III. PETROPHYSICAL STUDY OF THE HANDMADE POTTERY

Gennadii M. Kovnurko

In terms of tectonics, the north-western Crimea belongs to the platform structure. Near the Bay of Yarylgach and Lake Ğarylgach lower chalky clays possessing high plasticity are bedded at a great depth. On the surface there are outcrops of Neogenic depositions of the Sarmatian, Maeotian, and Pontic layers. These are depositions of the shallow sea represented by interjacent clays, loams, sands, marls, and limestones. The composition and thickness of these sedimentaries vary. The Quaternary depositions here are of a lacustrine and marine origin and in terms of their lithological composition they are close to the Neogenic ones.

Three types of clay were used for making the pottery studied in thin sections (see Table 1):[1]

1) Fat clay in which admixtures of nonplastic are small or indiscernible, *e.g.* samples *A-6*, *A-12*, *A-2*.
2) Lean clay with powdered (aleurite/silt) admixture uniformly distributed throughout the fabric. The grains of the inclusion measure less than 0.05 mm, and are only slightly smoothed and rounded by water; in the fabric, particles of quartz-feldspar material prevail. The percentage of silt (aleurite) content varies continuously from one clay sample to another (*e.g.* samples *A-24*, *A-28, etc.*).
3) Carbonaceous (lime-containing) clay including admixtures of calcite, remains of foraminifera with calcite skeletons; examples are *e.g. A-32* and *A-35*.

The products of firing the clay minerals are a latent-crystalline mass, in thin sections of which minute micaceous minerals are discernible. In the sections there is a thin layer of a relatively transparent ceramic mass on the outer surface of the vessels; in this layer, iron compounds give oxidic trivalent forms through the action of the ambient oxygen, and the finely dispersed carbonaceous substance burns out. In the inner part of the vessel material there is not enough oxygen for these changes. Among the examples of bicoloured texture are samples *A-10*, *A-19*, and *A-28*. In samples *A-24*, *A-34*, and similar, the clay fabric appears spotted. This is possibly the effect of using finely interlaid clays of various compositions. In certain thin sections, *e.g. A-14*, brightening of the texture along latent cracks is noticeable.

The temper added to the paste has many peculiar features. By the aid of thin sections it is possible to study the mineral composition, the shape, and the size of separate particles of inclusions, as well as the extent to which they are rounded, and their relative content. The most common inclusions are various organogenic and oolitic limestones, shell fragments, fine-grained calcite, quartz and feldspar, potsherd, basalts, clinopyroxenes, basaltic hornblende. Fragments of argillite, aleurolite, and ore minerals are found much more rarely.

A number of samples in which potsherd is the main component of the temper was identified in the collection. By examining the samples tempered with potsherd under a microscope it was possible to identify two distinct groups in this type of pottery. In the first group, crushed potsherd made in the same workshop was used as grog: the composition of the grog is identical to that of the ceramic paste in which it is included (*A-12* and *A-13*). In the other group, ceramics differing in their clay and temper(s) from the actual fragments of vessels under examination had been subjected to crushing: an example is sample *A-27*. A further

group of pottery is represented by fabric containing sea sand, the latter being identifiable by the extent to which the grains are rounded. In almost all the thin sections investigated the rounding of the particles was poor or medium. Only in one thin section (Pl. 190, *1*) were ideally rounded particles of carbonate composition observed: namely, in sample *A-4*, where small regular spheres of carbonate composition formed through the decomposition of poorly aggregated oolitic limestone could be discerned; however, their roundness was not due to the action of water upon the particles. The grain size in most cases does not exceed 1.5-2.0 mm. Only in one or two of the samples (*A-1* and *A-28*) have particles 4-5 mm in diameter been discovered.

On the surface of several vessels the imprints of plants are fairly plainly visible. The feasibility of distinguishing burnt-out plants in thin sections depends on the orientation of the stalks relative to the plane of the section. The plant remains are easily discernible when the stalks are positioned at acute angles to the section plane (*A-15*; Pl. 190, *3*).

Of the great variety of physical properties, the water-absorption value, the density, and the magnetic susceptibility of the ceramics were chosen for determination. These properties were investigated using the samples of irregular shape and small size that remained after the preparation of thin sections. In determining density, the sequence of operations was as follows: (*a*) weighing of the samples in air, correct to within 0.01 g – m_c; (*b*) weighing of the samples in water, to the same degree of precision – m_b; (*c*) determination of the sample volume according to the formula: m_c-m_b; (*d*) calculation of the sample density: $p = m_c/(m_c\text{-}m_b)$.

The value of water absorption is an indirect indication of the hidden porosity of the ceramic material. In determining this quantity, the operations were carried out in the following sequence: (*a*) weighing of the samples in air, correct to within 0.01 g – m_c; (*b*) saturation of the samples with water over periods of 1, 3, 5, and 10 days; (*c*) weighing of the samples saturated with moisture at the expiration of each of these periods – m_b; (*d*) determination of the water absorption: $W_a = (m_b\text{-}m_c)/m_c$.

It should be noted that there was practically no difference between the water-absorption values corresponding to the 1-, 3-, 5-, and 10-day cycles, *i.e.* the full saturation of the samples with water was complete within the first twenty-four hours.

The measurements showed that the water-absorption values fluctuated within a very wide range – from 7.3% to 34.0%. The ceramic-material density was determined by two parameters: the density of the mineral skeleton of the ceramics and the value of inaccessible porosity. The samples with low density not exceeding 2.0 g/cm,^{3} were evidently characterised by high inaccessible porosity. The material of which the density exceeded 2.2 g/cm^3 had low latent porosity.

Magnetic susceptibility was measured with a kappameter. It was found that the minimum values did not exceed 6000 units SI, the maximum values being greater than 18000 units SI.

In order to develop a classification of the pottery samples, the results of the microscopical examinations were compared with physical properties of the samples. It has been stated that the low-density ceramic materials (samples *A-12*, *A-15*, *A-18*, and similar) contain numerous imprints of burnt-out plant matter. The addition of grass or straw to the paste probably caused a high inaccessible porosity, which in its turn resulted in the material being of low density.

For the collection examined it was not possible to determine any correlation between the magnetic susceptibility values and the features of composition and structure of the ceramic materials.

The water-absorption values showed a good correlation with the mineral composition of the clays and tempers.

A combined treatment of the various data pertaining to the composition of clays and tem-

Table 2. Pottery classification according to the clay and temper composition.

		Clay			Temper, %							
Group	Colour	Aleurite (silt), %	Dispersed calcite	Foraminifera	Potsherd	Limestone, shell fragments	Basalt and clinopyroxenes	Quartz + feldspars	Other	Rounding	Plant remains	Water-absorption value, %
1	brown biscuit	5	–	+	90-100	–	–	–	–	poor	numerous	20-25
2	brown, brownish-red, spotted, bicoloured	>5	±	±	40-60	60-40	–	–	–	poor	+	25-30
3	brownish-red	<5	+	±	–	80-90	–	<5	<5	medium, poor	+	<20
4	brown, yellowish-red, one-colour, bicoloured	>5	–	–	–	<20	up to 80	–	–	poor, medium.	single	<20
5	brown, brownish-red, one-colour, bicoloured	>5	–	–	–	<10	–	up to 85	<10	medium, poor	–	<20
6	brown-biscuit, red	<5	–	±	40-60	60-40	–	–	<5	poor	+	<20

pers and their physical properties enables us to single out several relatively uniform groups having, albeit, rather indistinct boundaries. For, in terms of their composition and properties, many of the ceramic samples occupy an intermediate place, while some possess unique individual characteristics.

The essential features assumed as the basis for dividing the material into groups are listed in Table 2. Table 3 gives the numbers of the samples possessing the properties most characteristic for each group, and in the same table are also listed those samples close to one or other of the 'typical' groups but possessing certain individual peculiarities.

The percentage of temper was determined in the thin sections visually: therefore the quantitative characteristics presented in the table are approximate. In the 'Other' column the content of minerals and rocks that are found in single thin sections is noted, *i.e.* fragments of argillite, aleurolite, *etc.* The content of nonplastic (aleurite + temper) varies in the range 30-40%, and is not indicated in the table. Only in two samples (*A-5*, *A-26*) does the amount of temper reach 45%. The contents of individual temper components listed in Tables 1 and 2 are rounded down, so as to give an aggregate of 100%. A precise evaluation of the amount of plant remains was not possible.

Table 3. Distribution of pottery samples according to petrographic groups.

Group nos.	Typical samples	Close in composition	Notes
1	***A-8***, ***A-12***, ***A-13***, ***A-15***, ***A-27***	***A-3***, ***A-19***, ***A-24***, ***A-28***	***A-3*** may be included into group 6
2	***A-9***, ***A-22***, ***A-34***		
3	***A-6***, ***A-7***, ***A-16***, ***A-26***, ***A-30***	***A-4***, ***A-18***	
4	***A-1***, ***A-32***, ***A-33***, ***A-35***	***A-10***, ***A-14***	
5	***A-2***, ***A-5***, ***A-31***		
6	***A-19***, ***A-20***, ***A-23***, ***A-25***	***A-11***, ***A-28***	***A-23*** and ***A-25*** are close to group 1

A brief description of thin sections by group is presented below.

GROUP 1

The ceramic material in thin sections is brown biscuit; the fired clay is semi-transparent, and slightly birefringent. The inclusion of aleurite (silt) is insignificant – the clay is fat. There is no finely dispersed calcite in the clay. Foraminifera are present in varying quantities.

The distinctive feature of this group is the use of potsherd as temper. Particles of the potsherd usually have acute-angled or elongated contours and reach 2.5 mm in size. In thin section *A-13* fine single crystals of calcite were found. In thin sections *A-12* and *A-13* the potsherd clay does not differ in composition from the clay to which it had been added. In thin section *A-27*, however, the potsherd composition does vary: some of its particles include single grains of clinopyroxenes.

Another characteristic feature of this group of pottery is a considerable number of imprints of plant additives. When plants burn out during firing, formation of pores occurs; the latter look dark and semi-transparent under a microscope as they evidently contain fine-grained carbon. In thin section *A-7* the clay is similar to that of *A-12*, *A-13*, and *A-27*, but besides potsherd the clay also contains coarse grains of oolitic limestone. In thin section *A-28* the fabric is of a reddish shade and contains a slightly greater quantity of aleurite (silt). As in *A-3*, the ceramic material includes fragmented grains of limestone (*i.e.* these two samples may be included in group 6). Another characteristic peculiarity of this group is the fact that water absorption varies within the narrow range 20-25%.

GROUP 2

The ceramic material in this group is irregularly coloured in brown and brownish red shades. The fabric contains minute particles of calcite. In thin sections, coarse pores are visible, around which a reaction border is discernible (Pl. 190, *4-5*), the result of the calcite dissociating during firing (*A-9*, *A-22*). The fine calcite particles were formed through regeneration after firing. The dissociation of calcite with formation of calcium oxide and carbon dioxide

begins at 800°C and may be used in thermometry. A very high water-absorption value is a characteristic peculiarity of this group.

Besides the dissociated and regenerated carbonate, the ceramic material of this group contains potsherd and traces of burnt-out plant additives. Possibly, directly before modelling of the vessels, dry clay was added to the paste.

GROUP 3

In thin sections of this group of ceramics the material is yellowish red or brownish red. The latently-crystalline mass is birefringent owing to the presence of minute grains of lamellar silicates. The content of aleurite is not great. In the composition of the temper, grains of limestone and crushed shells prevail. The limestone is represented by various structural modifications: oolitic, organogenic, *etc.* The rounding of the grains is medium, more rarely poor, which indicates the use of limestone sand along with crushed limestone. Sand grains of 0.5 to 1.5 mm in size prevail; however, particles up to 3.0 mm in diameter are also encountered.

In some samples the temper content reaches 40-45%. Along with carbonate rock particles the temper includes occasional grains of quartz and aleurite particles. The presence of potsherd is not a feature of this group. In a number of samples, imprints of burnt-out plants are visible. The addition of latently-crystalline calcite uniformly distributed throughout the paste is discernible in *A-18*.

GROUP 4

This group includes brown and yellowish red ceramics. Mainly lean clays were used for producing the vessels. A characteristic peculiarity of this type of ceramic is the presence in the temper of basalt and minerals of magmatogenic origin: *viz.* augite, basaltic hornblende, zonal plagioclase. Having been formed during the middle Jurassic period as a result of underwater eruptions, volcanic rocks in the Crimea are found in certain isolated areas along the Main Ridge between the Baidar Gates and Kara Dag. The thickness of these rock layers reaches some hundreds of metres; intrusive massifs are located in the zone to the west of Alushta. The mechanical weathering of the magmatic formations led to the build-up of alluvial and proluvial deposits at a short distance from the Main Ridge, and it is probable that these deposits included the minerals mentioned above. Poor rounding of the grains found in the ceramics under examination indicates that the products of weathering were not carried any great distance.

Thin sections *A-32* and *A-35*, containing dispersed carbonate mineral, are very similar in their clay composition. The other samples have individual peculiarities. Besides basalt and augite, the ceramic material of this group includes, among other rocks, quartz, aleurolite, and limestone. Plant remains have been found only in *A-14*.

GROUP 5

The ceramic material is brown and brownish red, and made of lean clay. A characteristic feature of this group is the prevailing content of quartz and feldspar particles in the temper, amounting to 65-85% by volume of the artificial additive. Beside these minerals, particles of limestone, aleurolite, and sparse grains of basalt are also encountered. Traces of burnt-out plants are not a feature of this group.

GROUP 6

The clay is brownish red or brown, the latter type being characterised by a smaller content of aleurite (silt). A special feature of this group is the presence of approximately equal quantities of potsherd and limestone particles in the temper. In terms of its clay properties and temper composition this material is close to group 1.

The petrophysical characteristics of two of the collection samples (*A-17* and *A-29*) being unique to themselves, it was not possible to include these samples in any of the groups 1-6. The fabric of sample *A-17* is composed of a non-homogeneous clay. In thin section the clay is chocolate-brown. A semi-transparent birefringent mass is connected by a gradual transition to a dark brown and almost opaque isotropic clayey material. Both clay varieties contain much powdered (aleuritic) inclusion of quartz-feldspar type. The lean clay includes single grains of limestone of medium rounding. In *A-29* the basis of the fabric is a sandy clay. The natural admixture includes particles of quartz, feldspars, and limestone. The nonplastic is uniformly distributed throughout the ceramic volume. Along with the natural nonplastic are found coarse grains of limestone. The size of some fragments exceeds 4.0 mm; the rounding is medium.

NOTE

1. All samples were chosen by V.F. Stolba.

Table 1a.

		Clay			Temper, %									
Thin section nos.	Colour	Aleurite (silt), %	Dispersed calcite	Foraminifera	Potsherd	Limestone	Shell fragments	Basalt and clinopyroxenes	Quartz + feldspars	Other	Rounding	Plant remains	Homogeneity	**Notes**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Brown two-coloured	5	-	-	-	-	-	70	10–15	~5	poor	-	good	
2	Brown two-coloured	<5	-	-	-	5	single	-	80	10–15 ore aleurite	medium, poor	-	good	
3	Brown biscuit two-coloured	5–10	+	-	65–70	20–25	-	-	-	~5	poor	rare	medium	
4	Brown one-coloured	<5	-	-	-	95	-	-	-	~5	good	-	good	oolite limestone
5	Reddish-brown two-coloured	<5	-	-	-	20	single	single	70	10 ore aleurite	medium, poor	-	good	
6	Brown-red one-coloured	<5	-	-	single	10-15	70-75	-	10-15	~5	medium, poor	-	good	
7	Brown-red one-coloured	<5	-	-	-	45-50	~35	-	<10	~5	medium	-	good	
8	Brown one-coloured	5-10	-	single	80	-	-	5-10	-	~5	poor	-	medium	
9	Brown one-coloured	5-10	-	5-10	40-45	35-40	-	-	10-15	~5	poor	-	poor	dissociated limestone

Table 1b.

Thin section nos.	Clay: Colour	Clay: Aleurite (silt), %	Clay: Dispersed calcite	Clay: Foraminifera	Temper, %: Potsherd	Temper, %: Lime stone	Temper, %: Shell fragments	Temper, %: Basalt and clinopyroxenes	Temper, %: Quartz + feldspars	Temper, %: Other	Temper, %: Rounding	Temper, %: Plant remains	Homogeneity	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10	Spotty two-coloured	>5	-	-	-	20-25	~10	~10	~10	40 aleurite	poor	-	poor	fragments of basalt and pyroxene in aleurite
11	Brown-yellow spotty	>5	-	-	single	45-50	-	-	~10	30-35	poor	single	poor	possibly two clays: lean and sandy
12	Brown biscuit one-coloured	<5	-	numerous	95	-	-	-	-	-	poor	numerous	good	potsherd same as main clay
13	Brown biscuit one-coloured	<5	-	+	95	single	-	-	-	-	poor	+	good	same composition of potsherd and main clay
14	Brown biscuit inhomogeneous along the cracks	>5	-	-	?	-	-	+	-	?	poor	single	poor	indiscernible if it is potsherd or aleurite
15	Brown biscuit one-coloured	<5	-	-	70-75	-	-	single	-	-	poor	numerous	medium	
16	Light-beige inhomogenous	>5	?	-	?	>80	single	-	-	-	poor	?	medium	

Table 1c.

Thin section nos.	Clay: Colour	Clay: Aleurite (silt), %	Clay: Dispersed calcite	Clay: Foraminifera	Temper, %: Potsherd	Temper, %: Limestone	Temper, %: Shell fragments	Temper, %: Basalt and clinopyroxenes	Temper, %: Quartz + feldspars	Temper, %: Other	Temper, %: Rounding	Temper, %: Plant remains	Temper, %: Homogeneity	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
17	Brown brightened along the cracks	>5	?	-	-	single coarse	-	-	-	-	medium	-	poor	
18	Red-brown one-coloured	>5	+	?	-	single coarse	?	-	-	-	medium, poor	single	poor	carbonaceous clay
19	Brown semi-transparent spotted	>5	-	+	45-55	55-45	?	-	-	-	medium, poor	+	poor	
20	Brown biscuit semi-transparent	>5	-	-	40-45	50-55	?	single	-	~5	poor	+	poor	
21														
22	Reddish-brown spotted	<5	+	numerous	50-55	10-15	?	-	-	-	poor	-	poor	
23	Brown biscuit one-coloured	>5	-	-	50-55	40-45	-	-	-	-	poor	?	poor	
24	Brown biscuit spotted	>>10	-	-	50	single coarse	-	-	-	-	poor	-	poor	
25	Brown biscuit one-coloured	~5	-	numerous	45-40	55-60 oolites	-	-	-	-	poor	numerous	poor	
26	Red-brown one-coloured	~5	-	-	single	60-65	35-30	-	-	5	medium, poor	single	medium	
27	Brown biscuit one-coloured	<5	-	+	85-90	single	-	-	-	5-10	poor	numerous	medium	

Table 1d.

Thin section nos.	Clay: Colour	Clay: Aleurite (silt), %	Clay: Dispersed calcite	Clay: Foraminifera	Temper, %: Potsherd	Temper, %: Limestone	Temper, %: Shell fragments	Temper, %: Basalt and clinopyroxenes	Temper, %: Quartz + feldspars	Temper, %: Other	Temper, %: Rounding	Temper, %: Plant remains	Temper, %: Homogeneity	Notes
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
28	Red-brown two-coloured	>5	-	-	40-45	45-50	single	-	-	~5	poor	?	poor	
29	Red-brown two-coloured	>>5	-	-	-	85-90	-	-	-	~5	medium, poor	+	poor	loam
30	Beige inhomogeneous	>5	-	-	-	45-50	50-45	-	-	~5	medium, poor	+	poor	
31	Brown	>5	-	+	Single	20-25	15-20	-	50-55	5-10	medium, poor	-	medium	
32	Red-brown two-coloured	~5	-	-	-	-	-	50-55	15-20	10-15	medium, poor	-	medium	
33	Red-brown two-coloured	>5	-	-	-	-	-	5-10	80-85	5-10	medium, poor	-	medium	
34	Red-brown spotted	>5	-	-	20-25	60-65	-	-	-	-	medium, poor	-	poor	
35	Brown inhomogeneous	~5	-	-	?	10-15	-	60-65	~5	10-15	medium, poor	?	poor	