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Ceramic clays from the western part of the Tamnava Tertiary Basin, Serbia: deposits and clay types

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Abstract. Based on geological, mineralogical, physical, chemical and technological investigations in the Tamnava Tertiary Basin near Šabac town (western Serbia), deposits of ceramic clays were studied. These ceramic clays are composed of kaolin–illite with a variable content of quartz, feldspars, mica, iron oxides and hydroxides, and organic matter. Four main types of commercial clays were identified: i) red–yellow sandy–gravely (brick clays); ii) grey–white poor sandy (ceramic clays); iii) dark-carbonaceous (ceramic clays); and iv) lamellar (“interspersed”) fatty, poor sandy (highly aluminous and ferrous clays). Ceramic clays are defined as medium to high plastic with different ranges of sintering temperatures, which makes them suitable for the production of various kinds of materials in the ceramic industry.

Key words: ceramic clays, deposits and clay types, Tamnava Basin, western Serbia.

Апстракт. На основу геолошких, минералошких, физичких, хемијских и технолошких испитивања дати су резултати испитивања керамичких глина лежишта тамнавског терцијарног басена (западна Србија). Ове керамичке глине су углавном састављене од каолин-илита, са променљивим садржајем кварца, фелдспата, лискуна, оксида гвожђа и органске материје. Постоје четири главна типа комерцијалних глина: i) црвено-жута песковито-шљунковито опекарска глина, ii) сиво-бела слабо песковита керамичка и делом ватростална глина, iii) тамна-угљевита керамичка глина, iv) прошарана (ламеларна) слабо песковита, масна високо алуминозна и гвожђевита глина. Анализиране глине су средње до високо пластичне са различитим температурама синтеровања, што их чини погодним за производњу различитих производа у керамичкој индустрији.

Кључне речи: керамичке глине, лежишта и типови глина, тамнавски басен, западна Србија.

Introduction

Ceramic clay deposits, situated in Mio–Pliocene sediments of the western part of the Tamnava Tertiary Basin (western Serbia), were discovered in the middle of the last century. Most parts of these deposits are located in the areas of the villages Donje and Gornje Crniljevo (approximately 65 km to the South of Šabac, Fig. 1) with active open pits of grey–white clays Bele Vode and Zbegovi (the Jovanovića Brdo open-pit only produces brick clay and dark-carbonaceous clay). Besides these, Stare Kuće, Latkovac, Kisela Voda, Ramnava, and Brezaci are newly discovered deposits situated in the wider area (Radosavljević *et al.* 1994). The production of grey–white ceramic clay is about 100,000 tons per annum, and the total reserves are estimated at over 50 million tons (Radosavljević *et al.* 1986).

Generally, there are four main clay types (macroscopic description): a) red–yellow sandy–gravely (brick clays), b) grey–white (ceramic and partially refractory

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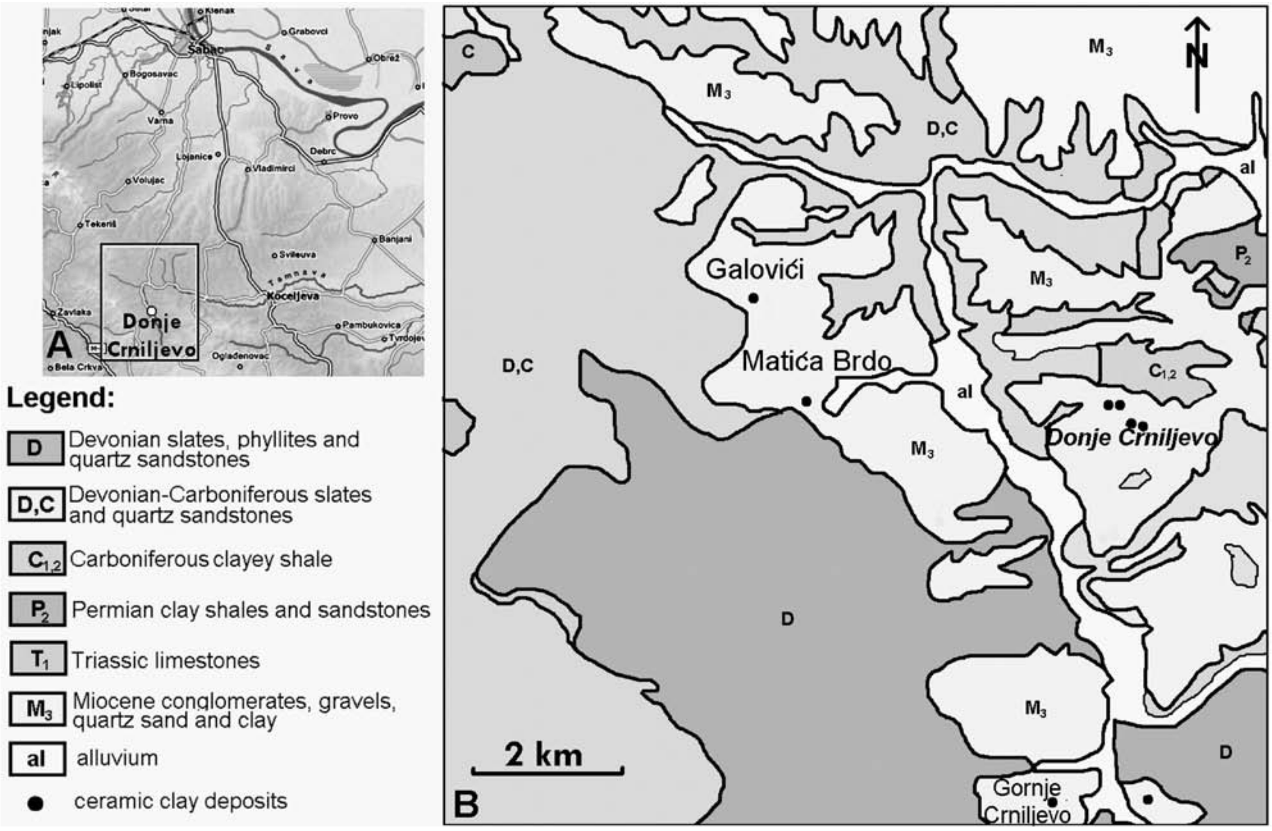

Fig. 1. Location and geological map of the Tamnava Tertiary Basin (modified according to Basic Geological Map of Serbia 1:100,000, Vladimirci sheet). **A,** Position of the Tamnava Tertiary Basin; **B,** Geological settings of the Tamnava Tertiary Basin.

clays - composite 1), c) dark-carbonaceous (ceramic clays - composite 2) and d) lamellar, fatty and poor sandy (highly aluminous and ferrous clays - composite 3). Brick clays are for local use only, and are therefore not the subject of this study (DESPOTOVIĆ *et al.* 2006). All these are sediments composed of clay minerals (kaolinite, smectite clay, illite/hydromica) with variable contents of aggregates (phyllites, and slates), clastic grains (quartz, feldspars, mica, Fe-, and heavy minerals), and organic matter (coal) (RADOSAVLJEVIĆ *et al*. 1994).

Modern plants for preparation and technological homogenization of different ceramic clay, for crushing and micronization, and façade brick factory are located in the Donje Crniljevo open-pit ("Zorka-Opeka"), while the production of wall and floor ceramic tiles is situated in Šabac ("Zorka-Keramika"). All open-pits plants and factories operate within the Alas-Holding ad, from Novi Sad.

The decision for new investments in research in this part of the Tamnava Tertiary Basin was, first of all, good clay quality, reliable reserves, existing infrastructure and processing, as well as the ability to export raw materials of the highest quality and finished products. Accordingly, the geological characteristics of active deposits of ceramic clays, as well as mineralogical, physical, chemical and technological features of the investigated clay types (grey–white, dark-carbonaceous, and interspersed-lamellar aluminous and ferrous clays) were investigated in detail in this study.

Location and geology

The Savinian-Tamnava Tertiary Basin covers a wide area between the River Sava to the North, the Vlašić Mountain to the South–West and the Tamnava River to the South–East. The Tamnava Tertiary Basin, in the narrow sense, occupies the valley of the Tamnava River and the Savinian-Tamnava watershed area. The oldest sediments represent a foot wall to the younger sediments and simultaneously create the frame of the Basin, represented by the Palaeozoic sediments Devonian–Carboniferous–Permian, Fig. 1).

These are most often found at the North–East slopes of the Vlašić Mountain in numerous erosive trenches. According to VESELINOVIĆ (1955), residual fossil flora is found in the small-grained mica sandstones, indicating their Devonian–Carboniferous–Permian age. In this series of flysch character, the Permian and Triassic formations in the form of smaller erosive portions were discovered, composed of bituminized and marlous limestones.

Tertiary formations of the Tamnava Basin are represented by Miocene–Tortonian, Sarmat and various Mio–Pliocene sediments. These sedimentary bodies are widely spread in very thick layers. They are located in areas of the villages: Galović, Donje Crniljevo, Šabačka Kamenica, Kaona, *etc*. (Fig. 1), and represented by heterogeneous lithological members where various gravels, sands, and clays are dominant.

The clays of this Basin do not have defined stratigraphic positions, but they appear on different levels of the Mio–Pliocene series, with frequent and gradual transitions from fatty clays over clayey sands to quartz sands. Economically interesting occurrences and deposits of ceramic clays appear from 2 to 35 m in depth, while productive Mio–Pliocene series finishes with various sands, gravels and conglomerates.

There are no greater disturbances of clay masses in the tectonics of the Mio–Pliocene sediments of this area. Landslides, *i.e.*, gravity movements of various intensities, are rather frequent.

Lenticular occurrences of clays in different levels throughout the Mio–Pliocene series could be explained by frequent oscillations of Mio–Pliocene waters, lifting and deepening of the Basin bed and precipitation of clastic sediments or fine pelitic clay materials. Erosion factors significantly contributed to the formation of today's outlook deposits in the Tamnava Tertiary Basin. Deposits of ceramic and brick clays were discovered in these sediments (Jovanović Brdo, Bele Vode, Stare Kuće, Burovica, Latkovac, Zbegovi, Kisela Voda, Brezaci, and Ramnava).

Ceramic clay deposits

The Jovanovića Brdo deposit is the largest, with characteristic grey–white ceramic clay, is mostly excavated. It is situated in the North–East slopes of the Vlašić Mountain at an elevation from 210 to 240 m. Within this deposit, exploitation of brick clays for local use only, as well as periodical exploitation of white-sandy, dark, and aluminous and ferrous ceramic clays, remains. Dark-carbonaceous clays interwoven with thin layers of coal (lignite, peat) were found only in this deposit (ĐURIŠIĆ *et al.* 1986; RADOSAVLJEVIĆ & MILIĆEVIĆ 1991; NIKOLIĆ 1998; FILIPOVIĆ-PETROVIĆ *et al.* 2008).

Above this deposit are quality brick clays, dark, and yellow–grey clays from 3 to 16 m in thickness. Depending on the configuration of the terrain, ceramic clays appear from 3 to 17 m in depth. Immediately beneath the ceramic clays, aluminous and ferrous clays with fine grained clayey sands are situated, representing below to the productive series. In the Bele Vode deposit, the layers are horizontal to sub-horizontal. Thus, in addition to other factors such as the spatial position of the deposit, hydrogeological characteristics, reserves and quality of clays provide all the conditions for a longer economic production of ceramic and brick clays. This deposit is the backbone of the current production for domestic and other producers of ceramic products.

The Stare Kuće deposit continues in the North part, as a logical extension of the already described Bele Vode deposit.

This deposit is composed of one lenticular layer gently sloping to the South–West. The deposit itself has the form of a horseshoe, of which the two legs end in the North, and the central part in the South. Above the ceramic clays are brick clays to a lesser extent, whereby most of it is gravely and sandy clays, unsuitable for façade bricks. Below the ceramic clays are quartz sands of different colours. Quality ceramic clays appear at a depth of 6–30 m, with a thickness of 1–10 m.

The Zbegovi deposit is lenticular, characterized by a somewhat longer strike axis and a shorter dip axis (Fig. 2). The central part is divided into two productive layers. In between these layers, clays with a similar mineral composition, but with an increased content of an iron component occur. Above, the clays are commonly gravely and sandy dark-red clays not suitable for the production of brick clays. Below the clays are yellow–red and grey–white clayey quartz sands, which without technological processing do not have the utility value for now. The thickness of the basic layer of grey–white ceramic clays ranges from 2 to 15 m at a depth of 0.5–20 m. There are no greater disturbances of horizontal layers in this deposit, which is characteristic for almost all deposits of the Tamnava Tertiary Basin.

Fig. 2. A view on the Zbegovi open pit, Donje Crniljevo (taken from the internal magazine "Alas Holding", No 3, 2007).

The localities Kisela Voda, Ramnava, and Brezaci are situated on the left bank of the Tamnava River to the South–East of Gornje Crniljevo village. According to up to date research data, it could be concluded that these deposits contain very interesting raw materials with an increased SiO_2 component in comparison to Al_2O_3 (DESPOTOVIĆ *et al.* 2006). Grey–white poor sandy clays appear beneath a thin layer of humus, and above, brick clays are at a depth from 2 to 35 m. Unlike the clays from Donje Crniljevo, they are characterised by an increased thickness (1–15 m) of grey–white sandy clays. These clays represent the raw material of the future for the ceramic industry (white façade bricks). The analyses of the obtained data of the chemical, physical, and mineralogical composition of the ceramic clays of the Tamnava Tertiary Basin clearly showed that these clays are of similar composition, as well as that the newly discovered deposits approach the standard quality of grey–white ceramic clays from the Jovanovića Brdo deposit.

Finally, all the ceramic clay deposits were discovered in the Mio–Pliocene sediments of the Tamnava Tertiary Basin along the easterly slopes of the Vlašić Mountain. These materials as transformational forms yielded different assortments of ceramics, bricks, and other clays, quartz sands, as well as all transitions between them (VELDE & MEUNIER 2008). During the ingression of Mio–Pliocene waters, feldspars and mica were transformed into clay minerals and precipitated into depressions along with gravely–sandy materials. Frequent uplifting and deepening of the basin bottom favoured the formation of characteristic lenticular bodies of ceramic clays.

Materials and methods of analysis

Three composite samples of raw materials from the active open pit mines Jovanovića Brdo, Bele Vode and Zbegovi were obtained. The composites were as follows: 1. grey–white poor sandy clays (Bele Vode and Zbegovi deposits); 2. dark-carbonaceous clays (Jovanovića Brdo deposit) 3. lamellar aluminous–ferrous clays (Jovanovića Brdo, Bele Vode and Zbegovi deposits). Composites of equal amounts from each deposit were taken by spot sampling.

Binocular studies were obtained using a Leitz Wetzlar stereo microscope, while microscopic analyses were realised on a Carl Zeiss, Jena, model JENAPOL-U polarisation microscope in transmitted light by the immersion method using xylene as an immersion liquid.

Chemical analyses were obtained by classical wet analytical methods: SiO_2, humidity and loss on ignition were determined gravimetrically; TiO_2, K_2O and Na_2O were determined by the AAS method after acid dissolution; Al_2O_3, Fe_2O_3, CaO and MgO were determined using AAS (AAS instrument Analyst 300) after acid dissolution and melting, (FILIPOVIĆ-PETROVIĆ *et al.* 2007).

Electron Probe Microanalyses (EPMA) and the observation of clay samples were performed on a JEOL JSM-6610LV scanning electron microscope (SEM) connected with an INCA energy-dispersion X-ray analysis unit; EDX analytical system (Faculty of Mining and Geology, University of Belgrade). An acceleration voltage of 20 kV was used. The samples were coated with gold (15 nm layer, density g/cm^3 19.32). The following standards and analytical lines were used: MgO (Mg K_α series), wollastonite (Ca K_α series), Al_2O_3 (Al K_α series), SiO_2 (Si K_α series), MAD-10 feldspar (K K_α series), Ti (Ti K_α series), Fe (Fe K_α series). The EDX detection limit amounts to $2\sigma \approx 0.3$ wt. %.

The XRD method was used to determine the mineral composition. The XRD patterns were obtained on a Philips PW-1710 automated diffractometer using a Cu tube operated at 40 kV and 30 mA. The instrument was equipped with a diffracted beam curved graphite monochromator and a Xe-filled proportional counter. The diffraction data were collected in 2θ Bragg angle range from 4 to 65°, counting for 1 s (qualitative identification) at every 0.02° step. The divergence and receiving slits were fixed at 1 and 0.1, respectively. All XRD measurements were performed at room temperature in a stationary sample holder.

Infrared (IR) absorption spectra were recorded on a Perkin-Elmer, model 377 spectrophotometer, using the KBr pellets technique in the wavelength range from 4000 to 400 cm^{-1}.

Thermal analysis (DTA/TGA) was performed under air atmosphere using a Netzsch STA-409EP instrument at heating rate of 10 C°/min. The cation exchange capacity (*CEC*) was determined by titration using Methylene Blue (FILIPOVIĆ-PETROVIĆ *et al.* 2008).

The ceramic-technological testing (basic technological parameters of raw materials) was obtained according to FILIPOVIĆ-PETROVIĆ *et al.* (2007).

Results and discussion

Raw ceramic clay composites had high SiO_2 contents, moderate Al_2O_3 contents, and low contents of other oxides (Table 1). The Fe_2O_3 contents varied; in the grey–white and dark composite clays, they were below 2 wt. %. EPMA of sample 3 (lamellar clay) were performed on red and white–yellow lamellae

Table 1. The comparative chemical analyses of the studied ceramic clay composites from the Tamnava Tertiary Basin (in wt%). Note: - not analyzed; 3a - red lamellae; 3b - yellow-white lamellae; * - average EDS analyses; n.d. not detected (< 0.40 wt%).

Ceramic clay composites	1	2	3	3a*	3b*
SiO_2	58.86	61.87	58.76	64.56	66.64
TiO_2	1.18	1.01	1.18	0.68	0.63
Al_2O_3	26.86	21.63	26.04	26.50	25.63
Fe_2O_3	1.69	1.17	2.47	2.71	2.17
CaO	0.61	1.05	0.65	n.d.	n.d.
MgO	0.61	0.46	0.61	1.01	0.86
Na_2O	0.12	0.07	0.11	n.d.	n.d.
K_2O	3.97	2.05	4.30	5.12	4.56
L.O.I.	6.08	10.67	5.85	–	–
Total	99.98	99.98	99.97		

(field analysis, 1.24 mm^2). The Fe_2O_3 content ranged from 2.53 to 2.92 (three analyses) in the red lamellae, while in the white–yellow lamellae, it was slightly lower, ranging from 1.99 to 2.37 wt. %. Minor deviations were noticed in the SiO_2, MgO and K_2O contents, while CaO and Na_2O were not detected (Table 1).

The grain size values were generally unique, and according to the distribution, the ceramic clays from the active deposits belong to poor sandy-powder clays. A results of a comparative analyses of grain size distribution of the three main ceramic clay composites, sand (<2–0.063 mm), powder (<0.063–0.011 mm) and clay (<0.011 mm), are shown in Figure 3.

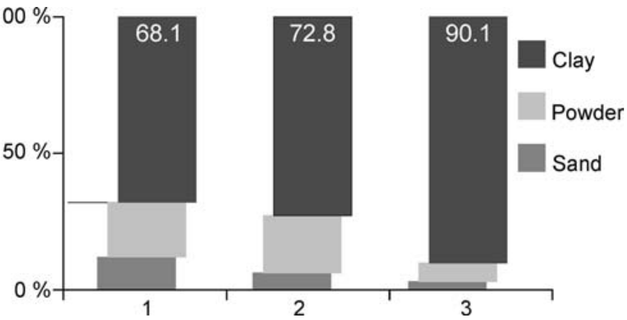

Fig. 3. The comparative grain size distribution of the main clay composites from the Tamnava Tertiary Basin (in wt%).

The mineralogical studies were concerned with the testing of the composite samples and fractions of sand, powder and clay using combined methods, *i.e.*, optical microscopy, XRD, IR, DTA/TGA and SEM.

According to the XRD method, the mineralogical composition was as follows: kaolinite, illite/hydromica, mica, quartz and feldspar. Illite/hydromica, mica and feldspars were not determined in the dark-carbonaceous ceramic clays (composite 2) because their contents were below the detection threshold. The presence of these minerals varies because small amounts were detected in previous research (FILIPOVIĆ-PETROVIĆ *et al.* 2008). Feldspars are connected to ceramic clays with lower amounts of kaolinite and higher amounts of illite/hydromica. The XRD patterns of raw ceramic clay composites are presented in Figure 4.

Comparing the three IR spectra in the range 3700–3600 cm^{-1}, no significant differences were observed incurred as a result of water in the layers. The IR-spectra show characteristic forms for kaolinite, which are in good agreement with literature data (KATO *et al.* 1981). Weak H_2O stretching vibrations near 3630 and 3640 cm^{-1} in composite 2 could correspond to montmorillonite (WORRAL 1986), but it was not enough to exclude other minerals with identical vibrations. These absorptions were assigned to water bound directly to cations and surface-bonded H_2O. The IR-spectra for the raw ceramic clay composites are shown in Figure 5.

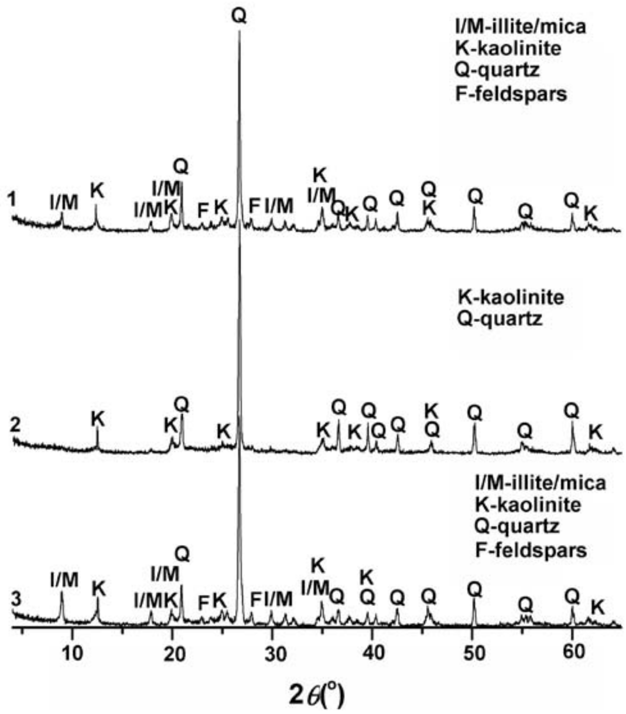

Fig. 4. The comparative XRD analyses of the main clay composites from the Tamnava Tertiary Basin.

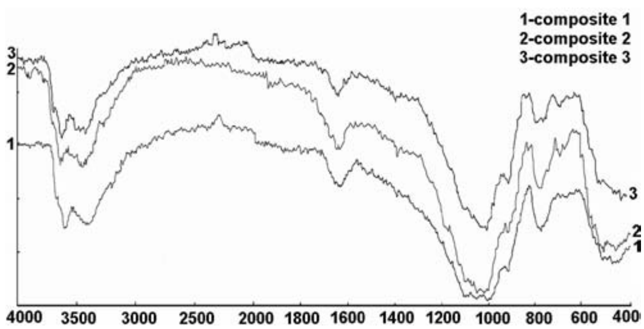

Fig. 5. The comparative IR spectra of the main clay composites from the Tamnava Tertiary Basin.

The DTA/TGA endothermic effects in the ranges of 83–106, 145–178, 535–540, and 886–924 °C correspond to clay minerals (illite/hydromica, kaolinite and smectite clays) accompanied by appropriate body losses. The first and second effects are related to loss of inter-layer water (dehydration) and the effect is caused by loss of structural water in form of OH^- group-constitution water (dehydroxylation). The fourth endo-effect is caused by the formation of the layer structure of clay minerals. The morphology of the first two peaks indicates to smectite clays (montmorillonite). The exothermic effects at 353 °C and 424 °C arise due to the combustion of organic matters at various temperatures (composite 2, Fig. 6). The exothermic effects in the range between 966 and 982 °C correspond to total decomposition of the clay minerals (kaolinite, illite/hydromica) and the beginning of a mullitization process (WORRAL 1986). The DTA/TGA results for the raw ceramic clay composites are presented in Figure 6.

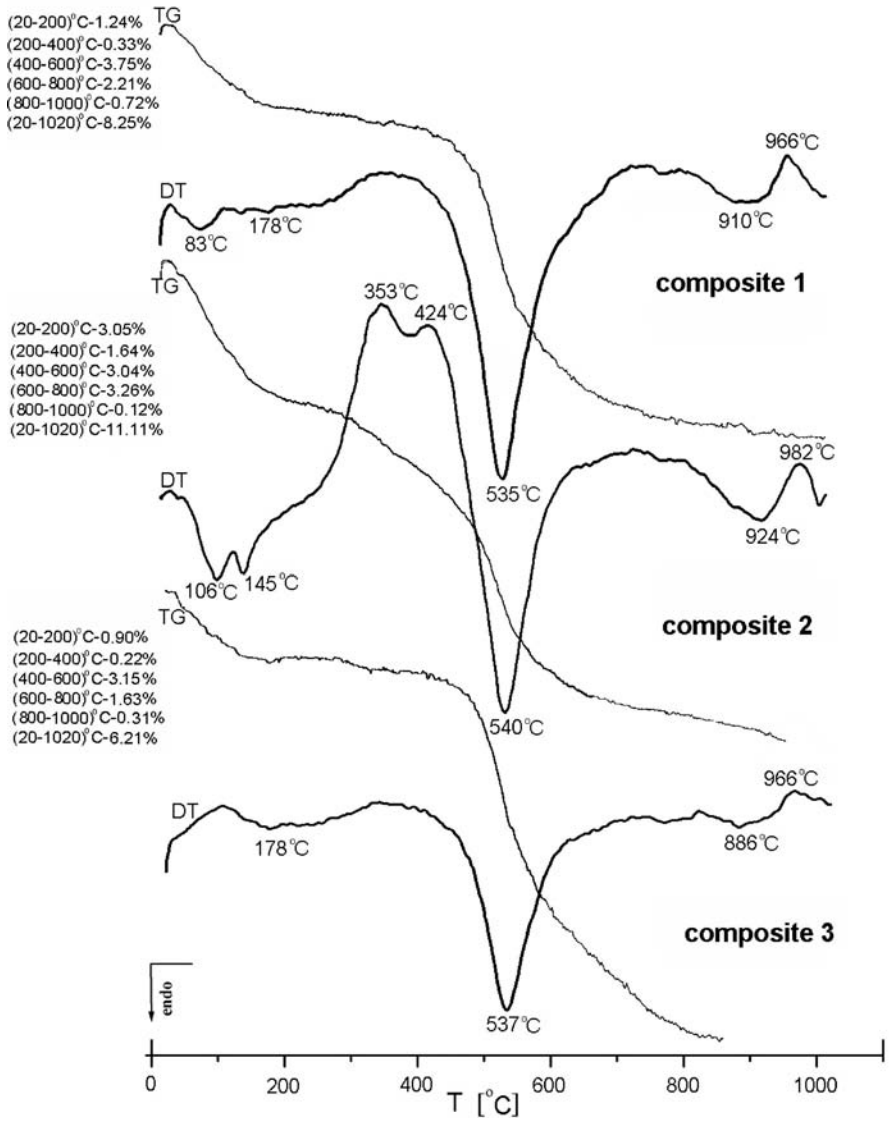

Fig. 6. The comparative DTA/TGA of the main clay composites from the Tamnava Tertiary Basin.

Optical photographs and SEM secondary electron images (SEI) of the ceramic clays composite samples are presented in Figure 7. The macroscopic appearances of all three composites are shown in Figures 7a–c, while SEI of the red and white–yellow lamellae of composite 3 are shown in Figures 7d–f and 7g–i, respectively.

Macroscopically, the grey–white poor sandy clays (composite 1) are compact-plastic semi-cohesive sediments, the textural appearances of which are monolithic (Fig. 7a). They are rather abrasive; hence, a large number of scratches caused by coarse grains could be observed on a glass surface.

Macroscopically, the dark-carbonaceous fatty clays (composite 2) are compact-plastic semi-cohesive sediments characterised by a layered or pseudo-breccia texture. They are composed of rhythmical light-grey, grey, dark to black layers with irregularly spaced inclusions of organic matter (Fig. 7b). Clay and coal lenticular layers are alternately replaced in the deposits, but their contact still remains unclear.

The lamellar aluminous–ferrous clays (composite 3) are highly plastic semi-cohesive sediments. Their textures are finely stratified with pseudo-paallel white, yellow, and red lamellae, which are alternately replaced without any regularity (Fig. 7c).

Mineralogical qualitative and semi-quantitative analyses were obtained using a stereo microscope, a polarised microscope and the XRD method. The samples were sieved in order to separate the grain size fractions. The >63 μm (sand) fractions were examined using stereo, and polarised microscopy, while –63+10 μm (powder), and –10+0 μm (clay) fractions were prepared for XRD analysis. Heavy minerals are separated from the light mineral fraction (<2.8 g/cm^3) by passing the >63 μm fractions through a separation column containing a heavy liquid (MORTON 1985). A fraction of the heavy mineral residue is mounted in Canada balsam and minerals identified using standard stereo and polarising microscopy.

Quartz, which was bright to milky white, rarely yellowish or black, was the most abundant mineral in the sand fraction in all three composites (up to 90 wt. %). Of other minerals, kaolinized feldspars, quartz–sericite sandstone aggregates, cherts, muscovite and sericite were also found in small amounts. Tourmaline, Ti-minerals, corundum, cordierite, and apatite were among the most frequent heavy minerals. This fraction rarely contained liberated Fe-minerals, but they quite often appeared as limonite–goethite coatings on quartz. Besides the clastic minerals, coal inclusions regularly appeared in the dark-carbonaceous clays.

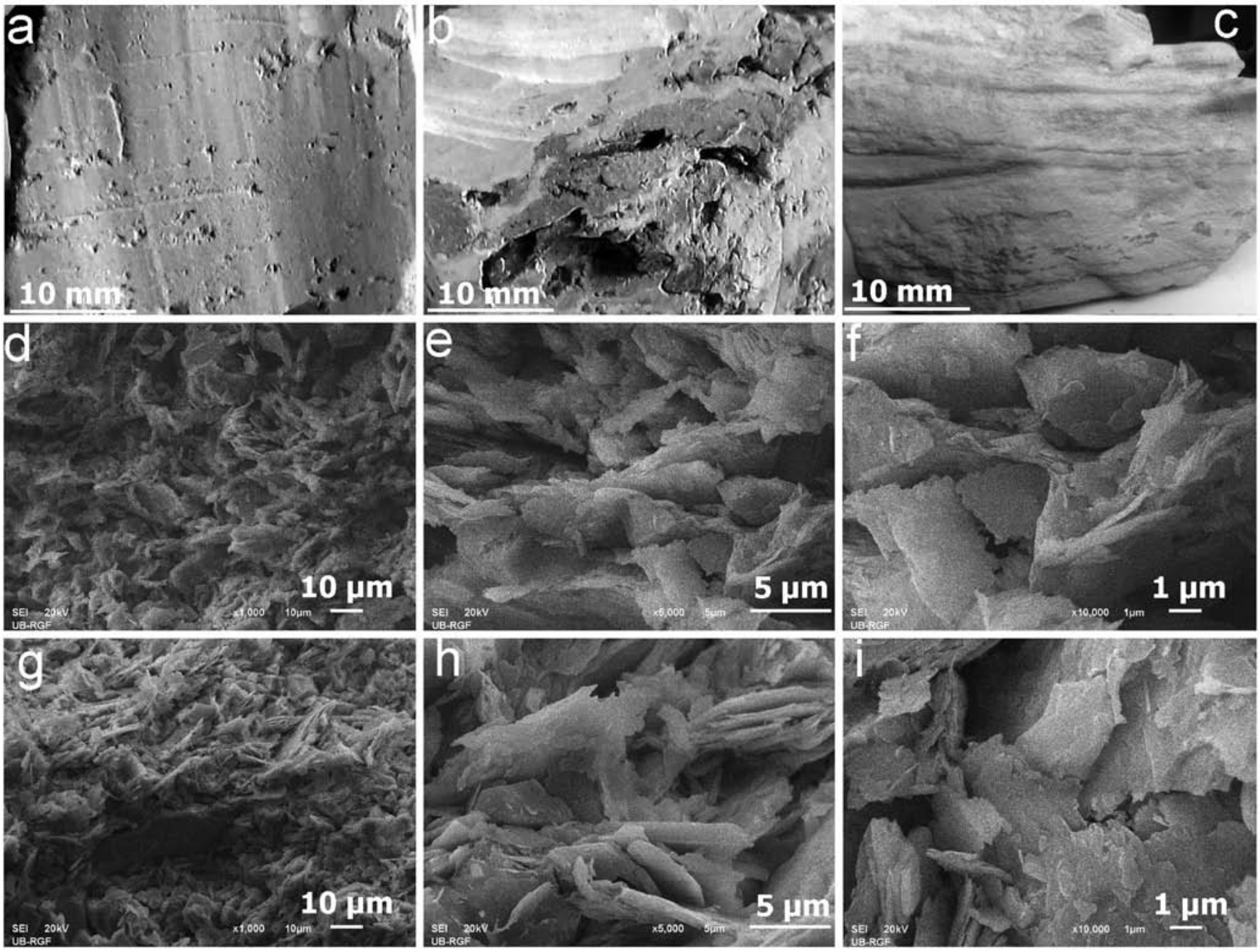

Fig. 7. The comparative optical microscopy microphotographs and SEI of studied clay composites: **a,** Macroscopic appearance of the grey-white poor sandy ceramic clay; **b,** Macroscopic appearance of the dark-carbonaceous ceramic clay; **c,** Macroscopic appearance of the lamellar aluminous and ferrous ceramic clay; **d-f,** Different magnifications of crystal aggregates of clay minerals in red lamellae (the sample in Figure 7c); **g-i,** Different magnifications of crystal aggregates of clay minerals in white-yellow lamellae (the sample in Figure 7c).

The mineralogical composition of the powder fraction was very similar to the previous fraction, differing in the abundance of sericite and illite/hydromica (up to ≈40 wt. %) compared to quartz.

Clay minerals appear habitually in “jaggy” plate-like forms without geometric regularity up to 30 μm^2. According to the SEM analyses, it is more than obvious that there were no differences in the clay habit between the white–yellow and red lamellae (Figs. 7d–f and 7g–i). In addition, liberated quartz grains were not observed in SEI, even though EMPA showed an increased content of SiO_2 compared to the classical quantitative chemical analysis (Table 1). Based on this phenomenon, it is possible to assume that most of the SiO_2 is in a form of submicronic silica dispersed with kaolinite–illite/hydromica flakes.

The kaolinite/illite ratio, which is generally around 1:1, varied, which could affect small differences in the basic technological parameters. Clay minerals are usually accompanied by quartz, amorphous silica and Fe-hydroxides. Depending on their content, Fe-hydroxides impart a yellow, ochre, red, or brown colour on the clay fraction. In the dark-carbonaceous clays, kaolinite is also the most abundant mineral, but the variable presence of smectite clays and illite/hydromica were also determined (Filipović-Petrović *et al.* 2008).

Ultimately, the general mineralogical composition of the raw composite sample was as follows: clay minerals (kaolinite, illite/hydromica and smectite clays), quartz, muscovite/sericite, altered alkali feldspars, heavy minerals (tourmaline, Ti-minerals, corundum, cordierite, and apatite) ± organic matter. This study confirmed that the ceramic clays from the active deposits belong to the kaolinite–illite/hydromica type, and are identical to the standard clay from the Jo-

Table 2. The comparative values of basic technological parameters of the main clay composites from the Tamnava Tertiary Basin.

Ceramic clay composites		1	2	3
Water for plastic processing, wt%		31.39	46.25	39.95
Plasticity index according to Pfefferkorn, wt%		35.32	47.15	41.55
Shrinkage drying, wt%		4.97	6.24	5.40
flexural strength, N/cm^2		242	373	170
Sintering area, °C		1079–1125	1045–1090	1014–1040
Refractoriness, SK		26	26/27	26
CEC **methylene blue, mmolM^+/100 g**		35	45	55
Characterization of firing process, °C	900	yellowish-creamy	grayish-white	reddish
	1.000	creamy	yellowish-creamy	dark red
	1.100	dark pink-creamy	dark yellow-creamy	**brownish-red**

vanovića Brdo deposit. Moreover, other deposits and occurrences from the Tamnava Tertiary Basin are of the same mineralogical composition.

According to the basic technological parameters, it could be concluded that the clays from the active deposits according to their characteristics belong to medium plastic clays with prolonged sintering time, which makes them suitable for the production of all types of ceramic tiles. The lamellar aluminous–ferrous clays could be used in part for the engobing of roof tiles (ERIĆ *et al.* 1989). The high ceramic clay refractory from the Tamnava Tertiary Basin is due to an increased content of quartz. According to the values of their refractoriness, these clays could be used in the production of some refractory products. Furthermore, the values obtained for the cation exchange capacity (*CEC*) suggest that these raw materials are suitable for further processing in activation processes. Their basic technological parameters are given in Table 2.

Conclusions

In the area of the western Tamnava Tertiary Basin, a large number of economically interesting ceramic clay deposits at a depth of 2–35 m were determined. The productive Miocene series finite with various sands, gravels, and conglomerates. The clays of this Basin do not have a specific stratigraphic place, but they occur in different levels of the Mio–Pliocene series with frequent gradual transitions from fatty clays over clayey sands to quartz sands. Kaolinite, illite/hydromica, and sometimes smectite clays are the most abundant clay minerals in the clay fraction.

According to the mineralogical, physical, chemical, and technological quality testing of the raw ceramic clay composites from the active deposits at Jovanovića Brdo, Bele Vode and Zbegovi, four types of clays were evidenced, i.e., red–yellow sandy–gravely (brick clays), grey–white poor sandy (ceramic and partly refractory clays), dark-carbonaceous (ceramic clays) and lamellar fatty, poor sandy (highly aluminous and ferrous clay).

The most important from the economic point of view are the grey–white (composite 1) clays, while the dark-carbonaceous (composite 2), and lamellar (composite 3) clays could be used independently or as a mixture of raw clays. According to analyses of the mineralogical composition data of the ceramic clays, it can be concluded that they differ from each other in grain size distribution (different ratios of sand, powder, and clay fractions) and in the contents of other minerals (quartz, smectite clays, Fe-minerals and organic matter). Finally, as all three types of ceramic clays from the Tamnava Tertiary Basin could be utilized for a wide range of non-metal materials, these deposits provide a full contribution for the further economic development of this part of SE Europe.

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Резиме

Керамичке глине западног дела тамнавског терцијарног басена, Србија: лежишта и типови глина

На подручју западног тамнавског терцијарног басена, утврђен је већи број лежишта керамичких глина у економски интересантним количинама, која се појављују на дубини од 2–35 m. Продуктивна миоценска серија завршава се различитим песковима, шљунковима и конгломератима. Глине овог басена немају одређено стратиграфско место већ се јављују у различитим нивоима миоплиоценске серије, са честим поступним прелазима од масних глина ка глиновитим песковима до кварцних пескова. Сочивасто појављивање глина у различитим нивоима миоценске серије може се објаснити, честим осцилацијама миоплиоценских вода, издизањем и продубљивањем дна басена, односно таложењем кластичних седимената.

На основу минералошких, физичких, хемијских и технолошких испитивања квалитета композита ровних керамичких глина са активних лежишта Јовановића Брдо, Беле Воде и Збегови издвојена су четири комерцијална типа глина: а) црвено-жуте песковито-шљунковите (опекарске глине); б) сиво-беле слабо песковите (керамичке и делом ватростални глине); ц) тамне угљевите (керамичке глине); д) прошаране (ламеларне), масне и слабо песковите (високо алуминозне и гвожђевите глине). Опекарске глине су за интерну употребу, а најважнија је сиво-песковите керамичка глина (композит 1). Тамне-угљевите масне (композит 2) и прошаране високо алуминозно-гвожђевите керамичке глине (композит 3), могу да се користе самостално или као део композитних ровних глина.

Анализом добијених података о минералошком саставу испитиванах керамичких глина лежишта тамнавског басена, може се закључити да су оне међусобно разликују у гранулометријском саставу (различити односи фракције песка, праха и глине) и садржавају примесе других минерала (кварц, смектитске глине, минерали гвожђа, органска материја). Сиво-беле слабо песковите керамичке глине са активних копова и нових налазишта су истоветне са стандардним квалитетом глина лежишта Јовановића Брдо. На крају, сва три типа керамичких глина из тамнавског терцијерног басена може се употребити за ширу прерађивачку индустрију неметала, те да ова лежишта пружају свој пуни допринос за даљи економски развој овог дела ЈИ Европе.