CORPUS PUBLISHERS

Journal of Mineral and Material Science (JMMS)

ISSN: 2833-3616

Volume 5 Issue 4, 2024

Article Information

Received date : August 21, 2024

Published date: November 15, 2024

*Corresponding author

Yanné Etienne, University of Maroua, National Advanced School of Engineering of Maroua, Cameroon

DOI: 10.54026/JMMS/1095

Key Words

Chemical; Mineralogical; Pegmatites; Ceramics and Glass Industries; Kaélé; Lagdo

Research Article

Chemical and Mineralogical Analysis of Pegmatites with Interesting Potential for the Ceramics and Glass Industries

Yanné Etienne[1*], Tchakouteu Mbakop Théophile[2], Souaibou[1], Baana Abouar[1], Juimo Tchamdjou Willy Hermann[1] and Djoda Pagoré Fréderic[1]

[1]*University of Maroua, National Advanced School of Engineering of Maroua, Cameroon*

[2]*University of Ngaoundéré, School of Chemical Engineering and Mineral Industries, Cameroon*

Abstract

Today, local resources are at the heart of research and experimentation into the levers of economic development. With this in mind, two pegmatite deposits, one MDM and the other PGL, from Kaélé and Lagdo respectively, were subjected to chemical and mineralogical analyses. Analyses included X-ray fluorescence spectrometry, Fourier Transform Infrared Spectroscopy (FTIR) and X-Ray Diffraction (XRD). X-ray fluorescence shows that SiO_2 (68.47 and 69.20%) and Al_2O_3 (12.44 and 14.39%) oxides are in the majority, followed by K_2O (6.82 and 6.69%) and Na_2O (4.83 and 5.84%) in both materials. The oxides Fe_2O_3 (3.05 and 1.54%) and CaO (0.85 and 1.03%) are in relatively small quantities. The FTIR and XRD spectra of MDM and PGL show quartz to be the dominant mineral, with feldspars (albite, K-feldspar, microcline and anorthite) and iron oxide fluoride associated with it. The glass industry uses large quantities of feldspars for their high alumina content and low melting point, which makes them excellent fluxes. They are also used in the manufacture of ceramics, porcelain and glazed pottery. More specifically, potassium feldspar is used in the manufacture of earthenware and sanitaryware. The results of the chemical and mineralogical compositions obtained from MDM and PGL materials show that they have the characteristics required for use as raw materials in the ceramics and glassmaking industries.

Introduction

Pegmatites are aluminosilicate rocks with large, often automorphic crystals (perfect crystals bounded by flat crystalline faces). They are related to granitoids or migmatites, so their essential minerals are those of a granite. These minerals are mostly composed of quartz, micas and feldspars [1]. The latter are highly prized for industrial applications. Feldspars are minerals composed of potassium, sodium and calcium aluminosilicates [2]. The cations can be isomorphically substituted, resulting in a large number of varieties. Feldspars are an important component of igneous rocks, and their presence in nature is therefore widespread. However, they are not found in pure form; potassium feldspar always contains sodium, and sodium feldspar generally contains calcium feldspar. In addition, feldspars contain accessory minerals, mainly quartz, mica and others. Alkali feldspars are used in fine ceramics as fluxes [3] and in ceramic bodies and slips for porcelain, sanitaryware and tiles. Their content ranges from 10 to 40% [4]. They are also used as fluxes in glazes; in the glass industry, as a source of Al_2O_3 and alkaline oxides. The properties of feldspars include their behavior around the melting point. Polymorphic transformations are less important, as alkali feldspars generally melt and glass after cooling.

Potassium feldspar melts incongruously at 990 °C. Above this temperature, it breaks down into leucine and a melt with a very high viscosity of around 107 dPa.s. The result is a slow melting of feldspar and an even slower formation of leucite [5]. Due to its high viscosity, the melt is easily subcooled, producing a softening of the glass at around 950 °C. The crystallization capacity of the melt in the temperature range of feldspar stability is so low that even very long exposures at high temperatures (of the order of several years) do not allow complete recrystallization. A pegmatite deposit has been identified in the Far North Region at Kaélé in the Tchéodé locality, called MDM, and another in the North Region at Lagdo called PGL. These materials are mainly used as aggregates for making concrete, as stones for delimiting spaces inside dwellings and as road surfacing. The aim of this work is to characterize the two materials from a chemical and mineralogical standpoint, in order to understand their compositions and extend their uses to other fields. The investigative methods used for these characterizations are: elemental chemical analysis by X-Ray Fluorescence (XRF), mineralogical analysis by powder X-Ray Diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) to determine the vibrations of chemical bonds characteristic of certain functional groups.

Materials and Methods

Materials

Kaélé materials (MDM): Material from the Kaélé deposit is located at Tchéodé, 10.3 km from Magada and 22 km from Kaélé, near Route Nationale 12. The materials are whitish in color according to Munshell Code N/9.5 and can be located at geographic coordinates X = 10.09059° and Y = 14.27418°. Figure 1 shows the location of the deposit.

Figure 1: Location map of the Tchéodé deposit (Kaélé).

Lagdo materials (PGL): The materials collected at Lagdo are located close to the D87 road leading to the Lagdo dam. They are pain red in color according to Munshell Code 10RP/7/8 and can be located at geographic coordinates X = 9.06638° and Y =13.67311°. The deposit site is shown in Figure 2.

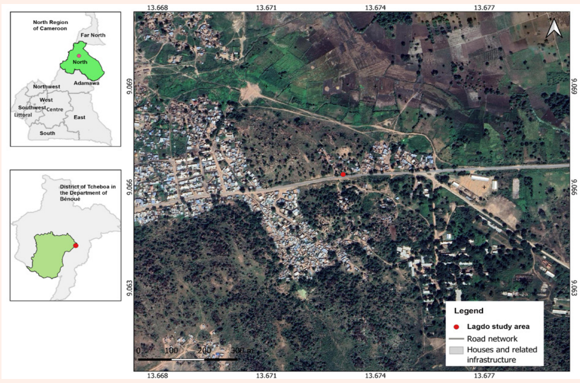

Figure 2: Location map of the Lagdo deposit.

Methods

X-ray fluorescence spectrometry: The chemical composition of the materials was determined by X-ray fluorescence spectrometry using the XRFSPW1404K spectrometer in the Quality Control laboratory of a local industrial company. The molten bead method was used. Beads were obtained by dissolving the materials in lithium tetraborate ($Li_2B_4O_7$) and homogenizing at 1150 °C.

Fourier transform infrared spectroscopy (FTIR): Fourier transform infrared spectroscopy provides a potentially rapid method of relatively non-destructive analysis that can be used to establish a database on the crystallinity and mineral constituents of rocks [6]. It was carried out on quartzite powders using a Bruker Vertex 80 V instrument operating in absorbance mode (4000 – 400 cm^{-1}).

X-ray diffraction: X-ray diffraction is obtained using a diffractometer adapted to the characterization of polycrystalline mineral materials, the Bruker D8 Advance diffractometer. The angular range scanned is between 2 and 70° in 2θ (angle of incidence). The copper Kα1 radiation (wavelength = 1.540598 Å) used was produced at a voltage of 40 kV and an intensity of 40 mA. Diffractograms were plotted using Panalytical X'Pert Highscore Plus 3.0 software. They were processed using the Powder Diffraction File (P.D.F.) of Materials Data Inc.'s MDI JADE 6.5 software, which matches the inter-lattice distances d to the 2θ angles recorded and the mineralogical phases contained in the material samples.

Results and Discussion

X-ray fluorescence spectrometry: determining the chemical composition of materials

The elemental chemical composition, expressed in mass percentages of the oxides contained in the materials, is shown in Table 1. The oxides SiO_2 (68.47 and 69.20%) and Al_2O_3 (12.44 and 14.39%) are in the majority, followed by K_2O (6.82 and 6.69%) and Na_2O (4.83 and 5.84%) in MDM and PGL materials respectively. The oxides Fe_2O_3 (3.05 and 1.54%) and CaO (0.85 and 1.03%) are in relatively small quantities. The proportions of SiO_2 and Al_2O_3 oxides are indicative of the presence of aluminosilicates in MDM and PGL natural materials [7]. The other oxides K_2O, Na_2O and CaO show that the materials studied contain feldspars of these metals. Iron oxide Fe_2O_3 revealed by X-ray fluorescence presages the presence of iron minerals in the materials studied (Figure 3).

Table 1: Chemical composition of MDM and PGL natural materials (Mass percentage relative to air-dried material, LOI = Loss on Ignition).

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2	Mn_2O_3	P_2O_5	LOI	Total
MDM	68.47	12.44	3.05	0.85	0.15	4.83	6.82	0.03	0.24	0.09	0.016	3.05	100.06
PGL	69.20	14.39	1.54	1.03	0.18	5.84	6.69	0.03	0.20	0.03	0.02	0.76	99.71

Fourier transform infrared spectroscopy (FTIR)

Figure 4 shows the Fourier Transform Infrared (FTIR) spectra of the natural materials MDM and PGL in the frequency range 4000 – 400 cm^{-1}. The spectra obtained are divided into the following bands:999, 768, 725, 648, 585, 532 and 417 cm^{-1} for MDM and 998, 763, 725, 648, 582, 533, 460 and 420 cm^{-1} for PGL. Bands between 1200 and 900 cm^{-1} can be attributed to asymmetric stretching vibration of Si-O groups (maximum at 1080 cm^{-1}), symmetric stretching at 800 and 780 cm^{-1} and symmetric stretching and asymmetric bending mode Si-O at 695, 520 and 450 cm^{-1}, respectively. Values of 999, 768, 725 and 648 cm^{-1} correspond to sodium feldspar, while 998, 767, 725 and 647 cm^{-1} to potassium feldspar. The presence of quartz is attributed to bands 999, 796, 777 and 690 cm^{-1} [8]. The presence of alumina is highlighted by bands around 580 cm^{-1} [9].

X-ray diffraction: mineralogical composition

X-ray diffraction spectra of the natural materials MDM and PGL are shown in Figures 3 & 4 respectively. The well-resolved peaks in the spectrum testify to the presence of crystallized mineralogical phases in the materials studied [10]. The minerals identified in the spectra of the MDM and PGL materials are shown in Table 2. The main mineral in MDM is quartz, to which must be added albite, microcline; iron oxide fluoride and anorthite sodian. The XRD spectrum of the PGL material shows that the most intense peak belongs to quartz. Next to it are albite, K-feldspar, microcline, anorthite, anorthite sodian and iron oxide fluoride. XRD spectra of the MDM and PGL materials show quartz to be the dominant mineral, with feldspars (albite, K-feldspar, microcline and anorthite) and iron oxide fluoride associated with it.

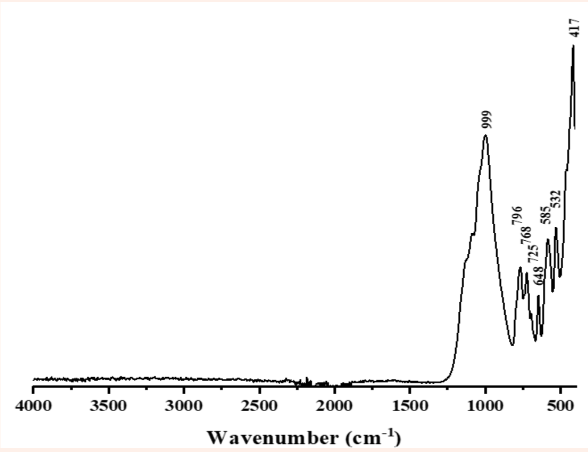

Figure 3: FTIR spectrum of MDM material.

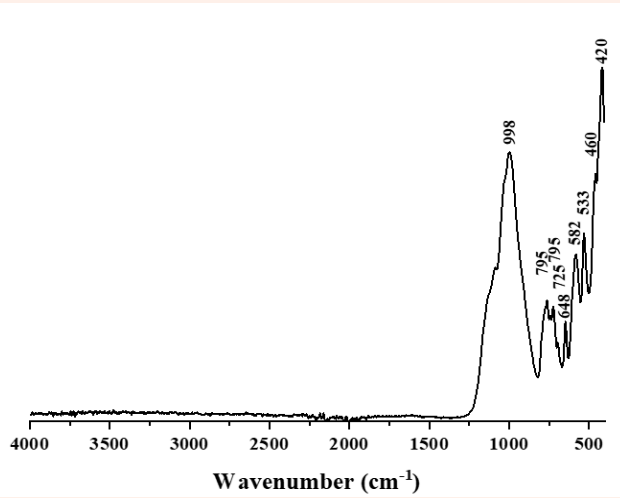

Figure 4: FTIR spectrum of PGL material.

Table 2: Minerals contained in MDM and PGL materials.

MDM Material		
Mineral	**Chemical Formula**	**PDF Number**
Quartz	SiO_2	46-1045
Albite	$NaAlSi_3O_8$	09-0466
Microcline	$KAlSi_3O_8$	19-0932
Iron Oxide Fluoride	FeOF	70-1522
Anorthite	$(Ca,Na)(Al,Si)_2Si_2O_8$	20-0528
Potassium-feldspar	$K_{0,9}4Na_{0,06}Al_{1,01}Si_{2,99}O_8$	76-0831
PGL Material		
Quartz	SiO_2	46-1045
Albite	$NaAlSi_3O_8$	09-0466
Albite calcian	$(Na,Ca)Al(Si,Al)_3O_8$	41-1480
Microcline	$KAlSi_3O_8$	19-0932
Anorthite	$CaAl_2Si_2O_8$	41-1486
Anorthite sodian	$(Ca,Na)(Al,Si)_2Si_2O_8$	20-0528
Iron Oxide Fluoride	FeOF	70-1522
Potassium-feldspar	$K_{0,94}Na_{0,06}Al_{1,01}Si_{2,99}O_8$	76-0831

Uses in ceramics and glass

The main consumers of feldspars are manufacturers of pottery, glazes and glazed bricks [11]. The most important use of these minerals is as a constituent of both the paste and the glaze of true porcelain, white tableware and glazed sanitaryware, and as a constituent of the slip (underglaze) and glaze of so-called "porcelain" sanitaryware and glazed bricks. The low percentage of iron oxides, responsible for the brown coloring of ceramics, means that MDM and PGL materials can be used naturally in white bodies without the need for magnetic purification. As feldspars have a lower melting point than other constituents, they are used as fluxes to bind clay and quartz particles together (Figures 5 & 6). Feldspars are used in ceramic bodies at a rate of 0-10% in earthenware, 5-25% in common and sanitaryware, and 20-40% in fine stoneware, vitreous and hard porcelain. Potassium feldspars are mainly used, as they melt less abruptly than sodium feldspars [12] and maintain a high viscosity over a wide temperature range, enabling the glaze to avoid flowing and to adapt to the shrinkage of the shard during cooling. In glassmaking, feldspars contribute alumina to furnace charges [13], as well as silica and soda ash, which confer fusibility [14]. The quantities of feldspars used in glassmaking vary from 2% to 20% [15].

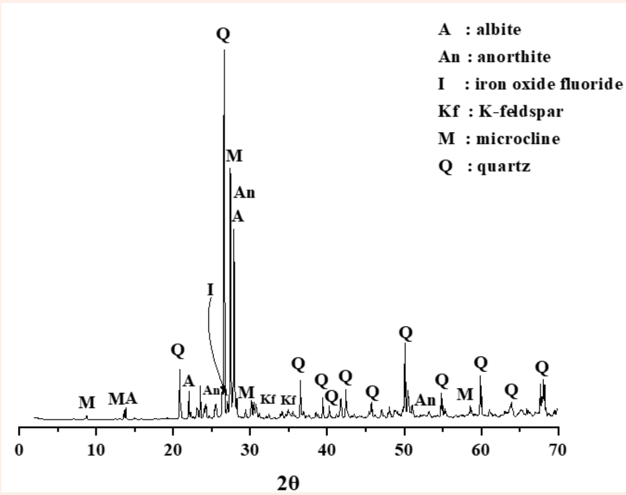

Figure 5: X-ray diffractogram of MDM material.

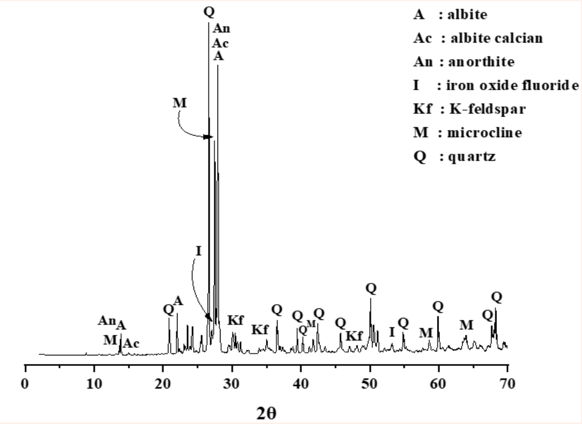

Figure 6: X-ray diffractogram of PGL material.

Conclusion

Chemical and mineralogical characterizations of pegmatites from the Kaélé and Lagdo deposits have identified quartz and potassium and sodium feldspars as the major phases. Calcium and iron minerals are poorly represented in MDM and PGL materials. Feldspars are used in the ceramics and glassmaking industries. They are sought-after for their melting properties. Potassium-bearing feldspars are preferred for glazing ceramics. Sodium and sodi-potassium feldspars are used in ceramic bodies, as their melting point is relatively low (1100 to 1200 °C). In glassmaking, feldspars are used for their ability to form a stable three-dimensional network when fused with sand and sodium carbonate. They help reduce the viscosity of molten glass, making it easier to work and transform into finished products. The pegmatites studied contain essential and versatile minerals that could play an important role in many aspects of people's daily lives. The results obtained predispose them for use as raw materials in the ceramics and glass-making industries.

References

1. Wise MA, Brown CD (2010) Mineral chemistry, petrology and geochemistry of the Sebago granite-pegmatite system, southern Maine, USA. Journal of Geosciences 55(1): 3-26.
2. Xu H, Van Deventer JS (2003) The effect of alkali metals on the formation of geopolymeric gels from alkali-feldspars. Colloids and Surfaces A: Physicochemical and Engineering Aspects 216(1-3): 27-44.
3. Njimbouombouo Mouliom S, Dodo EMA, Yannick OAE, Nangah CR, André N, et al. (2020) Potential of some granites from Foumban (West Region of Cameroon) as fluxing materials for ceramics. Journal of Minerals and Materials Characterization and Engineering 8(5): 353-363.
4. Albis AD (2011) Differences between hard and soft clay, stoneware and earthenware. Sevres. Review of the Society of Friends of the National Ceramics Museum 20(1): 21-34.
5. Demange MA (2012) Mineralogy for Petrologists: optics, chemistry and occurrences of rock-forming minerals. CRC Press, USA.
6. Parthasarathy G, Choudary BM, Sreedhar B, Kunwar AC, Srinivasan R (2003) Ferrous saponite from the Deccan Trap, India, and its application in adsorption and reduction of hexavalent chromium. American Mineralogist, 88(11-12): 1983-1988.
7. Wang R, Wang J, Dong T, Ouyang G (2020) Structural and mechanical properties of geopolymers made of aluminosilicate powder with different SiO_2/Al_2O_3 ratio: Molecular dynamics simulation and microstructural experimental study. Construction and Building Materials 240: 117935.
8. Bosch-Reig F, Gimeno-Adelantado JV, Bosch-Mossi F, Doménech-Carbó A (2017) Quantification of minerals from ATR-FTIR spectra with spectral interferences using the MRC method. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 181: 7-12.
9. Farcas F, Touzé P (2001) Fourier transform infrared spectrometry (FTIR). Bull Lab Bridges Causeways 230: 77-88.
10. Irina V, Alexey M, Ksenia V, Tyshkunova I, Mayer L, et al. (2023) A new method for determination of lignocellulose crystallinity from XRD data using NMR calibration. Carbohydrate Polymer Technologies and Applications 5: 100305.
11. Njoya D, Tadjuidje FS, Ndzana EJA, Pountouonchi A, Tessier-Doyen N, et al. (2017) Effect of flux content and heating rate on the microstructure and technological properties of Mayouom (Western-Cameroon) kaolinite clay-based ceramics. Journal of Asian Ceramic Societies 5(4): 422-426.
12. Boch P, Ni JC (Eds.) (2010) Ceramic materials: Processes, properties, and applications. 98, John Wiley & Sons, USA.
13. Aydin E (2000) Glass raw materials: cost and quality aspects. On Glass Science & Technology.
14. Moura LC, André FP, Miceli H, Neumann R, Tavares LM (2019) Manufactured feldspar-quartz sand for glass industry from gneiss quarry rock fines using dry rare-earth magnetic separation. Mineral Processing and Extractive Metallurgy Review 40(5): 333-343.
15. Odent BE (1994) Industrial rocks and minerals guide.