

Appraisal of the Talc Bodies of Kagara Area, North-western Nigeria and their Industrial Potentials

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Abstract

The study area, Kagara and its environs, lie within the Kushaka Schist belt of the Basement Complex of Nigeria, Tegna Sheet 142. Talcose bodies in the area occur in relatively small sizes except in Kumanu / Indaki area where they are massive and occur as inselbergs. The talc bodies occur in quartz ridge and pelitic-semi pelitic rocks and make contact with amphibolites and the migmatite-gneiss. Detailed geological mapping and sampling of the talc bearing and surrounding rocks were carried out using basic geological tools. This is to determine talc bodies that have not been reported before. Lithologically, the area comprises migmatite-gneiss, quartzites, amphibolites, pelitic-semi pelitic rocks, arkosic rocks, granites and undifferentiated rock bodies. Thirteen samples of talcose bodies and host rocks were evaluated for their physical, mineralogical and chemical properties by petrographic, XRD and XRF analyses and the results of eight representative samples are presented in this study. Mineralogically, the talc bodies contain varying proportions of talc, tremolite, chlorite, anthophyllite and minor amounts of phlogopites, sapionite and stevensite which are alteration minerals. Chemically, most of the samples have high silica and magnesia contents $>75\%$ and $\text{CaO} \leq 0.01\%$; $\text{Na}_2\text{O} + \text{K}_2\text{O} < 0.4\%$; $\text{As} < 0.05\text{ppm}$; $\text{Pb} < 0.3\text{ppm}$; Al_2O_3 generally $\leq 2.5\%$ in most cases; $\text{P}_2\text{O}_5 \leq 0.01\%$ and $\text{MnO} \leq 0.22\%$. Firing tests showed some properties of talc such as colour, shrinkage, permeability specific resistance, hardness, strength and pore structure. It was observed that the samples analysed are composed of a good percentage of talc and other minor minerals such as clay, chlorite, anthophyllite, tremolite, sapionite and phlogopite. Comparison of the petrographic, mineralogical, chemical and physical data with some industrial indices indicate that the different samples have industrial potentials for ceramics, paints, paper, textile, rubber, crayons and plastic making. With appropriate beneficiation like floatation and bleaching, the different talc samples can become valuable to the cosmetics, pharmaceuticals and food processing industries.

Keyword: *Talc, Kagara, Kushaka Schist belt, petrographic, chemical and mineralogical analyses, alteration minerals, beneficiation, industrial potentials.*

Introduction

Talc bodies are associated with mafic and ultra-mafic complexes and metasediments of the Basement Complex of Nigeria. They occur as lenses in amphibolite within mica schist, gneisses and migmatite complex. The existence of talc deposits in Nigeria has been reported by researchers. However, most of the reported occurrences have not been fully evaluated for their potential for commercial production.

Talc bearing rocks occur in various localities in Nigeria notably, Kogi- Odogbe (Ayoade, 1983), Oyo- Apomu(Ige,1983), Iseyin (Durotoye and Ige, 1991), Asegbo, Obalaru (Akin-Ojo,1992); Osun- Ilesha (Elueze and Ogunniyi,1985) Ile-Ife (Ige, 1988) and Esa-Oke . Other occurrences are Oke-Ila (Bolarinwa, 2001), Oro (Adekeye, 2001), Baba Ode (Okunlola et al., 2002) Erin-Omu (Okunlola and Anikulapo, 2006), Esie (Olorunfemi et al.,2009, 2010) and Ijero (Okunlola et.al. 2011) all found in south western Nigeria. They have also been found in northcentral Nigeria (Durotoye and Ige, 1991). Talc deposits have been reported in Niger -Kumanu, Tunga Bako (Elueze and Dosunmu,1987) which is part of this present study.

Talc is found in association with tremolite, chlorite, anthophyllite, actinolite, serpentine in south-western Nigeria (Elueze and Akin-Ojo, 1993). On the basis of mineralogical compositions, they differentiated four varieties: talcose, tremolitic, chloritic and anthophyllitic types, denoting the relative abundance of talc, tremolite, chlorite and anthophyllite respectively (op cit). They concluded that all the varieties were suitable for cordierite ceramics, rubber and roofing sheets manufacture; with the talcose type found to be applicable in other industries such as paint, paper, textile, cosmetics, pesticides and fertilizers.

This work therefore, focuses on elucidating on the geological occurrence, mineralogical, chemical composition and physical properties of the talc bodies in the area and their industrial potentials.

Geology of the Study Area

The study area lies within Tegna Sheet 142 and is delineated by latitudes $10^{\circ} 05'$ and $10^{\circ} 26'$ North and longitudes $06^{\circ} 08'$ and $06^{\circ} 28'$ East. Kagara is located about 15km NE of Tegna and situated along the Tegna-Pandogari-Birnin Gwari road (Fig.1). The study area lies between the Ushama and Birnin Gwari schist belts (Kushaka schist belt) of the Precambrian Basement Complex of Nigeria. The Basement Complex of Nigeria can be subdivided into Migmatite-Gneiss complexes; the Older Meta-Sediments, the Younger Metasediments; the Older Granites and the Younger Granite ring complexes and volcanic rocks (Rahaman, 1976). The occurrence of mafic-ultramafic rocks have been described from various localities within the schist belts. They are often classified as

amphibolites, metagabbros, epidiorites, talc schists and serpentinites (Elueze, 1982).

The Kushaka schist formation occupies a belt of about 50km wide and stretches from the Minna area up to Tsohon Birnin Gwari area of northwestern Nigeria. The rocks lie in a number of isoclinal fold structures trending NNE, which give rise to a strong foliation parallel to the axial planes of the fold (Truswell and Cope, 1963). The age of the Kushaka schist formation is tentatively put at about 1100Ma (Turner, 1983), but there is yet no report on radiometric dating.

The rock units in the study area can be divided into Migmatite – Gneisses, Meta – Arkosic Rocks and Semi – Pelitic Schists, Older Granites, Talc, Amphibolites / Epidote – Amphibolites (Fig.2). The schists in the area of study are mostly the semi – pelitic schists outcropping in the southwest end between the migmatite - gneiss and an intruded Older Granite. They are composed of phyllosilicates (mica and chlorite), quartz and feldspar. They range from muscovite – biotite schists to biotite – muscovite schists. The Older Granites in the mapped area are mainly coarse porphyritic granites. They intrude on the other rock bodies in the area especially in the southwestern axis and central part northwards, covering about 30% of the entire area. The porphyritic granite body is composed of biotite, feldspars, quartz and other minor/accessory minerals. Migmatite gneiss is extensive in the area, intruded by the Older Granites at the central part truncating its massive extension from the western part of the area to the east. It constitutes well over 60% of the rock types in the area of study (Fig.2.). A wide range of textural types of amphibolites and related rocks have been recognised in the area (Elueze, 1981). The outcrops are lenticular, texturally distinctive and are usually well oriented parallel to the N – S foliation trend. Samples are bluish green in colour, fine grained and show strong compositional layering marked by alteration of narrow to streak – like layers of hornblende and locally epidote, and of quartz and feldspars. They are foliated with hornblende defining the foliation. They occur mostly in lenticular and sometimes ovoid – like shapes.

The talcose bodies constitute about 4% of the rock types in the study area and occur in the central part close to Kagara in Tsaunin Agwaru area within a quartz – ridge of semi – pelitic schist surrounded by amphibolite and the Older Granite. The talc outcrops occur as lensoid shape boulders of moderate size and length. They also occur in the southwestern area at Karaya within schist body making contacts with the Migmatite – Gneiss and the Older Granite bodies in an oval shaped outcrop of about 15m above the surrounding ground level. In the southeastern part of Kumanu / Indaki areas, talc occurs as large inselbergs and massive exposures, and are bounded by the Older Granite and the migmatite gneiss in the western and eastern sides and within a Schist body that truncate the linearly elongated north – south amphibolite body (Fig.2). The talcose bodies are

largely extensive in this area with different grades, colours, sizes and texture in Kumanu / Indaki. In Ungwan Kwarau Wazamai (West of Tunga Bako) axis, they occur within the semi – pelitic schist on a quartz-ridge bounded by amphibolites towards the west of Tunga Bako.

The colour of the talc varies from greyish, whitish to pale brown colour with a soapy feel when handled. They occur in other parts as lenses and small boulders within the quartz ridge (or within the schist and granitic bodies) measuring 2-5 metres in width intermittently and about 20 – 100m in length; and sometimes occur as discrete outcrop of about 5-10 metres high and 10 – 50 metres wide. These are metamorphosed arkosic rocks mainly of sandstone containing at least 25% of feldspar easily recognisable due to the pink colour and angular shape of the feldspar grains. This unit runs in N – S direction in the southeastern part of the study area and also occurs in the North towards the East, though not as massive as in the southeastern part of the area.

Methodology

This work involves field work and laboratory analysis. The geological mapping of the study area was systematically carried out. The laboratory analysis includes petrographic study and geochemical analysis.

The geochemical analysis includes X-ray diffraction and X –ray fluorescence techniques. X-ray diffraction can be carried out in different ways including powder diffraction, crystal diffraction and oriented diffraction but powder diffraction was employed for this work.

The machine (SHIMADZU 6000) used for the X-ray diffraction analysis is very powerful and non – destructive, requiring only small amount of material. It is very rapid with reasonable accuracy, scanning rate of $1^\circ (2\theta)$ min over an angular range of $2^\circ - 65^\circ$ with filtered Cu, K and radiation, while one inch or 2cm of chart recording for $2^\circ (2\theta)$ min recording speed may be necessary. When the powdered mineral specimen consisting of thousands of minute crystals was placed in a beam of characteristic X – ray, numerous reflections from different sets of parallel atomic planes were produced. This occurs because the X – ray will strike the randomly oriented crystals at various angles, some of which will be correct to produce X – rays.

Samples for the XRF analysis were sun dried in order to remove moisture and make it easy to pulverize. The dried samples were then pulverized using agate mortar and pestle in the Department of Geology and Mineral Sciences, University of Ilorin, Nigeria. After each sample was pulverized, the agate mortar and pestle were rinsed with ethanol to prevent inter-sample contamination. Ethanol is chosen

for cleaning exercise instead of water because of its relative high volatile nature. After the pulverization exercise, 30 grams each of the pulverized samples were weighed out and sent for analysis at ACME Analytical Laboratory, Vancouver, Canada where 0.5g each of the samples analysed were fused with lithium borate – meta borate fluxes and then dissolved in about 30% nitric acid. The resulting solution was then analysed using ELAN 6000 ICP – MS manufactured by Peckin Elmer.

Samples were also subjected to firing tests for which pellets of the representative samples were prepared. About 10 grams of each sample was placed directly in a furnace and heated to temperature of 950⁰C, 1,000⁰C and 1050⁰C for two hours at the Geotechnical Laboratory of the Department of Geology, Obafemi Awolowo University, Ile-Ife, Osun State; Nigeria. The fired shrinkage, loss on Ignition, water absorption (porosity), and natural moisture content values expressed in percentage were all obtained via the firing tests; and the results are shown in Table 2.

Result Presentation

The mineralogical composition of the samples were revealed in thin-sections and XRD studies. Chemical analysis was carried out to determine the chemical composition while firing tests were conducted to determine some properties such as shrinkage, porosity, LOI, and natural moisture content.

The thin – section study reveals predominant talc in Locations 1,2,3,4 and 6 occurring as foliated mass, fine - coarse platy fibrous aggregates, and sometimes as wisps, columnar and flaky. From the petrographic studies, samples from L1, L2, L3, L4 and L6 (Plates 1 and 2) reveal a high proportion of talc constituting over 60% with other minor associations of chlorite, serpentinite, quartz and amphiboles.

X-ray diffractogram for all samples show conspicuous peaks for the essential constituents identified in thin – sections namely, talc, tremolite, chlorite, anthophyllite and alteration minerals such as phlogopites, sapionite and stevensite (Figs3-6). Quartz and enstatite also occur as minute constituents. The result of the geochemical analysis of the talc deposits are shown in Tables 1, 2 and 3 for major, trace and rare earth elements compositions respectively.

Discussion

The geochemical result shows that all the samples from the talc bodies contain high MgO with a range of 20.49% to 36.62% with the highest value recorded in sample L4 (Kumanu – Indaki) and the least in sample L5 (Tsaunin Agwaru). The SiO₂ contents in the samples vary from 24.7% to 59.0% with the highest value

recorded in sample L1 (Kumanu – Indaki) and the least in sample L2 (Table1). The CaO abundance in the samples are generally low except in the sample from L5 (Tsaunin Agwaru) with the value of 10.06% which is tremolitic (Elueze and Awonaiya, 1989). On the other hand, the Al_2O_3 concentrations are significantly higher in the chloritic varieties as seen in samples L2, L6, and L7 with the values of 17.81%, 15.17%, and 15.77% respectively compared with others with range between 0.36% - 4.25%. The high alumina content in the samples from the Kumanu – Indaki axes may be attributed to the presence of chlorite (up cit). All the samples show a relatively high value of Fe_2O_3 that varies from 4.3% - 22.55% with a mean average of 10.80% which is indicative of high iron concentration. Concentrations of Na_2O , MnO , P_2O_5 , K_2O and Ba are generally low, below 0.26% and TiO_2 averages between 0.01 – 2.87% with the highest in sample L7.

Results of the chemical analysis reflect mineralogical attributes. The high MgO (29.55%) and SiO_2 (59.0%) coupled with low CaO (<0.01%) and low Fe_2O_3 of 5.41% compared to others is reflective of high talc content in L1 (Table1). Samples L2, L6, and L7 reflects presence of chlorites in the outcrops due to the high concentration of alumina (Al_2O_3). Sample L7 distinctively has the characteristics of chloritic talc with chemical composition of SiO_2 (31.40%), alumina > 15%, MgO content of 32.93%, Fe_2O_3 7.4% and concentrations of CaO, Na_2O , K_2O , P_2O_5 and Ba values of 0.01 each respectively (Table1).

The chemical compositions of samples L2 and L8 are indicative of an anthophyllite, while that of sample L5 which has CaO > 10%, SiO_2 and MgO contents of 50.3% and 20.49% respectively is indicative of tremolitic body. The presence of tremolite, anthophyllite, chlorite, kaolinite, chromite and goethite was found in talc body at Wonu- Apomu (Ige, 1985).

The thin – section study reveals predominant talc in L1-L4 and L6 (Plate1). In L1, talc constitutes over 60% of the rock occurring with other minor minerals such as chlorite and serpentines. In L4, L6, L7, and L8; talc occurs in association with minor amounts of tremolites, chlorite and anthophyllites. Other opaque minerals like iron - oxide and manganese - oxide are also present. Chlorite is pronounced in L6 and L7 present as irregular flakes, laths and radiating aggregates. L5, L7 and L8 reveal a good proportion of anthophyllite and tremolite, with the tremolite occurring in bladed prismatic and acicular forms, randomly oriented with respect to each other.

Most of the samples from different localities in the area have total silica and magnesia contents exceeding 65% with that of sample L1 from the Kumanu – Indaki area conspicuously having over 88.0%, thus indicating that it is the purest talc from all the localities in the area. Therefore talc deposit in Kumanu – Indaki

area is of very good quality and can be exploited as filler material and as dusting agents in the manufacture of wires, nails and corks (Severinghus, 1975).

The LOI (Loss on Ignition) values are generally moderate to high ranging from 3.4% - 24.83% and having a mean value of 11.82% for all samples. L1 and L5 have the least LOI values, 5.1 and 3.4 respectively. This makes them suitable in the production of paints and refractory materials.

Lennon (1955) has shown that the addition of tremolite to talc will lower the temperature at which liquid and solid are in equilibrium with each other, which means that the shrinkage increases as the composition approaches that of tremolite. The presence of accessory minerals in the talc from Kagara and environs may be the cause of wide range in shrinkage (Lama, 1954).

The talc bodies of Kagara area when compared with other talc bodies in Nigeria can be explored as raw materials for varied industrial applications notably plastics, paints and ceramic. The chemical composition of L1 is similar to Chinese micronized talc (Table5). L1 has a high SiO₂ value of 59 %, CaO value of <0.01 and LOI IS 5.1. L1 is suitable in the paper, rubber, cosmetic, food and pharmaceutical industries. Sample L5 has a similar composition to Obalaru-Ilesha talc (Akin-Ojo, 1992). It is suitable for ceramic, having a CaO value higher than the recommended value of 6.0 %. It acts as a flux for lowering the maturing temperature of the ware (Okunlola et.al 2011). The mineralogical composition of sample L8 can be compared with the pharmaceutical and industrial grade varieties of Luzenac, France deposit (Table5) (Luzenac Mines Limited, 2003).

Conclusion

The result of the study reveals that the talc bodies at Kagara and environs have variable textural and mineralogical characteristics that generally reflect their physical properties and chemical composition. The samples from different locations in the area of study contain in addition to talc, appreciable amounts of chlorite, tremolite, anthophyllite and minor constituents of phlogopites, stevenites which are alteration minerals. Enstatite and quartz occur in negligible amounts.

The physical and mineralogical properties of the samples can make them suitable raw materials for the ceramics, paints, paper and pulp, rubber, crayon and textile industries. With appropriate processes of beneficiation like floatation and bleaching, samples L1 and L3 can become more valuable for the paper, rubber, cosmetics, pharmaceuticals and food processing industries. L5 is most useful in the ceramic and paint industries.

Chemical analyses reveal most of the samples have silica and magnesia concentrations of over 75% and CaO <0.01%; Na₂O + K₂O <0.4%; As <0.05ppm; Pb <0.3ppm; Al₂O₃ generally ≤2.5%. In most cases, they have P₂O₅ ≤0.01% and MnO ≤ 0.22%. All these values fall within the acceptable chemical limits for most industrial usage, except for Fe₂O₃ which is relatively high in most samples. Fortunately, the impurities in all the samples can be reduced with the available modern processing technologies to meet the specific requirements for usage.

Results of physical tests such as raw colour, feel, shrinkage, porosity and loss on ignition and firing characteristics reveal that the talc fall within the required limits of most industries that use them.

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Table 1: Major Elements of the Kagara and environs Talc bodies (wt. %).

Oxides	L1	L2	L3	L4	L5	L6	L7	L8	Mean Value
SiO ₂	59.0	24.7	37.8	32.0	50.3	31.4	32.1	40.2	38.43
Al ₂ O ₃	0.38	17.81	0.36	0.39	4.25	15.17	15.77	7.77	7.80
Fe ₂ O ₃	5.41	22.55	4.3	6.5	10.06	7.34	14.18	16.04	10.80
CaO	<0.01	<0.01	0.07	0.03	10.39	0.01	2.22	1.28	1.75
MgO	29.55	23.97	35.66	36.25	20.49	32.93	23.41	27.03	28.66
Na ₂ O	0.05	0.02	0.05	0.03	0.25	0.01	0.07	0.01	0.06
K ₂ O	0.02	<0.01	<0.01	<0.01	0.02	<0.01	0.05	0.02	0.02
MnO	0.02	0.22	0.08	0.07	0.16	0.03	0.25	0.20	0.10
TiO ₂	0.03	1.3	<0.01	0.02	0.19	1.05	2.87	0.73	0.77
P ₂ O ₅	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.23	0.10	0.03
FeO	4.87	20.28	3.87	5.85	9.05	6.60	12.75	14.42	9.71

L1. Kumanu / Indaki, L2. Kumanu / Indaki, L3. Kumanu / Indaki, L4. Kumanu / Indaki, L5. Tsaunin Agwaru, L6. Tsaunin Agwaru, L7. Karaya, L8 Ungwan Kwarau Wazami.

Table 2: Trace Element composition of the talcose bodies at Kagara and environs (All values in ppm)

Trace Element	L1	L2	L3	L4	L5	L6	L7	L8	Mean Value
Ba	4	2	1	2	7	2	17	39	9.25
Be	<1	<1	<1	<1	<1	<1	<1	<1	<1
Co	76.1	86.7	72.8	76.8	91.4	106.9	75.6	127.4	89.21
Cs	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	<0.1	<0.15
Ga	1.4	7.5	1.0	1.2	6.2	7.3	23.8	9.2	7.2
Hf	<0.1	1.3	<0.1	<0.1	0.2	10.7	3.9	1.3	<2.21
Nb	0.2	1.8	0.2	0.1	0.6	23.3	17.8	6.7	6.41
Rb	0.9	0.4	0.2	0.2	0.5	0.2	2.1	0.9	0.67
Sn	<1	<1	<1	<1	<1	<1	1	<1	<1
Sr	1.1	1.4	1.2	0.6	12	<0.5	18.5	17.4	<6.61
Ta	0.2	0.2	<0.1	<0.1	<0.1	1.2	1.2	0.4	<0.43
Th	0.2	1.0	<0.2	<0.2	<0.2	8.0	1.1	0.6	<1.44
U	<0.1	0.3	<0.1	<0.1	<0.1	0.6	0.5	0.2	<0.25
V	24	550	16	18	132	58	396	97	161.37
W	<0.5	0.8	<0.5	<0.5	<0.5	4.2	3.7	0.5	1.4
Zr	0.6	57.3	1.7	0.4	7.0	354.3	147.0	56.0	78.03
Y	0.2	35.8	0.3	0.2	6.1	45.1	35.4	11.4	16.81
Mo	<0.1	0.1	0.1	0.2	0.6	<0.1	0.2	0.5	<0.24
Cu	0.4	10.0	6.1	6.9	26.1	0.7	1.1	33.6	10.61
Pb	0.3	0.2	0.2	0.2	0.2	0.4	0.5	1.5	0.43
Zn	2	73	7	9	18	24	82	38	31.62
Ni	93.1	71	627.2	932.7	271.9	812.5	327.3	462	449.71
As	<0.5	<0.5	1.4	6.7	<0.5	1.5	0.6	<0.5	<1.53
Cd	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bi	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1
Ag	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Au	0.7	7.2	17.9	9.5	3.1	1.3	1.4	1.1	5.28
Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

L1. Kumanu / Indaki, L2. Kumanu / Indaki, L3. Kumanu / Indaki, L4. Kumanu / Indaki, L5. Tsaunin Agwaru, L6. Tsaunin Agwaru, L7. Karaya, L8. Ungwan Kwarau Wazami.

Table 3: Rare earth element composition of the talcose bodies at Kagara and environs (All values in ppm)

REE	L1	L2	L3	L4	L5	L6	L7	L8	Mean Value
Ce	0.6	9.6	0.2	0.2	2.8	64.5	42.1	12.6	16.58
Dy	<0.05	5.96	0.06	<0.05	0.95	6.49	6.31	1.93	<2.73
Er	<0.03	4.05	0.05	<0.03	0.55	4.32	3.18	1.07	<1.66
Gd	<0.05	3.78	<0.05	<0.05	0.83	6.23	6.58	2.15	<2.46
Ho	<0.02	1.31	<0.02	<0.02	0.21	1.43	1.21	0.41	<0.58
La	0.2	4.3	0.2	<0.1	1.8	32.7	21.2	11.5	<9.0
Lu	<0.01	0.66	<0.01	<0.01	0.1	0.75	0.4	0.15	<0.26
Nd	<0.3	6.7	<0.3	<0.3	2.4	32.1	29.0	12.4	<10.44
Pr	<0.05	1.44	<0.02	<0.02	0.49	7.41	6.18	2.62	<2.28
Sm	<0.05	2.11	<0.05	<0.05	0.57	5.76	5.96	2.14	<2.09
Tb	<0.01	0.8	<0.01	<0.01	0.14	1.03	1.07	0.34	<0.43
Tm	<0.01	0.63	0.02	<0.01	0.11	0.68	0.45	0.15	<0.26
Yb	<0.05	4.31	0.08	<0.05	0.66	4.49	2.73	1.01	<1.67
Eu	<0.02	0.63	<0.02	<0.02	0.19	0.87	1.02	0.96	<0.47

L1. Kumanu / Indaki, L2. Kumanu / Indaki, L3. Kumanu / Indaki, L4. Kumanu / Indaki, L5. Tsaunin Agwaru, L6. Tsaunin Agwaru, L7. Karaya, L8 Ungwan Kwarau Wazami.

Table 4: Shrinkage, Porosity and Natural Moisture content and LOI in the Talc Samples from Kagara and environs (All values in wt %).

Samples No. (Locations)	shrinkage(%)			porosity (%)			Nat. Moisture content (%)	LOI
	@ 950 C	@ 1000 C	@ 1050 C	@ 950 C	@ 1000 C	@ 1050 C		
L1	1.14	2.0	3.61	14.4	7.0	3.4	0.02	5.1
L2	2.70	4.2	6.16	12.5	6.0	2.5	0.04	10.34
L3	1.18	2.0	3.96	15.2	6.81	1.2	0.02	21.67
L4	0.98	1.7	2.85	15.7	7.3	2.7	0.03	24.83
L5	1.52	2.4	4.05	12.3	5.9	2.3	0.05	3.4
L6	1.63	3.2	4.18	15.5	7.23	2.5	0.08	12.62
L7	0.2	0.5	1.23	17.8	6.0	2.0	0.03	9.28
L8	1.44	2.9	4.31	12.7	4.3	1.0	0.06	7.31
Mean	1.32	2.36	3.79	14.51	6.37	2.2	0.041	11.82
Range	2.5	3.7	4.93	5.5	3.0	2.4	0.06	0.07

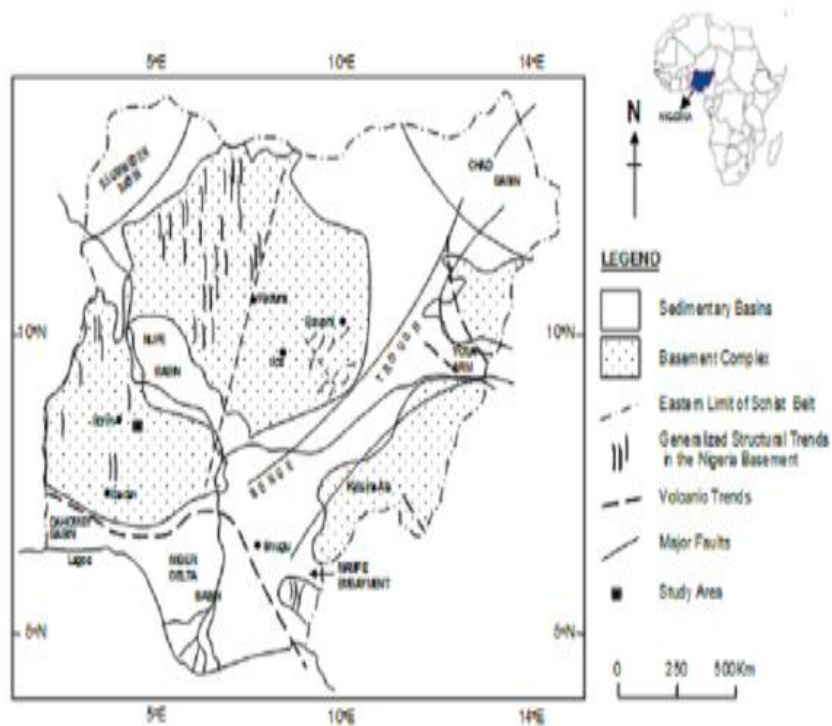
Table 5: Chemical composition of some commercial Talcs compared with occurrences in Kagara and environs

Oxide	1	2	3	4	5	6	7	8	9	10	11	12
SiO₂	59.4	40.57	57.52	47.5	39.80	34.80	60.39	51.49	51.55	53.99	59.09	52.67
Al₂O₃	0.68	1.55	3.08	13.25	1.30	1.30	1.11	1.57	3.69	1.83	6.97	9.13
CaO	0.66	0.65	0.53	1.05	0.40	0.40	0.20	-	0.25	0.09	1.28	1.45
MgO	31.4	30.75	31.60	26.05	34.5	34.50	29.82	32.19	31.82	31.73	27.70	27.42
LOI	7.10	5.69	6.48	9.00	23.60	4.90	4.38	7.36	5.69	5.40	3.50	5.45

Table 5 (contd): Chemical composition of some commercial Talcs compared with occurrences in Kagara and environs

Oxide	13	14	*15	*16	*17	*18	*19	*20	*21	*22
SiO₂	42.22	54.64	59.0	24.7	37.8	32.0	50.3	31.4	32.1	40.2
Al₂O₃	6.13	2.36	0.38	17.81	0.36	0.39	4.25	15.17	15.77	7.77
CaO	1.69	0.69	<0.01	<0.01	0.07	0.03	10.39	0.01	2.22	1.28
MgO	31.86	31.70	29.55	23.97	35.66	36.25	20.49	32.93	23.41	27.03
LOI	8.10	6.76	5.1	10.34	21.67	24.83	3.4	12.62	9.28	7.31

1. Chinese micronized Talc NW4; Rogers and Look Ltd.
 2. Italian (Pinerole Talc Extra A; Zach Cartwright Ltd.
 3. Luzenac Talc grade OOS; Luzenac Talc sales Ltd.
 4. Luzenac Talc grade 2S; Luzenac Talc sales Ltd.
 5. Norwegian Talc FWXO; Norwegian Talc (UK) Ltd.
 6. Unst Talc (Quey House Quarry); English China Clays Ltd.
 7. Odogbe; Kogi State
 8. Wonu – Apomu; Oyo State
 9. Obalaru – Ilesa; Osun State
 10. Asegbo – Ilesa; Osun State
 11. Kumanu; Niger State
 12. Yarada; Niger State
 13. Assaya; Niger State
 14. Suleja, Niger State.
 - 15 - 18. Kumanu, Niger State
 - 19 - 20 . Tsaunin Agwaru, Niger State
 21. Karaya, Niger State
 22. Ungwan Kwarau Wazami, Niger State
- N.B-*this study*



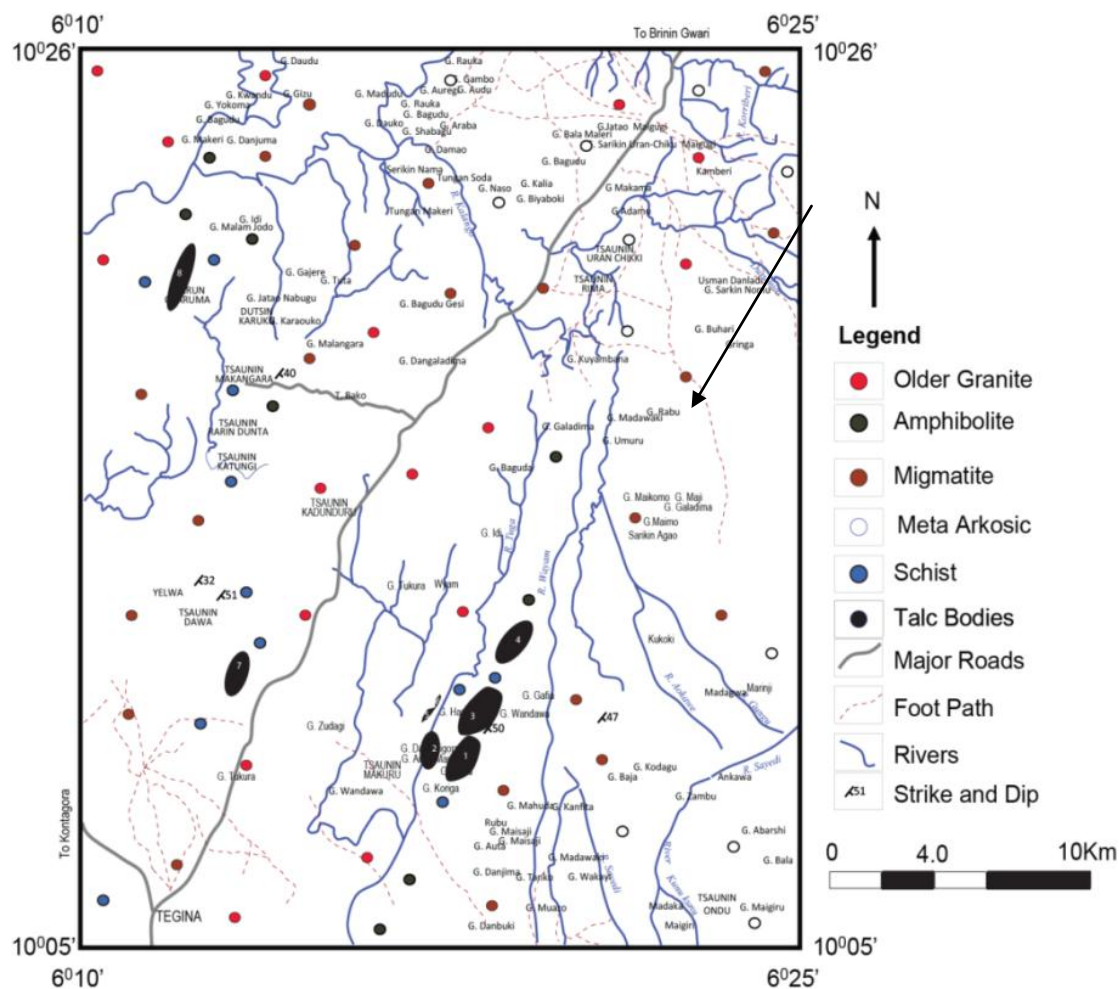


Fig.1: Map of the study area showing rock outcrops





Fig. 3: XRD diffractogram for sample L1 (Kumanu/Indaki)

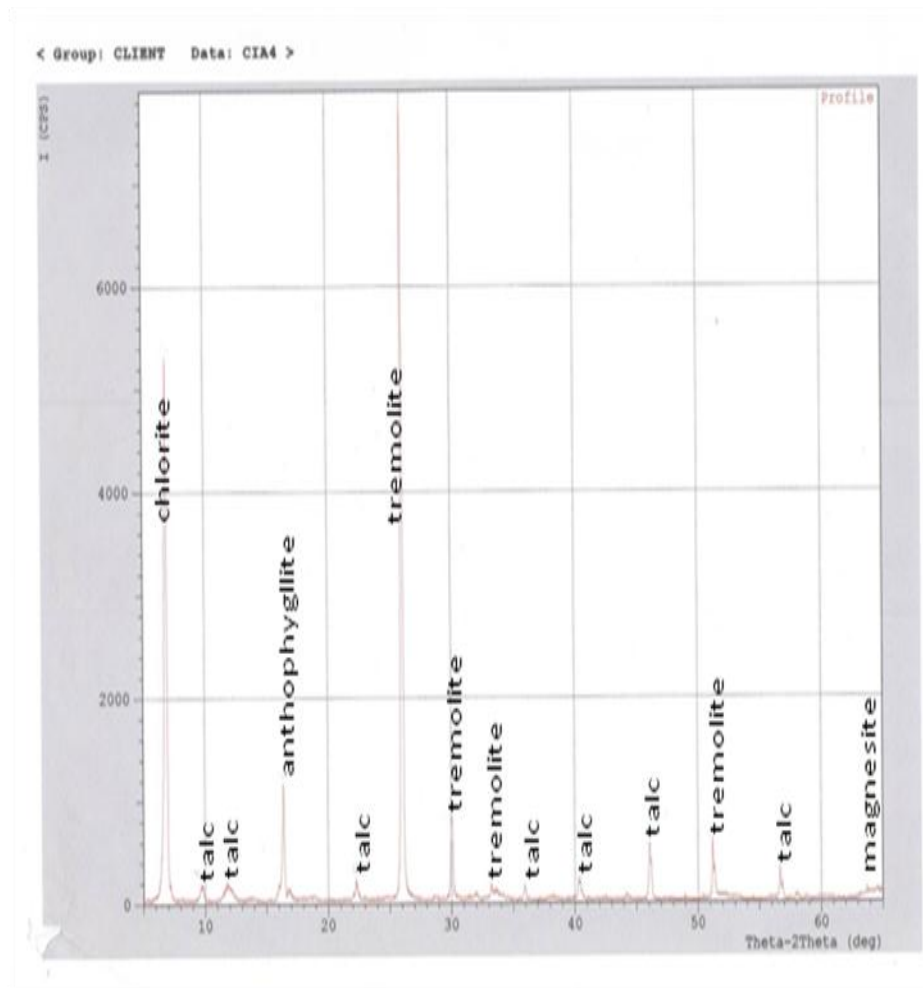


Fig. 4: XRD diffractogram for sample L3 (Kumanu/Indaki)

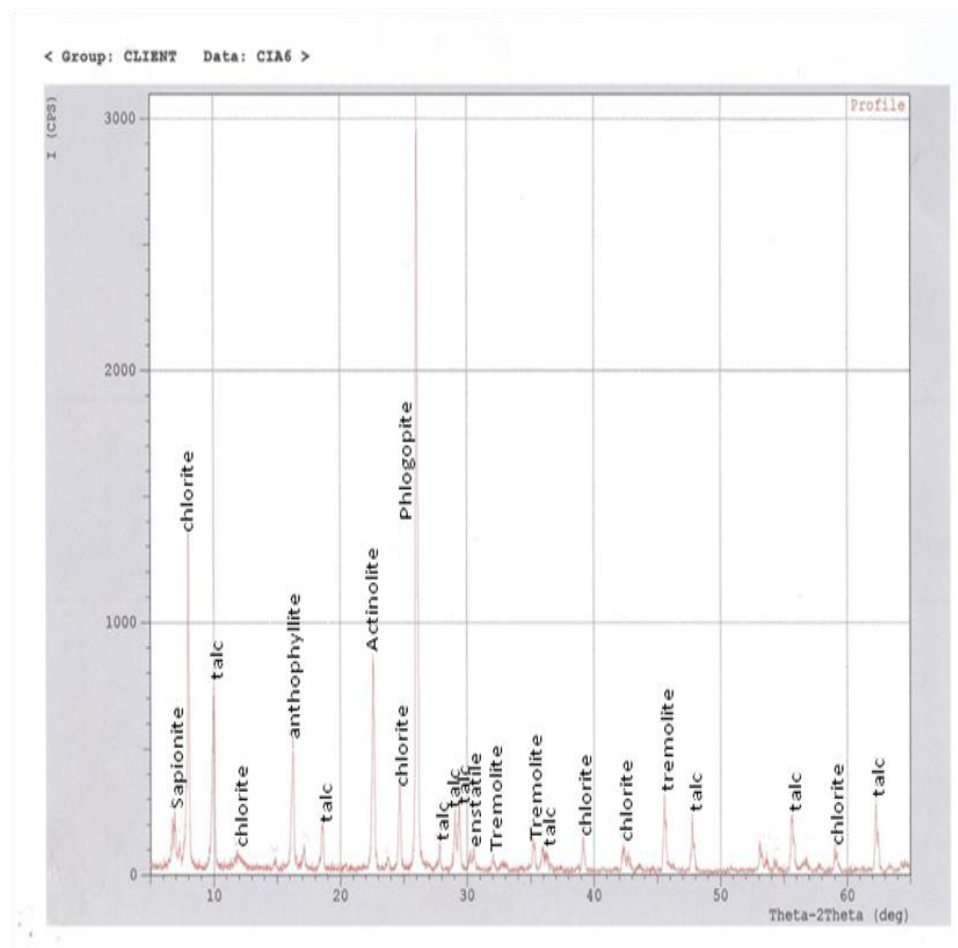


Fig. 5: XRD diffractogram for sample L5 (Tsaunin Agwaru)

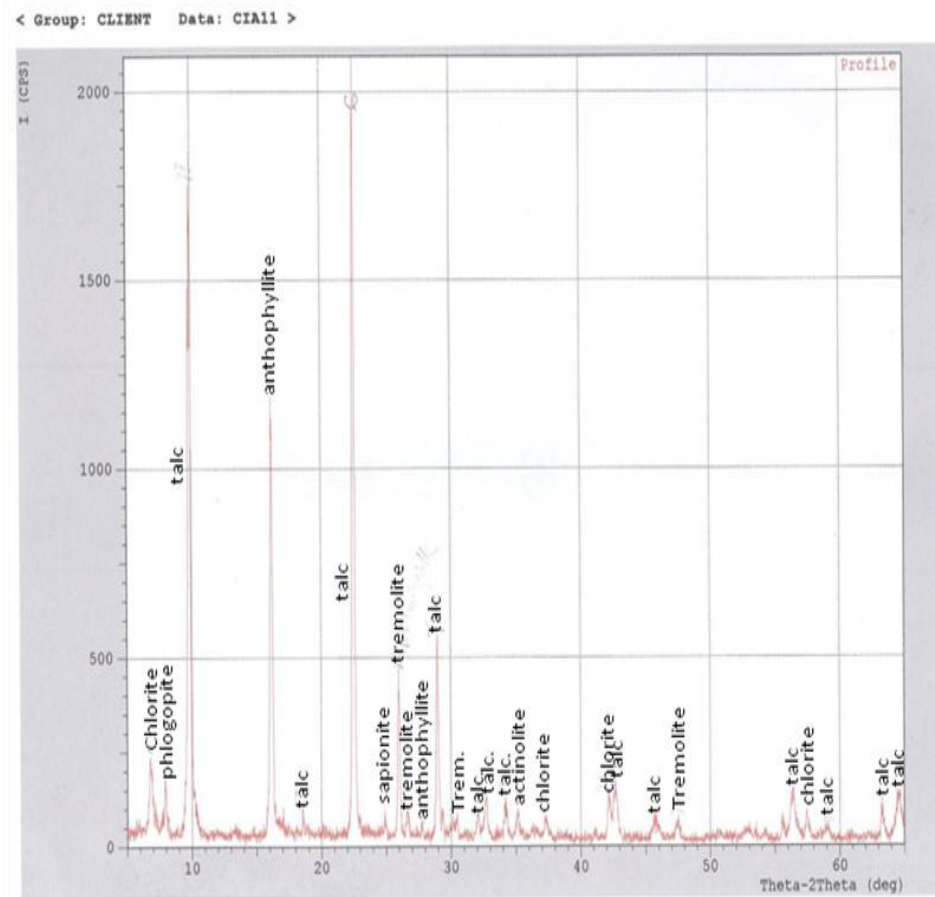


Fig. 6: XRD diffractogram for sample L7 (Karaya)

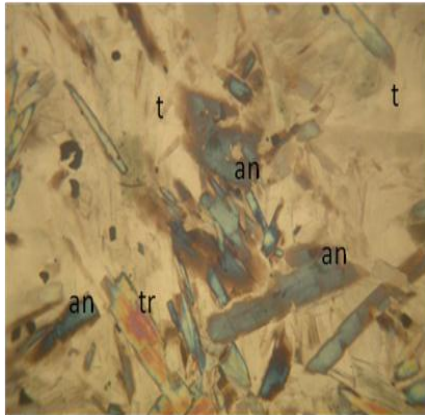


Plate 3a: Photomicrograph of L5 showing anthophyllite(an), tremolite(tr) with talc crystals(t). (x.40,PP)

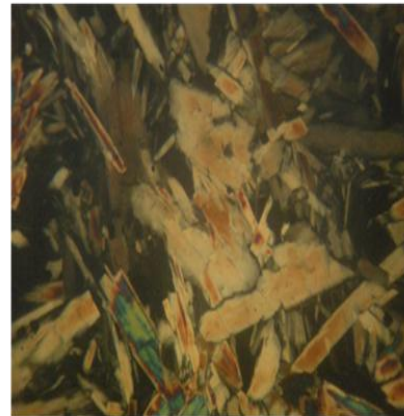


Plate 3b: Photomicrograph of L5 showing anthophyllite(an), tremolite(tr) with talc crystals(t). (x.40,XPL)

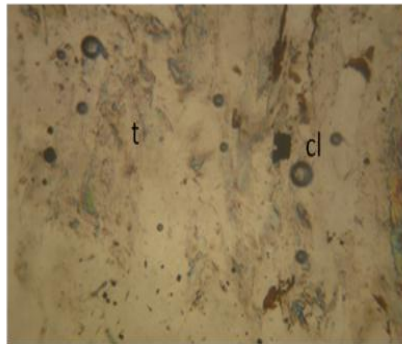


Plate 4a: Photomicrograph of L6 showing talc crystals(t), tint of chlorites(cl) and opaque minerals(x.40,PP)

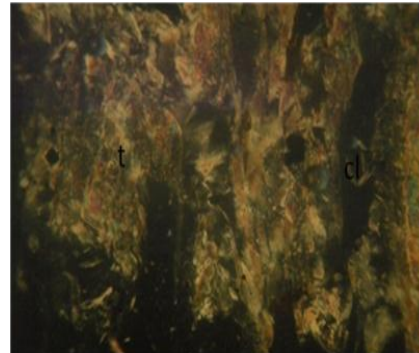


Plate 4b: Photomicrograph of L6 showing talc crystals(t), tint of chlorites(Cl) and opaque minerals(x.40,XPL)