (traces) and NAFCON recommended value (4%). The illite content of Kutigi clay constitutes about 1.18% which is lower than a value of 3% that was recorded for both Ibadan and Kaduna, absent in both Oza-Nagogo and NAFCON recommended value, and lower than 15% average mineralogical composition of China-clay.

Discussion

The study area was mapped and it covers an area of about 39.88km^2. It is generally underlain by Enagi siltstone. During the mapping exercise two clay deposits were encountered, both of which are situated near and between Kutigi town. Location A, measures N 20° W of Egbako SW with an average height of about 38m and a length of about 138m. While location B measures N 39° E of Egbako SW, with a height of about 30m and a length of about 110m. The deposits displayed a laterite – clay – sandstone lithological formation. The clay deposits are of varying thicknesses capped by thin lateritic soil. The clay varies from white to dirty white in colour and feels gritty to touch from hand specimen. Below the clay deposits lay deposits of sandstone. The area is also mark by a NW–SE and a NE–SE running ridges that are prominently composed of laterite. The ridges ranges from 15m to 50m in height as observed along the road cutting between Kutigi town and Ruga village.

Mineralogical investigation of the clay, revealed the presence of kaolinite, quartz and fairly, illite. Kaolinite constitutes about 43.64%, quartz about 54.55% and illite about 1.81% in the unprocessed samples. The high dominance of quartz in the clay deposits clearly explains its grittiness and also suggests the clay to be of residual origin._Kutigi clay differs significantly from those of other well-known deposits in terms of its mineralogical composition. These well-known deposits include Ibadan kaolin, Oza –Nagogo, Kaduna (Kankara) kaolin, China-clay and recommended clay values by NAFCON.

Geophysical investigation of Kutigi clay deposits of Alabi, (2005) revealed an area extent of about 57,400m^2 of clay bed in location A, and an area extent of 300m^2 in

location B. He estimated the total reserve to about 672, 579 tons. Similarly, the chemical analysis of the clay deposits of Alabi, (2005) revealed a high dominance of SiO_2 66%, Al_2O_3 26.87%, TiO_2 1.45%, Fe_2O_3 0.99%, other elements ranged between 0.39% to trace.

Conclusion

On the basis of the results from the geological mapping and x-ray diffraction analysis, it can be deduced that the Kutigi clay was deposited as alluvial deposit from braided and meandering streams, and it is predominantly kaolinitic in nature. The colour of the clay, which varies from white to dirty-white, is attributed to stains from the laterite overburden. The admixture of clay and sand is an indication of proximal overbank environment. A low percentage value recorded for Kutigi kaolin (43.64%) compared to higher percentage values recorded for some well-known kaolin deposit, in terms of their mineralogical composition are attributed to its high percentage of quartz.

More so, the grittiness of the clay is also attributed to the high dominance of quartz. The results of the mineralogical investigation of the Kutigi clay deposits carried out in this study and the geochemical analysis of Alabi (2005), suggest that they can be utilized in the manufacture of ceramics, refractory bricks, paper, paint and fertilizers.

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Table 1: Summary of X-ray diffraction results for Kutigi clay.

Sample No	Angle [° 2θ]	Rel. Int (%)	Diagnostic Mineral
Loc A_1/1	12.485	8.6	Kaolinite
	20.935	20.1	Quartz
	24.950	4.2	Kaolinite
	26.730	100.0	Quartz
	36.605	5.4	Quartz
	39.510	4.5	Quartz
	42.485	3.7	Kaolinite
	45.855	2.4	Kaolinite
	50.190	9.4	Quartz
	55.350	2.2	Kaolinite
	59.995	6.0	Quartz
	68.370	5.6	Quartz
Loc A_2/3	12.440	2.8	Kaolinite
	20.930	1.2	Quartz
	24.940	1.8	Kaolinite
	26.685	4.2	Quartz
	50.170	1.1	Quartz
	59.975	0.7	Kaolinite
Loc A_3/5	12.405	12.6	Kaolinite
	20.415	3.8	Kaolinite
	20.895	6.0	Quartz
	24.915	7.9	Kaolinite
	26.705	24.3	Quartz
Loc A_4/7	12.505	7.5	Kaolinite
	20.945	4.5	Quartz
	24.985	5.1	Kaolinite
	26.755	19.5	Quartz
	35.045	1.4	Illite
	38.475	2.1	Kaolinite
	50.190	2.0	Quartz
Loc A_5/9	12.470	5.7	Kaolinite
	20.945	15.4	Quartz
	24.960	3.5	Kaolinite
	26.725	100.0	Quartz
	36.620	5.2	Quartz
	39.550	6.7	Quartz
	42.555	4.5	Kaolinite
	45.830	3.7	Kaolinite
	50.160	8.4	Quartz
	54.930	3.2	Kaolinite
	59.980	8.2	Quartz
	68.175	5.9	Quartz

Loc B_1/11	12.405 20.875 24.905 26.695 36.575 50.145	1.3 1.5 0.8 4.5 0.7 0.7	Kaolinite Quartz Kaolinite Quartz Quartz Quartz
Loc B_2/16	12.430 20.900 24.965 26.670 39.480 50.145 59.985	11.3 3.8 7.7 26.4 2.8 3.6 2.4	Kaolinite Quartz Kaolinite Quartz Quartz Quartz Kaolinite

Table 2: Average Mineralogical composition (in percentages) of Kutigi clay with those of other clays.

Minerals %	**Kutigi clay**	**Well known Kaolin deposits**				
	Average (7) Samples	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**
Kaolinite	43.64	91	86	96	85	85
Quartz	54.55	6	14	2	Tr	4
Illite	1.81	3	-	3	15	-
K-feldspar	-	-	-	-	-	3
Others	-	-	-	-	-	8

Source: (Coker, Emofurieta and Kayode, 1992)