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Geochemistry and Mineralogy of Clays from the Kerri-Kerri Sub-Basin N.E Nigeria

Abdulmajid Isa Jibrin
Department of Geology, Abubakar Tafawa Balewa University, Nigeria
Abubakar Sadiq Maigari
Department of Geology, Abubakar Tafawa Balewa University, Nigeria
Abdullateef Lawal
Department of Geology, Abubakar Tafawa Balewa University, Nigeria
Ahmed Isah Haruna
, Department of Geology, Abubakar Tafawa Balewa University, Nigeria
Hamza Yalwa Mohammed
Department of Geology, Abubakar Tafawa Balewa University, Nigeria
Idris Ismail Kariya
Department of Geology, Abubakar Tafawa Balewa University Nigeria
Umar Lawan Dalorima
Department of Geology, University of Maiduguri,Borno State Nigeria

Abstract:
Clays from the Kerri-Kerri Formation were investigated in order to determine their mineralogical, chemical composition, weathering pattern and possible industrial applications. X-Ray Diffraction (XRD) and X-Ray Fluorescence (X-RF) analysis was used in order to achieved the desired objective. SiO_2 is dominant in all the sample with value ranging between 47.6-76.2 wt%, Al_2O_3 (14.10-36.40) wt%, Fe_2O_3 (0.35-8.69) wt%, Mno, MgO, CaO, Na_2O and K_2O are in minor amounts. Based on the Mineralogy the clays have kaolinite as the only clay mineral with values between 19.52 wt%-90.37wt%, quartz is the dominant non-clay mineral which has values between 4.75 wt %- 65.16wt%, anatase, rutile, microcline, hematite and muscovite are in minor amounts. All the clays indicate a source from region of intense chemical weathering under warm climate and they can be used in ceramic and refractory bricks.

Keywords: *Kerri-Kerri, kaolinite, mineralogy, weathering*

1. Introduction

The Kerri-Kerri is a continental sequence that represent sediments of Early Tertiary in the Upper Benue Trough, Northeastern Nigeria. The Formation was deposited under continental environment which is represented by deltaic, marginal lacustrine and transitional environment (Dike 1993). Kaolin is a white plastic clay composed of kaolinite $Al_4(OH)_8[Si_4O_{10}]$ and other clay minerals like nickerite and dickite. Kaolin deposit can be either primary or secondary based on genesis; primary deposit originate by in-situ alteration while secondary are sedimentary in origin (Murry 2002). Clay has a wide range of occurrences globally, in Nigeria clays are widely distributed in almost every part of the country. Clay is a major raw material in numerous industries among which are; ceramic, paint, paper, refractory, fertilizer and pharmaceuticals (Abel .O et al 2012). Kaolin has numerous industrial applications; each application requires some particular properties.

2. Literature Review

The Benue Trough is an intracratonic rift that evolved during the separation of the African continent from the South American continent (Benkhelil, 1989). It is partitioned into upper, middle and lower parts (Fig 1). The Upper Benue Trough has two arms: Gongola and Yola arms. The study area is within the Gongola arm, the stratigraphy of the Gongola arm comprises of the continental (Albian) Bima Formation, the transitional Yolde Formation (Cenomenian), marine Pindiga Formation (Turonian-Santonian), Fika shale (Santonian) the continental Gombe Sandstone (Campano-Maastrichtian) and the Tertiary Kerri-Kerri Formation, as shown in figure 2.

The Kerri-Kerri Formation is composed of coarse-grained sandstones, clayey grits, siltstones and clay stones. Three distinct lithofacies have been identified in the Kerri-Kerri Formation; Ferruginous sandstones, clayey sandstones and laterites (Adegoke et al 1986). According to Carter et al, (1963) and Wright (1976) the Kerri-Kerri Formation was derived from older sedimentary beds at the end of Maastichtian folding, uplift and erosion.

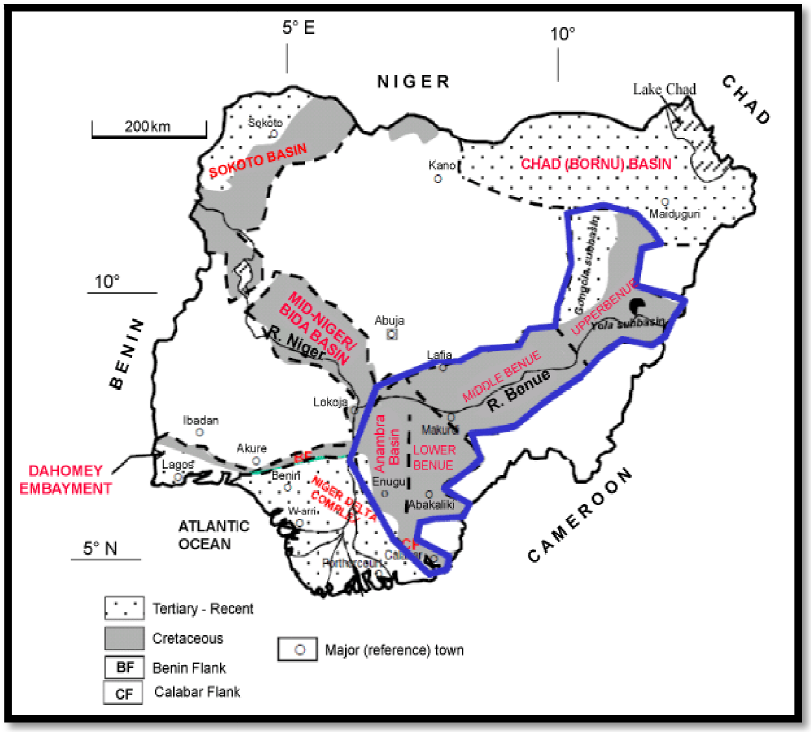

Figure 1: Map of Nigeria Showing the Gongola Basin

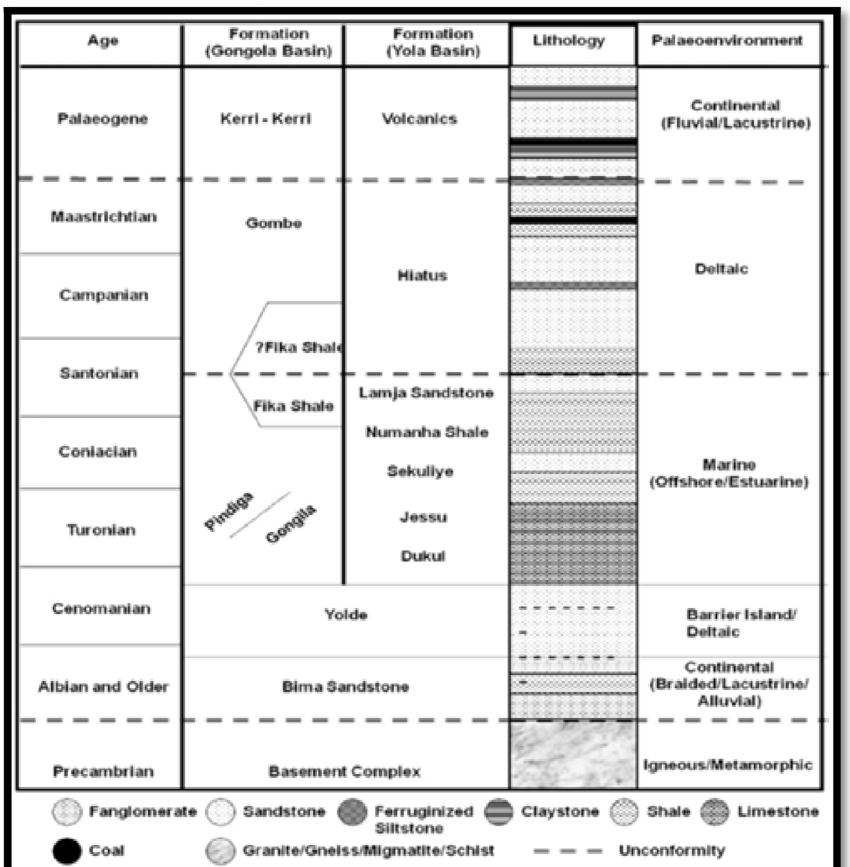

Figure 2: Stratigraphy of the Upper Benue Trough

3. Materials and Methods

Clay samples were collected from Gombe and Bauchi State in areas around;Alkaleri, Kirfi, Dukku, Gombe Abba, Papa, pindiga, Gombe and Bojude (Fig 1). The samples were pulverized to 0.07 mm size and packed for XRF and XRD analyses at University of Pretoria, South Africa.

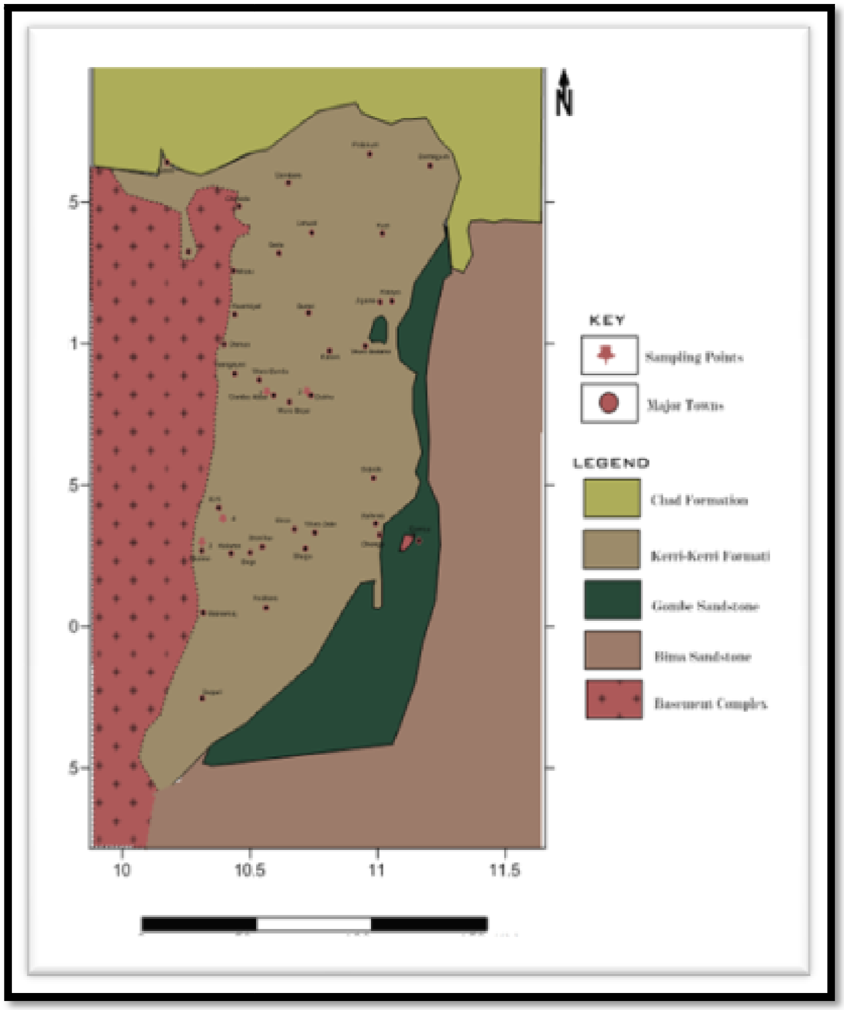

Figure 3: Sample Location Map

3.1. Mineralogical Analysis

The samples were analyzed using a Panalytical X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert High score plus software.

The relative phase amounts (weights %) were estimated using the Rietveld method (Autoquan Program). Errors are on the 3-sigma level in the column to the right of the amount.

3.2. Chemical Analysis

The samples were dried at 100°C and roasted at 1000°C to determine Loss on Ignition (LOI) values. 1g sample was mixed with 6g Lithiumteraborate flux and fused at 1050°C to make a stable fused glass bead. For trace element analyses the sample was mixed with PVA binder and pressed in an aluminium cup at 10 tons. The Thermo Fisher ARL Perform'X Sequential XRF with OXSAS software was used for the analysis.

4. Results and Discussion

4.1. Mineral Composition

Result from the diffractograms shows that kaolinite is the only clay mineral (19.52 wt%-90.37wt%) in all the analyzed samples, the non-clay minerals include; quartz (4.75 wt %- 65.16wt%), anatase (0-4.63wt%), rutile (0-1.14wt%), hematite (0-7.5wt%), microcline (0-16.09wt%) and muscovite (0-13.88wt%). Summary of the quantitative and qualitative analysis can be seen in Table 1 and figures 3,4,5,6,7,8 and 9. The presence of feldspar in kaolinite clays from Gombe, Dukku and Gombe Abba indicates incomplete alteration/weathering of the older crystalline rocks in the study area, samples with much quartz have poorer kaolinite content.

Minerals (wt%) I	II	III	IV	V	VI	VII	
Clay Mineral							
Kaolinite 87.34	48.35	48.16	75.31	81.84	19.52	90.37	
Non clay minerals							
Anatase01.73 0	04.63	4.43	2.80	0	3.35		
Hematite 0	07.5	0	0	0	0	0	
Microcline 0	06.94	16.09	0	0	10.12	0	
Muscovite 0	0	0	0	10.61	5.19	0	
Quartz 10.93	37.22	46.07	20.26	04.75	65.16	6.29	
Rutile 0 0	01.14	0	0	0	0		

Table 1: Mineralogical Composition of the Studied Clays from the Gongola Basin, Northern Benue Trough, Nigeria
Key: I=Papa, Ii=Gombe1, Iii=Dukku,
IV=Bojude, V=Alkaleri, VI=Gombe Abba, Vii=Gombe Abba

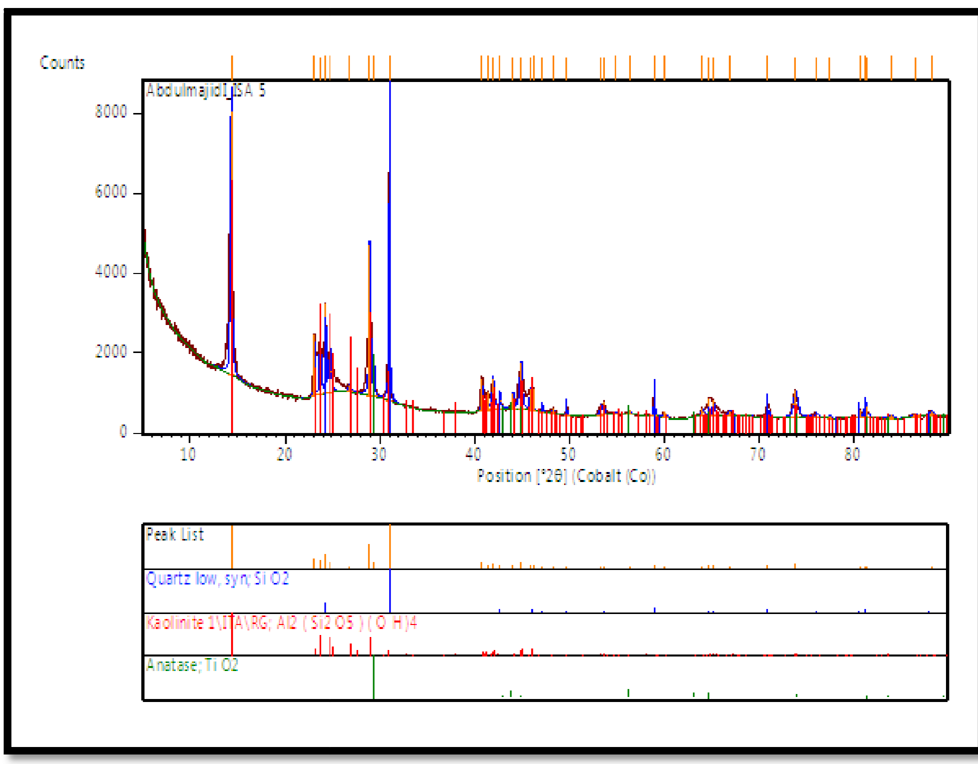

Figure 4: X-RD Pattern of Bojude Clay

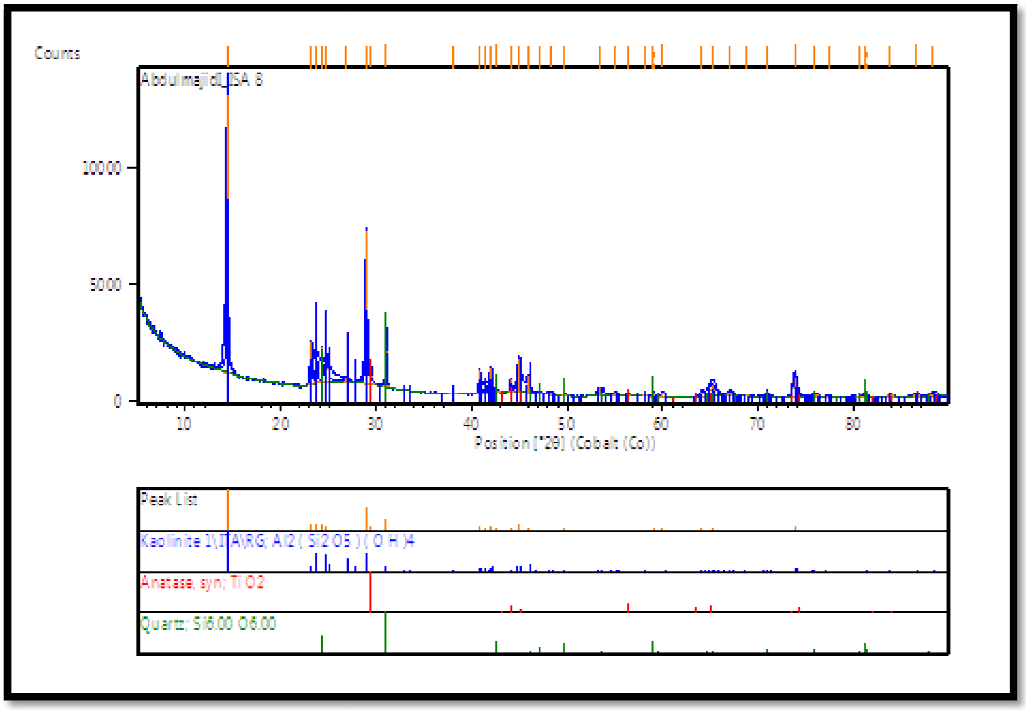

Figure 5: X-RD Pattern of Kirfi Clay

4.2. Geochemistry

The major element concentrations are presented in Tables 2 and 3 respectively. The major element will help in determining weathering pattern, province and suitability of the clays for use in different industries.

Silica (SiO_2) is the dominant oxide within all the studied clays with values ranging between (47.60-76.2) wt% and average value of 53.73wt%. it is followed by alumina with concentration of (14.10-36.40) wt% and average value of 28.40 wt%, Fe_2O_3 (0.35-8.69) wt% and average of 2.53 wt%. Mno, MgO, CaO, Na_2O and K_2O are in minor amounts.

Nesbitt and Young (1996) used ternary diagrams of Al_2O_3-(CaO+Na_2O)-K_2O, A-CN-K diagram and Fe_2O_3+MgO-(CaO+Na_2O+K_2O)- Al_2O_3 (A-CNK-FM) diagram to determine weathering trends. All the studied clays display intense weathering history. In figure 6 and 7 the studied clays falls in region close to high Al_2O_3 content which shows high and intense weathering at source. The weathering proceeds to the stage where most of the alkali elements were removed from the sediments. The high kaolinite content, the depletion of other mobile elements, enrichment of chemically immobile elements (Al_2O_3, TiO_3 and Zr) and high value of chemical index of alteration (CIA) suggest intense chemical weathering from source. The CIA range of the studied clay is (86.5-99.77%) which indicates intense chemical weathering, also the very low amount of alkali also indicates intense chemical weathering.

All the clays show CIA and CIW values greater than 70% indicating high or intense weathering at source or during transportation (Meleman 1993). Clay deposits in continental environment are generally whitish and contain mainly kaolinite (80-90%), based on the mineralogy in table 1, the studied clays are continental in origin. Enu et al 1986 suggest that kaolinization is associated with the removal of alkali and alkali earth metals such as Na, K, Ca and Mg, the presence and high abundance of kaolinite indicate intense chemical weathering of aluminum rich source rocks with steep relief under a worm humid and acidic medium, hence high amount of kaolinite is indicating continental setting. Clays from the Kerri-Kerri Formation are rich in kaolinite and quartz based on the mineralogy, this indicates a source from felsic source of granitic origin. Discrimination diagram in Figure 6 shows that the samples are felsic generally.

	Papa	Gombe 1	Dukku	Bojude	Alkaleri	Gombe Abba	Kirfi
SiO_2	48.90	56.20	62.60	49.50	47.60	76.20	49.10
TiO_2	2.88	1.42	2.88	2.20	1.72	1.48	1.97
Al_2O_3	34.30	23.60	23.40	31.60	36.40	14.10	35.40
Fe_2O_3	0.99	8.69	1.89	4.07	0.70	0.99	0.35
MnO	*0.01*	*0.01*	*0.01*	0.01	0.01	*0.01*	*0.01*
MgO	0.03	0.02	*0.01*	0.05	0.01	0.06	*0.01*
CaO	*0.01*	0.10	0.03	0.04	0.03	0.09	0.03
Na_2O	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
K_2O	0.06	1.60	0.05	0.19	0.16	2.10	0.06
P_2O_5	0.07	0.03	0.07	0.09	0.06	0.02	0.02
SiO_2/Fe_2O_3	49.39	6.47	33.12	12.16	68	77	140.29
$CaO+Na_2O$	0.02	0.02	0.04	0.05	0.04	0.1	0.04
$CaO+Na_2O+K_2C$	0.08	1.62	0.09	0.24	0.2	2.2	0.1
Fe_2O_3+MgO	1.02	8.71	1.9	4.12	0.71	1.05	0.36
CIW	99.94	99.58	99.83	99.84	99.90	99.30	99.89
CIA	99.77	93.24	99.62	99.25	99.45	86.50	99.72

Table 2: Chemical Composition of Kerri-Kerri Clays

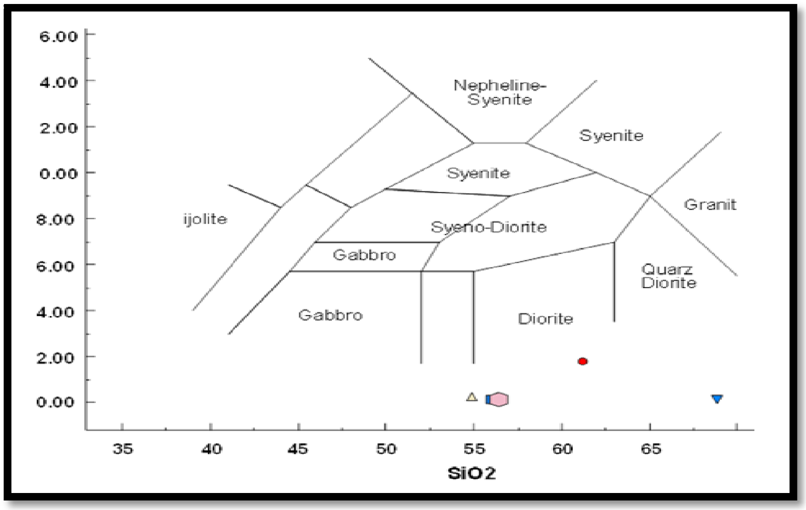

Figure 6: Discrimination Diagram of the Studied Clays

4.3. Resource Potential

Kaolinite clay is the major raw material in ceramic industry, paint and paper, the studied clays can be used in ceramic and coating material in paint and paper. The chemical composition is compared with some industrial standards in table 3 and Figure 7. The concentration is consistent with some of the standards. They are within the range of ceramic, refractories, textile, pharmacy and agricultural industries.

	Kerri-Kerr	Agricultur	Ceramic(S	Brick clay	Pharmacy	Refractory	Textile(N	Fertilizer(
SiO_2	48.8	49.88	67.5	48.67	47	51.7	45	46.07
Al_2O_3	24.85	37.65	26.5	19.45	40	25-44	38.1	38.07
Fe_2O_3	2.21	0.88	0.5	2.7	0	0.5-1.2	0.6	0.33
MnO	0.01	0	0	0	0	0	0	0
MgO	0.02	0.13	0.1	8.5	0	0.2-0.7	0	0.13
CaO	0.04	0.03	0.18	15.85	0	0.1-0.2	0	0.03
Na_2O	0.01	0.21	1.2	2.76	0	0.8-3.5	0	0.27
K_2O	0.53	1.6	1.1	2.76	0	0	0	0.43
T_iO_2	1.82	0.09	0	0	0	0	1.7	0.5
P_2O_5	0.05	0	0	0	0	0	0	0

Table 3: Average Chemical Composition Compared With Some Industrial Specifications

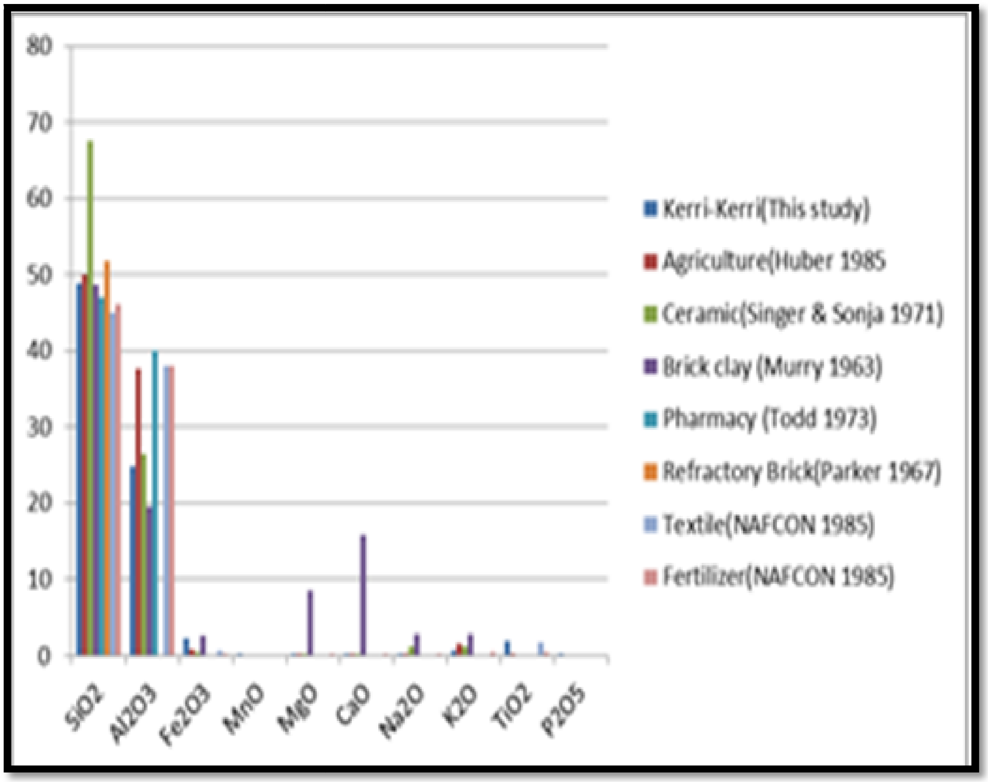

Figure 7: Plot of Average Chemical Composition against Some Industrial Standards

5. Conclusions

The Kerri-Kerri clays are composed of mostly kaolinite, the clay indicates a source from region of intense chemical weathering under warm climate.

The presence of kaolinite and absence of expansive clay, light colour, low iron content suggest its suitability for use in ceramic, refractories, textile, fertilizer and pharmaceutical industries.

6. Acknowledgement

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