White Firing Clays from Western Georgia

G.P. Bertolotti[1], D. Kuparadze[2]

Abstract: In Georgia during soviet period ceramic industry didn't have important developments and also in recent years there aren't ceramic factories still active in the country. In Western Georgia, some interesting deposits were identified as source for high quality ceramics in the last years. Preliminary prospection made on two clay deposits in Western Georgia and following laboratory tests indicate them as potentially interesting for a future industrial exploitaiton.

Keywords: Western Georgia, white firing clays, kaolinitic clay deposits, high quality ceramics

1. Introduction

Thoroughout its history, Georgia has had an old tradition in the use of clays for ceramics (Figure 1). During the Soviet period the ceramic industry in Georgia did not see any important developments – moreover, recently, there have not been any active ceramic factories in the country.

In any case, the fact that Georgia is located near important ceramic producers and the great local demand for ceramics make Georgian clay deposits more and more interesting as a strategic source for the country and for the international ceramics market .

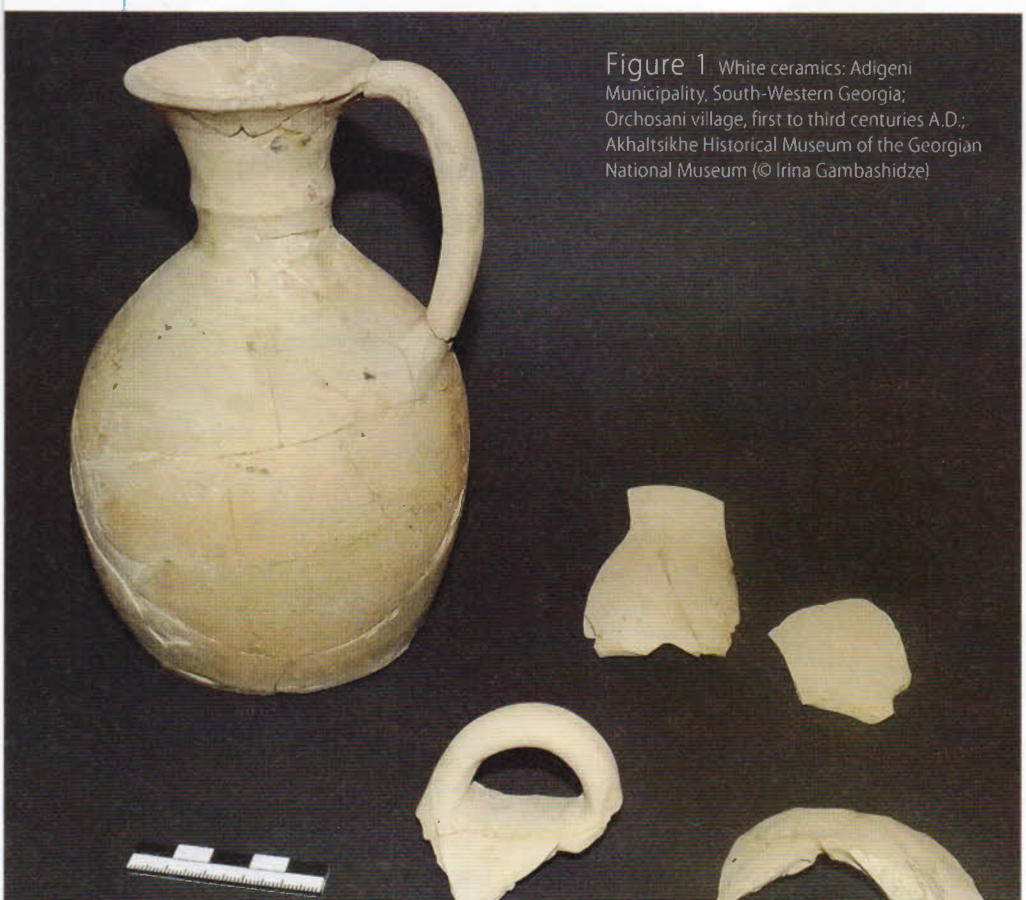

Figure 1 White ceramics: Adigeni Municipality, South-Western Georgia; Orchosani village, first to third centuries A.D.; Akhaltsikhe Historical Museum of the Georgian National Museum (© Irina Gambashidze)

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2. White firing clay deposits

The two most interesting clay deposits are located in Western Georgia, not far from the cities of Kutaisi and Batumi and near the Black Sea Coast (Figure 2). This article describes some field observations and preliminary laboratory evaluations on samples collected in the two areas called "Clay Deposit A" and "Clay Deposit B".

Figure 2 Location of clay Deposits (© Google Earth, modified)

2.1 Clay Deposit A

This deposit is located in the Imereti region, approximately 20 km NE of the city of Kutaisi. This raw material was investigated in the past through several vertical wells, and some excavations were made in the neighboring zone. At the time of the visits no exploitation activity was active in the area.

2.1.1 Geological environment

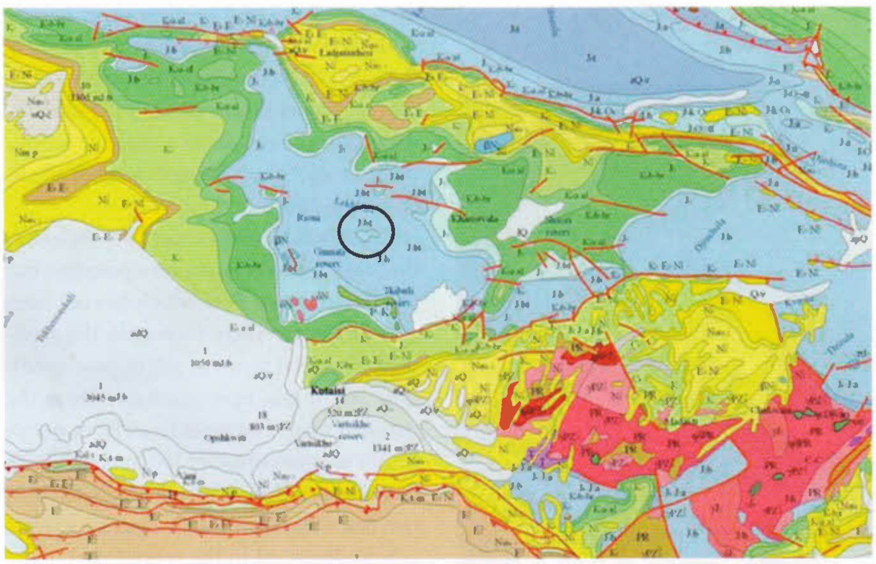
In this district (Figure 3), the oldest formations are represented by a Jurassic volcanic suite (called the "Bajocian porphyritic suite"). These are massive volcanic breccias, lava breccias, porphyritic tuffs, and an interleaving of tuff sandstones and mudstones (with a maximum thickness of 2500 m). The layers of deposit that are interesting for ceramic production are represented by white and yellow/brown kaolinitic clays and grey rocky levels of Bathonian age.

The thickness of clay levels ranges from 0.5 to 5 m (any individual layer is about 3–25 cm). Dark gray shales are present at the base of kaolinitic clays. The sedimentary layers in the mining area show sub-horizontal orientation with a maximum inclination of 5 to 35°.

The altitude of the Deposit is around 600–625 m above sea level. The area is connected by electricity and sources of drinking water are available. Not far from the area there are also known brick clay and peat deposits. During preliminary surveys made in the summers of 2016 and 2017 some representative samples were collected to enable a better understanding of the quality of the clays present in the area. Surface observations and trenches made with hydraulic excavators around the area helped to identify the presence of four main clay typologies:

- white clay ("kaolin")
- mixed clay
- white/grey lithic clay
- lower grey shale

Figure 3 Geological map of the area of clay Deposit 1 and description of the geological formation where the clays are present; the black circle indicates the explored area (zoom from Geological Map of Georgia, scale 1: 500,000 (© Georgian Department of Geology)



J_2bt	Georgian block. Shallow-waterlacustrine deposits: foliated shales with intercalations of tuffs of calc-alkalic basalts, tephroturbidites, sandstones, argillites coalbearing shales, anthracite beds.

2.1.2 White clay ("kaolin")

Is is the purest quality available in the area. Locally, this clay is known as "kaolin" (Figure 4). On "Deposit 1" these clays are present in levels with variable thickness ranging from less than 0.5 m to 2–3 m. In many cases, white clay is alternated with grey/rose/brownish clays and iron levels (mixed clay).

2.1.3 Mixed clay

This is not pure single clay quality but it represents a random mixture of clay levels of different colour ranging from white/light yellow until brown alternated with whiter levels (Figure 5). In some exploration trenches this variabilty was evident and without accurate selective exploitation work, which could mean that it wrongly represents the average quality of the Deposit. Some levels look dark brown and they could contaminate white/grey clay qualities (Figure 6).

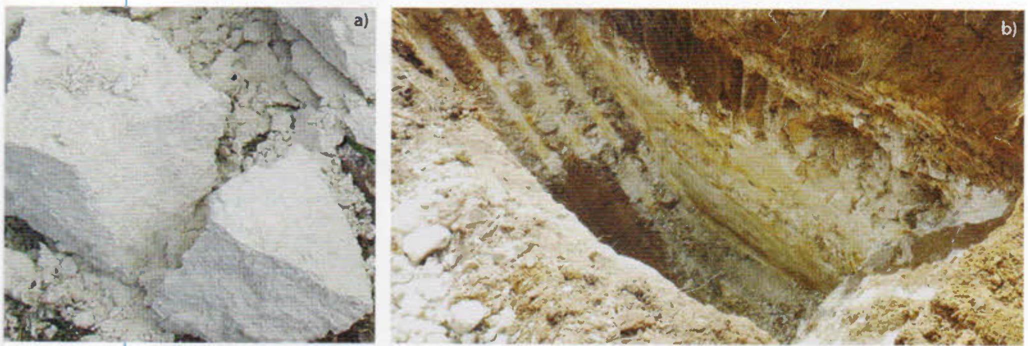


Figure 4 White clay samples and level present in a trench (© G.P. Bertolotti, D. Kuparadze)

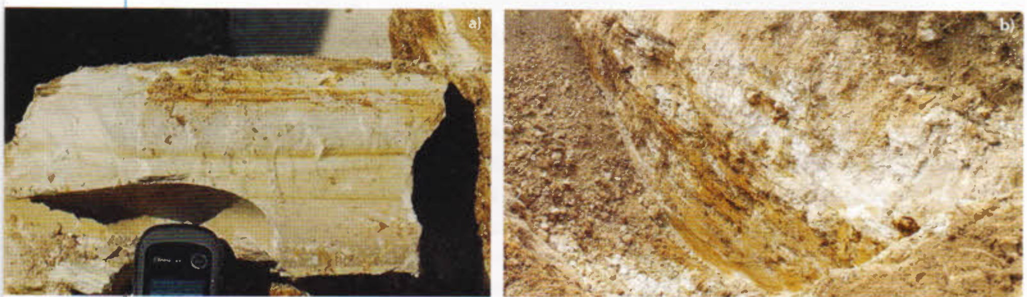


Figure 5 Mixed clay sample and level in a trench showing alternance of clays with different colours (© G.P. Bertolotti, D. Kuparadze)

Only further detailed core drilling exploration will permit us to identify the places where purest white clay levels are present in the entire area.

2.1.4 White/grey lithic clay

These raw materials are visible on small roads connecting different areas of Deposit 1 (Figure 7). Compared to previous clays, they do not look like a loose sediment but as a lithic material with conchoidal fracture. After 1 day in water their particles still did not dissolve. They can be defined as flint clays or kaolinite clayrock facies as described by Loughan (1978). Together with white and light grey litotypes darker grey and brown levels are also present. A sample of lithic clay was selected for laboratory analyses. Preliminary geological observations indicate that it is probably interstratified with the previous qualities.

2.1.5 Lower grey shale

Trench excavations under white, mixed and lithic clays, in most cases found dark grey shales. (Figure 8) . They probably represent he bottom of the deposit.

In conclusion, according to preliminary estimates of the authors, the quantity of kaolinitic clays in the explored area must be in the range of 600.000–1.000.000 tons in total. This is only a preliminary rough evaluation that can only be defined with precision by serious further prospecting work.

2.2 Clay Deposit B

In the Guria region several interesting outcorps of kaolinitic clays are present (Figure 9). The most important one is located approximately 100 km NW of the city of Kutaisi and 50 km from Batumi and Poti ports.

2.2.1 Geological environment

The Eocene formations represented by tuffs, tuff breccias, tuff conglomerates, andesites, trachite lavas and their tuffs are part of the geological structure of the area (Figure 10). According to previous geological-petrographic studies, these clays derive from decomposition and weathering of Eocene trachyte rocks. These clays were studied in the 1950–1960s in a Soviet Union geological survey. Although later there were made further studies on this district, the few available documents do not present detailed stratigraphical studies of the area.

The main deposit was partially utilized in the past as a kaolin source for a porcelain factory located near Poti, which has not been active for many years. Currently, the previously exploited area was still in good condition and it was easy reachable from the national road. The main front has a visible length of approximately 100 m and a width of more than 50 m. Along the exploited level two main clay qualites are evident: a white quality observed in the central part of the level and a yellow/orange quality present on the sides of the outcrop (Figure 11). The pas-

Figure 6 Dark brown clay levels present in clay Deposit 1 (© G.P. Bertolotti, D. Kuparadze)

Figure 7 White/grey lithic clay outcrops in the clay Deposit 1 area (© G.P. Bertolotti, D. Kuparadze)

Figure 8 Lower grey shales' stock and level present in a trench (© G.P. Bertolotti, D. Kuparadze)

sage between the two lithotypes show a band of a few metres where the quality is mixed. According to observations along the main outcrop, the length of white zone is around 25–30 m and it represents 30 % of the total length. As indicated for Deposit 1 further exploration with detailed laboratory studies will permit us to clarify the true origin of this Deposit and enable a correct estimate of the qualities and quantities available. Along the small road that connects the clay mine to the main road many metres of outcrops of clear rocks are present (Figure 12). A clear rock sample was collected for preliminary laboratory tests.

In conclusion, during the preliminary exploration made in the summer of 2016, the following samples were collected in the Deposit 2 area :

- white clay
- yellow clay
- lower clear rock.

Figure 9 Yellow-white kaolinitic clays, Guria region (© G.P. Bertolotti, D. Kuparadze)

3. Laboratory tests

On the clay samples collected during exploration, analyses were carried out in the Tecno Piemonte S.p.A. laboratory in Lenta, Italy. Only some of the tests were perfromed on the lower grey shale and lower clear rock samples for apreliminary indication of their quality.

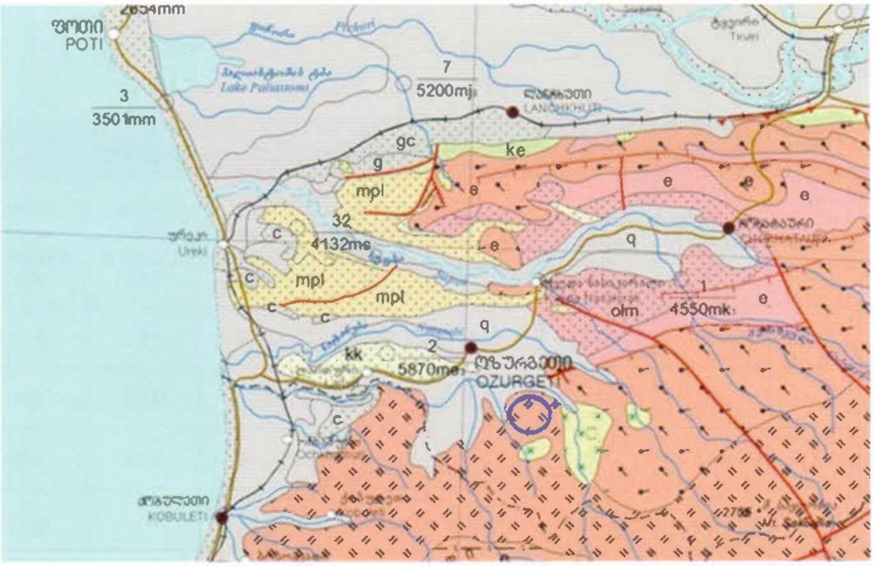
3.1 Residue

The evaluation of the residue was made after leaving 100 g of dried raw material in water for one night with the addition of a small amount of deflocculant agent. Then the material was sieved with water with 63 µm weighing after completely drying the resulting part of each sample. Table 1 presents the results obtained.

All the samples of Deposit 1 present a predominant coarse part due to partial lithification of the previous clay sediments, only the lower grey shale sample has a very low residue over 63 µm. On the contrary, white and yellow clay samples of Deposit 2 show a low residue.

3.2 MOR after drying

Bending strength tests were performed on 10 x 5 cm samples pressed at about 350 kg/cm². All the samples were measured after



δE_2^2	Middle Eocene diorites, quartz-diorites, monozonites, granosyenite

Figure 10 geological map of the area of clay Deposit 2; the blue circle indicates the explored area (zoom from Geological Map of Georgia, scale 1: 500.000 (© Georgian Department of Geology)

Figure 11 White kaolinitic clays previously exploited for porcelain production, Guria region (© G.P. Bertolotti, D. Kuparadze)

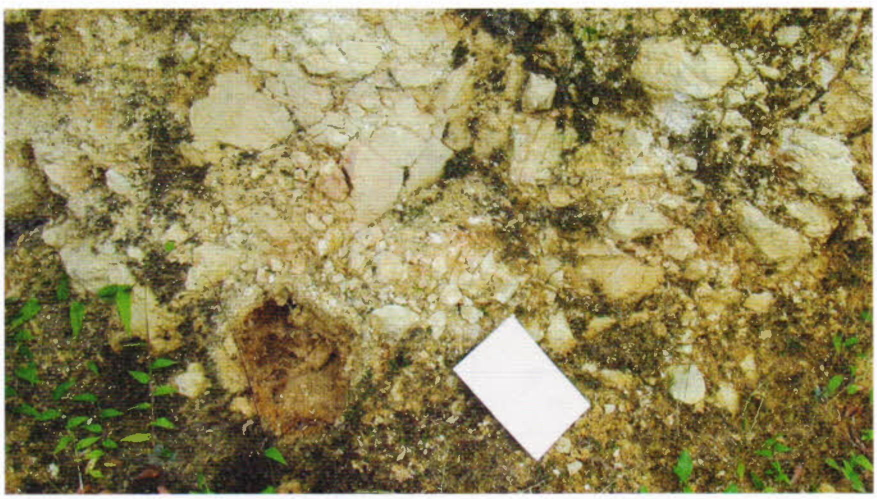


Figure 12 White and clear rocks present along the road near Deposit 2, Guria region (© G.P. Bertolotti, D. Kuparadze)

one night of drying at 105 °C and immediately being taken out of the dryer. The test was carried out on four samples of each sample. The bending strength or module of rupture (MOR) is calculated with the following Equation:

$$MOR = \frac{3 \times F \times d}{2 \times b \times h^2} \quad (1)$$

where:

- F = applied load (kg)
- d = distance between sample supports (cm)
- b = width of the sample where broken (cm)
- h = thickness of the sample where broken (cm)

The obtained average values are indicated in Table 2. The results of MOR tests indicate that all the clays of Deposit 1 show interesting medium/high values. The values in samples of Deposit 2, especially white clay, appeared lower than the first ones.

4.3 Chemical analysis (XRF)

Samples for chemical analysis were made by mixing 10 g of micronized powder with 2.5 g of wax Licowax C Micropowder PM used as binder. The mixtures were placed in the mould of an oleodynamic press and a specific pressure of 2000 kg/cm² was applied to produce round samples.

All the samples were analyzed with an EDXRF spectrometer Ametek Spectro IQ II

Table 1 Residue of clay samples over 63 µm (© G.P. Bertolotti, D. Kuparadze)

Sample	Residue > 63 µm [%]
White clay (Deposit 1)	52.9
Mixed clay (Deposit 1)	67.4
Lithic clay (Deposit 1)	68.8
Lower grey shale (Deposit 1)	1.5
White clay (Deposit 2)	3.8
Yellow clay (Deposit 2)	7.3

Table 2 MOR values for clay samples after drying (© G.P. Bertolotti, D. Kuparadze)

Sample	kg/cm²	N/mm²
White clay (Deposit 1)	34.8	3.6
Mixed Clay (Deposit 1)	28.9	2.9
Lithic clay (Deposit 1)	31.4	3.2
Lower grey shale (Deposit 1)	n. d.	n. d.
White clay (Deposit 2)	20.4	2.1
Yellow clay (Deposit 2)	37.4	2.6

Table 3 XRF chemical analyses with loss of ignition results (© G.P. Bertolotti, D. Kuparadze)

Oxide	White clay (Deposit 1) [%]	Mixed clay (Deposit 1) [%]	Lithic clay (Deposit 1) [%]	Lower grey shale (Deposit 1) [%]	White shale (Deposit 2) [%]	Yellow shale (Deposit 2) [%]	Lower rock (Deposit 2) [%]
SiO_2	57.0	67.0	67.1	57.4	55.4	58.2	64.6
Al_2O_3	27.4	19.7	20.3	24.0	27.7	23.6	19.6
Fe_2O_3	1.12	2.71	1.32	2.44	0.40	2.56	3.62
TiO_2	0.95	0.48	0.44	1.06	0.67	0.57	0.50
CaO	1.56	0.48	0.07	0.21	0.04	0.06	0.04
MgO	0.69	0.62	0.40	1.25	0.64	1.08	1.42
Na_2O	1.35	0.63	0.10	0.33	0.34	0.43	0.25
K_2O	0.38	0.39	0.22	1.08	6.24	6.34	5.72
SO_3	< 0.01	0.01	< 0.01	0.33	< 0.01	0.01	0.01
L.o.I.	9.07	7.84	9.40	11.24	8.07	6.90	3.63

and using X-LabPro 5.1 Ametek software. All the analyses were made with the same laboratory conditions and with suitable standard procedures.

To complete the analytical results, the loss of ignition was evaluated on micronized powder of each analyzed sample. The firing cycle of a laboratory muffle kiln was 3 h at 1050 °C with 1 hour at the maximum temperature. Table 3 presents the results of chemical analysis with loss of ignition. White clay of Deposits 1 and 2 and lithic grey clay show interesting chemical parameters for white body ceramic productions. Particularly white clay samples present a high alumina content, similar to the best clays used for porcelain tiles, and very low iron and titanium oxide. Also the other raw materials could be interesting for other ceramic production (e.g. floor tiles and glazed porcelain tiles).

3.4 Mineralogical analysis (XRD)

The mineralogical analyses were made with the X-ray diffractometer 5000D Bruker Axs and Miniflex 600 Rigaku. For the qualitative evaluation, PDF2 (powder diffraction file) database standards by JCPDS-ICDD (Joint Committee on Powder Diffraction Standards-International Centre for Diffraction Data) were used. Table 4 summarizes the main identified minerals for each sample and a semi-quantitative evaluation of each mineral recorded on the samples made with Rietveld methods and recalculated rational analysis. A more accurate

Table 4 Preliminary quantitative evaluation of minerals recognized in XRD analyses (using Rietveld method integrated with rational analysis considering XRF results) (© G.P. Bertolotti, D. Kuparadze)

Mineral	White clay (Deposit 1) [%]	Mixed clay (Deposit 1) [%]	Lithic clay (Deposit 1) [%]	Lower grey shale (Deposit 1) [%]	White shale (Deposit 2) [%]	Yellow shale (Deposit 2) [%]	Lower rock (Deposit 2) [%]
Kaolinite	55	35	35	40	40	25	–
Other clay minerals*	20	20	20	20	10	20	50
Quartz	10	35	35	25	5	10	45
Feldspars and others	15	10	10	15	45	45	5

* These include: montmorllonite, inter-layered clays, illite and muscovite

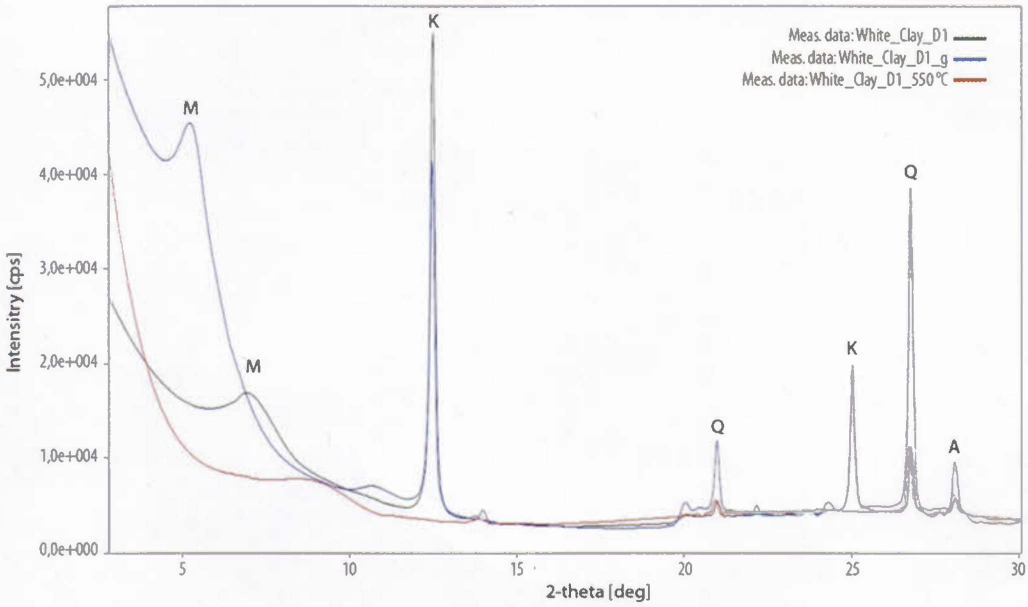


Figure 13 XRD resulting diagrams on white clay Deposit 1 samples (© G.P. Bertolotti, D. Kuparadze)

quantitative evalutation of the clay minerals will require more detailed sampling of each raw material quality.

To better understand clay mineralogy of the two most interesting raw materials more detalied X-ray analyses were made on white clay Deposit 1 and white clay Deposit 2 samples. Clay materials were dispersed in water in a laboratory test tube with the addition of a deflocculant (sodium pyrophosphate) and after that they were vigorously shaken to homogenize the suspension. They were left to settle for approximately 145 min. After this,some drops of the suspension on the upper part the test tube were collected with a pipette and deposed on glass slides and left to dry overnight.

For each clay sample there were three different analyses:

- on a sample sedimented on a glass slide
- on a sample sedimented on a glass slide, treated with ethylene glycol, placed in an essicator and heated at 80 °C in a laboratory stove for one night (g)
- on a sample sedimented on a glass slide heated for 1 h at 550 °C in a muffle kiln.

3.4.1 White clay Deposit 1

The overlapping diagrams (Figure 13) indicate the presence of kaolinite (K) and also

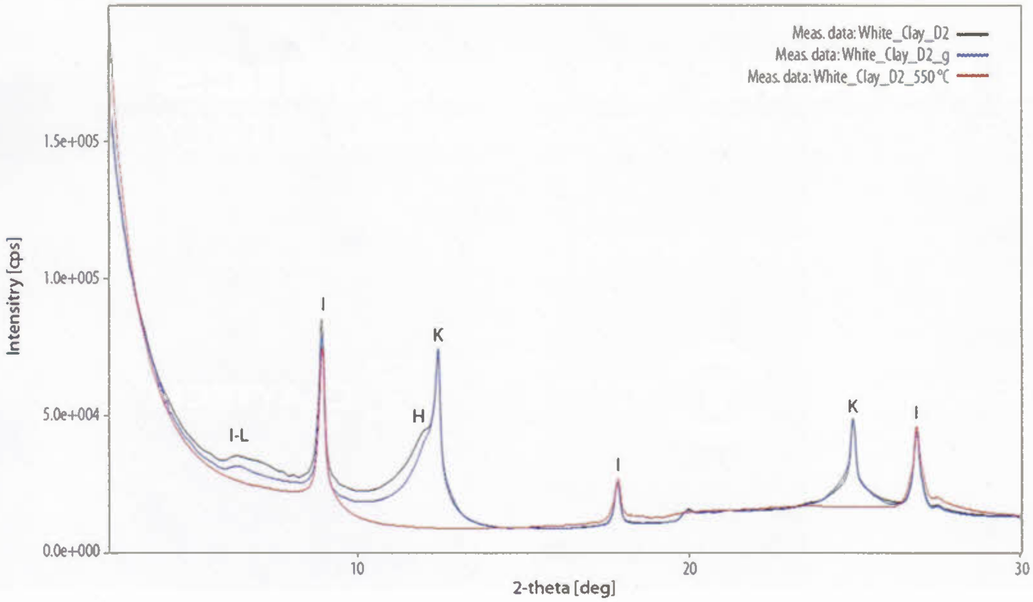


Figure 14 XRD resulting diagrams on white clay Deposit 2 samples (© G.P. Bertolotti, D. Kuparadze)

Table 5 Resulting data of firing tests in a laboratory muffle kiln (© G.P. Bertolotti, D. Kuparadze)

–	White clay (Deposit 1)	Mixed clay (Deposit 1)	Lithic grey clay (Deposit 1)	Lower grey shale (Deposit 1)	White clay (Deposit 2)	Yellow clay (Deposit 2)
Cycle: 1160 °C, 5 h (5 min at max. T)						
Water absorption [%]	7.32	11.38	9.61	–	2.72	0.30
Total shrinkage [%]	6.94	3.99	5.87	–	9.42	10.31
Cycle: 1190 °C, 5 h (5 min at max. T)						
Water absorption [%]	6.13	11.10	7.38	2.58	0.66	0.22
Total shrinkage [%]	7.69	4.94	7.01	12.71	10.15	10.38
Colour after firing						

an important phase in the area of montmorillonite clays (M). With ethylene glycol treatment the main peak of this mineral moved to a lower angle, as has been confirmed in the literature.

The presence of quartz (Q) and sodium feldspar (A) are residues of non-clay minerals present in the raw material.

3.4.2 White clay Deposit 2

In this case, the overlapping diagrams (Figure 14) indicate the presence of illite (I), kaolinite (K), and also the presence of a peak that can probably be linked to halloysite or colloidal kaolinite (H). At a lower angle there is also the presence of inter-layered clays (I-L).

4. Firing tests in a laboratory muffle kiln

The micronized powder of each raw material prepared for all the other analyses was also utilized to prepare round samples pressed at 350 kg/cm^2. The resulting samples were fired in laboratory muffle kiln with cycle of 5 h at temperatures of 1160 °C and 1190 °C (5 min at the maximum temperature). Water absorption and total shrinkage of the samples were measured after firing. In Table 5 are presented the obtained results with images of the samples after firing. Samples of Deposit 1 (except lower grey shale) looked more refractory than the samples of Deposit 2; this difference is probably due to the higher content of potassium feldspar present in the second Deposit.

5. Conclusions

Preliminary prospection made on two clay Deposits present in Western Georgia and the following laboratory tests indicate that they may be potentially interesting for future industrial exploitation. Only detailed prospecting activity with core drilling will permit us to accurately estimate the real size of these raw materials. White Clay of the Deposit 1 and 2 samples look very interesting and they are comparable to the best clays currently used for porcelain tiles, sanitaryware, and whiteware. Also other clay qualities could be very helpful for other ceramic production, especially for future local ceramic productions.

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