CHEMICAL ANALYSIS OF CLAY RESOURCES OF ILIGAN CITY AND LANAO DEL NORTE*

Zenaida Legaspi Ochotorena, Ph.D.

Introduction

In a clay sampling survey conducted in Iligan City and Lanao del Norte by the Indigenous Crafts and Technology Research Center of the Coordinating Center for Research and Development (CCRD), MSU-Iligan Institute of Technology, fourteen barangays in Iligan City and twelve municipalities in Lanao del Norte were found to have substantial deposits of clay materials. Physical tests conducted by the team (Molina and Silayro, 1982) showed that the materials have properties compatible with its use as ceramic raw materials.

The ceramic industry in the country, particularly pot-making, has not changed much through the centuries, unlike that of Japan, China and Korea. Local users of ceramic materials still resort to importation of ready-mixed raw materials although commercial deposits of high-grade clay have been known to be available throughout the country.

With the tight dollar situation, local raw materials must instead be utilized. However, a closer look into the industry reveals a very anemic information bank of local clay resources. Incentives to utilize the local resources are absent.

The main objective of this study was to gather information on the chemical components and composition of the clay available in the area to complement the work of the Indigenous Crafts and Technology Center on its possible utilization.

Although the study lacks documentation obtainable only from modern instrumental analysis (Scanning Electron Microscopy, X-Ray Diffraction Analysis, Thermogravimetric Differential Thermal Analysis) due to unavailable instruments to undertake a complete chemical and mineralogical investigation, this preliminary work can serve as a catalyst and a starting point for more studies especially on beneficiation, preparation of desired ceramic mixtures, and other attempts at

* Research project funded by CCRD, MSU-Iligan Institute of Technology, Iligan City, 1984.

modifying, correcting and preparing desired ceramic raw materials. It can also assist local ceramic users and prospectors to venture into finding new commercial uses for the resource.

Related Studies

Clay is a mixture of clay material and impurities such as feldspar, mica, calcia, magnesia, ferric compounds, titanium oxide, quartz sand, and organic matter. The impurities and the clay minerals that make up the clay materials influence the properties. Thus, by knowing the chemical, mineralogical, and grain composition of the raw materials, one can roughly assess its properties, hence, its use.

According to Budnikov (1964), clays are fine-grain mixtures of several minerals which form a plastic mass with water and which upon drying retain any shape imparted to it and acquire the strength of stone when it had been fired. Its formation which is a result of the constant changes in the composition of the argillaceous materials of the rocks influenced by environmental factors such as pH, moisture, minerals, etc., give rise to different types of clay minerals (halloysite, kaolinite, montmorillonite, etc.). The clay mineral consists of the argillaceous matter which are the hydrous aluminum silicates, the metal impurities (K, Na, Mg, Ca, Fe, etc.) which may be part of the mineral crystal lattice, and the organic impurities which may consist of humus compounds, bitumens, etc. The chemical and grain compositions of clays vary within limits. The different nature of the Argillaceous constituents and impurities causes considerable variations in the chemical and grain compositions making it difficult to establish with certainty the properties of the raw materials except through certain tendencies. For example, low-melting clay characteristically have high contents of SiO_2 and fluxing agents ($M_2^* Q$, M^*O, and Fe_2O_3) and low contents of Al_2O_3 than high-melting or refractory clays. A low Al_2O_3 with a high SiO_2 content is an indication of a large amount of free silica, which is basically present in the coarser fractions in the form of quartz sand. A large amount of fluxing agents particularly M_2^*O when the Al_2O_3 content is small indicates low refractoriness of the clay. In turn an increased amount of Al_2O_3 in the clay indicates a greater degree of dispersion and consequently greater plasticity and cohesion. A smaller content of fluxing agents in the clay raises its refractoriness and its sintering temperature. However, the presence of a large amount of alkali-metal oxides (chiefly K_2O along with a large amount of Al_2O_3 and small amount of other fluxing agents may result in high refractoriness and the ability to sinter at lower temperatures making possible the manufacture of a wide variety of porous and sintered parts.

Kitagaki (1980) stated that porcelain and other ceramic products are not made only from clay materials but it has to be added with flux. The kind and amount of flux and other additives cause changes in firing shrinkage and vitrification and other properties, i.e. sodium feldspar lowers melting point; potassium feldspar increases melting point; calcic materials increase porosity at drying and at high temperature cause the vitrification point of clay to decrease; magnesia whose melting point is higher than calcic (2000°C) are used to make cordierite, a heat-resisting body; and ferric compounds influence the color of clay and lowers the vitrification point of clay.

Inaseito Co., Ltd. also presented the importance of alumina, silica and lime as ingredients of the tile body. If Al_2O_3 or SiO_2 content in ceramic body increases, the following characteristics become eminent proportionately:

a) Al_2O_3

- o thermal expansion decreases
- o mechanical strength increases
- o softening temperature rises up
- o abrasive resistance becomes strong
- o chemical property becomes stable

b) SiO_2

- o polymorphic transformation with volume change occurs
- o firing shrinkage decreases and thermal expansion increases
- o coking property and white tint increase

c) CaO

- o lime in ceramic body forms anothite by reaction with clay and causes thermal expansion to increase.

Budnikov (1964) had reported on the chemical composition of the different types of clay as given below:

Types of clay	Compounds %							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Loss on ignition
Refractory	46–62	25–39	0.4–2.1 or more	0.2–0.8	0.2–1	Traces –0.5	0.3–3	8–18
High-melting	53–73	16–29	1–9	0.5–2	0.3–2.6	Traces –0.6	0.7–3.2	4–12
Low-melting	55–80	7–21	3–12	0.5–15 or more	0.5–3	Traces	1–5	3–13 or more

Also he had given the composition of raw materials for different uses such as the clay used to make stone tiles and majolica are as follows:

SiO_2	—	41.0 — 59.1%
Al_2O_3	—	9.9 — 29.7%
$Fe_2O_3 + TiO_2$	—	2.5 — 5.1%
CaO	—	1.4 — 37.8%
MgO	—	0.25 — 2.1%
M_2O	—	0.89 — 4%
H_2O	—	0.02 — 8.15%

In the Philippines the Ceramic Research and Development Center (CRDC) of the Material Science Research Institute, has started work on the evaluation of Philippine ceramic raw material. Recently, Torilla, et.al. (1984) had given data on the chemical analysis, mineralogical analysis, physical properties and particle size of clay materials obtained from different places in the Philippines although not a sample from Iligan City and Lanao del Norte was included. He reported on the chemical analyses of some clays, for example Talacag and Iloilo white, which the researcher had used as model clays.

Experimental Method

1. Sampling/Clay Samples

Samples used in the study were donated by the Indigenous. Crafts and Technology Research Center Team, CCRD-MSU-Iligan Institute of Technology, which conducted a sampling survey of clay resources in Iligan City and Lanao del Norte.

Clay samples were obtained from diggings of 0.5 — 2 meters deep. From each sampling area 3 or more holes were dug and from each hole 3 to 5 kilograms of clay samples were taken. The clay samples were sun-dried from one to two days, crushed/ground and passed through a 100-mesh sieve (Molina and Silayro, 1982).

The clay sample was coded with the name of the municipality/barangay from where it was obtained and a letter indicating a certain location.

Each available clay sample was analyzed separately from other samples obtrained from the same locality, hence some localities had more than one sample.

2. *Qualitative Analysis*

Cation analysis of each sample was performed following the procedure of Hogness, et al. (1966).

To avoid interference from organic matter, the test solution was prepared following the procedure of Gilreath (1954).

3. *Quantitative Analysis*

A combination of various methods — gravimetric calometric, EDTA titration — were used following the Rapid Method procedure of Bennett (1971).

4. *Reagents Used*

All chemicals used were of the Analytical Grade (AR) and were no longer subjected to further purification.

5. *Instrument*

Absorbance measurements were taken with a Pye Unicam Sp 450 UV-VIS Spectrophotometer.

Results and Discussion

Physical Attributes of Clay Samples

A. Iligan City.

Clay samples from Bunawan, Dulag, K-Malinao, Palao, Hanggas, Pugaan, Rogongon, Suarez, Tipanoy, and Upper Tominobo had fine textures whereas those from Bulalang and Sta. Filomena were coarse. The fine textured samples from Palao, Manggas, Tipanoy, and Suarez were smooth and/or slimy when rubbed between fingers while those from Bunawan, K-Malinao, Upper Timonobo and Rogongon were rough.

Samples obtained from the barangays of Iligan City were brownish except for Bunawan and K-Malinao which had a yellowish tint.

When the samples were heated to 1000°C the K-Malinao, Manggas and Rogongon samples turned reddish brown; the Sta. Filomena, Suarez, and Upper Tominobo samples turned dark reddish brown; those from Bulalang turned dark brown; those from Bunawan brown, Dulag red; Tipanoy light red; and Pugaan and Palao dark brown with a reddish tint.

The clay samples from Lanao del Norte coded as indicated in parenthesis were of varied textures. The Bacolod, Kauswagan (A), Salvador (NNa), Lala, and Tubod (C) samples were fine and smooth to feel; those from Baroy (B), Karomatan (B) and Tubod (B) were fine but felt rough while all the other samples were coarse.

Table 1. Physical Characteristics of Clay Samples

Sample	Texture	Color (unfired)	Color (fired at 1000°C)
A. Iligan City			
1. Bulalang	coarse, rough	brown	dark-brown
2. Bunawan	fine, rough	yellowish-brown	brown
3. K-Malinao	fine, rough	yellowish-brown	reddish brown
4. Sta. Filomena	coarse, sandy, rough	brown	dark reddish-brown
5. Dulag	fine, rough	brown	red
6. Pugaan	coarse, sandy, rough	brown	brownish-red
7. Palao	very fine, smooth	brown	brownish-red
8. Manggas	very fine, slimy	dark brown	reddish-brown
9. Tipanoy	very fine smooth	brown	light red
10. Suarez	very fine slimy	brown	dark reddish-brown
11. Upper Tominobo	fine, rough	brown	dark reddish-brown
12. Rogongon	fine, rough	reddish-brown	reddish-brown
B. Lanao del Norte			
1. Bacolod	fine, smooth	brown	reddish-brown
2. Baroy (A)	coarse	grayish-yellow	reddish-brown
3. Baroy (B)	fine, rough	yellowish-brown	light orange
4. Kapatagan	coarse, light in weight	creamy-white	yellowish-light orange
5. Karomatan (A)	coarse	brownish-yellow	brownish-orange
6. Karomatan (B)	fine, rough	white	yellowish-light brown
7. Karomatan (C)	coarse	yellowish-brown	brownish-orange
8. Karomatan (D)	coarse	yellowish-gray	brown
9. Karomatan (E)	coarse	gray	light-brown
10. Karomatan (F)	coarse	yellowish-brown	brownish-orange

11. Karomatan (G)	coarse	grayish-white	yellowish-brown
12. Kauswagan (A)	fine, smooth	yellowish-brown	reddish-brown
13. Kauswagan (B)	coarse	orange-brown	reddish-brown
14. Kolambogan	coarse	reddish-brown	dark red
15. Lala	fine, smooth	dull yellow	yellow-light brown
16. Sapad (A)	coarse	yellowish-gray	brown
17. Sapad (B)	coarse	yellowish-gray	brown
18. Sapad (C)	coarse	yellowish-gray	dark brown
19. Salvador	fine, smooth	grayish-white	yellow-light brown
20. Tubod (A)	coarse	creamy-white	yellow-light brown
21. Tubod (B)	fine, rough	creamy-white	yellow-light brown
22. Tubod (C)	fine, smooth	yellowish-white	light brown

C. Model Clay Samples

1. Talacag	fine, smooth	creamy-white	yellowish-white
2. Iloilo White	fine, smooth	creamy-white	yellowish-gray
3. Camarines	fine, smooth	creamy-white	yellow-light brown
4. Iloilo Gray	fine, smooth	gray	light yellowish-gray
5. Iloilo Black	fine, smooth	black	pinkish gray

Table 2. Physical Properties of Clay in its Unfired State.

Sample	Workability	Per Cent H_2O of Plasticity	Per Cent Linear Shrinkage
A. Iligan City			
1. Abuno	very good	29.24	15.47
2. Bulalang	good	24.04	21.50
3. Bunawan	good	26.69	14.73
4. Dulag	very good	24.42	10.46
5. K-Malinao	good	24.56	13.11
6. Kiwalan	sufficient	21.70	14.00
7. Manggas	good	26.94	13.26
8. Palao	very good	24.42	11.57
9. Pugaan	good	55.33	11.55
10. Rogongon	sufficient	28.09	13.37
11. St. Elena	good	24.28	12.90
12. Suarez	good	25.54	11.42
13. Tipanoy	good	28.52	12.70
14. Tuburan	good	27.05	11.14
15. Upper Tominobo	good	23.79	13.25
B. Lanao del Norte			
1. Bacolod	sufficient	27.14	7.91
2. Baroy	good	24.85	9.25
3. Kapatagan	good	20.40	9.78
4. Karomatan	sufficient	21.39	10.66
5. Kolambogan	sufficient	30.76	9.36
6. Lala	good	28.98	11.40
7. Magsaysay	sufficient	26.70	6.16
8. Salvador	sufficient	25.37	8.26
9. Sapad	very good	29.39	12.58
10. Tagoloan	good	20.82	11.73
11. Tubod	good	20.63	8.15

*Molina, Marife and Angela Silayro, "Survey of Clay Resources in Iligan City and Lanao del Norte." 1982.

Table 3. Physical Properties of Clay Samples Fired at 800°C and 1000°C*

Clay Samples	Fired at 800°C				Fired at 1000°C			
	Colors	% Linear Shrinkage	% Absorption	% Porosity	Color	% Linear Shrinkage	% Absorption	% Porosity
A. Iligan City								
Abuno	brown	3.60	cracked	cracked	brown	cracked	cracked	cracked
Bulalang	dark brown	4.50	cracked	cracked	dark brown	cracked	cracked	cracked
Bunawan	brown	3.80	cracked	cracked	brown	cracked	creacked	cracked
Dulag	red	2.09	22.20	72.20	red	5.17	15.82	29.40
K-Malinao	reddish brown	3.07	19.90	77.24	reddish brown	9.64	10.80	22.29
Kiwalan	dark reddish brown	cracked	cracked	cracked	dark reddish brown		cracked	cracked
Manggas	reddish brown	cracked	cracked	cracked	reddish brown	cracked	cracked	cracked
Palao	brownish red	3.25	16.75	59.06	brownish red	3.97	15.11	27.74
Pugaan	brownish red	1.50	19.55	62.46				
Rogongon	brownish red	3.48	18.50	70.51	brownish red	6.84	15.56	29.24
Sta. Elena	dark reddish brown	3.95	5.78	27.29	dark reddish brown	cracked	cracked	cracked
Sta. Filomena	dark reddish brown	3.43	15.11	66.18	dark reddish brown	5.98	cracked	cracked
Suarez	dark reddish brown	3.80	9.80	43.75	dark reddish brown	cracked	cracked	cracked
Tipanoy	light red	3.12	14.41	55.53	light red	7.27	12.12	23.37

*Molina and Silayro (1982)

Table 3. Physical Propertees of Clay Samples Fired at 800°C and 1000°C* (cont.)

Clay Samples	Fired at 800°C				Fired at 1000°C			
	Colors	% Linear Shrinkage	% Absorption	% Porosity	Color	% Linear Shrinkage	% Absorption	% Porosity
Tuburan	light brown	2.40	14.48	58.59	light brown	4.15	16.16	27.23
Upper Tominobo	dark reddish brown	3.35	17.10	62.85	dark reddish brown	cracked	cracked	cracked
B. Lanao Norte								
Bacolod	red	4.80	12.46	39.23	red	11.16	22.15	39.47
Baroy	red	1.80	20.68	33.79	red	cracked	19.90	38.83
Kapatagan	dark reddish brown	2.80	19.56	30.34	brown	5.06	16.65	29.67
Karomatan	brown	1.90	17.45	30.24	red	7.28	13.20	24.92
Kauswagan	light brown	cracked	15.76	26.34	light brown	6.28	14.14	27.61
Kolambogan	red	3.57	32.90	49.26	red	cracked	32.13	48.88
Lala	light brown	2.30	11.63	22.14	light brown	7.21	9.89	19.74
Magsaysay	red	cracked	35.07	49.26	red	12.49	31.50	48.78
Salvador	red	cracked	24.79	39.18	red	4.79	24.50	48.10
Sapad	reddish brown	cracked	10.88	22.57	brownish	cracked	7.54	17.24
Tagoloan	reddish brown	1.45	11.48	22.95	red	2.13	12.43	24.37
Tubod	light brown	cracked	20.56	34.13	light brown	6.15	17.87	30.87

*[illegible]

The physical attribute of color is indicative of some of its components and particle size. The impurities of iron compound usually found as pyrite (iron hydrosulfide), iron oxides and iron carbonates when finally dispersed, could give the clay a color ranging from yellow to rust-brown and, after firing, from pink to red.

Organic impurities in clay which may be discrete particles of wood, leaf matter, spores, etc. adsorbed on the surface of the clay mineral particles or intercalated between silicate layers could give a gray or dark gray color which burns out during firing.

The fineness and smoothness of a clay sample may be due to some impurities in the clay such as mica which are commonly found in clay samples although not usually in large quantities. This may also be due to fine-size clay particles.

Qualitative Analysis for Metal Ions

Results of the qualitative analysis for metal ions given in Table 4 shows that clay samples of Lanao del Norte contain more metals than the Iligan City samples.

Table 4. Metal Content of Clay Samples.

Sample	K	Na	Ca	Mg	Sr	Ba	Fe	Al	Zn	As	Sn	Sb	Mn	Ti
A. Iligan City														
1. Bulalang	—	+	+	+			+	+						+
2. Bunawan	—	+	+	+			+	+						—
3. K-Malinao	+	+	+	+			+	+						+
4. Sta. Filomena	+	+	—	+			+	—						—
5. Dulag	—	+	+	+			+	—						—
6. Pugaan	—	+	—	+			+	—						—
7. Palao	—	+	—	+			+	—						—
8. Manggas	+	+	+	+			+	+						+
9. Tipanoy	—	+	+	+			+	+						—
10. Upper Tominobo	+	+	+	+			+	+						—
11. Suarez	—	+	+	+			+	+						—
12. Rogongon	+	+	—	+			+	+						+
B. Lanao del Norte														
1. Bacolod	+	—	—	—	—	—	+	+	+	+	+	—	—	+
2. Baroy(A)	—	+	+	+	—	—	+	+	+	—	—	+	—	+

*Molina and Silvero (1982)

Sample	K	Na	Ca	Mg	Sr	Ba	Fe	A1	Zn	As	Sn	Sb	Mn	Ti
3. Baroy(B)	—	+	+	+	—	—	+	+	+	—	+	—	—	+
4. Kapatagan	—	+	+	+	—	—	+	+	—	—	—	+	—	+
5. Karomatan(A)	+	+	+	+	+	—	+	+	—	—	—	—	+	+
6. Karomatan(B)	+	+	+	—	—	—	+	+	+	—	—	—	+	—
7. Karomatan(C)	+	+	+	—	—	—	+	+	+	—	—	—	—	—
8. Karomatan(D)	—	+	+	—	—	—	+	+	+	—	—	—	—	+
9. Karomatan(E)	+	+	+	—	—	—	+	+	+	—	—	—	+	+
10. Karomatan(F)	+	+	+	—	—	—	+	+	+	—	—	—	—	+
11. Karomatan(G)	—	+	+	+	—	—	+	+	—	—	—	—	+	—
12. Kauswagan(A)	—	+	+	—	—	—	+	+	+	—	—	—	—	+
13. Kauswagan(B)	—	+	—	—	—	—	+	+	+	—	—	—	—	+
14. Kolambogan	—	—	—	—	—	—	+	+	+	+	—	—	—	+
15. Lala	—	+	+	+	—	—	+	+	+	—	+	—	—	—
16. Sapad(A)	+	+	+	—	—	—	+	+	+	—	—	—	—	+
17. Sapad(B)	+	+	+	+	+	+	+	+	+	—	—	—	—	+
18. Sapad(C)	—	+	+	+	—	—	+	+	+	—	—	—	—	+
19. Salvador	—	+	+	+	—	—	+	+	+	—	—	—	+	+
20. Tubod(A)	—	+	+	—	—	—	+	+	+	—	—	—	—	+
21. Tubod(B)	+	+	+	—	—	—	+	+	—	—	—	—	+	—
22. Tubod(C)	—	+	—	—	—	—	+	+	+	+	+	—	—	+
C. Model Clay Sample														
1. Talacag	—	+	+	—	—	—	+	+	—	—	—	—	—	—
2. Iloilo White	—	+	+	—	—	—	+	+	—	—	—	—	—	—
4. Camarines	—	+	+	+	—	—	+	+	—	—	—	—	—	—

Legend: + present
— absent

While only K, Na, Ca, Mg, Fe, A1, and Ti were found in the Iligan City samples, Zn, Sn, As, Sb, Mn, Sr, Ba, were additional metals found in the Lanao del Norte samples.

All the samples tested showed that there is no presence of Lead, Mercury, Silver, Bismuth, Copper, Cadmium, Cobalt, Nickel or Chromium.

Of the Ilig-n City samples tested for Titanium only those from Manggas, Rogongon, Bulalang and K-Malinao showed presence of Titanium. However, iron was present in all samples from both Iligan City and Lanao del Norte. The presence of iron was not only shown by the qualitative test but also indicated by the brown and reddish-brown color especially after firing as shown in Table 1.

As regards the Lanao del Norte samples, aside from Iron and Aluminum, Zinc was also present in all the samples except those from Kapatagan, Karomatan (A, G) Tubod (B); Sodium in all samples except those from Bacolod and Kolambogan; Barium in the Sapad sample only; Strontium in the Karomatan(A) and Sapad(B) samples; and Potassium in the Bacolod, Karomatan(A,B,C,E,F,), Sapad (A,B), and Tubod(B) samples. The other metals which are not so common were also found, such as: Arsenic in the Bacolod, Kolambogan, and Tubod(C) samples; Tin in the Bacolod, Baroy(B), Lala, and Tubod(C) samples; Antimony in the Baroy(A) and Kapatagan samples; and Manganese in the Karomatan (A,B,E,G), Salvador, and Tibud(B) samples. Traces of Titanium were found in all the samples except those of Karomatan(B,G), Lala, and Tubod(B).

The results of the qualitative analysis showed that the Iligan City samples of Bunawan, Dulag, Palao and Suarez resembled the Camarines clay samples. Likewise, samples from Tipanoy and Upper Tominobo also resembled Camarines clay except for the presence of Potassium, Bulalang except for the presence of Titanium, K-Malinao and Manggas except for the presence of Potassium and Titanium; and Rogongon, Pugaan, and Sta. Filomena except for the absence of Calcium.

Not one of the samples of Lanao del Norte resembled the model clay studied. Tubod(A), Karomatan(D), Kauswagan(A), which closely resembled Talacag clay did not contain Antimony and Manganese.

The presence of metals in the mineral crystal lattice and impurities of the alumina and silica of the clay minerals modify the characteristics of clay. For instance, the presence of soluble salts, especially large quantities of Sodium and Potassium salts, makes clay spongy and reduce sharply the refractoriness and sintering point of clays.

Loss on Ignition

The loss in weight upon heating to about 100^{o} to $150^{o}C$ is indicative of the clay-water system and is a measure of the water extracted. This water loss may be the water in the pores, on the surfaces, and around the edges of the discrete particle of the minerals composing the clay materials and in the interlayer between the unit-cell layers in the case of Vermiculite, Smectite, and the hydrated forms of halloysite which cause the swelling of smectite or the water that occurs within the tubular opening between the elongated structural units in the case of the sepiolite-attapulgite-polygorskite minerals. The nature of this low temperature water and the factors that control its release largely determine the plastic, bonding, compaction, suspension and other properties of clay which in turn frequently control their commercial utilization. In Table 2, this loss in weight is given as the percent water of plasticity. The clay samples with high percentage H_2O of plasticity like those of Abuno, Rogongon, Tipanoy, Tuburan, Kolambogan, Sapad, Bacolod, and Magsaysay are the most plastic clays whereas those with low percentages H_2O of plasticity, like those of Kiwalan, Kapatagan, Lala, Tagoloan and Tubod are the least plastic.

The loss on ignition represents mostly the organic materials present in the clay which could be discrete particles of wood, leaf matter, spores, etc. and organic molecules adsorbed on the surface of the clay mineral particle or intercalated between silicate layers. They could give a clay sample a gray or dark-gray color which burns during firing. They could also cause a rapid rise in temperature in low-melting clay and cause the clay to bloat.

Results given in Table 5 show that the loss on ignition ranges from 8.6% to 21.2% for Iligan City clay samples and from 3.6% to 14.7% for the Lanao del Norte samples. The samples grouped according to their percent loss on ignition (taken as a measure of its content of organic impurities) are as follows:

A. 18.1% – 22% range
   Palao

B. 14.1% – 18%
   1. Talacag
   2. Kolambogan
   3. Bacolod

C. 10.1% – 14%
   1. Camarines
   2. Iloilo White
   3. Dulag
   4. Bunawan
   5. Kauswagan (A)
   6. Kauswagan (B)
   7. Sapad (C)
   8. Sapad (A)
   9. Rogongon
   10. Bulalang
   11. Baroy (B)
   12. Upper Tominobo
   13. Suarez
   14. Lala
   15. Karomatan (D)
   16. Manggas
   17. Karomatan (G)
   18. K-Malinao
   19. Tubod (C)

D. 6.1% – 10% range
   1. Pugaan
   2. Tubod
   3. Tipanoy
   4. Kapatagan
   5. Sta. Filomena
   6. Sapad (B)
   7. Karomatan (F)
   8. Karomatan (C)
   9. Tubod (A)
   10. Karomatan (B)
   11. Baroy (A)

E. 2% – 6% range
   1. Karomatan (B)
   2. Karomatan (E)
   3. Salvador

Table 5. Loss on Ignition

Samples	Wt. at 100°C (g)	Wt. at 1000°C (g)	Wt. loss on ignition (g)	% loss on ignition
A. Iligan City				
1. Bulalang	1.1328	0.9987	0.1941	11.8
2. Bunawan	1.1397	0.9921	0.1476	13.0
3. K-Malinao	1.0588	0.9463	0.1095	10.4
4. Sta. Filomena	1.0924	0.9981	0.0943	8.6
5. Dulag	1.1495	0.9940	0.1500	13.0
6. Pugaan	1.7005	1.5352	0.1651	9.7
7. Palao	1.2324	0.9716	0.2608	21.2
8. Manggas	1.2924	1.1531	0.1393	10.8
9. Tipanoy	1.0999	0.9951	0.1048	9.5
10. Suarez	1.1290	1.0018	0.1292	11.3
11. Upper Tominobo	1.1077	0.9799	0.1278	11.5
12. Rogongon	1.0913	0.9600	0.1313	12.0
B. Lanao del Norte				
1. Bacolod	1.1665	0.9991	0.1674	14.4
2. Baroy (A)	1.0643	0.9947	0.0696	6.5
3. Baroy (B)	1.1250	0.9935	0.1313	11.7
4. Kapatagan	1.0655	0.9725	0.0930	8.7
5. Karomatan (A)	1.0790	0.9948	0.0842	7.8
6. Karomatan (B)	1.0424	0.9840	0.0584	5.6
7. Karomatan (C)	1.1109	0.9909	0.1200	10.8
8. Karomatan (D)	1.1813	1.0821	0.0992	8.4
9. Karomatan (E)	0.9705	0.9239	0.0466	4.8
10. Karomatan (F)	1.0927	1.0000	0.0927	8.5
11. Karomatan (G)	1.1167	1.0000	0.1167	10.5
12. Kauswagan (A)	1.1930	1.0391	0.1539	12.9
13. Kauswagan (B)	1.1427	0.9953	0.1474	12.9
14. Kolambogan	1.1719	0.9953	0.1474	12.9
15. Lala	1.1165	0.9948	0.1217	10.9
16. Sapad (A)	1.1432	1.0003	0.1429	12.5
17. Sapad (B)	1.0852	0.9930	0.0922	8.5
18. Sapad (C)	1.1751	1.0282	0.1469	12.5
19. Salvador	1.0181	0.9814	0.0367	3.6

20. Tubod (A)	1.1081	1.0161	0.0920	8.3
21. Tubod (B)	1.0271	0.9706	0.0565	5.5
22. Tubod (C)	1.1010	0.9942	0.1068	9.7
C. Model Clays				
1. Talacag	1.1925	0.9874	0.2051	17.2
2. Iloilo White	1.1025	0.9967	0.1058	9.6
3. Camarines	1.2148	1.0581	0.1567	12.9

Alumina and Silica Contents

Clays consist of argillaceous matters and impurities. The argillaceous matters may be a single argillaceous mineral (monomineral clay) or a mixture of clay minerals (polymineral clay). These clay minerals are generally hydrous aluminum silicates which are chemically represented as m Al_2O_3.n SiO_2.pH_2O, (where the values of m,n, and p differ according to the mineral) and crystal lattices which may include K, Na, Mg, Ca, and Fe. Types of argillaceous minerals, their impurities, and the ratios between their components determine their properties (Budnikov, 1964).

Table 7 presents the alumina and silica contents of the clay samples of Iligan City and Lanao del Norte. The alumina and silica contents of the Iligan City clay samples range from 15 — 28% and 34 — 55%, respectively; Lanao del Norte 13 — 37% and 40 — 70%, respectively.

Budnikov (1964) has classified clay types as refractory, high-melting and low-melting based on the percentage of Silica, Alumina, iron oxide, magnesia, calcium oxide, potassium and sodium oxide and loss on ignition. In accordance with this classification, clay samples of Iligan Cigy and Lanao del Norte can be grouped as follows:

a) Refractory type
- — Bulalang, Dulag, K-Malinao, Manggas, Suarez
- — Baroy (B), Karomatan (C), Kauswagan (B), Sapad (A), Sapad (B), Sapad (C), Tubod (A)
- — Talacag, Camarines

b) High-melting type
- — Pugaan, Sta. Filomena
- — Baroy (A), Karomatan (B), Karomatan (D), Karomatan (C), Kauswagan (A), Lala, Tubod (C)
- — Iloilo white

c) Low-melting type
- — Bunawan, Upper Tominobo
- — Kapatagan, Karomatan (A), Salvador, and Tubod (B)

The samples from Palao, Rogongon, Tipanoy of Iligan City and Bacolod, Karomatan(G), and Kolambogan of Lanao del Norte do not belong to any of these types because of the low SiO_2 content and Karomatan(E) because of its high Al_2O_3 content.

The silica content as shown in Table 6 given as residual and gravimetric silica has not been distinguished as to whether it was silica from the impurities of quartz sand or the silica of the clay minerals but instead assumed as the total silica content of the clay minerals.

Taking the alumina and silica (total) contents, the moles of each were calculated and the Al_2O_3 to SiO_2 ratios were determined and used to indicate the clay mineral component predominantly present in the samples.

As shown in Table 7, the mole ratios of Al_2O_3 to SiO_2 were generally 1:4 except the Dulag, Rogongon, and Tipanoy clays which have a mole ratio of 1:3 and Pugaan 1:5 for the Iligan City samples. For Lanao del Norte samples, the mole ratio of Al_2O_3 to SiO_2 was generally 1:4 except the following which showed other mole ratios:

1:2 — Bacolod, Karomatan(C), Karomatan(E), Kolambogan
1:3 — Baroy(A), Kauswagan(B), Sapad(C), Tubod(A).
1:5 — Karomatan(B), Karomatan(D), Karomatan(C), Salvador and Tubod(C).
1:7 — Karomatan(A)
1:8 — Tubod(B)
1:9 — Kapatagan

For the model clay samples used in this study — Talacag, Iloilo White, and Camarines — the ratios of 1:2, 1:4 and 1:3, respectively, were obtained.

According to Budnikov (1964), the kaolinite group comprising kaolinite, dickite, and nacrite exists commonly in nature and has a chemical composition of $Al_2O_3.2SiO_2.2H_2O$. The halloysite group of clay minerals which includes halloysite, ferrihalloysite, and metahalloysite and frequently associated with kaolin and kaolinite clays has a chemical composition of $Al_2O_3.\ SiO_2.4H_2O$. The kaolinite and halloysite have the same mole ratio of Al_2O_3 to SiO_2 of 1:2 although the water content differs. The montmorillonite, notronite, and beidellite are made up of complex hydrous aluminum-silicates together with Mg, Ca, and Fe. Generally their chemical composition is $Al_2O_3.3 - 5SiO_2.nH_2O$. The alumina to silica ratio is 1:3-5 but the ratio can go up to 1:9 as in some types of montmorillonite. The monothermiges which are present in some refractory clays and in high-melting clays together with kaolinite exist as $0.2(K_2, Na_2, Mg, Ca)O.Al_2O_3.3SiO_2.5H_2O.5H_2O$, a ratio of Al_2O_3 to SiO2 of 1:3.

Based on the mole ratio calculation given in Table 7 and shown in Table 8, Bacolod, Karomatan(C), Karomatan(E), Kolambogan, and Talacag have predominantly the halloysite and/or the kaolinite group of the clay minerals.

Table 6. Silica Content of Clay Samples

Sample	Gravimetric Silica %	Residual Silica %	Total Silica %
A. Iligan City			
1. Bulalang	47.6	0.7	48.3
2. Bunawan	51.0	0.6	51.6
3. Dulag	47.0	0.9	4 .9
4. K-Malinao	48.0	0.8	48.8
5. Manggas	49.4	0.8	50.2
6. Payao (B)	33.4	0.8	34.2
7. Pugaan	54.1	0.5	54.6
8. Rogongon	38.8	0.8	39.6
9. Sta. Filomena	49.2	1.6	52.8
10. Suarez	46.6	0.8	47.4
11. Tipanoy	42.5	0.9	43.4
12. Upper Tominobo	48.8	0.5	49.3
B. Lanao del Norte			
1. Bacolod	39.3	0.5	39.8
2. Baroy (B)	50.2	0.9	51.1
3. Baroy (A)	51.8	0.8	52.6
4. Kapatagan	67.9	1.6	69.5
5. Karomatan (A)	61.8	1.8	62.6
6. Karomatan (B)	60.8	1.2	62.0
7. Karomatan (C)	45.4	1.3	46.7
8. Karomatan (D)	53.7	1.4	55.3
9. Karomatan (E)	49.4	0.7	50x1
10. Karomatan (F)	53.9	0.9	54.8
11. Karomatan (G)	40.5	1.0	41.5
12. Kauswagan (A)	46.7	1.0	47.7
13. Kauswagan (B)	44.0	1.0	45.0
14. Kolambogan	38.5	0.4	39.9
15. Lala	51.2	1.6	52.8
16. Sapad (A)	49.4	0.6	50.0
17. Sapad (B)	51.1	0.8	51.9
18. Sapad (C)	46.1	1.4	47.9
19. Salvador	57.0	1.6	58.6
20. Tubod (A)	51.4	1.0	52.4
21. Tubod (B)	66.0	1.3	68.0
22. Tubod (C)	54.7	1.2	55.9

C. Model Clays			
1. Talacag	40.5	1.5	42.0
2. Iloilo White	59.5	0.7	60.2
3. Camarines	49.1	1.2	50.3

According to Budnikov halloysite shows greater dispersion and plasticity and absorption capacity compared with kaolinite. Dulag, Rogongon, Tipanoy, Baroy (A), Kauswagan(B), Sapad(C), Tubod(A), and Camarines clays contain the monothermite clays mineral. The monothermites, according to Budnikov, which are present in some refractory clays, are high-melting clays, more finely dispersed, and show greater swelling and plasticity than kaolinite. Bulalang, Bunawan, K-Malinao, Manggas, Palao, Pugaan, Sta. Filomena, Suarez, Upper Tominobo, Baroy(B), Kapatagan, Karomatan(A,B,D,F,G), Kauswagan(A), Lala, Sapad(A,B), Salvador, Tubod (B,C) and Iloilo White are predominantly the montmorillonite clay mineral. These clay mineral groups according to Budnikov have a higher degree of dispersion, greater swelling capacity, plasticity and coherence, and sensitiveness to drying and firing compared with the other clay minerals.

Table 7. Alumina-Silica Composition of Clay Samples

Sample	Alumina % Al_2O_3	Total Silica % SiO_2	Moles SiO_2	Mole Ratio Al_2O_3:SiO_2
A. Iligan City				
1. Bulalang	22.1	48.3	0.8	1:4
2. Bunawan	18.0	51.6	0.8	1:4
3. Dulag	27.9	47.9	0.8	1:3
4. K-Malinao	21.6	48.8	0.8	1:4
5. Manggas	21.5	50.2	0.8	1:4
6. Palao	15.1	34.2	0.6	1:4
7. Pugaan	20.6	54.6	0.9	1:5
8. Rogongon	26.0	39.6	0.7	1:3
9. Sta. Filomena	20.1	50.8	0.8	1:4
10. Suarez	23.7	47.4	0.8	1:4
11. Tipanoy	23.7	43.4	0.7	1:3
12. Upper Tominobo	19.6	49.3	0.8	1:4

C. Model Clays			
1. Talacag	40.5	1.5	42.0
2. Iloilo White	59.5	0.7	60.2
3. Camarines	49.1	1.2	50.3

According to Budnikov halloysite shows greater dispersion and plasticity and absorption capacity compared with kaolinite. Dulag, Rogongon, Tipanoy, Baroy (A), Kauswagan(B), Sapad(C), Tubod(A), and Camarines clays contain the monothermite clays mineral. The monothermites, according to Budnikov, which are present in some refractory clays, are high-melting clays, more finely dispersed, and show greater swelling and plasticity than kaolinite. Bulalang, Bunawan, K-Malinao, Manggas, Palao, Pugaan, Sta. Filomena, Suarez, Upper Tominobo, Baroy(B), Kapatagan, Karomatan(A,B,D,F,G), Kauswagan(A), Lala, Sapad(A,B), Salvador, Tubod (B,C) and Iloilo White are predominantly the montmorillonite clay mineral. These clay mineral groups according to Budnikov have a higher degree of dispersion, greater swelling capacity, plasticity and coherence, and sensitiveness to drying and firing compared with the other clay minerals.

Table 7. Alumina-Silica Composition of Clay Samples

Sample	Alumina % Al_2O_3	Total Silica % SiO_2	Moles SiO_2	Mole Ratio $Al_2O_3:SiO_2$
A. Iligan City				
1. Bulalang	22.1	48.3	0.8	1:4
2. Bunawan	18.0	51.6	0.8	1:4
3. Dulag	27.9	47.9	0.8	1:3
4. K-Malinao	21.6	48.8	0.8	1:4
5. Manggas	21.5	50.2	0.8	1:4
6. Palao	15.1	34.2	0.6	1:4
7. Pugaan	20.6	54.6	0.9	1:5
8. Rogongon	26.0	39.6	0.7	1:3
9. Sta. Filomena	20.1	50.8	0.8	1:4
10. Suarez	23.7	47.4	0.8	1:4
11. Tipanoy	23.7	43.4	0.7	1:3
12. Upper Tominobo	19.6	49.3	0.8	1:4

B. Lanao del Norte

1. Bacolod	35.0	39.8	0.6	1:2
2. Baroy (B)	23.0	51.1	0.85	1:4
3. Baroy (A)	28.0	52.6	0.9	1:3
4. Kapatagan	13.4	69.5	1.16	1:9
5. Karomatan (A)	14.7	62.6	1.04	1:7
6. Karomatan (B)	24.4	62.0	1.0	1:5
7. Karomatan (C)	36.5	46.7	0.78	1:2
8. Karomatan (D)	22.1	55.3	0.9	1:5
9. Karomatan (E)	40.1	50.1	0.8	1:2
10. Karomatan (F)	18.0	54.8	0.9	1:5
11. Karomantan (G)	18.3	41.5	0.7	1:4
12. Kauswagan (A)	22.2	47.7	0.8	1:4
13. Kauswagan (B)	28.0	45.0	0.75	1:3
14. Kolambogan	34.3	39.9	0.67	1:2
15. Lala	24.8	52.8	0.9	1:4
16. Sapad (A)	23.8	50.0	0.9	1:4
17. Sapad (B)	24.1	51.9	0.87	1:4
18. Sapad (C)	27.6	47.5	0.79	1:3
29. Salvador	19.5	58.6	1.0	1:5
20. Tubod (A)	32.3	52.4	0.9	1:3
21. Tubod (B)	15.5	68.0	1.13	1:8
22. Tubod (C)	20.7	55.9	0.93	1:5

C. Model Clays

1. Talacag	36.4	40.0	0.7	1:2
2. Iloilo White	26.6	60.2	1.0	1:4
3. Camarines	33.2	50.3	0.84	1:3

Other Mineral Contents

The other mineral contents of clay determined in this study may or may not be a component of the lattice of the clay minerals. The iron compounds which are usually in the form of pyrite (FeS_2), iron hydroxide, iron carbonates and iron oxide were analyzed and summed up as iron oxide (Fe_2O_3). The magnesium and calcium compounds which are often present as carbonates and sulfates were taken up as magnesium oxide (MgO) and calcium oxide (CaO). K, Na, Sr, Ba, Zn, Sn, Sb, and Mn were only qualitatively analyzed and the percent given in Table 9 is the difference of 100% and the sum (% Al_2O_3 + $\$SiO_2$ + %Fe_2O_3 +% MgO + %CaO + % loss on ignition).

Table 8. Clay Types and Clay Mineral Content

Sample	% SiO_2	% Al_2O_3	% Fe_2O_3	% CaO	% MgO	% K_2O% + Na_2O and others	% Loss on Ignition	Clay Type	Clay Mineral Group
Budnikov	46–62	25–39*	0.4–2.7 or more	0.2–0.8	0.2–1	0.3–3**	8–18	Refractory	
Budnikov	53–73	16–29*	1–9	0.5–2	0.3–2.6	0.7–3.2**	4–12	High-melting	
Budnikov	55–80	7–21*	3–12	0.5–15 or more	0.5–3	1–5**	3–15	Low-melting	
A. Iligan City									
Bulalang	48.3	22.1	8.4	3.7	2.8	2.9	11.8	Refractory	Montmorillonite
Bunawan	51.6	18.0	8.6	2.9	2.3	3.6	13.0	Low-melting	Montmorillonite
Dulag	47.9	27.9	8.7	1.6	1.6	traces	13.0	Refractory	Monothermite
K-Malinao	48.8	21.6	11.4	3.4	2.9	1.5	10.4	Refractory	Montmorillonite
Manggas	50.2	21.5	8.6	2.6	3.1	3.2	10.8	Refractory	Montmorillonite
Palao	34.2	15.1	6.5	18.3	3.0	1.7	21.2	—	Montmorillonite
Pugaan	54.6	20.6	7.8	—	5.7	1.6	9. 7	High-melting	Montmorillonite
Rogongon	39.6	26.0	9.6	—	3.1	0.7	12.0	—	Monothermite
Sta. Filomena	50.8	20.1	7.8	—	4.7	8.0	8.6	High-melting	Montmorillonite
Suarez	47.4	23.7	9.7	2.6	3.8	1.5	11.3	Refractory	Montmorillonite
Tipanoy	43.4	23.7	8.9	3.1	3.2	8.2	9.5	—	Monothermite
Upper Tominobo	49.3	19.6	9.4	2.3	2.2	5.7	11.5	Low-melting	Montmorillonite

* % Al_2O_3 ± TiO_2
** % K_2 ± Na_2O

Table 8. Clay Types and Clay Mineral Content

Sample	% SiO_2	% Al_2O_3	% Fe_2O_3	% CaO	% MgO	% K_2O + Na_2O and others	% Loss on Ignition	Clay Type	Clay Mineral Group
B. Lanao del Norte									
Bacolod	39.8	35.0	8.0	—	—	2.8	14.4	—	Kaolinite/ Halloysite
Baroy (A)	52.6	28.0	9.0	2.2	0.6	1.0	6.5	High-melting	Monothermite
Baroy (B)	51.1	23x0	5.1	2.4	1.4	4.3	11.7	Refractory	Montmorillonite
Kapatagan	69.5	13.4	3.9	2.5	1.6	0.7	8.7	Low-melting	Montmorillonite
Karomatan (A)	62.6	14.7	7.8	3.2	2.4	1.5	7.8	Low-melting	Montmorillonite
Karomatan (B)	62.0	24.4	1.9	2.8	—	3.3	5.6	High-melting	Montmorillonite
Karomatan (C)	46.7	36.5	1.9	4.0	—	1.1	10.8	Refractory	Kaolinite/ Halloysite
Karomatan (D)	55.3	22.1	59.	3.4	—	2.9	8.4	High-melting	Montmorillonite
Karomatan (E)	50.1	40.1	1.5	2.0	—	1.5	4.8	—	Kaolinite/ Halloysite
Karomatan (F)	54.8	18.0	10.5	5.2	—	3.0	8.5	High-melting	Montmorillonite
Karomatan (G)	41.5	18.3	9.5	8.3	8.8	3.1	10.5	—	Montmorillonite
Karomatan (A)	47.7	22.2	11.8	2.6	—	2.8	12.9	High-melting	Montmorillonite
Kauswagan (B)	45.0	28.0	12.2	—	—	1.9	12.9	Refractory	Monothermite
Kolambugan	39.9	34.3	11.8	—	—	traces	14.7	—	
Lala	52.8	24.8	8.0	2.3	0.4	0.8	10.9	High-melting	
Sapad (A)	50.0	23.8	10.0	2.6	—	1.1	12.5	Refractory	

Sapad (B)	51.9	24.1	10.0	2.0	2.6	1.4	8.5	Refractory	
Sapad (C)	47.5	27.6	10.1	2.0	1.1	traces	12.5	Refractory	
Salvador	58.6	19.5	6.6	6.1	1.9	1.7	3.6	Low-melting	
Tubod (A)	52.4	32.3	5.0	2.0	—	traces	8.3	Refractory	
Tubod (B)	68.0	15.5	4.4	3.3	—	1.3	5.5	Low-melting	
Tubod (C)	55.9	20.7	9.4	—	—	2.3	9.7	High-melting	
C. Model Clay									
Talacag	42.0	36.4	2.5	—	—	1.9	17.2	Refractory***	Kaolinite/ Halloysite***
Iloilo White	60.2	26.6	2.4	—	—	—	9.6	High-melting	Montmorillonite
Camarines	50.3	33.2	3.0	traces	traces	traces	12.9	Refractory	Monothermite

***Confirmed by Torillo, et.al.

Iron Oxide

As shown in Table 9, the Fe_2O_3 content of the Iligan City samples ranges from 6.5% to 11.4%. This high Fe_2O_3 content may have caused the red or reddish-brown coloration of the samples. It may also reduce the melting point of clay especially when present in bivalent form (Kitagaki, 1980).

For the Lanao del Norte samples, Karomatan (B), Karomatan (F) and Karomatan (E) were the only samples with noticeably low Fe_2O_3 content of 1.5 – 1.9%. This was even lower than the Fe_2O_3 contents of the model clays, Talacag, Iloilo White, or the Camarines. Kauswagan (A,B), Kolambogan, Karomatan(F,G), Sapad (A,B,C), Tubod (C) and Baroy(A) were among the highest in Fe_2O_3 content of the Lanao del Norte samples.

Magnesium and Calcium *Oxide* Content

Magnesium and calcium present as carbonates in clay, especially calcium, are harmful impurities which can cause destruction of the product after firing. When finely dispersed they can cause increased porosity and a reduction of the strength of the fired parts. They also reduce the refractoriness and the temperature range over which the clays sinter.

As shown in Table 9, the % CaO of the Iligan City clay samples generally vary from about 1.6% to 3.0% to 3.7% with only Palao clay having a high CaO content of 18.3%. Pugaan, Rogongon and Sta. Filomena clays were found negative for calcium in the qualitative analysis, hence may be present but in very low concentration.

For its magnesium oxide content, all have % MgO of 1.6 to 3.2% except those from Pugaan with 5.7%, Sta. Filomena with 4.7% and Suarez with 3.8%.

For Lanao del Norte samples, the % CaO varied from 2.0 to 3.4% except Karomatan(G) with 8.3%, Karomatan(F) 5.2%. Salvador, Kauswagan, Kolambogan, Tubod(C) were found negative for calcium in the qualitative analysis. Likewise, Talacag and Iloilo White were negative for magnesium and Camarines with only traces of this mineral. Magnesium oxide content is generally low with about 0.4% to 2.6% except Karomatan(G) with 8.8%. Karomatan(B,C,D,E,F), Kauswagan (A,B), Kolambogan, Sapad(A), and Tubod(A,B,C) were all negative for magnesium.

Zinc, Arsenic, Tin, Antimony, Manganese, and Titanium Content

Quantative analysis was not undertaken for these metals. The % shown in Table 9 was obtained by taking the difference of 100% and the sum of % SiO_2 + %Al_2O_3 + % Fe_2O_3 + % CaO + % MgO + % loss on ignition. Their presence however was observed to be low and hence, assumed not to affect the commercial value of the clay appreciably.

Table 9. Non Alumina-Silica Component of Clay Samples

Sample	Iron oxide % Fe_2O_3	Calcium oxide % CaO	Magnesia % MgO	Other component %
A. Iligan City				
1. Bulalang	8.4	3.7	2.8	2.9 Na, Ti
2. Bunawan	8.6	2.9	2.3	3.6 Na
3. Dulag	8.7	1.6	1.6	Traces Na
4. K-Malinao	11.4	3.4	2.9	1.5 K, Na, Ti
5. Manggas	8.6	2.6	3.1	3.2 K, Na, Ti
6. Palao	6.5	18.3	3.0	1.7 Na
7. Pugaan	7.8	–	5.7	1.6 Na
8. Rogongon	9.6	–	3.1	0.7 K, Na, Ti
9. Sta. Filomena	7.8	–	4.7	8.0 K, Na
10. Suarez	9.7	2.6	3.8	1.5 Na
11. Tipanoy	8.9	3.1	3.2	8.2 K, Na
12. Upper Tominobo	9.4	2.3	2.2	5.7 K, Na
B. Lanao del Norte				
1. Bacolod	8.0	–	–	2.8 K, Zn, Sn, As
2. Baroy (B)	5.1	2.4	1.4	4.3 Na, Zn, Sn
3. Baroy (A)	9.0	2.2	0.6	1.0 Na, Zn, Sb
4. Kapatagan	3.9	2.5	1.6	0.7 Na, Sb
5. Karomatan (A)	7.8	3.2	2.4	1.5 K, Na, Sr, Mn
6. Karomatan (B)	1.9	2.8	–	3.3 K, Na, Zn
7. Karomatan (C)	1.9	4.0	–	1.1 K, Na, Zn
8. Karomatan (D)	5.9	3.4	–	2.9 Na, Zn
9. Karomatan (E)	1.5	2.0	–	1.5 K, Na, Zn,
10. Karomatan (F)	10.5	5.2	–	3.0 K, Na, Zn
11. Karomatan (G)	9.5	8.3	8.8	3.1 Na, Zn
12. Kauswagan (A)	11.8	2.6	–	2.8 Na, Zn
13. Kauswagan (B)	12.2	–	–	1.9 Na, Zn
14. Kolambogan	11.8	–	–	Trances Zn, As
15. Lala	8.0	2.3	0.4	0.8 Na, Zn, Sn
16. Sapad (A)	10.0	2.6	–	1.1 K, Na, Zn
17. Sapad (B)	10.0	2.0	2.6	1.4 K, Na, Ba, Sr, Z
18. Sapad (C)	10.1	2.0	1.1	Traces Na, Zn
19. Salvador	6.6	6.1	1.9	1.7 Na, Zn

20. Tubod (A)	5.0	2.0	—	Traces Na, Zn
21. Tubod (B)	4.4	3.3	—	1.3 K, Na
22. Tubod (C)	9.4	—	—	2.3 Na, Zn, As, Sb
C. Model Clay				
1. Talacag	2.4	—	—	—
2. Iloilo White	2.4	—	—	—
3. Camarines	3.0	Traces	Traces	—

Summary and Conclusion

The chemical analysis conducted on the clay samples of Iligan City and Lanao del Norte shows that some of the clay deposits are comparable in composition to the Talacag clay of Bukidnon, to the Iloilo White and the Camarines samples.

The composition of some of the samples were comparable to the composition of clays classified by Budnikov (1964) as refractory, high-melting and low-melting clays.

The Iligan City clay samples were high in iron compounds, a disadvantage since iron compounds can never be totally removed from the clay, hence will always have the disadvantage of what is known as "beauty spots" in ceramics.

Lanao del Norte clay samples were also high in iron compounds, however, some had low iron content comparable to the Iloilo White, Talacag and Camarines samples.

Generally, the calcium and magnesium compounds of both the Iligan City and Lanao del Norte samples were high. However, there were some samples of Lanao del Norte whose Ca and Mg content were even lower than the model samples (Talacag, Iloilo White, and Camarines).

Most of the samples from both sources belonged to the high melting and refractory types.

The samples from Iligan City had less metal impurities present compared with the Lanao del Norte samples.

The type of clay minerals indicated as present in the samples had been based only on the mole ratio of Al_2O_3 to SiO_2 and its loss on ignition. It had been assumed that the clay samples were cleaned and that quartz sand impurities were very minimal, hence data on this should be used with caution.

Recommendations

Inasmuch as the facilities of MSU-Iligan Institute of Technology do not allow for a complete chemical study of the clay samples, it is recommended that the clay samples whose chemical compositions have been found promising and comparable to the best clays in the country, should be sent for more intensive studies to the Ceramics Research and Development Center of the National Science and Technology Authority, Manila.

Since the chemical analysis used was largely the classical method, documentation should be made on the promising clay samples with the modern instrumental methods (X-ray Diffraction Analysis, Thermal Analysis, Scanning Electron Microscopy) which are available at the CRDC of NSTA. Results of this study can not be considered final but as a catalyst for further investigation.

Finally it is recommended that studies on beneficiation of the promising samples be started and that the Ceramics Center of MSU-IIT start studies on using the clays as classified (refractory, high-melting, low-melting).

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