The characterization of Talcose rocks by X-Ray Diffraction in Kagara Area (Sheet 142 SE and Part of Sheet 142 SW) North Central, Nigeria

Abstract

The unequivocal identification of mineral impurities in talcose rock requires definitive analytical techniques due to the very similar structure of many naturally occurring silicates and the small quantities of associated minerals frequently found. Light microscopy and X-ray diffractometry have been found to be particularly useful, complementary, and practical for both exploratory and routine determinations of mineral impurities in the talcose rock.

The major rock units in the study area are migmatitic gneiss, banded gneiss, granitic gneiss, meta-arkosic rock, amphibolite, talcose rock, phyllite, granodiorite, porphyritic granite, fine-medium grained granite, and pegmatite. Petrographical studies revealed that quartz, microcline, plagioclase and biotite constitute the major minerals present in the migmatitic gneiss, porphyritic granite, fine-medium grained granite, meta- arkosic rocks and pegmatite with epidote as the dominant accessory mineral. The talcose rock contains in addition to talc, appreciable amount of chlorite, magnesite, anthophyillte with magnesite and quartz forming the accessory minerals. X-Ray Diffraction of the talcose rock also revealed talc as major mineral. Other constituent minerals of the talcose rock are chlorite, tremolite, actonilite, magnesite, and magnetite while spinel and quartz are the accessory minerals.

KEYWORD: X-Ray Diffraction, basement complex, Kagara, North central Nigeria.

INTRODUCTION

The study area is lies within the Pan – African complex of the north-central part of Nigeria, which is a part of an Upper Proterozoic mobile belt, extending from Algeria across the Southern Sahara into Nigeria, Benin and Cameroon. The Pan-African belt continues into north-eastern Brazil, where talcose rocks are also known to occur (Elueze, 1981, Olobaniyi and Annor, 2003). It is situated between the Archean - Paleoproterozoic blocks of West African Craton in the west, the Congo Craton in the southeast and the east Sahara block in the northeast (Durotoye and Ige, 1991) (Figure 1).

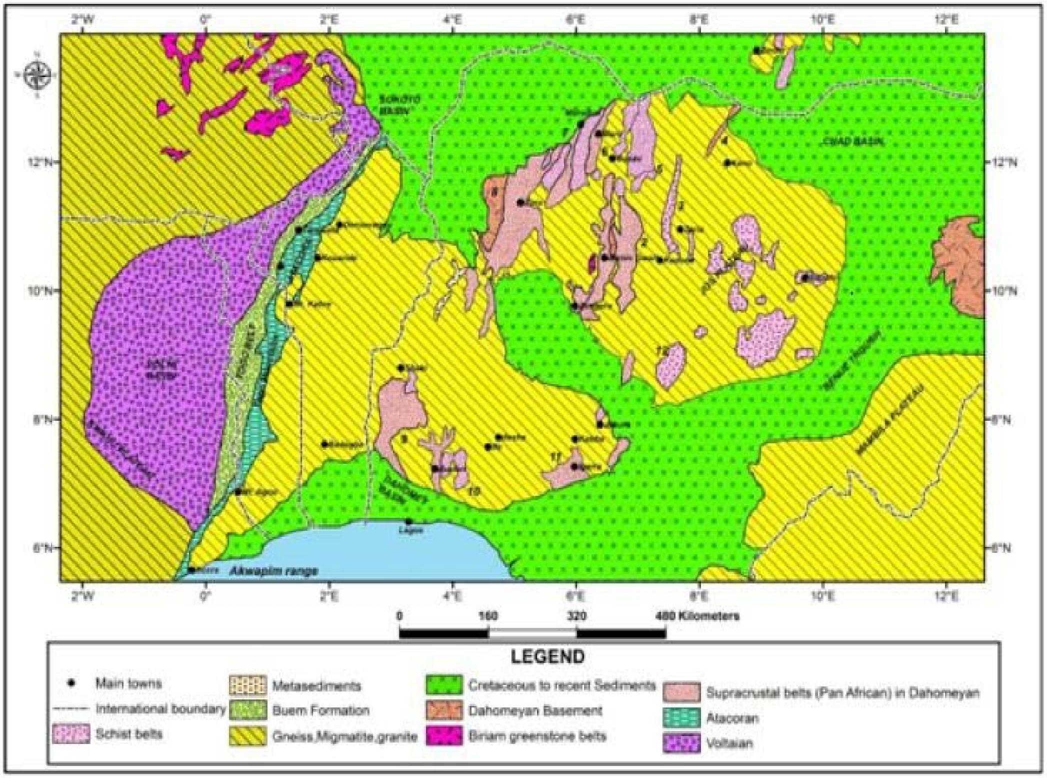


Figure 1: Generalized geological map of Nigerian- Dahomeyan sub region: The Migmatite–Gneiss comlplex (mgc); Schist Belts (Sb); Older Granites (og), (after Woakes et al., 1987).

The Nigerian basement complex (Figure 1) consists of Precambrian gneisses and migmatitic rocks into which belts of N-S trending low to medium grade supracrustal rocks are infolded (Ajibade et al 1987).This supracrustal rocks consist of low to medium- grade metasediments of politic to semi-pelitic compositions, belonging to carbonates, psammitic rocks as well as mafic and ultramafic (talcose) rocks. These occur as lenticular to ovoid shaped bodies intercalated within the metasediments. Both basement and supracrustal cover sequence that have suffered polyphase deformation and metamorphism and are intruded in some places by Pan- African granitoids.

Talc is a hydrated silicate of magnesium $Mg_3Si_4O_{10}(OH)_2$. It is an alteration product of original or secondary magnesian minerals or rocks resulting from mild hydrothermal processess, aided by simple dynamic metamorphism but never from weathering (Hecht et al., 1999). **Minerals** commonly associated with talc are serpentine (3MgO.2SiO2.2H2O), chlorite (MgO.FeO.Al2O3.3SiO2.4H2O), quartz (SiO2), Scheelite (CaWO4) Calcite Ca(CO2)3, anthophllite (7MgO.7FeO.16SiO2.2H2O), pholopite (5MgO.8SiO2), Enstatite (5MgSiO3) among others depending on the rocks from which the talc is derived (Piniazkiewicz et al., 1994; Virta, 2009). The major unique characteristics are lamellarity, softness, chemical inertness, affinity for organic chemicals, and whiteness. Talc properties that are considered most important for possible applications include mineral composition, chemical composition, dry brightness, whiteness, oil absorption, particle size distribution, and density (Schandl et al;1999).

LOCATION AND ACCESSIBILTY

The study area is bounded by latitudes 10° 00′N and 10°15′N and longitudes 6°10′E and 6°30′E. It is a part of the Basement Complex of Nigeria and it is located towards the central part of the N-S trending Kushaka Schist belts. The Kushaka belt occupies a belt of about 50 Km wide and stretches from Minna area up to Tsohon Birnin Gwari area in northwestern Nigeria. Kagara is located about 15 km northeast of Tegina along Tegina – Pandogari –Birnin Gwari road (Figure 1). The study area is assessible from the north and south through Lagos - Tegina - Kaduna highway. The study area can also be accessed from Abuja – Minna– Zugeru en - route Tegina, while the Lagos rail line which trasverses Ibadan – Ilorin - Jebba – Mokwa - Tegina, also provide good access to Kagara and environs. Good accessibility is also provided by numerous untarred roads, foot paths, cattle tracks as well as streams and rivers channels.

RELIEF AND DRAINAGE

The study area is generally undunlating lowland. The eastern half of the area rises a gradual from plain to gently sloping highlands with height ranging from 350 to 365m above the sea level. The terrain on the western half of the area is dominated by lowland with elevation well below 300 m. The pattern of these rivers seems to suggest features of structural significance, which tend to drain almost radially from the central part. These rivers as well as their tributaries make up the drainage system in the area and display a dendritic pattern of flow*(*Figure 2).

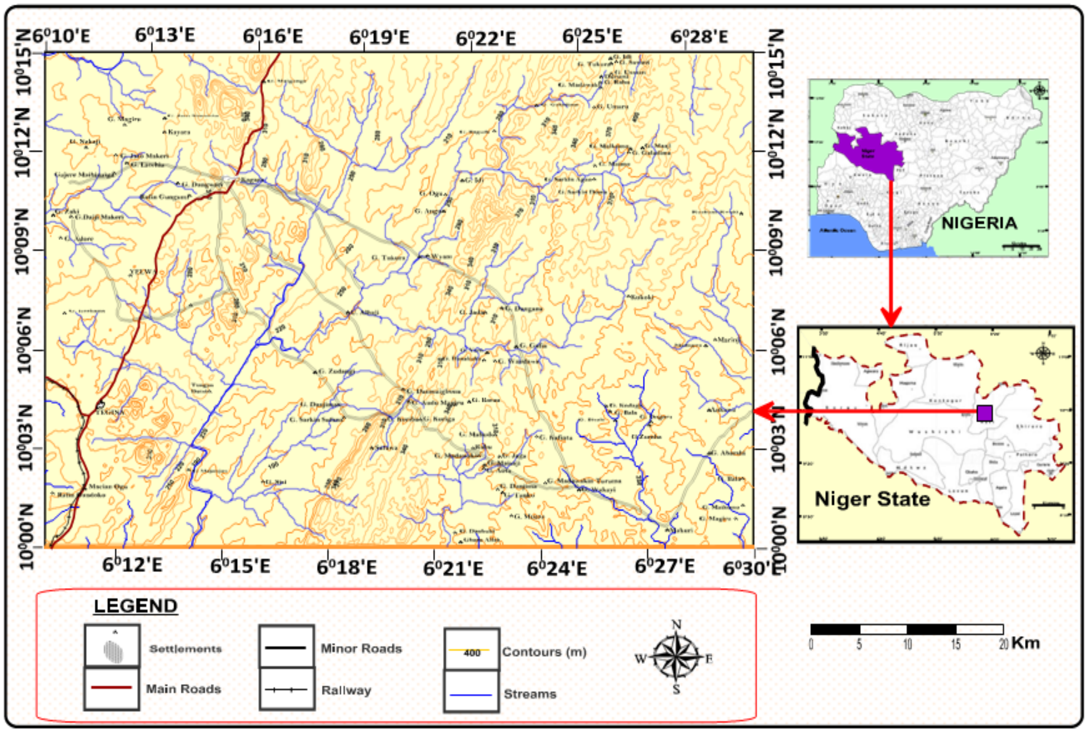


Figure 2: Location map of the study area.

PREVIOUS WORK

The occurrences of talcose rock in ultramafic rocks in Kagara area have previously been reported by Truswell and Cope, (1963); Elueze, (1982); Elueze and Dosunmu (1987); RMRDC, (2010). Elueze (1983; 1986) were speculated on tectonic affinity of the amphibolites in the area. Other works done in the past were related to the geochemistry and general geology of the area without special preference to deposits like talcose occurring within the Kushaka schist belt (Ajibade, (1982).

Recently, geochemical studies by Ihaza et al., (2014) focused on appraisal of talcose bodies in the area with emphasis on its industral application while Amoka (2000); Ogunbanjo and Amoka (2005, 2006; 2010) worked on decolourization of talcose rock from Kagara using magnetic separation and acid bleaching as route for colour enhancement; Since strong colours are objectionable in most industrial applications, most of the talc deposits require bleaching before usage. Apart from the aforementioned previous studies, no further work has been done on talcose deposits in this area.The aim of this study is to determine its minerals compositions of the talcose rocks through X- ray diffraction analysis.

MATERIALS AND METHODS

The methodology adopted in the execution of this research work consists of field study and laboratory analyses. The field study involved geological mapping on a scale of 1:50 000 which was undertaken with topographic map, geologic hammer, compass - clinometers and Global positioning system (GPS). The laboratory work involved sample preparation, petrographic study and geochemical analysis.

The petrographic study was undertaken with the petrological microscope at petrographic laboratory, Department of Geology, Ahmadu Bello University, Zaria. Seven (7) samples of talcose rock were prepared for petrographic study and two (2) selected samples of talcose rock were analysed for x-ray diffraction (XRD) at Activation Laboratories Limited (ACTLAB), Ancaster, Ontario, Canada.

FIELD INVESTIGATION

The field work started with a reconnaissance survey of the area principally to determine traverse route and for logistic planning. This was followed by the detailed geological mapping on a scale of 1:50,000 using traverse method. Collection of representative rock samples from outcrops, road cuts e.t.c alongside the field mapping was also undertaken. Altogether, seven (7) representative rock samples were collected from exposures in the study area. In the field, each outcrop was observed and described based on it's mode of occurrence, macroscopic characteristics, structural elements and field relation with adjacent outcrops.

Fresh samples were taken during the field work with the aid of sledge hammer and chisel and examined with hand lens. Germain Global positioning system (GPS) was used to determine the elevation, longitudes and latitudes of the samples. Careful observation of lithological boundaries was made by observing changes in rock exposures, nature of soil, vegetation and topography. A Silva compass clinometer facilitated traversing and was also used to take strike and dip values of the various structures. Linear measurements were taken with the aid of meter rule. Other materials that were used for the field work are digital Camera to obtain photographs of the rocks and important features where possible. The field note book was used to record the daily activities and rocks description on the field. All the samples were labelled so as to prevent mis-identification and later bagged for sample preparation.

X-RAY DIFFRACTION ANALYSIS

Two (2) representative's samples of talcose rock were analysed for x-ray diffraction (XRD). About 1 kg of each sample was broken into pieces with a hammer and crushed into smaller piece with a jaw crusher. The samples were thereafter pulverized in a disc mill for about two minutes. Each pulverized sample was thoroughly homogenized to obtain a representatatives portion. The samples were thereafter shipped for X-ray diffraction analysis at ACTLAB analytical Laboratory Ontario in Canada.

X-ray diffraction analysis was performed on a Panalytical X'Pert Pro diffractometer, equipped with a Cu X-ray source and an X'celerator detector, operating at the following X-ray settings: voltage: 40 kV; current: 40 mA; range: 5-70 deg 2θ; step size: 0.017 deg 2θ; time per step: 50.165 sec; divergence slit: fixed, angle 0.5°. The crystalline mineral phases were identified in X'Pert

High Score Plus using the PDF-4 Minerals ICDD database.

RESULTS AND DISCUSSION

GEOLOGY OF THE STUDY AREA

The lithologies in Kagara area are migmatitic gneiss, banded gneiss, granitic gneiss, meta-arkosic rock, amphibolites, talcose rock, phyllite, granodiorite, porphyritic granite, fine-medium grained granite, and pegmatite. Migmatitic–gneisses are extensive in the area, intruded by the Older Granites at the northern part truncating its massive extension from the western part of the area to the east ern. It constitutes well over 52% of the rock types in the study area. The Older Granites in the study area are porphyritic and fine-medium grained granites. The porphyritic granites intruded the other rocks in the area especially in the southwestern axis and central part northwards, covering about 30% of the entire area while fine- medium grained granites covers 4% of the area notably in the northeast and toward the central part of the study area. The amphibolites and phyllites consititute about 8% of the rock types in the area. Outcrops of the amphibolite in are lenticular, texturally distinctive and well oriented sub - parallel to the N-S foliated trend.

The talcose rocks constitute about 6% of the rocks in the study area and occur in the northwestern part close to Kagara in Tsaunin Agwaru area in a ridge surrounded by amphiobolite and the Older Granites. The colour of the talc varies from grey, white to pale brown and green depending on the relative mineral constituent with a soapy feel when touched. The chlorite content of the talcose rock is reflected in its green colour. Outcrop of the talc occurs as lensoid bodies of moderate size and length. It extends to the southwestern part having contacts with the migmatitic–gneisses and the Older Granites in an oval shaped outcrops of about 15 m above the surrounding ground surface. In the southern part of Kumunu, talcose rocks occurs as large inselbergs and massives exposures, and are bounded by the Older Granites and migmatitic gneiss in the western and eastern sides. The talcose rock truncate the linearly elongated north - south amphibolite bodies (Figure 3).The talcose bodies are largely extensive in Kagara area with different grade, colours, sizes, and textures. The colour of talc varies from grey, white to pale brown colour with a soapy feel when handled.

There are metamorphosed arkosic rocks mainly of sandstone containing at least 25 % of feldspar. 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 southeastern part of the study area. The geological map of the study area is presented as (Figure 3).

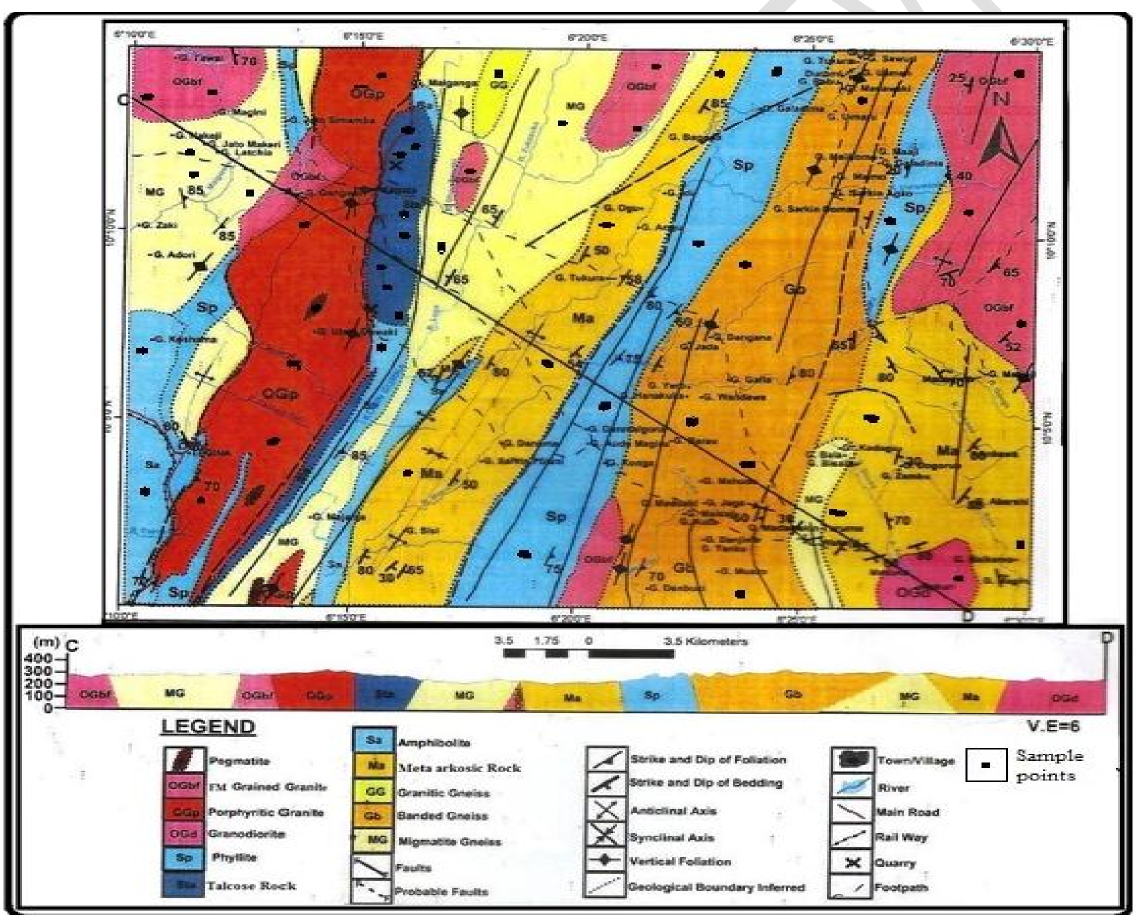


Figure 3: Geological map of the Kagara area.

X-RAY DIFFRACTION ANALYSIS

X-ray diffraction studies were carried out in order to determine the mineralogical compositions of talc and host rocks. The mineralogical compositions of talcose rock (Table 1) and the host rocks from Kagara are shown in Table (2) while the mineral assemblages developed in individual samples including talc are listed in Appendices (1-2)

The result of X-ray diffraction show conspicuous peaks of talc, chlorite and magnetite in assemblage of the talcose rock. Ferroan and quartz are minor constituents in the amphibolites. Other minor peaks include those with spinel structure, magnesite and biotite minerals from biotite group.

The X-ray diffractogram identified the following minerals namely talc, chlorite, tremolite, magnesite, anthophyllite, and opaque minerals. XRD studies indicate ‘‘talc + chlorites’’ coexistence which indicate that the study area is a typical metamorphic terrains (Table 2).

Table 1: Composition of the Samples from the XRD Analysis.

Sample Code	**Fomular**	**Mineral**	**Percentage (%)**
$L13a_2$ (talcose rock)	$Mg(CO_3)$	Magnesite	20
	$(Mg,Fe)Al)_6(Si,Cr)_4O_{10}(OH)_8$	Clinochlore,/ Ferroan	40
	Fe_3O_4	Magnetite	3
	$Mg_3Si_4O_{10}(OH)_2$	Talc	38
$L15_a$ (talcose rock)	SiO_2	Quartz	5
	$(Na,Ca)Al(SiAl)_3O_8$	Albite	3
	$KMg_{1.3}Ti_{0.3}Fe_{1.7}Al_{1.2}Si_{2.8}O_{11(OH)}$	Biotite	7
	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$	Clinochlore	37
	$Mg_3Si_4O_{10}(OH)_2$	Talc	45
	$KA_{l2}(Si_{3Al}O_{10}(O)_{10}(OH,F)_2$	Muscovite	3

Table 2: Mineral paragenesis of talcose rock from Kagara

Sample number	**Mineral Paragenesis**
$L13_a$(Talcose rock)	talc + tremolite+ chlorite + magnesite + anthophyllite + magnetite

$L8_a$(Talcose rock) talc + actinolite + chlorite + anthophyllite + quartz

MINERALIZATION PROCESS OF TALCOSE ROCK IN THE STUDY AREA

The study area is a typical metamorphic terrain. The potential sources of the fluids are through dehydration and decarbonation processes, which occur during the metamorphic event in the area. The mineral constituents of talcose rocks are talc, chlorite, anthophyllite, tremolite /actinolite, and magnesite . Tremolite and actinolite are slightly to moderately altered to chlorite and or talc, where fine relics of actinolite laths are randomly distributed within the talc matrix Plate (1). Chlorite occurs in the form of disseminated anhedral plates and massive lenses of very fine-grained mineral.

The excess water circulate through the surrounding rocks, scavenge and transport minerals to the sites where they can be precipitated as talcose rock (Plate l). The change in temperature affected the grade of metamorphism and with low temperature, hydrous minerals recrystallized into new, higher temperature, anhydrous minerals. The order is from primary phases through alteration to final products as actinolite and clinochore altered to chlorite with talcose rocks as the final product from chlorite.

The major factor that control the mineral assemblage is the partial pressure of carbon (iv) oxide within the metamorphic fluid, here in designated as called the $^{X}CO_2$ which support talcose mineralization.

The role of mixed volatiles as a factor of metamorphsims has been highlighted by Winkler (1979) who observed that metamorphism of basalts to chlorite-green shists or amphibolite is impoosible if sufficient amount of water is present during metamorphism. Decarbonation and dehydration reactions are examples of solid—> solid + vapour reactions.

a) Solid ——> solid + vapour reaction (dehydration process) where brucite liberates water.

$Mg(OH)_2$ ——> MgO + H_2O……………………..(iii)
Brucite ——> Periclase + Vapour

b) Solid——> solid + gas reaction (decarbonation process) where magnesite liberates CO_2.
$MgCO_3$ ——> MgO + CO_2 ……………….............. (iv)
Magnesite Periclase

In the study area, the effects of metamorphism on clinochlore at a low pressure proceed to the right. The crystallization of the tremolite was contemporaneous with reactions as successive metamorphic reactions have replaced or dissolved all primary minerals in the study area in the presence of carbon (iv) oxide that form magnesite ($MgCO_3$).The possible reactions are shown below;

$5Mg_5Al_3Si_3O_{10}(OH)_8$—>$7Mg_2SiO_4 + 2Mg_3Si_4O_{12}(OH)_2 + 5MgAl_2O_4 + 18H_2O$…..(vii)

Clinochlore ——> forsterite + talc + spinel + Vapour

CONCLUSIONS

The study area is underlain by migmatitic-gneiss, banded gneiss, granitic gneiss, meta-arkosic rock, amphibolite, talcose rock, phyllite, porphyritic granite, fine to medium grained granite, granodiorite, and pegmatite. Two distinct varieties of talcose rock are distinguished by colour (white and black). Green chunks of chlorite and bands of quartz veins were also observed in the field as megascopic examination shows typical greasy lustre and basal cleavage of talc.

Mineralogically, the talcose rock contains in addition to talc, appreciable amounts of chlorite, magnesite, and anthophyiltes with quartz and magnetite forming the accessory minerals. Talc mineralization is controlled by many factors particularly silica activity in the liquid phase. Fluid coming from the surrounding was most probably rocks may be rich in dissolved SiO_2 as shown in equations (i) and (ii).

$$Ca_2Mg_5Si_8O_{22}(OH)_2 + 4CO_2 \longrightarrow Mg_3Si_4O_{10}(OH)_2 + 2CaMgCO_3 + 4SiO_2 \ldots\ldots\ldots\ldots(i)$$

Tremolite + carbonic acid ——> talc + magnesite + quartz

$$Mg_5Al_2Si_3O_{10}(OH)_8 + SiO_2 + 2CO_2 \longrightarrow Mg_3Si_4O_{10}(OH)_2 + 2MgCO_3 + 2(AlOH)_3 \ldots(ii)$$

Actinolite + silica + carbonic acid ——> talc + magnesite + spinel

In the study area, the effects of metamorphism on clinochlore at low pressure proceed to the right as crystallization of the tremolite was contemporaneous with reactions as successive event. During metamorphism some of all primary minerals in the study area were replaced or altered the presence of carbon (iv) oxide that produced magnesite ($MgCO_3$). The possible reactions are as shown in equations (iii) and (iv).

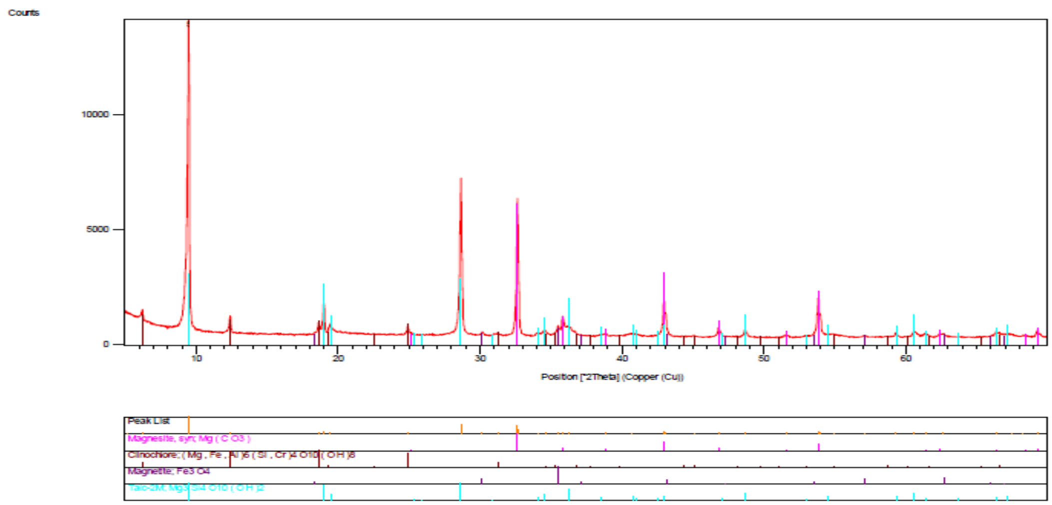
$$5Mg_5Al_3Si_3O_{10}(OH)_8 \longrightarrow 7Mg_2SiO_4 + 2Mg_3Si_4O_{12}(OH)_2 + 5MgAl_2O_4 + 18H_2O \ldots(iii)$$

Clinochlore ——> forsterite + talc + spinel + Vapour

On the basis of the physical, mineralogicall characteristics of the talcose rock, this works has established that the coexistence of chlorite with talc is not detrimental to talc for many applications because they have similar mineralogical composition.

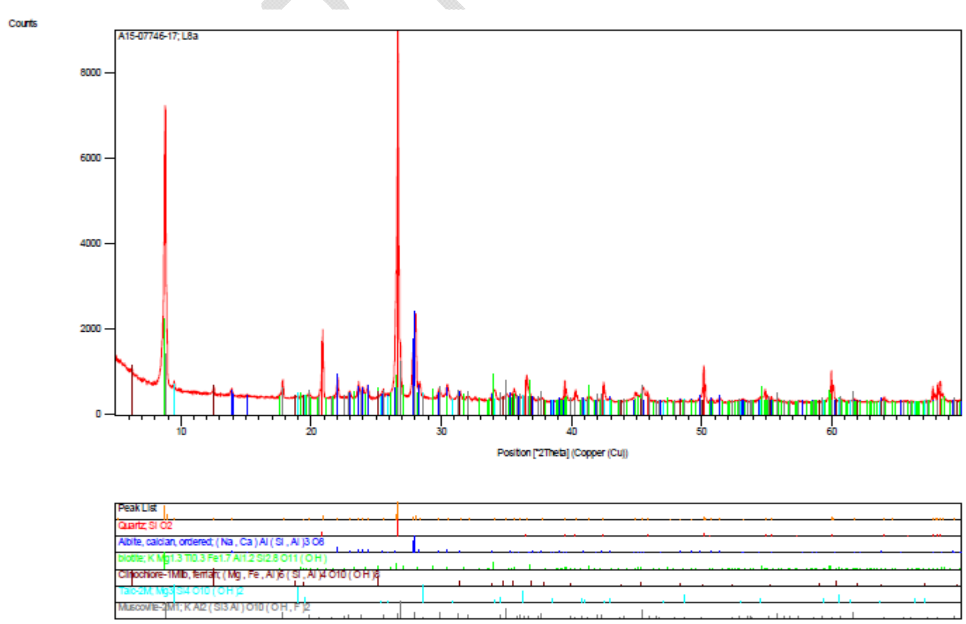
APPENDIX 1

X-ray diffraction (XRD) pattern for talcose rock: Sample (a)



APPENDIX 2

X-ray diffraction (XRD) pattern for talcose rock: Sample (b)



REFERENCES

Ajibade, A.C. (1982). The Origin of the Older Granites of Nigeria: Some evidence from the Zungeru region. *Journal of Mining and Geology,* **19**, pp. 223-230.

Ajibade, A.C., Rahaman, M.A. and Woakes. M. (1987). Proterozoic crustal Development in the Pan - African regime of Nigeria. In: Proterozoic Lithospheric Evolution (Kroner, A., Ed.), *American Geophysicists Union*, **17**, pp. 259–271.

Amoka, I.S. (2000). Beneficiation of talcose rock from Kagara,North-Western Nigeria.Unpublished Master Technology Thesis, Federal University of Technology, Minna, Nigeria. 211p.

Amoka, I.S. (2010). Characterization and processing of talcose rock from Kagara and Isanlu mineral deposits, North-Western and south-western Nigeria Unpublished Phd Thesis, Federal University of Technology, Minna, Nigeria.231p

Durotoye, M.A. and Ige, O.A.(1991). An inventory of talc deposits in Nigeria and their Industrial application potentials. *Journal of Mining and Geology,* **2,** pp27-31.

Elueze, A.A. (1981). Petrographic studies of metabasic rocks and meta-ultramafites in relation to mineralization in Nigerian schist belts. *Journal of Mining and Geology*,**1**, pp.31-37

Elueze, A. A. (1982). Mineralogy and chemical nature of meta-ultramafics in Nigerian schist belts, Nigeria. *Journal of Mining andGeology,* **19,** pp.21-29.

Elueze, A.A. (1983). Dynamic Metamorphism and Oxidation of Amphibolites of, Tegina Area, Northwestern Nigeria. *Precambrian Research.,***14:** pp 379 – 388

Elueze, A.A. (1986). Petrology and gold mineralization of the amphibolite belt, Ilesha area, Southwestern Nigeria. *Geologie en Mijnbouw*, **65**, pp.189-195.

Elueze, A.A and Dosumu, O.O (1987). Preliminary investigation of industrial properties of magnesia bearing rocks in Tungan Bako district, Tegina area North-western Nigeria, *Nigeria Journal of Science,* **21**, pp.133-139.

Hecht, L., Freiberger, R., Gilg, H.A., Grundmann, G. and Kostitsyn, Y.A., (1999). Rare earth element and isotope (C, O, Sr) characteristics of hydrothermal carbonates: genetic Implications for dolomite- hosted talc mineralization at Gopfersgrun (Fichtelgebirge, Germany). *Chemical Geology.* **155**, pp.115–130.

Ihaza, C.A., Adekeye, J.I.D. and Omorinoye, O.A (2014). Appraisal of the Talc Bodies of Kagara Area, North-western Nigeria and their Industrial Potentials. *Centre point journal of science,* **20**, pp. 151-171

Ogunbanjo M.I. and Amoka, I.S. (2005). Froth floatation studies on Kagara talc. *Journal of Engineering, Technology and Industrial Applications*. **1**, pp. 66-71.

Ogunbanjo, M.I. and Amoka, I.S. (2006). Decolourization of Kagara talc using Magnetic separation and acid bleaching. *Journal of Engineering Technology and* Industrial Applications**. 2**, pp.1-5

Olobaniyi, S.B and Annor.A.E, (2003). Petrology and age implication of ultramafic schist in the Isanlu area of the Isanlu–Egbe schist belt SouthWestern Nigeria. *Journal of Mining and Geology,* **39,** pp.1-9.

Piniazkiewicz, R.J, McCarthy.E.F and Mallo, J.S (1994). Talc in industrial minerals and rocks, 6th edition, *Littleton*, pp.1049-1068.

Schandl, E.S., Gorton, M.P., Bleeker, W. (1999). A systematic study of rare earth and trace element geochemistry of host rocks to the Kidd Creek volcanogenic massive sulphide deposit. In:Hannington, M.D.,Barrie, C.T.(Eds.), *Economic Geology Monograph*, 1**0,** pp.309–334

Truswell, J.F. and Cope, R.N. (1963). The geology of parts of Niger and Zaria provinces, Northern Nigeria, *Bulletin, Geological Survey of Nigeria*, **29**. Pp. 1-104.

Virta, R.L. (2009). Talc and pyrophyllite, Minerals Year book of United State of America Geological Society, **1**, pp. 67-72.

Winkler, H.G.F.(1979). Petrogenesis of metamorphic rocks 4th editions, Springer- Verlag, Berlin.169p.

Woakes, M. Ajibade C.A., Rahaman, M.A., (1987): Some metallogenic features of the Nigerian Basement, *Journal of Africa Science*. **5.** pp. 655-664.