Mineralogical and Geochemical Characteristics of Mfyome Talc-Bearing Rocks from Usagaran Belt, Tanzania: Implication for Industrial Applications

[1,2]*LIGALWIKE J H., [2]MSABI M M. [2]MISHRA D

[1]Minerals Division, Ministry of Minerals, P.O Box 422, Dodoma, Tanzania
[2]Department of Geology, College of Earth Sciences and Engineering, The University of Dodoma, P.O. Box 11090 Dodoma, Tanzania

*Corresponding author: ligajudge@gmail.com

Abstract

The Mfyome talc-bearing rocks occurrence is found in the Konse Group of the Paleoproterozoic Usagaran Belt. Despite its known occurrence, the mineralogical, geochemical, and physical properties have not been studied to ascertain its potential for industrial applications. This study, therefore, investigated the mineralogical and geochemical characteristics of talc-bearing rocks in the Mfyome area to determine industrial suitability. Integration of fieldwork, petrographic studies, X-ray diffraction, and geochemical (XRF and ICP-MS) analyses were employed to comprehensively characterize them. Mineralogical studies reveal talc (average 57.5%) is the dominant mineral phase and it is associated with quartz, feldspar, muscovite, sericite, calcite and opaque minerals. This diverse range of mineral associations suggests that the protolith of the talc-bearing rocks is of sedimentary origin, particularly dolomitic carbonate rocks. The geochemical analysis indicates that the talc-bearing rocks are characterized by high SiO_2 (52.93%) and MgO (36.59%) contents, with low Fe_2O_3 (1.17%), Al_2O_3 (3.12%), and CaO (0.26%). Notably, the low concentrations of Ni (40.83ppm), Co (16.74ppm), and Cr (16ppm) further support the sedimentary provenance of the talc-bearing rocks, as these trace elements are typically enriched in talc deposits of ultramafic origin. Based on the mineralogical and geochemical characteristics, the talc-bearing resources are suitable for use in the manufacturing of low-loss electron ceramics, paper, plastic, and roofing and the talc-bearing rocks of "talc + chlorite" assemblages are suitable for the paint industry. It requires appropriate beneficiation to be suitable for the rubber and textiles industries. Further, its composition doesn't meet the necessary criteria as a raw material for wall and floor tiles, electrical insulation ceramics, paints, cosmetics, pharmaceuticals, food, and refractory industries. This study provided valuable insights into the geology and industrial potential of the talc-bearing resources in the Mfyome area, which contribute to the sustainable development of the mining and manufacturing sectors in Tanzania.

Introduction

 Talc-bearing rock occurrences have been reported in altered ultra-basic rocks of Archean and Proterozoic ages, in various parts of Tanzania. Talc mineralization can occur through various mechanisms within a diverse range of host rocks of different ages and geological environments. These include the retrograde metamorphism and metasomatism of silica-rich dolomitic carbonate rocks (Moine *et al.,* 1989; Anderson *et al.,* 1990; Sandrone *et al.,* 1993; Schandl *et al.,* 2002; Shin and Lee 2003) and ultramafic rocks (Naldrett, 1966; Linder *et al.,* 1992; El-Sharkawy, 2000; Tornos and Spiro, 2000). Talc can also form through the metamorphism of submarine hydrothermal rocks associated with massive sulfide deposits (Aggarwal and Nesbitt, 1984; Bjerkgard and Bjorlykke, 1996), as well as within hydrothermal systems and assemblages (Huston *et al.,* 1993; Hecht *et al.,* 1999). Additionally, talc mineralization can occur through the prograde metamorphism of Mg-rich silicates (Sandrone *et al.,* 1993) and the supergene formation in laterites (Noack *et al.,* 1986). The formation of talc is influenced by a variety of factors, including the characteristics of the original rock (protolith), the composition of the fluids involved, the pressure and temperature (P-T) conditions during its formation, as well as the presence, density, and geometry of fractures that serve as pathways for fluid circulation (Moine *et al.,* 1989; Schandl *et al.,* 2002; Bucher, 2023; Wölfler *et al.,* 2015).

Talc is a hydrous, magnesium-rich layered silicate mineral, with the ideal chemical formula $Mg_3Si_4O_{10}(OH)_2$ (Li *et al.,* 2013; Ersoy *et al.,* 2013; Akintola *et al.,* 2019). The theoretical chemical composition of talc is 63.5 wt.% of SiO_2, 31.7 wt.% of MgO, and 4.8 wt.% of H_2O (Pi-Puig *et al.,* 2020). Talc is the primary constituent of the economically viable deposits of soapstone or steatites (Yalçin and Bozkaya, 2006; Pereira *et al.,* 2023). Other minerals that are commonly associated with talc include dolomite, calcite, micas, tremolite, magnesite, quartz, asbestiform and non-asbestiform minerals, antigorite, pyrophyllite, chlorite, anthophyllite, and, more rarely, lizardite and chrysotile (Woguia *et al.,* 2021).

Talc is a universal industrial mineral, that has found application in numerous industries including ceramics, cosmetics, rubber, roofing sheets, paper, food, pharmaceuticals, paint, and insecticides products (Okunlola *et al.,* 2011; Ersoy *et al.,* 2013; Nelson, 2015; Pi-Puig *et al.,* 2020)). In 2023, the total sales of talc, both domestic and export, by producers in the United States (U.S.) were estimated to be around 460,000 tons, valued at approximately $140 million. The talc produced and sold within the U.S. was primarily utilized in the following industries: rubber (5%), roofing (8%), paper (9%), paint (17%), ceramics (including automotive catalytic converters) (27%), and plastics (30%). The remaining 4% of the talc was used in various other applications, such as cosmetics, insecticides, agriculture, export, and other various uses (Brioche, 2024). Talc's applicability for several industrial uses is largely determined by its mineralogical, chemical, and physical characteristics. Desirable attributes include low electrical conductivity, high thermal stability, good absorption and desorption capabilities, wide particle-size distribution, and a large specific surface area. These properties collectively determine the versatility and effectiveness of talc for use in different industrial sectors (Nkoumbou *et al.,* 2008; Ersoy *et al.,* 2013; Dumas *et al.,* 2013; Kagonbé *et al.,* 2021; Emmanuel, 2022). The growth of industries in Tanzania, particularly those that utilize talc-bearing rocks as raw materials in the manufacture of ceramic, paint, paper, and plastic products, has led to an increased demand for these talc-bearing resources (URT, 2019). The extensive demand for talc minerals resulted in the search for talc deposits and the exploitation of talc-bearing rocks in various parts of the country.

Occurrences of talc-bearing rocks in altered ultra-basic rocks of Archean and Proterozoic age, including Chipogolo, Chunya, Hedaru, Kwekivu, Mahoma, and Mfyome areas have been reported by Leger et al. (2015). The talc– and kyanite–bearing amphibolites in the Isimani Suite of the Paleo Proterozoic Usagaran Belt are studied in detail by describing the paragenesis and its geological significance (Mori et al, 2018). The Mfyome talc-bearing rocks have never been thoroughly investigated geologically, although found to be associated with the rocks of the Konse

Group, which is composed of low-grade (lower amphibolite to greenschist facies) metavolcanic and metasedimentary rocks (Leger *et al.*, 2015). Thus, talc-bearing rocks at the Mfyome area associated with the rocks of the Konse Group in the Usagaran Belt were mined through opencast to service the need for raw material by the ceramic industry (B. Ipoliti, personal communication). However, its domestic consumption has been limited due to insufficient information on the origin, mineralogical composition, geochemical, and physical properties which are critical for industrial applications. This study aims to investigate the mineralogical and geochemical composition of talc-bearing rocks, with the view to assessing the suitability of talc-bearing rocks for industrial applications. The findings of this research would contribute to the general awareness of government and prospective investors with respect to the status and potential of talc exploitation and investment in Tanzania.

Geology of Study Area

The Mfyome area is found within the Konse Group of Palaeoprotorozoic Usagaran Belts (**Figure 1**). The Paleoproterozoic Usagaran Belt in central Tanzania is located at the southeastern margin of the Archean Tanzania Craton and constitutes a NE–SW to E–W trending orogenic belt that borders the Neoproterozoic Mozambique Belt (MZB) of the East African Orogen (Mori *et al.,* 2018; Boniface and Tsujimori, 2019; Boniface and Tsujimori, 2021). The Usagaran Belt is subdivided into three major litho–tectonic units including the Isimani Suite, the Konse Group, and Ndembera Group (Leger *et al.,* 2015). The Konse Group unconformably overlies the Isimani Suite and the Tanzania Craton and is composed of low-grade (greenschist to lower amphibolites-facies) meta-volcanic and meta-sedimentary rocks (Mruma, 1995).

Figure 1

A simplified geological map of the Usagaran Belt (modified from Leger et al., 2015) showing the location of the study area (inserted map shows sampling points within the study area)
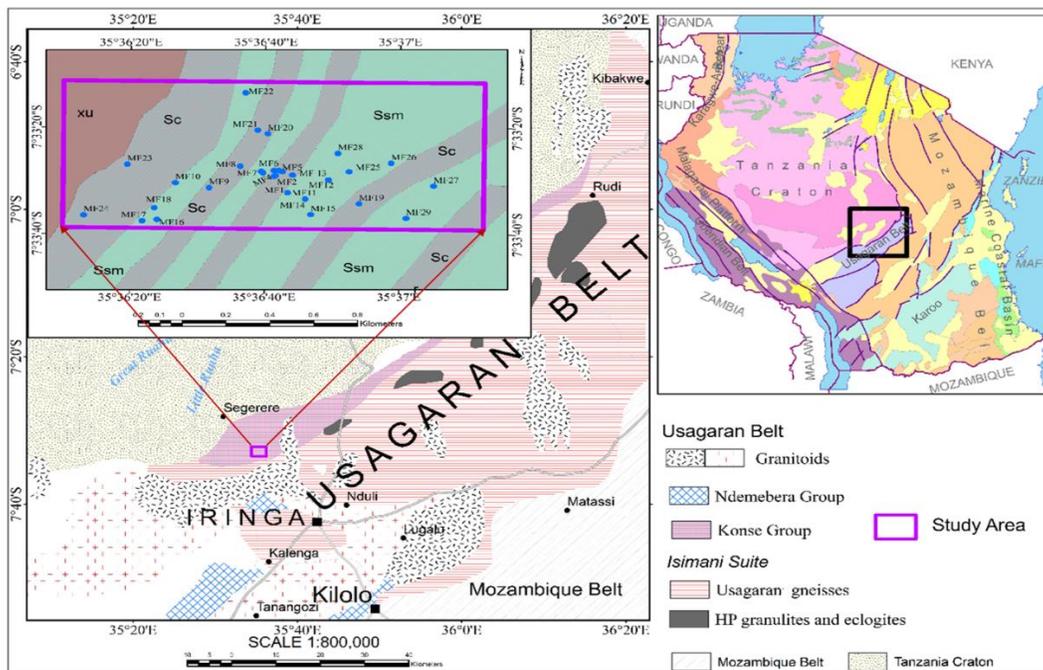
Locally, on Quarter Degree Sheet (QDS) 215 of the Iringa Region, the rock units at the Mfyome area include porphyroblastic migmatitic biotite and hornblende gneiss, migmatitic granodiorite, metadolite, crystalline dolomitic limestone locally silicified and crystalline limestone unspecified, and phyllonite. Also, it consists of biotite gneiss, biotite–epidote schist, mica schist, chlorite-mica schist, and Actinolite.

Materials and Methods

Fieldwork involved documentation of lithological units, which was performed through systematic traversing at the study area bounded by a latitude from 7° 33′ 12″ S to 7° 33′ 39″ S and a longitude from 35° 36′ 12″ E to 35° 37′ 12″ E. The appropriate locations of different lithological units encountered in the course of traversing were recorded with the aid of the Global Positioning System (GPS). Sampling of talc-bearing rocks was done at the outcropped rocks and at the open cast mine where it was quarried. Representative portions of each lithological unit were randomly sampled from outcropping rocks and labelled accordingly in the sample bags. A total of sixteen (16) talc-bearing rock samples were collected for further analysis.

Six (6) thin-section slides were prepared from the representative samples of talc-bearing rocks and studied for their mineralogical assemblages under the petrographic microscope at the Geological Survey of Tanzania (GST). The modal composition of mineral phases within the talc-bearing rock samples was determined through a systematic point-counting method on petrographic thin sections. The percentage of each mineral constituent was calculated by dividing the number of points occupied by that mineral by the total number of points counted and multiplying by 100. This quantitative assessment of the relative mineral abundances provided crucial insights into the mineralogical composition of the talc-bearing rocks. Further, to corroborate the results of the petrographic microscope, three (3) samples of talc-bearing rocks were analyzed by X-ray diffraction (XRD) using the Bruker D2 PHASER A26-X1-A2B0D2C diffractometer, equipped with a Cu X-ray source and LynxEye detector, operating at a voltage of 30 kV and current of 10 mA. The diffraction patterns were recorded in the 5.001°- 64.996° 2θ range, with 0.020° 2θ steps and 57.6-second counting per step. The crystalline mineral phases were identified in X'Pert High Score Plus using the PDF-4 Minerals ICDD database.

The chemical compositions, especially major oxides as well as loss on ignition, for nine (9) samples of talc-bearing rocks were performed with X-ray fluorescence (XRF) using the NEX CG-Rigaku machine at the Geological Survey of Tanzania. For analysis of REE and trace elements, the pulp samples (<200 mesh size) weighing 20 grams each for nine (9) representative talc-bearing rocks were taken and thereafter, sent to Bureau Veritas Mineral Services, Vancouver, Canada to analyze REE and trace elements using Inductively-Coupled Plasma Mass Spectrometry (ICP-MS).

Results

Field observation and rock relationship

Talc-bearing rocks occur as schists with colour ranges from white, grey, whitish-grey, and greenish-grey (**Figure 2**). The colour variation is due to the mineral constituents and weathering. The soapy feel of the rock tends to vary between the rock samples following the amount of talc mineral it contains. The rock has a variety of mineral constituents which are fine to medium-grained. The dominant minerals observed on the rock samples are talc, quartz, feldspar, and muscovite seen by the naked eye and with the aid of a hand lens. Other dominant lithological units in the study area associated with the talc-bearing rocks include quartzite, metabasalt, granite, and crystalline limestone.

Figure 2

Field photographs of different talc-bearing rocks outcropped at Mfyome area; White coloured talc schist (A), Gray talc schist (B), Greenish grey talc schist (C), and Whitish-grey talc (D)
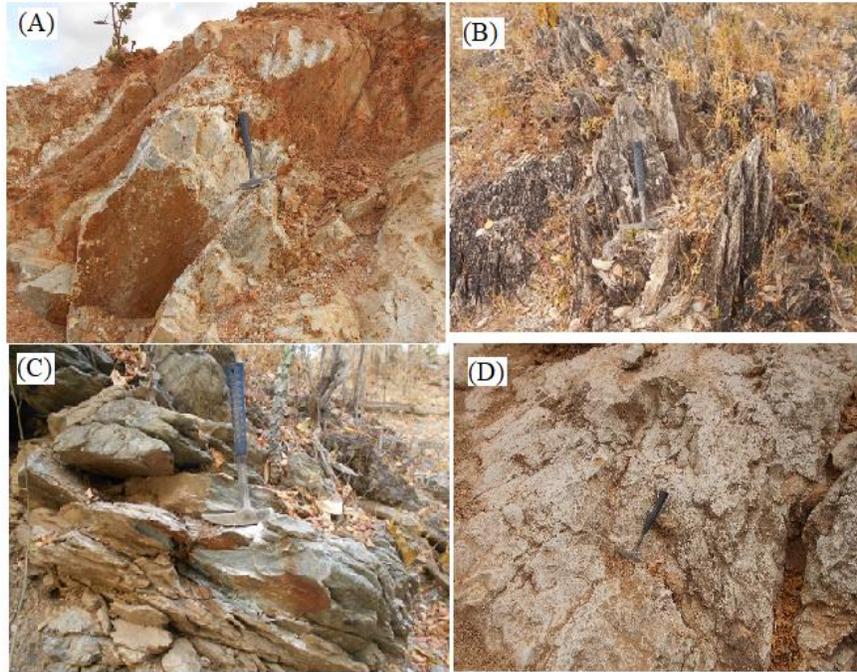
The crystalline limestone occurs as a band and lenses of white, cream-coloured, and grey having finely mineral grains of carbonates. Furthermore, quartzite occurs as flat-lying bodies with lateral extension and also forms impressive ridges in some areas, composed mainly of quartz with medium-sized grains. The metabasalt appears as the hill in most parts of the study area which is fine to medium-grained with mineral constituents including amphibole and plagioclase. Moreover, granite rock is a medium-grained grained size composed of feldspar, quartz, and muscovite minerals. Talc-bearing rocks in the study area for the most part appear to be intruded with amphibolite and granite. Also, metabasalt rock intrudes quartzite and crystalline limestone.

Mineralogy of talc-bearing rocks

Microscopic observation of the talc-bearing rock samples from the Mfyome area reveals a notable variability in their mineralogical composition. Talc represents the dominant phase, and it is associated with a range of other minerals, including quartz, sericite, feldspar (plagioclase), muscovite, calcite, and opaque minerals (Figure 3). The compositional range of the mineral was talc 35-80 wt. %; feldspar 8-25 wt. %; quartz 10-28 wt.%; sericite 2-35 wt. %; muscovite 35 wt. %; calcite 10 wt. % and opaque 1-2 wt.% (**Table 1**). On the other hand, X-ray diffraction shows conspicuous peaks of talc in samples analyzed and other peaks of the minerals observed are albite, anorthoclase, pyroxene, oligoclase, quartz, and chlorite (**Figure 4**). Generally, the X-ray results confirm identified minerals in thin sections under microscopic observation.

5

Table 1

Mineralogical composition of selected talc-bearing rocks at Mfyome as revealed in the petrographic study (Modal composition)

Rocks and Samples ID		Mineralogical composition (wt. %)						
Rock	**Sample ID**	**Talc**	**Feldspar**	**Quartz**	**Sericite**	**Muscovite**	**Calcite**	**Opaque**
Plagioclase- talc schist	MF 01	60	25	-	15	-	-	-
	MF 21	55	9	-	35	-	-	1
Talc –quartz schist	MF 12	65	15	10	2	-	-	2
Muscovite- talc schist	MF 16	35	-	28		35	-	2
Carbonate- talc schist	MF 17	50	8	-	15	-	20	2
Talc –sericite	MF 28	80	-	-	19	-	-	1

Figure 3

Photomicrograph of Talc-bearing rocks under polarized light; (a-b) Plagioclase-talc schist, (c) Carbonate-talc schist, (d) Tal-quartz schist (e) sericite-talc, and (f) Muscovite-talc schist foliation. Abbreviation; Tlc-talc, Pl-plagioclase, Fsp-Feldspar, Ser-Sericite, Ms- Muscovite, Qz-quartz and Cal-Calcite.
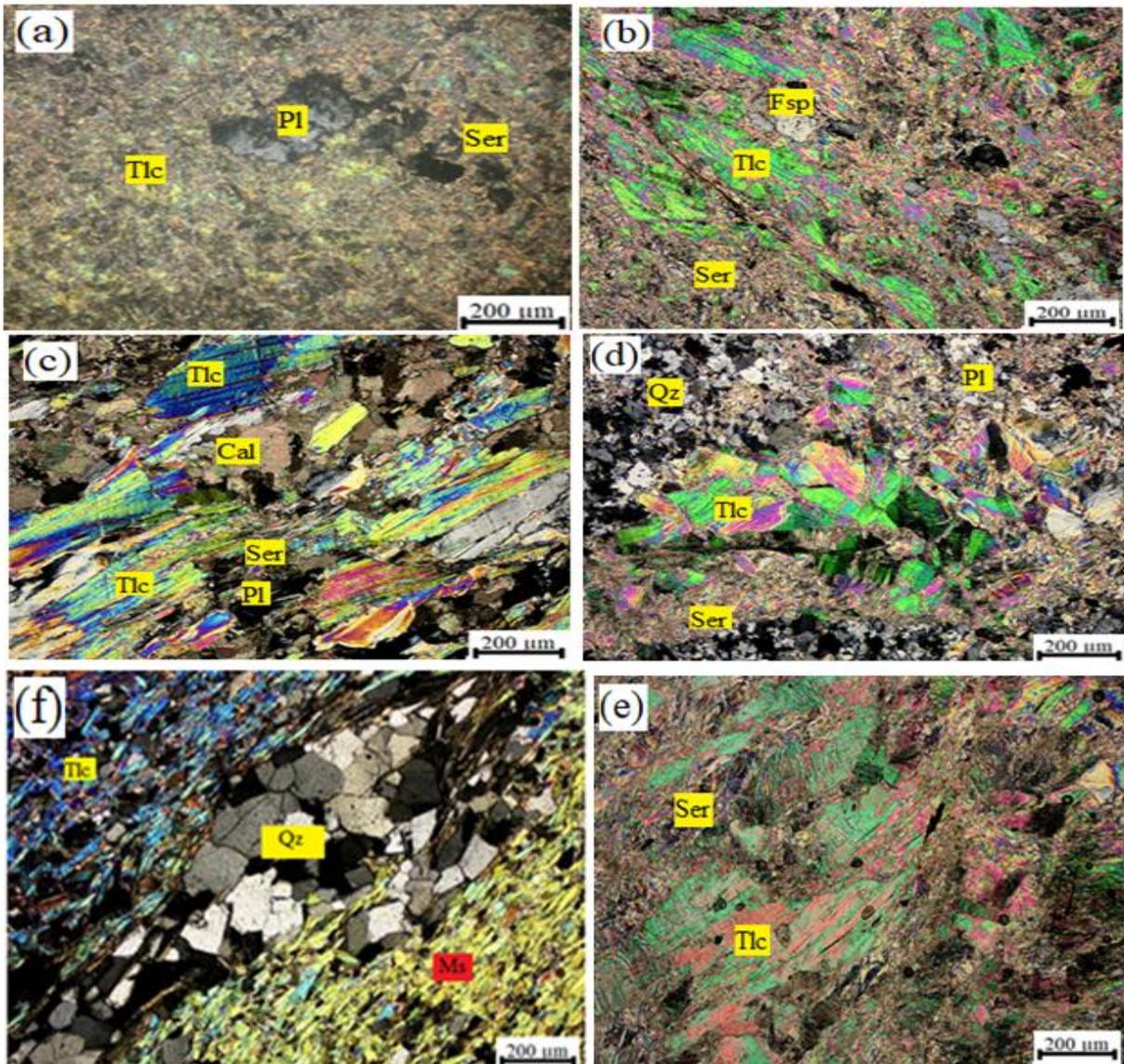
Figure 4

X-ray diffractograms for the Talc bearing rocks (Diffractograms of talc-bearing rocks in the study area depict predominant talc, albite, oligoclase, anorthoclase, quartz, pyroxene and chlorite)
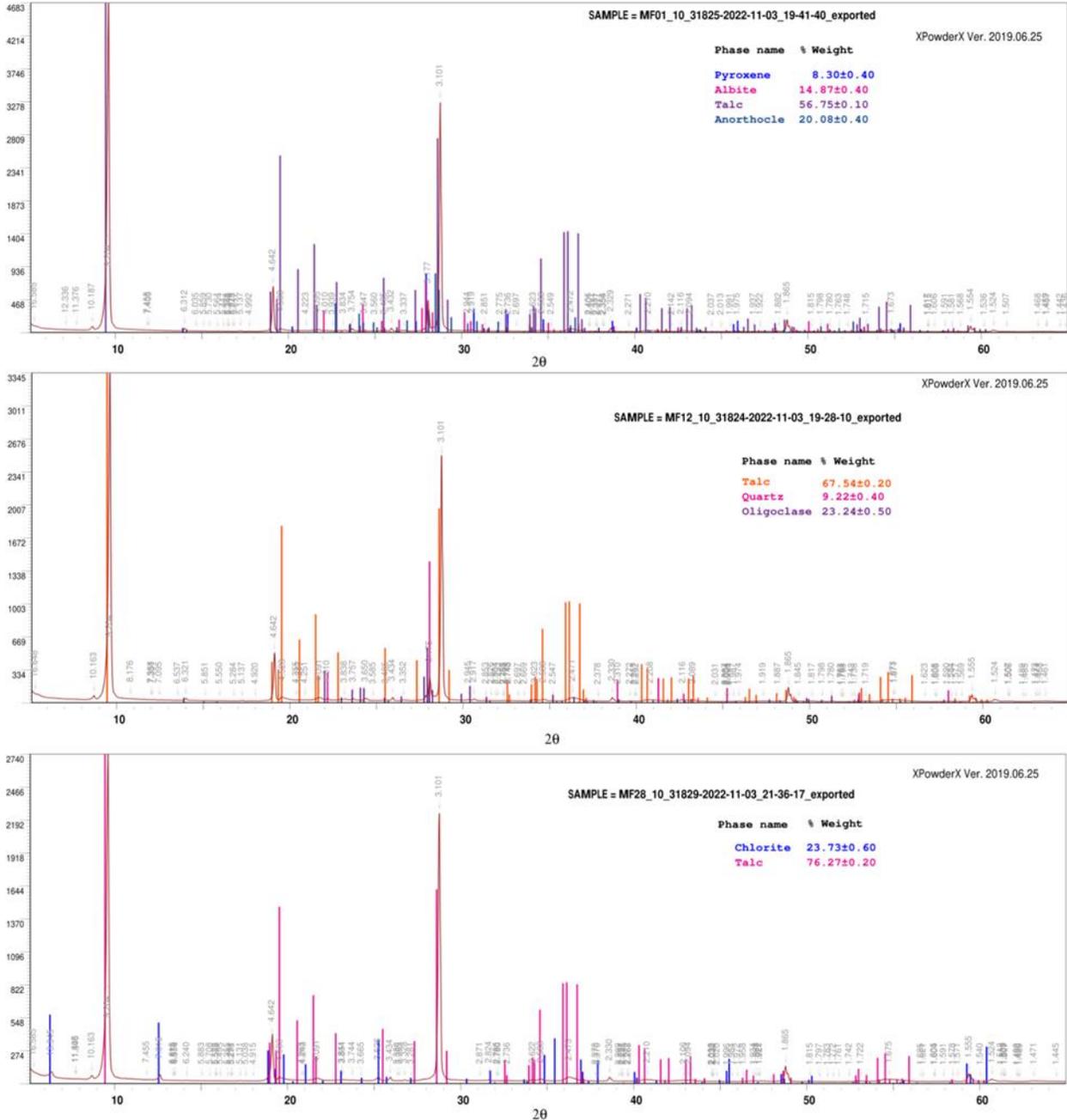
Geochemistry of talc-bearing rocks

Major oxides analyzed in the selected talc-bearing rocks are presented in **Table 2**. Silica (SiO_2) composition varies from 45.18 wt. % to 55.02 wt. % with 52.93 wt. % as the average silica composition. The average value of Al_2O_3 is 3.12 wt. % calculated from it is range 1.12-6.33 wt. %. Fe_2O_3 ranges from 0.81 wt. % to 2.47 wt. % with calculated as the average value of 1.15 wt. %. The range of CaO is from 0.0 wt.% to 1.59 wt. % with a mean value of 0.26 wt. %. The range of K_2O and Na_2O, are 0-1.29 wt. % and 0 - 2.37 wt. %

8

respectively, with their average values are 0.15 wt. % and 0.76 wt. % accordingly. The MgO ranges from 31.46 wt. % to 39.69 wt. % with an average value of 36.59 wt. %. P_2O_5 value of 0.02 wt. % and 0.01 wt. % are recorded in the sample MF01 and MF16 respectively. The value of MnO of 0.02 wt. % recorded in the sample MF16. TiO_2 values range from 0.0 to 0.58 wt. % with a mean value of 0.06 wt. %. Loss on ignition (LOI) value ranges from 4.01-8.17 wt. % with an average value of 4.77 wt. %.

Table 2

Major oxides composition of talc-bearing rocks of Mfyome Area in wt %

Rocks	Samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	TiO_2	LOI
Plagioclase-talc schist	MF01	54.47	2.51	0.82	0	37.14	0	0.6	0.02	0	0.01	4.27
	MF07	54.58	2.65	0.81	0.11	36.5	0	1.02	0	0	0	4.24
	MF08	54.81	4.16	0.91	0.13	34.11	0.01	1.48	0	0	0.02	4.18
	MF21	55.02	1.12	1	0.17	37.85	0	0	0	0	0	4.65
Talc- quartz schist	MF12	53.65	2.35	0.86	0.11	38.01	0	0.89	0	0	0	4.02
Carbonate-talc schist	MF 17	45.18	6.53	1.06	1.59	35.35	1.29	0.51	0	0	0.01	8.17
Muscovite-talc schist	MF16	53.99	4.72	2.47	0.12	31.46	0.01	2.37	0.01	0.02	0.58	4.1
Sericite -talc schist	MF25	50.68	2.68	1.29	0.12	39.69	0	0	0	0	0	5.27
Chlorite-talc schist	MF28	53.95	1.4	1.29	0.01	39.16	0	0	0	0	0	4.01

Trace element concentrations of investigated talc-bearing rock samples are displayed in **Table 3**. Nickel (Ni) values range from 20.7– 62 ppm, cobalt (Co) ranges from 5.6 – 26.9 ppm and chromium ranges from 7– 31 ppm with their mean values of 40.83 ppm, 16.74 ppm and 16 ppm respectively. Furthermore, Copper (Cu) values range from 1.3 – 14.4 ppm with a mean value of 4.01 ppm as well as zinc range from 6.1– 27.8 ppm with an average value of 12.4 ppm. The average value of Sc is 4.88 ppm as calculated from the range 2.3 – 15.6 ppm and the values of Y range from 0.5 – 6.7 ppm with the mean value of 1.63 ppm. Zirconium (Zr) values range from 4.9 – 20.6 ppm, niobium (Nb) range from 0.05 – 0.36 ppm and hafnium (Hf) range from 0.15 – 0.67 ppm; their average values are 12.32 ppm, 0.15 ppm and 0.39 ppm, respectively. Values for Thorium (Th) range from 2.8 ppm – 10.2 ppm with an average of 6.82 ppm.

Concentration values for Barium (Ba) are variably among the samples which range from 2– 11 ppm with the exception of samples MF 17, MF 25 and MF 28; however, samples MF 25 and MF 28 show relatively high values of 52 and 55 ppm respectively. Sample MF 17 shows a high value of about 307 ppm. The average value of rubidium (Rb) is 0.75 calculated from the range value 0.3 – 2.6 ppm with the exception of sample MF 17. Lead (Pb) ranges from 0.37-2.37 ppm with an average value of 1.01 ppm. Strontium (Sr) range value is 2 – 24 ppm with a mean of 9.7 ppm. Values for vanadium (V) range from 7 – 52.00 ppm and the mean value is 25.44 ppm.

Table 3

Trace element composition (in ppm) of the Mfyome talc-bearing rocks

					Samples				
Location (X,Y)	788184 9163767	788192 9163766	788133 9163787	788205 9163801	788268 9163775	787582 9163500	788109 9164034	788525 9163794	788475 9163900
Trace Elements	MF 01	MF 07	MF 08	MF 11	MF 12	MF 17	MF 21	MF 25	MF 28
Ba	2	11	6	10	2	307	7	52	55
Ni	44.6	54.7	62	48.5	28.7	20.7	40.8	32.7	34.8
Cr	8	30	17	14	7	20	11	31	10
Co	20	10	21.9	15.2	17.3	5.6	15.5	18.3	26.9
Sc	2.5	2.6	3.1	15.6	3	4.4	2.3	5.3	5.2
Hf	0.15	0.62	0.54	0.61	0.24	0.23	0.29	0.67	0.16
Nb	0.11	0.12	0.05	0.14	<0.04	0.36	<0.04	0.14	0.13
Y	0.6	1	0.8	2.8	0.5	6.7	0.8	0.7	0.8
Rb	0.3	0.5	0.5	0.7	0.3	70	0.4	2.6	0.7
Sn	0.2	0.3	0.2	0.7	0.1	0.8	0.2	0.2	0.2
Sr	4	19	9	15	5	24	4	6	2
Ta	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Th	8.1	6.2	9.9	5.2	4.4	10.2	7.7	2.8	6.9
V	7	30	15	52	7	12	45	23	38
Zr	4.9	20.6	17.9	19.1	8.5	6.7	9.2	14.3	9.7
Cu	1.3	2.2	2.9	5.1	1.6	14.4	1.9	2.3	4.4
Pb	0.87	1.49	1.15	1.1	0.37	2.37	0.85	0.42	0.51
As	<0.2	<0.2	<0.2	<0.2	0.5	4.3	<0.2	0.8	0.6
Zn	10.5	6.1	9.8	6.9	11	27.8	12.9	10.1	16.5

The result of elemental analysis for the Rare Earth Elements (REEs) is presented in **Table 4**. The concentration of Lanthanum (La) ranges from 0.40 – 2 ppm and showed a mean value of 1.22 ppm with the exception of Sample MF 17. Values for cerium (Ce) range from 1.15 – 4.64 ppm and neodymium (Nd) ranges from 0.5 ppm – 1.7 ppm. Mean values calculated for Ce is 2.7 ppm and Nd is 1.13 ppm. Sm ranged from 0.1 ppm to 0.4 ppm with an average value of 0.24 ppm. The range for Pr is 0.1 ppm to 5.5 ppm with an average value of 1.01 ppm excluding MF 17. Europium (Eu) values in most of the samples are below the detection, however sample MF11 detected 0.1ppm and 0.5ppm is detected in MF 17. Gd values ranged from 0.1 ppm – 2 ppm with an average value of 0.43 ppm. Dy value range is 0.1 ppm -1.5 ppm with an average of 0.35 ppm.

Table 4

Rare earth element composition (in ppm) of Mfyome talc-bearing rocks

					Samples				
Location	788184	788192	788133	788205	788268	787582	788109	788525	788475
(X, Y)	9163767	9163766	9163787	9163801	9163775	9163500	9164034	9163794	9163900
REE	**MF 01**	**MF 07**	**MF 08**	**MF 11**	**MF 12**	**MF 17**	**MF 21**	**MF 25**	**MF 28**
La	0.7	2	1	1.3	0.4	30.4	1.6	2	0.8
Ce	1.4	4.09	2.4	2.73	1.15	45.87	3.51	4.64	1.95
Pr	0.2	0.4	0.1	0.3	<0.1	5.5	0.3	0.3	<0.1
Nd	0.7	1.5	0.8	1.6	0.5	19.3	1.7	1.5	0.8
Sm	0.2	0.3	0.1	0.4	<0.1	3	0.3	0.2	0.2
Eu	<0.1	<0.1	<0.1	0.1	<0.1	0.5	<0.1	<0.1	<0.1
Gd	0.2	0.3	0.1	0.4	<0.1	2	0.2	0.2	0.1
Tb	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1
Dy	0.1	0.2	0.1	0.5	<0.1	1.5	0.2	0.1	0.1
Ho	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1
Er	<0.1	0.1	<0.1	0.3	<0.1	0.8	<0.1	<0.1	<0.1
Tm	<0.1	<0.1	<0.1	<0.1	<0.1	20.1	<0.1	<0.1	<0.1
Yb	<0.1	0.2	<0.1	0.4	<0.1	0.6	<0.1	<0.1	<0.1
Lu	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ΣREE	3.5	8.89	4.6	8.03	2.05	130.7	7.81	8.94	3.95

Discussion

Mineralogy

Talc bearing rocks revealed the dominant minerals assemblages as talc + feldspar (oligoclase) + quartz + sericite", talc + feldspar + quartz", "talc + feldspar (plagioclase) + calcite + sericite", talc + feldspar (albite + oligoclase) ± pyroxene + sericite", "talc + quartz + muscovite", "talc + sericite" and "talc + chlorite. The talc-bearing rocks are classified into five (5) groups of rock based on the result of mineralogy which are Plagioclase-talc schist, Muscovite-talc schist, Quartz-talc schist, Carbonate-talc schist and Chlorite-talc schist. These mineral assemblages imply that the protolith of Mfyome talc-bearing rocks is of sedimentary origin (Tahir *et al.,* 2018). Talc of sedimentary origin is generally formed by the hydrothermal alteration of dolomite and magnesite through an influx of silica-containing fluids (Prochaska, 1989; Anderson *et al.,* 1990; Moine *et al.,* 1989).

Talc-bearing rocks of the Mfyome area are referred to as commercial talc of economic value as they contain more than 20% of the mineral talc (McCarthy et al. 2006). Karlsen et al. (2000) classified talc products as (i). High-purity talc (talc content >95%) is used in cosmetics, steatite, cordierite ceramics, paper and plastics; and (ii). Medium-purity talc (e.g., talc content 75-95%) is used in paper, plastics, wall tiling, paint and rubber and (iii). low-purity talc (e.g., <75%) is used in paint, roofing materials, flooring and fertilizers. Thus, based on the talc content observed in the Mfyome talc-bearing rocks, they fall into medium-purity talc to low-purity talc.

Geochemical Characteristics

Results of major oxides show that the Mfyome talc-bearing rocks are characterized by high SiO_2 and MgO, and low Fe_2O_3, Al_2O_3, and CaO as well as other alkaline oxides. The high MgO content of the talc-bearing rocks is thought to be inherited from the protolith mainly dolomitic limestone in which magnesium is being leached (Prochaska,

1989; Schandl *et al.,* 2002) or supplied by another source probably amphibolite which appears as an intrusion. According to Joshi (2009), the alterations of siliceous dolomite and magnesite to talc are marked by a decrease in CaO and an increase in SiO_2 content. Thus, the enrichment of SiO_2 in talc-bearing rocks is thought to be inherited from the protolith. Moreover, the enrichment of SiO_2 in talc-bearing rocks may be due to the effect of chemical weathering (Bolarinwa, 2015). The depletion of Na_2O, CaO and K_2O in talc-bearing rocks has been influenced by chemical weathering and relative chemical mobility of Na, Ca and K during hydrothermal alteration respectively (Omotunde *et al.,* 2020; Olajide-Kayode *et al.,* 2018; Bolarinwa, 2001). On the SiO_2-CaO-MgO ternary diagram, the samples of talc-bearing rock fall in the talc region (**Figure 5**). This is due to the high content of SiO_2 and low CaO content and also, consistently plotted along the MgO – SiO_2 tie line indicating a mixture of magnesium silicates and carbonates.

Figure 5

SiO2 – CaO – MgO diagram of the talc bearings rocks of Mfyome area
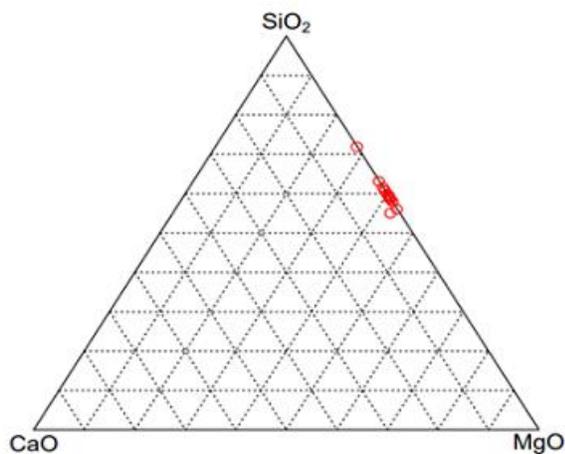
The concentration of trace elements in talc-bearing rocks such as Ni, Co, Cr, Ba, Cu, Zn, Sc, Y, Zr, Nb, Hf, Th, Ga, Sn, Rb, As, Sr, V and Pb are low. Ni, Cr, and Co are important elements for the identification of the origin of talc-bearing rocks or deposits. Their abundances are low in Mg-carbonatic talc deposits but are concentrated in ultramafic talc deposits (Prochaska 1989). Thus, Mfyome talc-bearing rocks are related to

sedimentary rocks with respect to parental affinity due to their low Ni, Co and Cr (Yalçin and Bozkaya, 2006; Tahir *et al.,* 2018). In terms of Ni, Cr, and Co, the Mfyome talc-bearing rocks are similar to the sedimentary-related talc of Rabenwald and Lassing in the Eastern Alps, Austria (Prochaska 1989), but differ from ultramafic-related talcose rocks of Orangun-Oyan (Omotunde *et al.,* 2020), Wonu-Apomu and Ilesha (Bolarinwa, 2015), and Itagunmondi-Igun (Olajide-Kayode *et al.,* 2018) found within the Ilesa Schist Belt, Southwestern Nigeria. High-field strength trace elements like Ta, Hf, Zr, and Th are generally inert under most geological environments, and their concentrations are expected to reflect the composition of the original rock (Schandl *et al.,* 1999). The low concentrations of these elements in the Mfyome talc-bearing rocks are inconsistent with a felsic igneous protolith (Schandl *et al.,* 1999).

Carbonates typically have low concentrations of most trace and rare earth elements (REEs) (Schandl *et al.,* 2002). Additionally, marine carbonates are characterized by a scarcity of REEs and trace elements, inherited from the very low REE abundances in seawater (Piper, 1974; Palmer, 1985). The depletion of total REEs observed in the Mfyome talc-bearing rocks is interpreted to be inherited from the carbonate sedimentary rocks, such as dolomitic limestone (Schandl *et al.,* 2002; Tahir *et al.,* 2018). Therefore, based on the geochemical evidence, the carbonate sedimentary rocks are the most probable precursor (protolith) for the talc-bearing rocks in the Mfyome area (Schandl *et al.,* 2002; Tahir *et al.,* 2018).

Potential Industrial Application

The Mfyme talc-bearing rocks have been evaluated for their potential industrial applications through a comprehensive analysis of their mineralogical and geochemical properties. Additionally, the industrial applications of talc were compiled by Ann Bazar et al. (2021), as detailed below:

Ceramics Industry

In the ceramics industry, particularly for the manufacture of wall and floor tiles, whitewares, and enamels, talc is incorporated as an additive to enhance the translucency and mechanical

strength of the final products (Kumar *et al.*, 2016; Qin *et al.*, 2018; Dondi *et al.*, 2019; Kagonbé *et al.*, 2021; Kalendova *et al.*, 2024). According to Mitchell (1975), the optimal firing colour (white) and an average CaO content of 6% are required to function as a flux, thereby lowering the maturing temperature of the ceramic ware. However, the Mfyome talc-bearing rock samples analyzed do not meet these specifications, as the average CaO content of 0.26% is lower than the recommended 6.0%. Conversely, the Mfyome talc-bearing rocks appear suitable for low-loss electron ceramics, given their low Fe_2O_3, Al_2O_3, and CaO (≤ 1 wt.%) concentrations. Nonetheless, the Mfyome talc-bearing rocks are unsuitable for electrical insulation ceramics, as the SiO_2 content is marginally lower than the required level, and some samples exhibit $Na_2O + K_2O$ higher than the specified range.

Paint Industry

Paint manufacturers have specific requirements for the talc raw material, which include a good white colour, small particle size with at least 97% passing through a 325-mesh sieve, absence of hard particles, an Al_2O_3 composition of less than 2%, $MgO + SiO_2$ content greater than 75%, and a Loss on Ignition (LOI) range of 4% to 8% (Payne, 1981). Pulverized talc is employed in the paint industry as an inert filler and extender, and it also helps reduce the risk of cracks in the paint film (Kumar *et al.*, 2016; Castillo and Barbosa, 2020). The analysis of the Mfyome talc-bearing rocks reveals that most of the samples meet the $MgO + SiO_2$ ($> 75\%$) and LOI (4.01-8.17%) requirements. However, only the talc-bearing rocks with the "Talc + Chlorite" mineral assemblage have an Al_2O_3 composition of less than 2%, while the other assemblages contain Al_2O_3 over 2%. Therefore, based on these compositional criteria, only the Mfyome talc-bearing rocks with the "Talc + Chlorite" assemblage are considered suitable for application in the paint industry.

Paper Industry

Talc finds utility as a filler and extender in the paper manufacturing industry (Kumar *et al.*, 2016; Andrade Jr, and Pastore, 2016; Qin *et al.*, 2018). It also serves as a coating pigment, enhancing the smoothness and glossiness of high-quality print papers and magazines. For this application, Noble (1988) specified that the talc should be white, fine-grained, mica-free, and

have very low Fe_2O_3 and CaO (less than 5%). The majority of the Mfyome talc-bearing rock samples meet these requirements, as they exhibit low Fe2O3 content and an average CaO concentration of 0.26 wt.%. Nevertheless, talc-bearing rocks of the Mfyome area with assemblage containing mica minerals such as muscovite need to be benefited to remove muscovite to make it suitable for the paper industry. Hence, most of the Mfyome talc-bearing rocks are suitable for the application in paper industry except that contain muscovite in the mineral assemblages.

Cosmetics, Pharmaceuticals and Food Processing Industry

Talc is utilized in the manufacture of various cosmetic products, such as creams, powders, salves, rouge, and soaps (Andrade Jr, and Pastore, 2016; Kumar *et al.*, 2016; Qin *et al.*, 2018; Pi-Puig *et al.*, 2020). Additionally, talc serves as a dusting agent for tablets and wound treatments, as well as for odour absorption in wounds. It also finds use as a dusting agent for foods, a food colouring absorbent, and a polishing agent in cereals. For cosmetic, pharmaceutical, and food-grade applications, talc must meet stringent specifications, including being odourless, grit-free, and highly pure (at least 90% talc), with a white colour, Loss on Ignition of 5%, pH between 8-10, and a CaO content of 1.6% (American Society for Testing of Materials, 1988). The cosmetics industry, in particular, requires talc deposits of exceptional quality, with up to 90% talc composition and the absence of any fibrous or asbestos-like minerals (Fiume *et al.*, 2015). Additionally, the talc particles must have extremely low lead (< 20 ppm) and arsenic (< 3 ppm) contents, and be free of quartz. The presence of carbonate minerals can also complicate the use of talc in cosmetics, as they are granular and lack the desired softness (Nkoumbou *et al.*, 2006, Nkoumbou *et al.*, 2008). When considering these stringent requirements, the Mfyome talc-bearing rocks appear to fall short, necessitating extensive beneficiation to increase the mineralogical purity and remove gritty particles before they can be used in cosmetic, pharmaceutical, and food applications.

Rubber Industry

In the rubber manufacturing industry, the ideal talc raw material should have no gritty particles, an off-white colour, and low MnO and CaO values (Severinghus, 1975; Kumar *et al.,* 2016; Andrade Jr, and Pastore, 2016). Talc is valued for its ability to enhance tear and abrasion resistance, as well as stiffness, in rubber products. Additionally, talc serves as a highly effective dusting agent to lubricate moulds during the rubber manufacturing process. The Mfyome talc bearing rocks samples have low CaO and MnO contents, off-white colour such as grey colour, and some have gritty particles while others do not. Therefore, the Mfyome talc-bearing rocks are suitable for use in the rubber industry, however, those samples having gritty particles such as calcite and quartz need adequate pulverization and milling to reduce gritty particles.

Plastic Industry

For use as a raw material in the production of polypropylene plastics, desirable talc characteristics include low specific gravity, fine particle size distribution, softness, and good color. These properties are essential for enhancing the rigidity and thermal stability of the final polypropylene products, particularly at elevated temperatures. The talc raw material should exhibit these specific attributes to effectively contribute to the improvement of the polypropylene's physical and performance characteristics during the manufacturing process. (Noble, 1988; Kumar *et al.,* 2016; Andrade Jr, and Pastore, 2016; Qin *et al.,* 2018). Mfyome talc-bearing rocks meet most of these criteria and are suitable in the application for the plastic industry.

Textile Industry

For use in textile manufacturing, the ideal talc raw material must be free of hard or gritty particles, such as calcite and quartz, and instead possess a smooth, greasy feel. Additionally, the talc should have a good colour and a moisture content of less than 0.3% (American Texture Manufacturer's Institute, 1975). These specific characteristics, including the absence of gritty particles, a smooth and greasy feel, good color, and low moisture content, are essential for the effective utilization of talc as a raw material in textile production processes. The assessment of the Mfyome talc-bearing rocks reveals that some samples possess the desired properties, being free of gritty particles and exhibiting the appropriate smoothness, color, and greasy texture. However, other Mfyome talc-bearing rock samples do contain gritty particles, which would require proper processing and purification to remove the impurities before they can be used in textile manufacturing applications.

Roofing Industry

This product requires relatively low-grade, coarsely-grained talc as filler and as inert fireproof overcoating in roofing (National Paint and Coating Association, 1975). Therefore, Mfyome talc-bearing rocks are low-grade and are suitable for this application.

Refractory Materials

The addition of talc to high-alumina clay and subsequent firing at temperatures between 1250°C and 1400°C results in the production of materials with low thermal expansion, high thermal shock resistance, and desirable electrical properties. These characteristics make them suitable for application in the manufacture of electrical coils, water boiler insulators, fire bricks, and burners (Omidiji *et al.,* 2024). For this specific application, the American Society for Testing of Materials (1988) has specified that the talc should exhibit a low fired shrinkage value, along with the following chemical composition: $CaO < 1\%$, $Fe_2O_3 < 1.5\%$, $SiO_2 > 60\%$, $MgO > 30\%$, $Na_2O + K_2O < 0.4\%$, and Loss on Ignition (L.O.I.) less than 6%. While the chemical composition of some of the talc-bearing rocks from the Mfyome area meets most of these requirements, the SiO_2 content is marginally lower than the specified level, and some samples have $Na_2O + K_2O$ higher than the recommended range. Therefore, the Mfyome talc-bearing rocks, in general, are not considered suitable for this specific application due to these compositional limitations.

Conclusion

The primary objective of this study was to investigate the mineralogical and geochemical composition of talc-bearing rocks from the Mfyome area in Tanzania and assess their suitability for various industrial applications. The key findings indicate that the talc-bearing rocks in the Mfyome area can be classified into five distinct groups based on their mineral assemblages: Plagioclase-talc schist, Muscovite-

talc schist, Quartz-talc schist, Carbonate-talc schist, and Chlorite-talc schist. This diverse range of mineral associations suggests that the protolith of the talc-bearing rocks is of sedimentary origin, and was formed through the hydrothermal alteration of dolomitic carbonate rocks. The geochemical data further corroborates the sedimentary provenance of the Mfyome talc-bearing rocks, as evidenced by the low concentrations of Ni, Co, and Cr. These trace elements are typically enriched in talc deposits of ultramafic origin, but their depletion in the Mfyome samples indicates a sedimentary, rather than an ultramafic, source for the talc mineralization. Based on the comprehensive characterization, the Mfyome talc-bearing rocks are found to be suitable for use in the paint, paper, and plastic industries. However, further beneficiation may be required to meet the stringent specifications for the rubber and textiles industries. Further, its composition doesn't meet the necessary criteria as a raw material for wall and floor tiles, electrical insulation ceramics, paints, cosmetics, pharmaceuticals, food, and refractory industries. This study provided crucial insights into the geology and industrial potential of the talc-bearing resources in the Mfyome area, which potentially contribute to the sustainable development of the mining and manufacturing sectors in Tanzania.

Recommendation

The industrial application of talc is not only dependent on its mineralogical and chemical properties but also on its physical properties. Therefore, a detailed study should be conducted on the physical properties of the talc-bearing rocks from the Mfyome area to complete their characterization for industrial applications. Additionally, work on beneficiation processes, such as froth flotation and other mineral separation techniques, should be done on the Mfyome talc-bearing rocks to broaden their potential industrial applications.

Furthermore, before venturing into mine development and operations, comprehensive studies should be conducted to evaluate the deposit and estimate the available resources. This will ensure a thorough understanding of the talc-bearing deposits in the Mfyome area, enabling this mineral resource's effective and sustainable exploitation to support Tanzania's industrial growth and development.

References

Aggarwal, P.K., & Nesbitt, B.E. (1984). Geology and geochemistry of the Chu Chua massive sulfide deposit, British Columbia. *Economic Geology*. 79(5):815–825. https://doi.org/10.2113/gsecongeo.79.5.815

Akintola, O.A., Aderonke, O.M., & Jonathan, J. (2019). The Characterization of Talcose Rocks by X-Ray Diffraction in Tegina Sheets 142, North Central, Nigeria. Asian Journal of Geological Research, 2(1):42-53. http://ebooks.netkumar1.in/id/eprint/1815

American Society for Testing of Materials (1988). Handbook of Construction Materials, p.45.

American Texture Manufacturer's Institute (1975). Industrial Specification for Raw Materials in the Textile Industry, p.54.

Anderson, D.L., Mogk, D.W., & Childs, J.F. (1990). Petrogenesis and timing of talc formation in the Ruby Range, southwestern Montana. *Economic Geology*, 85(3):585-600. https://doi.org/10.2113/gsecongeo.85.3.585

Andrade Jr, M.A., & Pastore, H.O. (2016). Toward a Delaminated Organotalc: The Use of Polyamidoamine Dendrons. ACS Appl. Mater. Interfaces. 8(3):1884–1892. https://doi.org/10.1021/acsami.5b09963

Ann Bazar, J., Rahimi, M., Fathinia, S., Jafari, M., Chipakwe, V., Chehreh Chelgani, S. (2021). Talc Flotation-An Overview. Minerals. 11:662. https://doi.org/10.3390/min1107066 2.

Bjerkgard, T., & Bjorlykke, A. (1996). Sulfide deposits in Folldal, southern Trondheim region Caledonides, Norway; source of metals and wall-rock alterations related to host rocks. *Economic Geology.* 91(4):676–696. https://doi.org/10.2113/gsecongeo .91.4.676

Bolarinwa, A.T. (2001). Compositional and industrial evaluation of talc bodies of the Oke-Ila area. Ilesa Schist Belt, Southwestern Nigeria. *Mineral* Wealth, 118:48–52.

Bolarinwa, A.T. & Adeleye, M.A. (2015). Petrogenesis and Functional Applications of Talcose Rocks in Wonu-Apomu and Ilesa Areas, Southwestern Nigeria. *Materials and Geoenvironment*, 62:81-93.

Boniface, N., & Tsujimori, T. (2019). Pillow lava basalts with back-arc MORB affinity from the Usagaran Belt, Tanzania: relics of Orosirian ophiolites. Journal of the Geological Society, 176:1007–1021. https://doi.org/10.1144/jgs2018-205

Boniface, N., & Tsujimori, T. (2021). "New tectonic model and division of the Ubendian-Usagaran Belt, Tanzania: A review and in-situ dating of eclogites", Plate Tectonics, Ophiolites, and Societal Significance of Geology: A Celebration of the Career of Eldridge Moores, John Wakabayashi, Yildirim Dilek, John Wakabayashi. https://doi.org/10.1130/2021.2552(08)

Brioche, A.S. (2024). Talc and pyrophyllite: U.S. Geological Survey, Mineral Commodity Summaries, January 2024, p. 174-175.

Bucher, K. (2023). Petrogenesis of metamorphic rocks, Ninth Edition, Springer Nature, Freiburg Germany. p. 467. https://doi.org/10.1007/978-3-031-12595-9

Castillo, L.A., & Barbosa, S.E. (2020). Comparative analysis of crystallization behaviour induced by different mineral fillers in polypropylene nanocomposites. *Nanomaterials and Nanotechnology.* Volume 10:1–12. https://doi.org/10.1177/184798042 0922752.

Dondi, M., Guarini, G., Conte, S., Molinari, C., Soldati, R., & Zanelli, C. (2019). Deposits, composition and technological behaviour of fluxes for ceramic tiles. *Periodico di Mineralogia*, *88*(3). https://doi.org/10.2451/2019PM86 1

Dumas, A., Martin, F., Le Roux, C., Micoud, P., Petit, S., Ferrage, E., Brendl´e, J., Grauby, O., & Greenhill-Hooper, M., (2013). Phyllosilicates synthesis: a way of accessing edge contributions in NMR and FTIR spectroscopies. Example of synthetic talc. *Phys Chem Minerals* 40:361–373. https://doi.org/10.1007/s00269-013-0577-5

El-Sharkawy, M. (2000). Talc mineralization of ultramafic affinity in the Eastern Desert of Egypt. *Mineral. Deposita* 35:346–363. https://doi.org/10.1007/s00126005 0246

Emmanuel, S.A. (2022). Physicochemical Evaluation of some Talc Mineral Deposits Collected from four States in Nigeria. *Journal of Chemical Society of Nigeria*, 47(4). https://doi.org/10.46602/jcsn.v47i4 .779

Ersoy, B., Dikmen, S., Yildiz, A., Goren, R., and Elitolk, O. (2013). Mineralogical and physicochemical properties of talc from Emirdağ, Afyonkarahisar, Turkey. *Turkish Journal of Earth Sciences*: Vol. 22(4), Article 8. https://doi.org/10.3906/yer-1112-14

Fiume, M.M., Boyer, I., Bergfeld, W.F., Belsito, D.V., Hill, R.A., Klaassen, C.D., Liebler, D.C., Shank, R.C., Slaga, T.J., Snyder, P.W., & Andersen, F.A. (2015). Safety Assessment of Talc as Used in Cosmetics. *International Journal of Toxicology*. Vol. 34, Issue 1_suppl, p. 66S-129S. https://doi.org/10.1177/1091581815586797

Hecht, L., Freiberger, R., Gilg, H.A., Grundmann, G. & Kostitsyn, Y.A. (1999). Rare earth element and isotope (C, O, Sr) characteristics of hydrothermal carbonates: genetic implications for dolomite-hosted talc mineralization at Göpfersgrün (Fichtelgebirge, Germany). Chemical Geology, 155(1-2):115-130. https://doi.org/10.1016/S0009-2541(98)00144-2.

Huston, D.L., Bolgar, C., & Cozens, G. (1993). A comparison of mineral deposits at the Gecko and White Devil deposits; implications for ore genesis in the Tennant Creek District, Northern Territory, Australia. *Economic Geology*. 88(5):1198–1225. https://doi.org/10.2113/gsecongeo.88.5.1198

Joshi, P. (2009). Petrography and geochemistry of magnesite and talc deposits of Jhiroli, Kumaun Lesser Himalaya.

Kagonbé, B.P., Tsozué, D., Nzeukou, A.N., & Ngos III, S. (2021). Mineralogical, physico-chemical and ceramic properties of clay materials from Sekandé and Gashiga (North, Cameroon) and their suitability in earthenware production. *Heliyon*. 7.

https://doi.org/10.1016/j.heliyon.2021.e07608.

Kalendova, A., Kupkova, J., Urbaskova, M., & Merinska, D. (2024). Applications of Clays in Nanocomposites and Ceramics. Minerals, 14(1):93. https://doi.org/10.3390/min14010093

Karlsen, T.A., Rian, E., & Olesen, O., (2000). Overview of talc resources and reserves in the Altermark talc province, northern Norway and possible uses of the talc ore. Norges geologiske undersøkelse Bulletin, 436:93-102. https://hdl.handle.net/11250/2674217

Kogel, J.E., Trivedi, N.C., Barker, J.M., & Krukowski, S.T. (Eds.). (2006). Industrial minerals & rocks: commodities, markets, and uses. SME.

Kumar, S.H.; Singh, K.J., & Somani, A.K. (2016). Estimation of talc properties after milling. AIP Conf. Proc. 1728:020139. https://doi.org/10.1063/1.4946190.

Leger, C., Barth, A., Knobloch, A., Mruma, A.H., Myumbilwa, Y., Magigita, M., Msechu, M., Ngole, T., Stanek, K.P., Boniface, N., Kagya, M., Manya, S., Berndt, T., Stahl, M., Gebremichael, M., Dickmayer, E., Repper, C., Falk, D., & Stephan, T. (2015) Minerogenic Map of Tanzania and Explanatory Notes for the Minerogenic Map of Tanzania 1:1.5M, Geological Survey of Tanzania

Li, C., Wang, R., Lu, X., & Zhang, M. (2013). Mineralogical characteristics of unusual black talc ores in Guangfeng County, Jiangxi Province, China. Appli. Clay Sci. 74:37–46. https://doi.org/10.1016/j.clay.2012.12.004

Linder, D. A., Wylie, A.G., & Candela, P.A., (1992). Mineralogy and origin of the State Line talc deposit,

Pennsylvania. *Economic Geology.* 87(6):1607–1615. https://doi.org/10.2113/gsecongeo.87.6.1607

McCarthy, E.F., Genco, N.A., and Reade, E.H. Jr. (2006) In Kogel, J.E., Trivedi, N.C., Barker, J.M. & Krukowski, S.T. (eds.) Industrial minerals and rocks. 7th edn. Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, 971–986.

Mitchel, L. (1975). Ceramic Raw Materials. In: Lethond, J., Ed., Industrial Minerals and Rocks, American Institute of Mining, Metallurgical and Petroleum Engineers, New York, 333.

Moine, B., Fortunea, J.P., Moreau, P., & Viguier, F. (1989). Comparative mineralogy, geochemistry, and conditions of formation of two metasomatic talc and chlorite deposits: Trimouns, (Pyrenees, France) and Rabenwald (Eastern Alps, Austria). Economic Geology 84:1398-1416. https://doi.org/10.2113/gsecongeo.84.5.1398

Mori, K., Tsujimori, T., & Boniface, N. (2018). Finding of talc–and kyanite–bearing amphibolite from the Paleoproterozoic Usagaran Belt, Tanzania. *Journal of Mineralogical and Petrological Sciences*, 113(6):316-321. https://doi.org/10.2465/jmps.180713

Mruma, A.H. (1995). Stratigraphy and palaeo-depositional environment of the Palaeo-proterozoic volcano-sedimentary Konse Group in Tanzania. *Journal of African Earth Sciences*, 21(2):281-290. https://doi.org/10.1016/0899-5362(95)00065-2

Naldrett, A.J. (1966). Tale–Carbonate Alteration of some Serpentinized Ultramafic Rocks south of Timmins, Ontario, *Journal of Petrology*, 7(3):489–

499, https://doi.org/10.1093/petrology/7.3.489

National Paint and Coating Association (1975): Industrial specification for the paint industry, New York, 25 p

Nelson, S.A. (2015). Phyllosilicates (Micas, Chlorite, Talc, & Serpentine). *Tulane University.*

Nkoumbou, C., Njopwouo, D., Villieras, F., Njoya, A., Yonta, N.C., Ngo Njock, L., Tchoua, F.M., & Yvon, J. (2006). Talc indices from Boumnyebel (Central Cameroon), physico-chemical characteristics and geochemistry. J. Afr. Earth Sci. 45(1):61–73. https://doi.org/10.1016/j.jafrearsci.2006.01.007

Nkoumbou, C., Villieras, F., Njopwouo, D., Yonta, N.C., Barres, O., Pelletier, M., Razafitianamaharavo, A., & Yvon, J. (2008). Physicochemical properties of talc ore from three deposits of Lamal Pougu´e area (Yaound´e Pan-African Belt, Cameroon), in relation to industrial uses. Appl. Clay Sci. 41(3–4):113–132. https://doi.org/10.1016/j.clay.2007.10.006

Noack, Y., Decarreau, A. & Manceau, A. (1986). Spectroscopic and oxygen isotopic evidence for low and high-temperature origin of talc. In: Bulletin de Minéralogie. 109(3):253-263. https://doi.org/10.3406/bulmi.1986.7932

Noble, P. (1988). Marketing Guide to the Paper and Pulp Industry. Fairfield, NJ, 148 p.

Okunlola, A.O., Akinola, O.O., & Olorunfemi, A.O. (2011). Petrochemical characteristics and industrial features of Talcose Rock in Ijero-Ekiti Area, Southwestern Nigeria. *Ife Journal of Science*, 13(2):317-326.

Olajide-Kayode, J.O., Okunlola, O.A., & Olatunji, A.S. (2018). Compositional Features

and Industrial Assessment of Talcose Rocks of Itagunmodi-Igun Area, Southwestern Nigeria. *Journal of Geoscience and Environment Protection*, 6(01):59. https://doi.org/10.4236/gep.2018.61005

Omidiji, B.V., Ajewole, R., & Oluwajobi, A. (2024). Refractory Coating Technology: A Review: Coating Technology. *Ife Journal of Technology*, 29(1):49-54. https://ijt.ng/index.php/ijt/article/view/235

Omotunde, V.B., Olatunji, A.S., Ehinola, O.A., Afolabi, O.A., Abdus-Salam, M.O., & Olajide-Kayode, O.J. (2020). Mineralogy and Geochemistry of Hydrothermally altered Talcose rocks from Ila Orangun-Oyan areas, part of Southwestern Nigeria. Indian Journal of Science and Technology 13(40):4244-4261. https://doi.org/10.17485/IJST/v13i40.1686

Palmer, M.R. (1985) Rare earth elements in foraminifera tests. Earth Planet. Sci. Lett., 73:287–298. https://doi.org/10.1016/0012-821X(85)90077-9

Payne, H. F. (1954): Organic coating technology. John Wiley, New York, 2, 725 p

Pereira, D., Rivas, T., López, A.J., Ramil, A., & Bloise, A. (2023). Characterization of Talcose Rocks Derived from Serpentinite—Pilot Study in the Ultramafic Complex of Cabo Ortegal (Spain) for Potential Use and Commercialization. Appl. Sci. 13:12183. https://doi.org/10.3390/app132212183

Piper, D.Z. (1974). Rare earth elements in sedimentary cycle: A summary. Chem. Geol., 14(4): 285–304. https://doi.org/10.1016/0009-2541(74)90066-7

Pi-Puig, T., Animas-Torices, D.Y., & Solé, J. (2020). Mineralogical and geochemical characterization of talc from two Mexican ore deposits (Oaxaca and Puebla) and nine talcs marketed in Mexico: Evaluation of its cosmetic uses. *Minerals*, 10(5):388. https://doi.org/10.3390/min10050388

Prochaska, W., Mogessie, A., & Raith, J.G. (1992). Formation of the talc deposit of Kibanda (Rwanda) and its relation to the regional metamorphic evolution. J. Afr. Earth Sci. 14(4), 499–509. https://doi.org/10.1016/0899-5362(92)90082-N

Qin, W.L.; Xia, T.; Ye, Y., & Zhang, P.P. (2018). Fabrication and electromagnetic performance of talc/NiTiO3 composite. R. Soc. Open Sci. 5:171083. https://doi.org/10.1098/rsos.171083.

Sandrone, R., Fenoll, P., Torres, J., & Gervilla, F. (1993). Talc deposits in the Italian Western Alps. pp. 697-700 in: Geology Applied to Ore Deposits (P. Fenoll, J. Torres and F. Gevilla, editors). Current Research, Granada.

Schandl, E.S., Gorton, M.P., & Sharara, N.A. (2002). The origin of major talc deposits in the Eastern Desert of Egypt: relict fragments of a metamorphosed carbonate horizon? J. Afr. Earth Sci. 34 (3–4):259–273. https://doi.org/10.1016/S0899-5362(02)00024-6

Schandl, E.S., Sharara, N.A., & Gorton, M.P. (1999). The origin of the Atshan talc deposit in the Hamata area, eastern desert, Egypt: A geochemical and mineralogical study. *Canadian Mineralogist*, 37(5):1211-1228.

Severinghus, N. (1975). Fillers, Filters and Absorbents. In: Lefond, J.S., 4th Ed., Industrial Minerals and Rocks, publisher, New York, p.1372.

Shin, D., & Lee, I. (2003). Carbonate-hosted talc deposits in the contact aureole of an igneous intrusion (Hwanggangri mineralized zone, South Korea): geochemistry, phase relationships, and stable isotope studies. *Ore Geology Reviews*, 22(1-2):17-39. https://doi.org/10.1016/S0169-1368(02)00085-9

Tahir, M., Imai, A., Takahashi, R., & Yano, S., (2018). Ore genesis and geochemical characteristics of carbonate-hosted talc deposits in Nangarhar province. Afghanistan. Res. Geol. 68 (4):352–372. https://doi.org/10.1111/rge.12174

Tornos, F., & Spiro, B.F. (2000). The Geology and Isotope Geochemistry of the Talc Deposits of Puebla de Lillo (Cantabrian Zone, Northern Spain). *Economic Geology*. 95(6): 1277–1296. https://doi.org/10.2113/gsecongeo.95.6.1277

URT (2019). Monitoring the consumption of Industrial Minerals in the paints, ceramic, iron and cement manufacturing industries in Dar-es-salaam and Coastal Regions.

Ministry of Minerals, Dodoma Tanzania.

Whittingham, J.K. (1959). Geological Map of QDS 216, Iringa, compiled and published by Geological Survey Division in 1962, 1st Edition

Woguia, D.L., Fagel, N., Pirard, E., & Gourfi, A. (2021). Talc schist deposits from central Cameroon: Mineralogical and physico-chemical characterization. *Journal of African Earth Science*, 178:104182. https://doi.org/10.1016/j.jafrearsci.2021.104182

Wölfler, A., Prochaska, W., & Fritz, H. (2015). Shear zone-related talc mineralizations in the Veitsch nappe of the eastern Greywacke Zone (Eastern Alps, Austria). *Austrian Journal of Earth Sciences*, 108(1):50-72. https://doi.org/10.17738/ajes.2015.0004

Yalçin, H., & Bozkaya, Ö. (2006). Mineralogy and Geochemistry of Paleocene Ultramafic- and Sedimentary-Hosted Talc Deposits in the Southern Part of the Sivas Basin, Turkey. *Clays and Clay Minerals*. 54(3):333-350. https://doi.org/10.1346/CCMN.2006.0540305