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CHEMICAL AND MINERALOGICAL CHARACTERIZATION AND CERAMIC SUITABILITY OF RAW FELDSPATHIC MATERIALS FROM DSCHANG (CAMEROON)

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ABSTRACT. The chemical and mineralogical characterization of raw feldspathic materials from Dschang (Cameroon) was realized by means of X-ray diffraction, differential thermal analyses, optical and scanning electron microscopies, and analytical techniques. It was found that these materials consist of albite (43 ± 3 wt.%), microcline (41 and 26 wt.%), quartz (14.5 ± 1.5 wt.%), plagioclase (oligoclase type) (6 and 12 wt.%) and a minor content of biotite. The amount of fluxing oxides is about 12 wt.% and those of pigments are quasi-null. The ceramic suitability of these materials was assessed in the light of the obtained chemical data and physical characteristics (fusibility, viscosity, colour). The results showed that these raw materials are convenient, as fluxing compounds, for manufacturing white ceramic.

KEY WORDS: Raw feldspathic materials, Mineralogy, Chemical composition, Ceramic suitability, Cameroon

INTRODUCTION

Some kinds of feldspars are commonly used as feeding materials for porcelain and vitreous manufacturing [1-5]. Upon firing, such materials result in the development of melt (glassy phase at room temperature), which plays a key role in the sintering process. Moreover, they contribute to the lowering of firing temperature and consequently to energy saving.

The technological properties (mechanical strength, water absorption, shrinkage, etc.) of porcelain and vitreous products are tightly linked to, among others, the chemical and mineralogical compositions of the used raw materials [6-8]. Regarding the ceramic use of feldspars, it may be noticed that the presence of a quantitative amount of albite – a congruent melting compound – as compared to that of microcline or oligoclase, may have an adverse effect on the uniformity of ceramic products. Thus, it is of great importance to determine the appropriate amounts of these fluxing compounds. On the other hand, in spite of their extensive use in white ceramic production, feldspars have been the subject of few reported studies relevant to their suitability [6, 7].

Cameroon has extensive kaolinite rich clay deposits [9-13], which could be used as basic materials for porcelain and vitreous elaboration. However, because of the lack of local fluxing compounds, no porcelain industry is implemented in the country. Thereby, studies concerning

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with the exploration and charaterization of local raw feldspar materials were undertaken [14, 15].

This work is devoted to the chemical and mineralogical characterization of raw feldspar materials from Dschang (Cameroon) and the evaluation of their suitability for manufacturing white ceramic products.

EXPERIMENTAL

The studied materials, labelled F1 and F2, were from the pegmatite outcrop in Dschang region (Figure 1). The geographical coordinates for F1 are 5° 27' 06'' N, 10° 03' 18'' E (altitude 1088 m). F_2 is located at about 600 m to the North of F1. Both materials crop out in a set of undifferentiated gneisses along the Dschang-Santchou road (Figure 1) as adjacent veins in metagabbro (Figure 2).

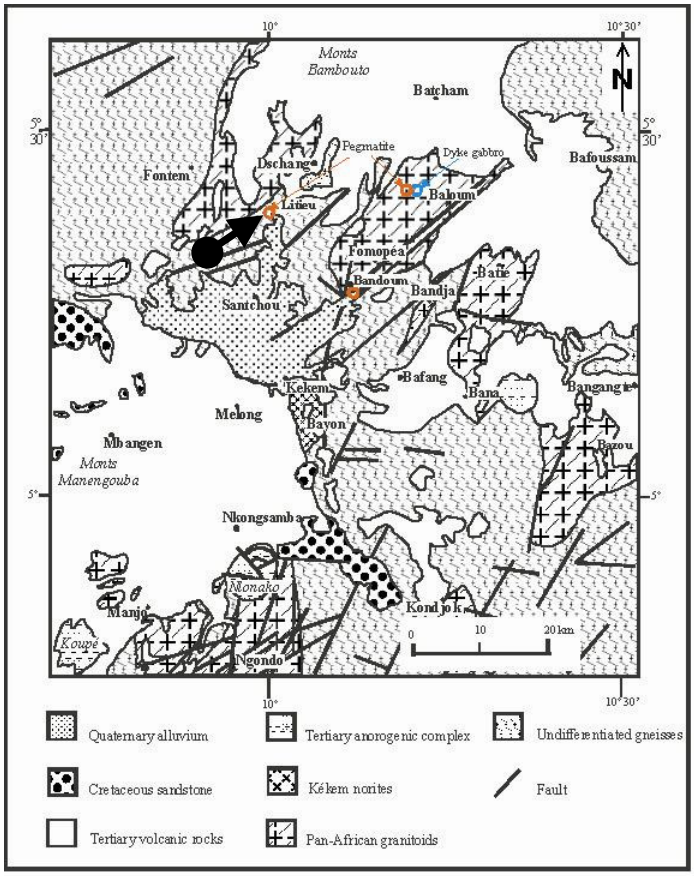

Figure 1. Geological map of Dschang region showing pegmatite outcrops at Baloum, Bandjoun and south west of Dschang city. Samples F1 and F2 were collected from the pegmatite of south west of Dschang city indicated by a dark thick arrow.

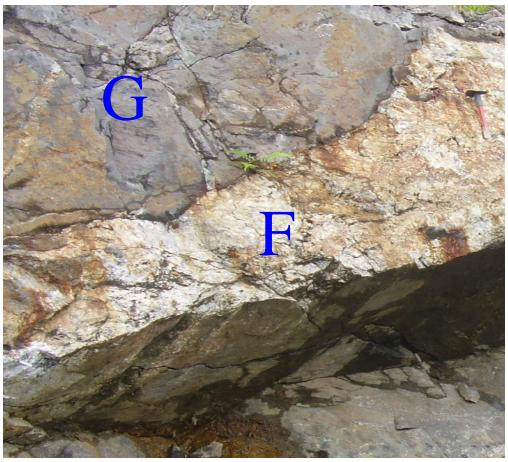

Figure 2. Location of feldspathic vein (F) in the metagabbro (G).

The as-taken materials were water cleaned, dried and ground (particle size < 90 µm), then subjected to different analyses. X-ray diffraction examinations were carried out at LEM (Nancy, France) on randomly oriented powder specimens using a D8 Advance BRUKER diffractometer operating with a cobalt anticathode ($K\alpha_1$ = 1,789 Å). Differential thermal curves were obtained by a Netzsch STA 409 apparatus (Ceramurgy Laboratory, Trento University, Italy) functioning in static air with heating rate 10 °C/min. Chemical analysis were performed at CRPG (Nancy, France) by emission spectroscopy using inductive coupled plasma and atomic emission source (ICP-AES) after fusion with lithium metaborate ($LiBO_2$) and dissolution in nitric acid (HNO_3) [16]. Thin sections were prepared from feldspar rocks and examined by optical microscopy (SARTORIUS). Rock pieces were carbon coated and investigated by a JEOL JMS 5500 scanning electron microscopy (Laboratory of Physico-Chemistry of Materials and Environment, Cadi Ayyad University, Morocco). Fusibility tests were performed on shaped cones of feldspar ground samples at the Laboratory of Physico-Chemistry of Mineral Materials, University of Yaounde I (Cameroon). For these tests, temperatures varied in the range 1050-1300 °C and the heating rate and soaking time were 5 °C/min and 2 h, respectively.

The colour change was determined using Munsell code [17]. Samples density was measured at room temperature by picnometry using water as a solvent. The viscosity (η) values were evaluated by a software [18] basing on the equation $\log\eta\,(Pa.s) = (A+B)/(T(^{o}C) - T_o)$ (A, B and T_0 are constants which depend on the material chemical composition. T is the firing temperature). Details relevant to this equation are reported in Lakatos *et al.* [18]. Values for A, B and T_o are –1.9595; 5276.11; 261.971 for F1 and –1.8436; 4994.17; 309.128 for F2. The mineralogical composition was determined on the basis of chemical analysis and the X-ray diffraction results and taking into account of the ideal formula of the identified minerals [9, 10].

RESULTS AND DISCUSSION

Chemical and mineralogical characterization

The typical X-ray diffraction patterns of the studied raw materials are shown in Figure 3 which clearly indicate that both the studied raw materials consist of quartz, albite, microcline and

oligoclase ($0.84NaAlSi_3O_8$-$0.16CaAl_2Si_2O_8$) (JCPDS 9-457). Quartz manifested as large featureless domains while feldspars exhibited a fragmented pseudo-lamellar structure (Figure 4).

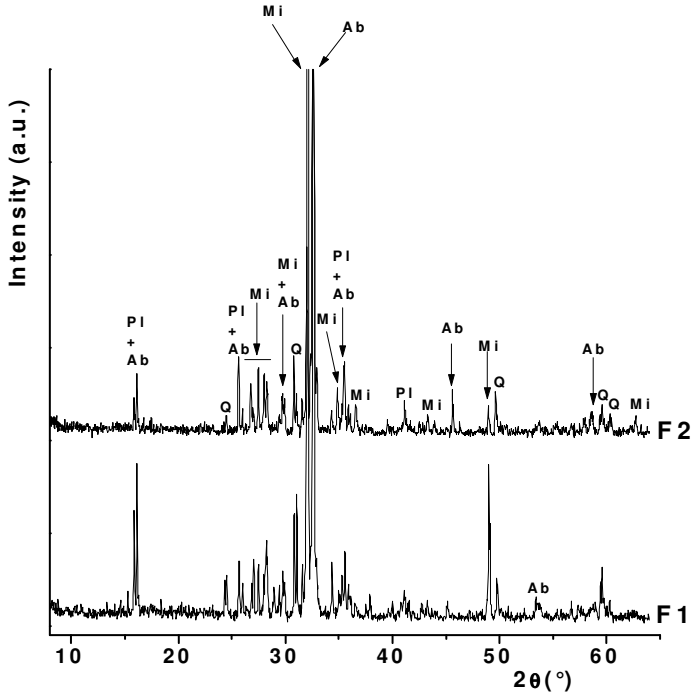

Figure 3. X-ray diffraction patterns of the studied raw materials (Ab: albite; Mi: microcline; Pl: plagioclase (oligoclase type); Q: quartz).

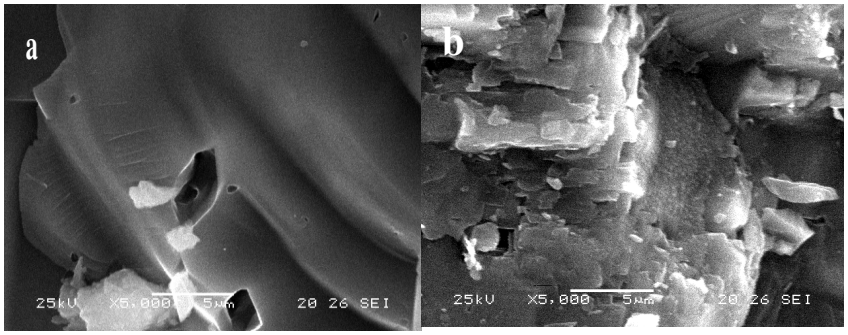

Figure 4. SEM micrographs of F1 (a: quartz coarse particle; b: pseudo-lamellar particles of feldspar).

Basing on the thermal curves of Figure 5, it seems that the mixture consisting of Na- and K-feldspars decomposed at 1270 ± 5 °C. As far as the thermal analyses are concerned, the weak endotherm manifesting nearby 1358 °C (Figure 5) is apparently linked to the oligoclase decomposition, since it only manifested for F2 sample.

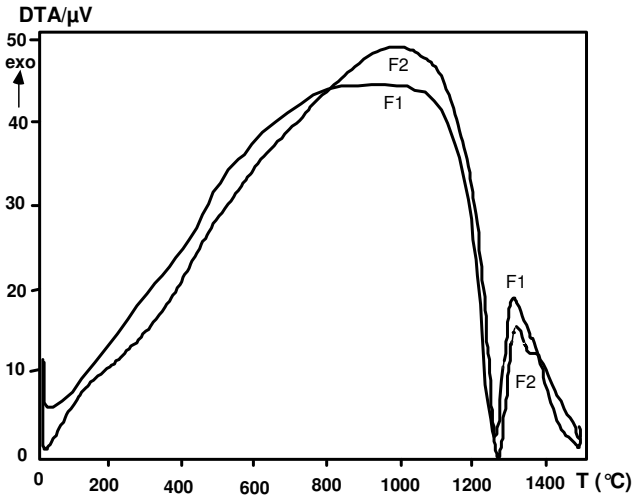

Figure 5. DTA curves of F1 and F2 samples.

The representative chemical analyses of the studied raw materials (Table 1) show that the content of alkalis oxides is about 12 wt.% and those of pigments (iron and titanium oxides) are negligible. They also show the presence of minor amounts of heavy metals and the quasi absence of volatile matters.

The amounts of the identified minerals are reported in Table 2. It shows that F1 and F2 are feldspar rich materials and they chiefly differ in the contents of microcline and oligoclase.

Table 1. Chemical compositions of the studied feldspar materials (a: mass%; b: ppm).

a	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI
F1	67.61	19.00	0.15	0.02	1.19	5.38	6.95	0.01	<dtl	0.49
F2	65.51	20.81	0.06	<dtl	2.44	6.83	4.33	<dtl	<dtl	0.22

dtl: detection threshold limit; LOI: loss on ignition.

b	As	Ba	Bi	Nb	Pb	Rb	Sr	Th	U	Y	Zr
F1	<dtl	267.9	0.334	1.008	49.936	189.6	112.9	0.328	1.618	0.544	<dtl
F2	<dtl	279.3	<dtl	0.08	41.01	94.86	270	0.081	0.349	<dtl	<dtl

Table 2. Mineralogical compositions (wt.%) of the studied materials.

Sampling zone	Albite	Microcline	Plagioclase (oligoclase type)	Quartz
F1	40	41	6	13
F2	46	26	12	16

Optical microscopic examinations show that both samples comprise scarce particles of biotite, locating especially in microcline rich zones (Figure 6). The content of this mineral is under the detection threshold of X-ray diffraction.

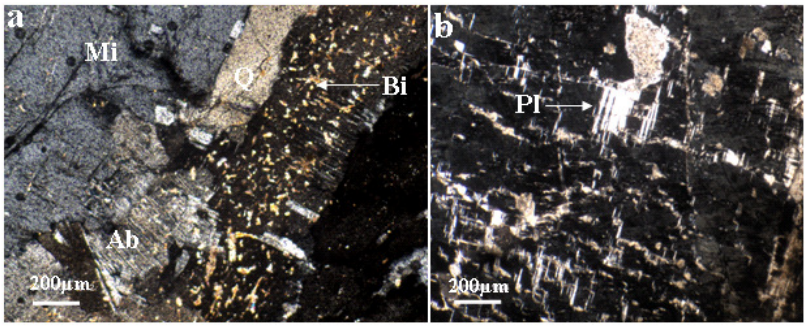

Figure 6. Optical microscope micrographs of the studied samples (a: F1; b: F2) Ab: albite; Bi: biotite; Mi: microcline; Pl: plagioclase (oligoclase type); Q: quartz.

Ceramic suitability

The results of thermal behaviour of the studied materials are summarized in Table 3 and Figure 7 describes the state of the cones.

Table 3. Thermal behaviour of the studied materials.

Sample	T (°C)	25	1050	1100	1150	1200	1250	1300
F1	Munsell color	10 YR8/1	5YR8/2	10 YR8/1	5YR8/1	5YR8/1	5YR8/1	5YR8/1
	Visual color	White	White pinkish	White	White	White	White	White
	Material cone texture	Cone of fine particles adhering to the touch	Identical to 25 °C	Granular particle cone, weakly compact, not adhering to the touch	- Cone of vitrified, translucent, reflecting particles. - Adherence of the cone on the support	-Cone of vitrified, translucent, reflecting particles. -Display beginning and adherence of the cone on the support	-Cone of vitrified, translucent, reflecting particles. -Display and adherence of the cone on the support.	Identical to 1250 °C
F2	Munsell color	10 YR8/1	5YR8/1	10 YR8/1	5YR8/1	5YR8/1	5YR8/1	5YR8/1
	Visual color	White	White	White	White	White	White	White
	Material cone texture	Identical to F1	Identical to F1	Identical to F1	Cone of compact particles, weakly vitrified	-Cone of vitrified, translucent, reflecting particles. - Adherence of the cone on the support	Identical to F1	Identical to F1

Basing on the fusibility tests (Figure 7), samples melting are well perceptible at 1250 °C. For higher temperature, an extensive fusion is manifested for the sodium oxide rich material (F2).

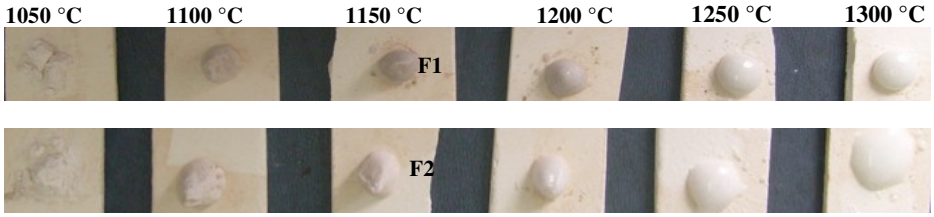

Figure 7. Effect of heating on the morphology of shaped cones of feldspar ground F1 and F2 samples.

The change of viscosity with firing temperature (Figure 8) shows that under the same firing conditions, F2 samples are more viscous. This fact is apparently linked to the higher ratio $Na_2O/(Na_2O + K_2O)$ (70 mol%) and CaO content. Still, F1 and F2 viscosities are close to those determined for different glassy phases [20].

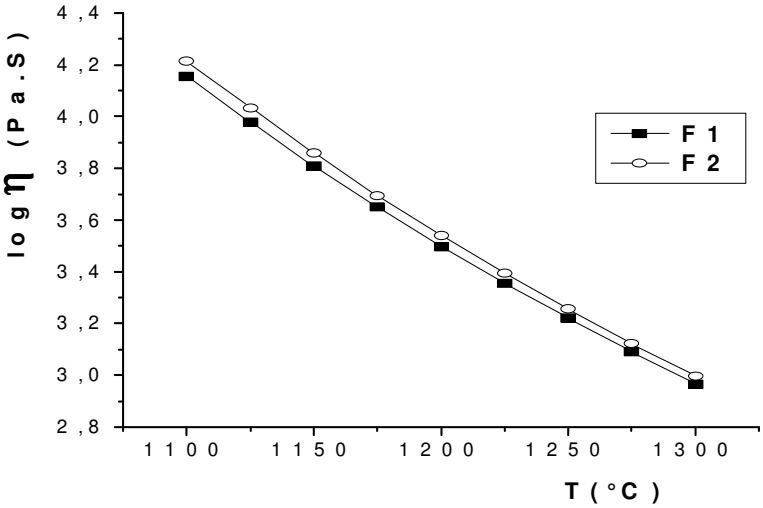

Figure 8. Variation of the viscosity of F1 and F2 samples as a function of temperature.

The measured density of the studied materials is 2.58 ± 0.03. This is comparable to those relevant to commercial feldspars [21].

On the other hand, the naked eye control of the hue change of fired samples showed that the white colour of F1 and F2 samples is almost insensitive to the tested firing temperatures. Apparently the presence of biotite did not alter the hue of the fired materials.

CONCLUSIONS

The studied raw feldspathic materials from Dschang are feldspar (albite, microcline, oligoclase) rich materials (85 ± 1) wt.%. Their alkalis oxides contents exceed 9 wt.% and that of uranium is less than 4 ppm. Moreover, their melt viscosity lies in the range 10^3 - 1.6 x 10^5 Pa.s and their white colour is not altered by firing. In view of these data and basing on the required properties

for white ceramic fluxing compounds [6, 22], these materials are convenient for manufacturing porcelain or vitreous products.

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