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Archaeometrical analysis of Neolithic pottery from the Divača region, Slovenia

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ABSTRACT – *The results of the mineralogical and chemical analyses of pottery from the Neolithic period from the Divača region are presented. Pottery samples from two rock shelters, i.e. Mala Triglavca and Trhlovca, were included in the analyses, as well as sediment samples from other rock shelters, caves and rivers around this area. The mineralogical and chemical composition of the ceramic is uniform in most of the samples; the differences between the clay pastes of the vessels are in the use of a tempering material, mostly calcite grains. The sediment samples, especially from the cave deposits, point to a local production of the Neolithic pottery on the Karst plateau.*

IZVLEČEK – *Arheometrične analize neolitske keramike iz področja Divače. Predstavljeni so rezultati mineraloških in kemijskih analiz neolitske keramike iz okolice Divače na Krasu. V analizo so bili vključeni vzorci keramike iz dveh spodmolov, Male Triglavce in Trhlovce, pa tudi vzorci jamskih in rečnih sedimentov iz bližnje okolice arheoloških najdišč. Mineraloška in kemijska sestava keramike je enotna v skoraj vseh vzorcih; glavne razlike pa se pojavijo v tehnologiji neolitskih lončarjev, ki so naravni glineni masi dodajali mineralna zrna, predvsem kalcitna zrna ali sigo. Analiza sedimentov iz jamskih najdišč pa kaže na lokalen izvor naravne glinene mase na Krasu.*

KEY WORDS – *mineralogy; Neolithic; pottery; provenience studies; transhumance*

INTRODUCTION

Although investigations of the mineralogy and chemistry of pottery and other materials in archaeology are widely used (*Rice 1987; Shepard 1965; Spataro 1999; 2002*), they have not been extensively applied to the study of pottery technology in Slovenia (*Osterc 1975; 1986; Zupančič and Bole 1997*). These studies, although also carried out on samples of Neolithic pottery, have never reached beyond the mere technological aspect of the results. This paper will show that such applications are not just essential for the study of technology, but useful also in the study of social structures in the Neolithic period and the palae-oeconomy in the region.

Pottery samples of the Neolithic and Eneolithic period from two cave sites near Divača in the south west part of Slovenia, located on the Karst plateau, were used for the archaeometrical studies in the present paper. The pottery of the Neolithic period was attributed to the Danilo culture, originating in the eastern Adriatic, according to J. Korošec (*1960*), Š. Batović (*1973; 1979*) and F. Leben (*1973*). Similar assemblages in the Triestine Karst in Italy, on the other hand, are usually ascribed to the so-called Vlaška group, which was first described by L. H. Barfield (*1972; 1999*), and is still used as a description for certain pottery types in Italian archaeology (*Gilli and Montagnari Koklej 1993; 1994; Montagnari Kokelj 2001*). These vessels are predominantly found in caves all along the Karst plateau, mostly on the Italian side of the border, in the Triestine Karst region. Nevertheless, this group has many similarities with the middle Neolithic Danilo culture on the Dalmatian coast. The samples from the Eneolithic period were selected for comparison with the Neolithic pottery.

As a first, step all the pottery fragments were analysed on a macroscopic level in order to describe the potsherds according to their technological and typological properties. Within this range of information, samples for a detailed mineralogical description and analysis were selected. The samples were chosen according to their technological groups, their stratigraphic position, and their typological and cultural properties. For a first provenience study, some samples of clays and sediments around the two archaeological sites were also sampled and analysed.

THE ARCHAEOLOGICAL SITES

The rock shelters at Mala Triglavca and Trhlovca, sited only one kilometre apart, are located on the Karst plateau near the town Divača (Fig. 1). The caves were excavated from the mid-1970's to the mid-1980's by the Ljubljana Institute for Archaeology under the supervision of Dr. France Leben. In both caves there was a long stratigraphic sequence of layers dating from the Neolithic to the Modern Era; in Mala Triglavca there were also layers containing archaeological finds dating to the Mesolithic (*Leben 1988*). The principles of arbitrary excavation were employed, and all the material remains were documented in this context; in Mala Triglavca the finds are attributed to horizontal sections[1] and in Trhlovca as layers. The Neolithic layers[2] included pottery, various bone and stone artefacts, and numerous animal bones, both wild and domestic species. Wild animals yielded the majority of bones: stag, wild boar, and brown bear; among the domestic species were many sheep, goat, cattle and dog bones (*Budja 1995; 1996; 2001; Leben 1967; 1988; Petru 1997; Pohar 1990*). The pottery assemblage from the Neolithic and Eneolithic layers is quite modest, since only 690 fragments were found in Mala Triglavca and 785 potsherds from Trhlovca[3]. The assemblage included some typical ceramic vessels of the Neolithic period in this region, including bowls ornamented with triangles and tulip shaped cups (*Dacar 1999; Tomaž 1999.18–57; Žibrat 2002*). A *rhyton* fragment has been excavated at Mala Triglavca that has similarities with the rhyta of the Danilo culture on the Dalmatian Coast (*Žibrat 2002.t.19:8*), as well as a potsherd ornamented with barbotine, a decorating technique traditionally attributed to the Starčevo culture in the central Balkans (*Dacar 1999. t.18:1; Žibrat 2002.t.6:7, t.12:4*).

METHODOLOGY

The macroscopic observation

We observed three main groups of ceramic matrixes on the macroscopic level (as described by *Horvat 1999*)[4] at Mala Triglavca. The group with calcium carbonate is by far the most abundant, since 78.3% of all the samples from the Neolithic and Eneolithic period belong to this group. The group with calcium carbonate and quartz was 18.9%, and the group with quartz only 2.7% of the total assemblage that is of the 690 potsherds analysed. In the oldest Neolithic layer all the samples (i.e. 215 fragments) belong to the group with calcium carbonate. In the second Neolithic layer the group with calcium carbonate comprised 97.6%, and the group with calcium carbonate and quartz 2.4% (of 329 potsherds from this layer). The group with quartz, but no calcium carbonate, comprised 0.7%, and for the first time appears in the Eneolithic layer; the group with calcium carbonate nevertheless still predominates, with 94.5% from a total of 146 potsherds (*Žibrat 2002.sl. 8–9, 14–17, 60*).

At Trhlovca most of the potsherd from Neolithic layers H and G also belong to the group with calcium carbonate (98.5% from 68 fragments from layer H, and 98.5% from 212 fragments from layer G). The group with quartz and calcium carbonate is represented by 1.5% each in layer H and G. The vessels from the younger layer, F, also contain calcium carbonate, but in a smaller part of the assemblage

1 The assemblage from Mala Triglavca is especially problematic since the material from some of the horizontal planums is evidently mixed (*Žibrat 2002.68–73*).

2 In Mala Triglavca the oldest Neolithic layer includes the horizontal planums 3,05–3,25m/2,90–3,25m; the second Neolithic layer includes planums 2,70–3,00m/2,70–2,90m/2,75–2,90m and the Eneolithic layer includes planums 2,70m/2,60–2,75m (*Žibrat 2002.60–61*). In Trhlovca the layers H, G and F are all Neolithic layers, only layer F has material with similarities to the Eneolithic layer E at this site (*Tomaž 1999.47–50*) (Tab. 1).

3 The pottery assemblage from both cave sites has been already sorted by the excavation team in the 1980's, mostly according to known typological finds. Therefore we must stress that all the later analyses on pottery were done on a smaller sample than originally excavated.

4 The technological description on the macroscopic level included the presence of mineral and organic inclusions, their size and frequency in the vessels, but also the surface treatment, hardness, colour and the firing methods and atmosphere (*Horvat 1999. 159–161*).

(79.6% from a total of 505 fragments). A higher percentage of potsherds, i.e. 19.2%, were attributed to the group with quartz and calcium carbonate on the macroscopic level in this layer. The group with quartz inclusions was 1.2%, and appears for the first time in layer F (*Tomaž 1999. 26, sl. 9*).

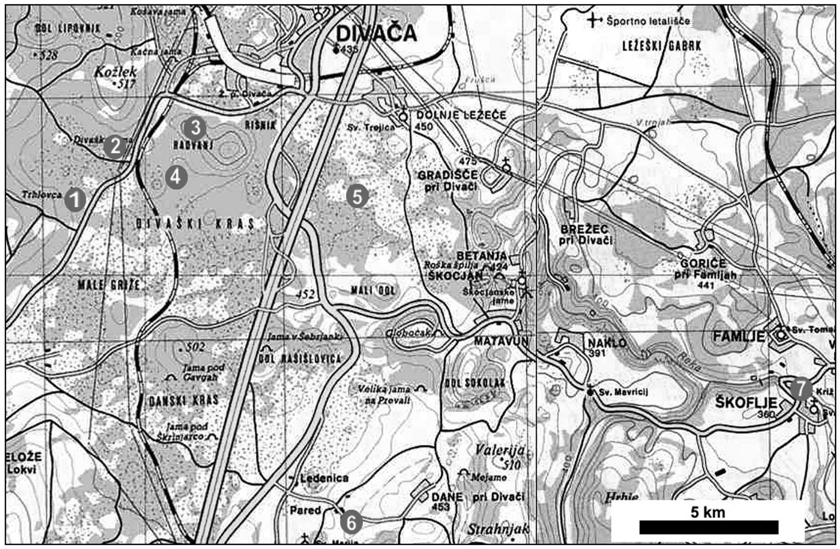

Fig. 1. Locations of the archaeological sites and the locations of the sediment samples: 1 – Trhlovca; 2 – Divaška jama; 3 – dolina Radvanj; 4 – Mala Triglavca; 5 – Lipove doline; 6 – Pared near Dane; 7 – Škoflje (river Reka).

In the pottery assemblages from both rock shelters the group with calcium carbonate inclusions predominates according to results of macroscopic observation. Only in layer F from Trhlovca does the percentage of such potsherds drop to below 90%. The group with quartz and calcium carbonate was approximately 2% at both sites, but increases in layer F in Trhlovca to 20%. This group appears only in the second Neolithic layer in Mala Triglavca, but is not present in the oldest layer. The group with quartz inclusions appears in the Eneolithic layer at Mala Triglavca and in layer F at Trhlovca for the first time, but forms only some 1% of the total assemblage in these layers.

Sampling

We analysed 43 pottery samples from both rock shelters (24 from Mala Triglavca and 19 from Trhlovca cave) (Tab. 1) and 6 sediment samples from different locations in the microregion (the site catchment analysis was carried out within a radius of 5 km) (Fig. 1). One of the sediment samples was taken directly from the archaeological layer at Trhlovca, the other from Divačka jama and two samples were taken from denuded caves[5] called Radvanj, near the Mala Triglavca rock shelter, and Lipove doline. Also, two alluvial samples were taken from a stream, Globoki potok near the village of Dane and another from the River Reka near Škoflje (Tab. 4). Pottery samples were chosen from the macroscopic observations, on the basis of their stratigraphic position, the typology of the vessels, and their cultural relevance (Fig. 2). The sediments were gathered according to their proximity to the archaeological sites in question, their workability (high clay content) and origin. Only the alluvial sediments failed to meet the workability criterion, since they were mainly composed of quartz sand.

The analyses

Various methods of analysis were used for the determination of minerals in the pottery and sediment samples. The mineralogical composition was determined by means of optical microscopy, X-ray powder diffraction, and scanning electron microscopy. The pottery and sediment samples were analysed for their chemical composition with the inductively coupled plasma optical emission spectrometry (ICP-OES) method (*Bishop et al. 1982; Nölte 2003*) in the ACME Laboratory in Vancouver, Canada.

The optical mineralogy and X-ray powder diffraction techniques applied at the Department of Geology in Ljubljana. For the optical microscopy we used samples, prepared as polished thin sections, which are useful for the identification of different kinds of minerals and other grains in pottery, their abundance and associations, particle orientation, void size, shapes and locations, surface treatments, and alterations due to firing or post-depositional factors. One of the more useful characterizations was granulometry and heavy mineral analysis (*Barić and Tajder 1967; Grimshaw 1971; Rice 1987.348–350; Whitbread*

5 Caves, in which denudation had removed their upper parts, yet are recognized as caves due to the typical sediments they contained and other features. There are three types of relief features controlled by denudation of rocks above the caves. One of the types are roofless caves, that present a longer section of passages and have been filled by flowstone and allochthonous fluvial sediments that have been deposited in a cave environment (*Mihevc, Slabe and Šebela 1998.167–170; Mihevc 2001.15–41*).

1986). With this method we could determine the mineralogical composition of pottery, distinguish between clay pastes and temper, discover secondary minerals, and estimate the firing temperature. We also analysed the sediments with optical mineralogy, although we could only observe individual grains under the microscope. Smaller particles of the sediment samples were sieved out (i.e. particles smaller than 0.063mm or 630μm).

With the X-ray powder diffraction technique we analysed the bulk mineralogical composition of the pot-

SAMPLES	YEAR OF SAMPLING	THIN SECTION NUM.	SITE	LAYERS	DESCRIPTION
1	2003	1	Mala Triglavca	3,05-3,25m	the wall of the vessel
2	2003	2	Mala Triglavca	3,05-3,25m	the wall of the vessel
3	2003	3	Mala Triglavca	2,70-2,90m	the wall of the vessel
4	2003	4	Mala Triglavca	2,70-3,00m	the wall of the vessel
5	2003	5	Mala Triglavca	2,75-2,90m	piece of plain rim with wall
6	2003	6	Mala Triglavca	2,70m	piece of rim with wall
13	2000	15	Mala Triglavca	3,05-3,25m	the wall of the vessel
14	2000	13	Mala Triglavca	2,70-3,00m	the wall of the vessel
15	2000	3	Mala Triglavca	2,70-3,00m	handle
16	2000	5	Mala Triglavca	2,70-3,00m	the wall of the vessel
17	2000	10	Mala Triglavca	2,75-2,90m	the wall of the vessel
18	2000	14	Mala Triglavca	2,70-2,90m	the wall of the vessel
19	2000	11	Mala Triglavca	2,70-2,90m	the wall of the vessel
20	2000	4	Mala Triglavca	2,90-3,05m	the wall of the vessel
20	2003	144	Mala Triglavca	2,90m	the wall of the vessel
21	2000	16	Mala Triglavca	2,75-2,90m	the wall of the vessel
22	2000	9	Mala Triglavca	2,90-3,05m	bowl
22	2003	119	Mala Triglavca	2,90-3,05m	the wall of the vessel
23	2000	7	Mala Triglavca	2,70m	piece of rim with wall
23	2003	68	Mala Triglavca	2,90-3,05m	plate
24	2000	1	Mala Triglavca	2,90-3,05m	the wall of the vessel
24	2003	148	Mala Triglavca	2,70-3,00m	handle
25	2003	153	Mala Triglavca	2,70-3,00m	piece of plain rim with wall
29	2003	374	Mala Triglavca	2,60-2,75m	piece of base with wall
1	2000	28	Trhlovca	H	the wall of the vessel
2	2000	26	Trhlovca	H	the wall of the vessel
3	2000	27	Trhlovca	H	the wall of the vessel
4	2000	29	Trhlovca	F,3,4	footed bowl
5	2000	30	Trhlovca	G	the wall of the vessel
6	2000	18	Trhlovca	G	the wall of the vessel
7	2003	7	Trhlovca	G	the wall of the vessel
8	2000	24	Trhlovca	G	the wall of the vessel
8	2003	8	Trhlovca	G	pot
9	2000	25	Trhlovca	H	the wall of the vessel
9	2003	9	Trhlovca	G	the wall of the vessel
10	2000	2	Trhlovca	F	piece of plain rim with wall
10	2003	10	Trhlovca	G	the wall of the vessel
11	2000	21	Trhlovca	G	bowl
11	2003	10109	Trhlovca	F	the wall of the vessel
12	2003	10115	Trhlovca	F, E	piece of plain rim with wall
13	2003	10123	Trhlovca	F,D	dish
14	2003	10101	Trhlovca	F	dish
15	2003	10066	Trhlovca	G	bowl

Tab.1. Pottery samples for optical and x-ray analysis from Mala Triglavca and Trhlovca, the description of pottery types and their stratigraphic context.

tery and sediment samples (*Grimshaw 1971; Klein and Hurlbut 1993*). Approximately 2g of a sample was ground into fine powder for this method. All the results were presented on the computer as diagrams and detailed data. Since this technique gives the results of the bulk composition of a sample, we could not distinguish between natural and added inclusions. Nevertheless, we were able to identify most of the minerals present in the samples.

The analysis with the scanning electron microscope (*Goldstein et al. 2003; Reed 1996*) was provided by the Institute Jožef Stefan in Ljubljana at the centre for electron microscopy. Six samples of pottery from both sites have been analysed with this technique so far. We also performed a point chemical analysis using an energy dispersive spectrometer (EDS) for a detailed study, in which we were interested not only in the chemical composition of calcite and quartz grains, but also in limestone and chert grains in the samples. We tried to establish whether these grains are of a uniform composition in the pottery. We will present only some of the preliminary results obtained by electron microscopy, since only a fraction of the samples have been analysed (i.e. 5 samples).

Some of the pottery samples from both archaeological sites (i.e. 10 samples from Mala Triglavca and 10 samples from Trhlovca) and all the sediment samples were sent to ACME Laboratory in Vancouver, Canada for a chemical analysis. All the samples were crushed into powder and some 5g of each sample were sent for analysis by inductively-coupled plasma emission spectrometer for major, minor, and trace elements[6]. In this paper we present only some preliminary results of this analysis (Tab. 5).

THE RESULTS

Pottery

The mineralogical composition of the pottery samples contained quartz, mica (i.e. muscovite) and feldspar in all of the analysed samples (Tab. 2; 3). Hematite was determined in 6 out of 24 samples from Mala Triglavca and 7 out of 19 samples from Trhlovca. We also found grains of clay pellets, argillaceous rock fragments, limestone, chert, and quartz sandstone in various quantities by optical mineralogy (Tab. 2). Argillaceous rock fragments were present in 8 samples from Mala Triglavca and 10 samples from Trhlovca; clay pellets were present in all of the analysed samples. Limestone was present in 11 samples from Mala Triglavca, and 9 samples from Trhlovca. Chert grains were present as individual grains or as part of quartz sandstone; these grains were discovered in 18 samples from Mala Triglavca and 16 samples from Trhlovca. In most of the samples (i. e. in 22 samples from Mala Triglavca and 14 samples from Trhlovca) calcite grains[7] were found in various quantities (Fig. 3), but it was most probably added as temper; only on rare occasions were calcite grains naturally included in the clay (for example, in sample 6/2003 from Mala Triglavca). In a smaller percentage of samples, secondary calcite was observed inside pores or on the surface of the vessels, i.e. in 3 samples from Mala Triglavca and in 6 samples from Trhlovca. Calcite grains were present abundantly or very abundantly in 75% of all samples from Mala Triglavca and in 42.1% of all samples from Trhlovca (Tab. 2). The grains are of angular shape, poorly sorted, and of an average size of around 0.35mm (350μm), but they can be a few millimetres in some samples; these criteria are usually attributed to tempering materials (*Rice 1987.406–411*). In our opinion most of the grains, especially in the sand and pebble grain range, can be attributed to human activity, and that calcite was indeed used as a tempering material in the manufacture of the Neolithic pottery in this area.

Calcite grains can be a problematic material in pottery making, because of its decomposition into quicklime in firing, and the effect of "lime popping" when the vessel is being cooled. Many solutions have been proposed for this problem, from wetting the vessels after heating, to adding salt to the paste and firing the vessels below the decomposition temperature, which means less than 850°C (*Grimshaw 1971. 280; Rice 1987.97–98*). This last solution applies to the pottery from Mala Triglavca and Trhlovca, since we already proved that the firing temperature for vessels with calcite temper rarely exceeded this level. Again, the question remains whether this was done deliberately, or the potters were not able to reach a higher firing temperature with their firing technology. Nevertheless, calcite can be very useful in cooking pots, as assumed by other researchers (*Rice 1987.410; Rye 1981.33*).

6 A major or main component means that the concentration of a given element in the sample is at least 10%; the minor component means that the concentration is between 10 and 0,01%; and a trace element means that the component has a lower concentration, less than 0,01%, therefore usually expressed in part per million (ppm) (*Nölte 2003.8*).

7 The calcite grains in these samples are in fact composed of calc-sinter.

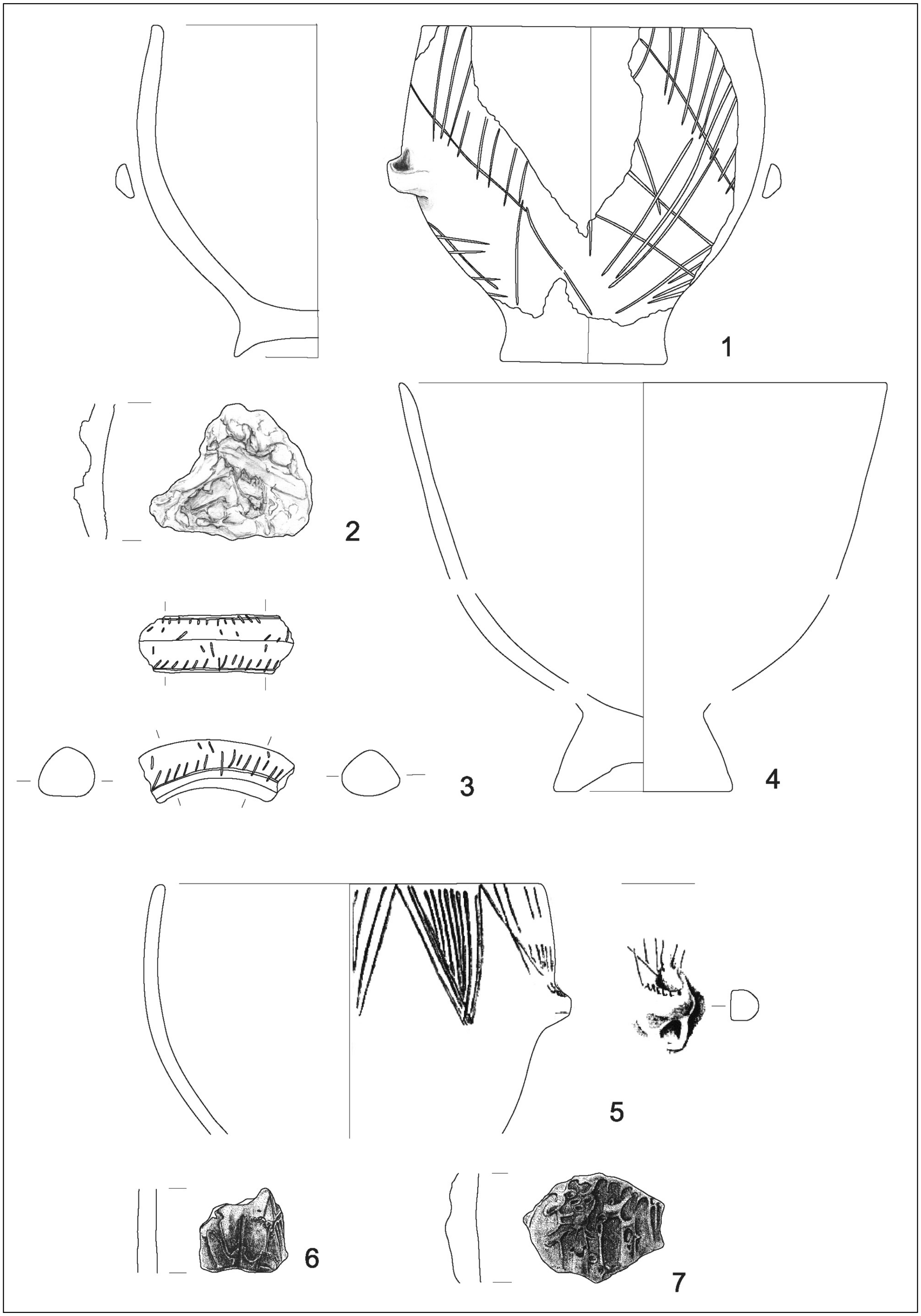

Fig. 2. Neolithic pottery from Mala Triglavca (1 – sample 22/2000; 2 – sample 24/2000; 3 – sample 24/2003; Žibrat 2002.t.7:4, 12:4, 19:8*) and Trhlovca (4 – sample 4/2000; 5 – sample 11/2000; 6 – sample 9/2000; 7 – sample 11/2003;* Dacar 1999.t.3:2, 18:1-2, 34:2*). (1:2)*

The vessels from the Neolithic and Eneolithic period have great strength[8] and this may be due to two reasons: the formation of secondary calcite on the surface and inside the walls of the potsherds in post-deposition; and the relatively high content of mica, i.e. muscovite flakes in the natural pastes of these vessels. Strength is associated with the ability of a material to withstand pressure being applied to it without rupturing or deforming (*Grimshaw 1971.832*).

The pottery from both rock shelters shows many similarities in terms of technological properties and a more uniform mineralogical composition than previously hypothesised on the basis of macroscopic observation. The basic mineralogical composition is essentially the same in most of the vessels analysed, in those with calcite temper as well as in vessels without any tempering materials (Figs. 3, 4). Even in terms of chronological differences, we could establish almost no variation in the mineralogical composition of the ceramic pastes; the use of calcite as a temper is somewhat less popular in the Eneolithic than in the Neolithic period, but this was already determined on the macroscopic level of observation (*Žibrat 2002.52–58*). When we consider the stylistic and typological data and the composition of such pottery, we can establish that all the typical Neolithic vessels from this region that have similarities with the Danilo culture are of a similar mineralogical and chemical composition (Fig. 2:1, 3–5). In terms of production centres and trade we can say that the Neolithic pottery from the Karst plateau was manufactured in this area by using locally available mate-

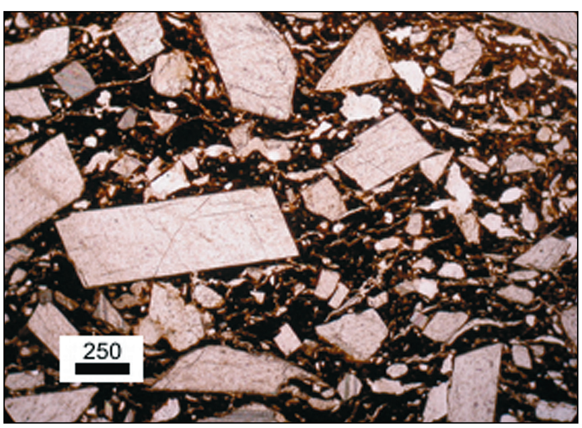

Fig. 3. Thin section photomicrograph of sample 14 (2000) from Mala Triglavca. The clay matrix contains calcite grains (x40; || N; the black line is 250 µm wide).

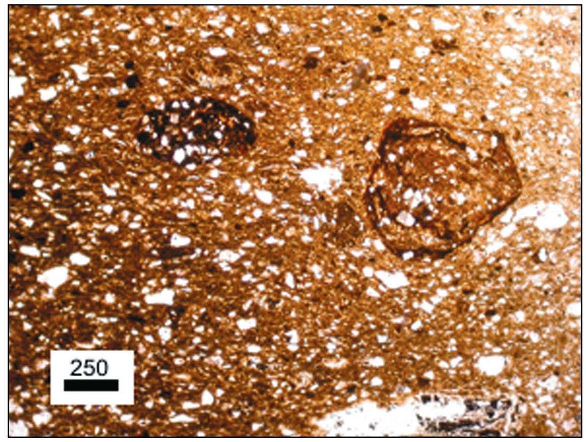

Fig. 4. Thin section photomicrograph of sample 9 (2000) from Trhlovca. The potsherd is decorated with barbotine and the clay matrix includes quartz grains and clay pellets (x40; || N; the black line is 250µm wide).

rials for all kinds of pottery. This is proved by a certain type of pottery, namely that of the barbotine decorated potsherds (Fig. 2:2, 6–7), which can be best linked to the Starčevo and Starčevo-Impresso culture in the eastern and central Balkans. These potsherds from Mala Triglavca and Trhlovca do not differ in any way from the rest of the ceramic assemblage and were as such also manufactured on the Karst (Tab. 2; 3).

On the other hand, there is one pottery sample from Trhlovca (i.e. sample 10/2000; Tab. 1–3) – dating to the Eneolithic period – that has a somewhat different chemical composition than all the other pottery and sediment samples analysed with the inductively coupled plasma optical emission spectrometer (ICP-OES). The composition of major and minor elements is similar to the other samples, but there is a significant change in the quantity of some trace elements (manganese, molybdenum and lead among others). These results could point to a different natural clay source having been used for this vessel, since none of the sampled sediments contained a similar quantity of these elements. There was a slight difference in the amount and variety of clay pellets and argillaceous rock fragments than was observed on the macroscopic and microscopic levels in this sample, but only the chemical analysis pointed to such diversity in composition.

One aspect that is common in pottery analysis is archaeothermometry, i.e. the determination of the

8 Strength is a measure of the response to stresses involving the entire ceramic body, while hardness denotes deformations affecting the surface of the vessel (*Rice 1987.354*).

temperature at which the pottery was initially fired. For the estimation of the initial firing temperature we can use different techniques (*Rice 1987.426–435*). In our analysis we also tried to establish the working firing temperature for pottery from the physical properties and mineralogy of the samples. Our results show that the temperature was below 700°C for most of the pottery, because of the very

SAMPLE	YEAR OF SAMPLING	SITE	quartz	quartz sandstone	chert	calcite	limestone	seconday calcite	muscovie	hematite	feldspars	chlorite	anhydrite	zircon	clay pellets	ARF[1]
1	2003	Mala Triglavca	A	R	R	VA	R		R		R				P	
2	2003	Mala Triglavca	VA	R	R	VA			P		R				P	R
3	2003	Mala Triglavca	A			A	R		P	R	R				P	
4	2003	Mala Triglavca	VA	R	R				A	R	R				P	R
5	2003	Mala Triglavca	A		R	A			P						A	
6	2003	Mala Triglavca	A		R	R	R	R	P	R	R				A	R
13	2000	Mala Triglavca	A		R	A			P						A	
14	2000	Mala Triglavca	P			VA	R		R						A	
15	2000	Mala Triglavca	VA	R	R	P	R		P		R				A	
16	2000	Mala Triglavca	P		R	VA	R		A						A	
17	2000	Mala Triglavca	A		R	A			P						A	R
18	2000	Mala Triglavca	VA		R	P			R						A	
19	2000	Mala Triglavca	A	R	R	A	P		P		R				A	
20	2000	Mala Triglavca	P			A			P						A	
20	2003	Mala Triglavca	P			P		R	R						P	R
21	2000	Mala Triglavca	A		R	A			R						A	
22	2000	Mala Triglavca	P			A			P						A	
22	2003	Mala Triglavca	VA		R	VA		R	P						A	
23	2000	Mala Triglavca	A	R	R				R		R				ZO	R
23	2003	Mala Triglavca	P	R	R	A	R		R						P	
24	2000	Mala Triglavca	R			A	R		R						A	
24	2003	Mala Triglavca	A		R	A			R						P	
25	2003	Mala Triglavca	P	R		VA	R		R						P	
29	2003	Mala Triglavca	VA	R	P	A			R						P	R
1	2000	Trhlovca	VA		R	P			R		R			R	A	
2	2000	Trhlovca	P	P	R	A	R		R		R				A	
3	2000	Trhlovca	A		R	VA			P						P	
4	2000	Trhlovca	P	R	R	P			R						A	
5	2000	Trhlovca	A	R	R	R	VA		R		R				P	R
6	2000	Trhlovca	A			A			R						P	
7	2003	Trhlovca	VA		R				P		R				P	R
8	2000	Trhlovca	R			A	R		R						A	R
8	2003	Trhlovca	A	R	R	A	R	P	P		R				R	
9	2000	Trhlovca	VA		R				P		R				A	
9	2003	Trhlovca	A	R	R	VA	P	R	R	R	R				P	
10	2000	Trhlovca	VA	R	R				P		R				VA	P
10	2003	Trhlovca	A	P	P	P	R	R	P		P	R	R	R	A	R
11	2000	Trhlovca	R			A					R				R	
11	2003	Trhlovca	VA		R				A						A	R
12	2003	Trhlovca	VA		P			R	P		R				A	P
13	2003	Trhlovca	A	R	R	R	P	R	P						P	R
14	2003	Trhlovca	P		R	VA	R	A	R						P	R
15	2003	Trhlovca	A		R	P	R		P		R				P	R

Tab. 2. The results of the optical microscopy analysis for the pottery samples (VA – very abundant; A – abundant; P – present; R – rare; [1] – argillaceous rock fragments).

good state of preservation of calcite grains, which did not decompose[9], as observed under the microscope. In addition, most quartz grains in our samples were cracked because of the volume change in quartz inversion around 573°C[10]. Therefore, we conclude that most of the pottery was fired at low temperature, only around 600 to 700°C. Only a small number of potsherds contained calcite grains that were partly decomposed, and those vessels could have been fired to a higher temperature, that is, up to 800°C, but not higher, since the grains did not decompose completely. These firing temperatures could only be estimated for the potsherds containing calcite grains – for the rest of the pottery we do not have enough information to ascertain the firing temperature. The only guideline in the samples without calcite is quartz, and its inversions to β-quartz around 573°C and tridymite around 870°C (*Grimshaw 1971.158*). Since tridymite was not discovered in the samples we can estimate that most of the samples were fired at around 600 to 800°C.

Sediments

All of the sediment samples were composed of quartz, feldspar, mica (i.e. muscovite, biotite) and chlorite, according to the mineralogical analyses (Tab. 4). Ferrous oxides, such as hematite and goethite, were discovered only in the cave sediments. A similar mineralogical composition has been attested for sediments from doline on the Karst (*Zupan Hajna 1998. 279–290*). Sediments from Trhlovca, Divaška jama and both of the alluvial samples showed traces of calcite or calcium oxides according to the X-ray diffraction and chemical analyses (Tab. 4; 5). The alluvial sediments contained some minor quantities of calcite, but this can be explained by the presence of mollusc shells in these samples, as was observed on the macroscopic level. Mollusc shells were not discovered in the cave sediments or the pottery sample – therefore, we conclude that these alluvial sediments were not used for pottery production at Mala Triglavca and Trhlovca. Nevertheless, all the sediments show a similar mineralogical composition, which is not surprising since those sediments all originate in the same type of rock, flysch[11]. Flysch rocks are common around the Karst plateau, as they are present along the Slovene coastal region, in the Vipava valley to the northeast and in the Brkini and the Reka valleys to the southeast (*Gams 1988, 81–83*).

According to our results, the mineralogical composition of pottery from Mala Triglavca and Trhlovca can be better compared with the composition of the analysed cave sediments than with the alluvial samples (Tabs. 2–5). Our main arguments for this are the much higher quartz sand content, the lack of hematite or other ferrous minerals, and the presence of mollusc shells in the alluvial sediments, as opposed to the cave sediments and the pottery. In contrast, we have to stress that the alluvial sediments we sampled did not contain enough clay for pottery manufacture to begin with.

Discussion

Our results can be best compared to archaeometric studies of pottery from Edera Cave/Stenašca in the Triestine Karst (*Spataro 1999*) and from various open air and cave sites along the eastern Adriatic Coast (*Spataro 2002*). Most of the pottery analysed from these sites are Neolithic and Eneolithic. In Edera, which is located some 25 km away from our two archaeological sites, the potsherds could be divided into two main groups according to thin section and X-ray diffraction analyses. The best represented group includes vessels made from local materials, as demonstrated by the inclusion of many calcite grains; and the second group is that of imported ware. In the fabrics of the second group several chert, granite and quartz sandstone grains were detected. The granite grains, part of an igneous rock, contained minerals K-feldspar, quartz and biotite. Some traces of chlorite were also discovered (*Spataro 1999.70–72*). The main problem with this analysis is the fact that no real provenience studies took place, since no samples of locally available sediments, clays or rocks were analysed. The author concluded that one group was comprised of locally-made vessels only on the present of calcite in the samples. No real comparison was made between both groups on the basis of their pastes without considering calcite grains, which were probably added as temper.

The pottery from layer 2a at Edera/Stenašca that was attributed to the Vlaška group (*Biagi et al. 1993. 49; Spataro 1999.70–72*) is typologically and stylistically similar to the vessels from Mala Triglavca and Trhlovca. The local group of clays as described at Edera/Stenašca, which contained calcite grains, and the clay pastes from the rock shelters Mala Tri-

9 The calcite decomposition happens in the temperature range from 700 to 900°C (*Rice 1987.98*).
10 The first inversion of quartz occurs rather rapidly around this temperature and is a chamge from low to high quartz (*Rice 1987.95*).
11 Flysch rocks of this region are composed of layers of sandstone and carbonate marl.

glavca and Trhlovca, also have a similar mineralogical composition. The presence of the non-local group with granite grains as described in Edera/Stenašca was discovered in the pottery samples from the Slovene Karst region. Some of the vessels with this non-local composition are from the late Castelnovien layer 3a in Edera/Stenašca (*Biagi et al. 1993.47–49; Biagi and Spataro 2001.32–35; Boschin and Riedel 2000*). Whether granite grains in the clay pastes are in fact a non-local material should have been tested with an appropriate sampling of sediments and rocks in this region.

SAMPLES	YEAR OF SAMPLING	SITE	quartz	calcite	muscovite	plagioclase	K-feldspars	chlorite	hematite
1	2003	Mala Triglavca	xx	xx	x	x			
2	2003	Mala Triglavca	xx	xx	x	x			
3	2003	Mala Triglavca	xx	xx	x	x	*		x
4	2003	Mala Triglavca	xx	x	x	x			*
5	2003	Mala Triglavca	xx	xx	x	x			x
6	2003	Mala Triglavca	xx	x	x	x	x		x
13	2000	Mala Triglavca	xx	xx	x	x			
14	2000	Mala Triglavca	xx	xx	x	x			
15	2000	Mala Triglavca	xx	xx	x	x	*		
16	2000	Mala Triglavca	xx	xx	x	x			
17	2000	Mala Triglavca	xx	xx	x	x	*		*
18	2000	Mala Triglavca	xx	xx	x	x	*	*	
19	2000	Mala Triglavca	xx	xx	x	x	*		
20	2003	Mala Triglavca	xx	xx	x	x	*		
21	2000	Mala Triglavca	xx	xx	x	x	*		
22	2000	Mala Triglavca	xx	xx	x	x			
22	2003	Mala Triglavca	xx	xx	x	x	*		
23	2000	Mala Triglavca	xx	x	x	x	*		
23	2003	Mala Triglavca	xx	xx	x	x			x
24	2000	Mala Triglavca	xx	xx	x	x			
24	2003	Mala Triglavca	xx	xx	x	x			
25	2003	Mala Triglavca	xx	xx	x	x			
29	2003	Mala Triglavca	xx	xx	x	x	*		x
1	2000	Trhlovca	xx	xx	x	x	*		
2	2000	Trhlovca	xx	xx	x	x			
3	2000	Trhlovca	xx	xx	x	x			
4	2000	Trhlovca	xx	xx	x	x			
5	2000	Trhlovca	xx	xx	x	x	*		*
6	2000	Trhlovca	xx	xx	x	x	*		
7	2003	Trhlovca	xx	x	x	x	*		*
8	2000	Trhlovca	xx	xx	x	*	*		
8	2003	Trhlovca	xx	xx		x			*
9	2000	Trhlovca	xx	*	x	x			x
9	2003	Trhlovca	xx	xx	x	x			
10	2000	Trhlovca	xx		x	x	*		*
10	2003	Trhlovca	xx	xx	x	x	x		*
11	2000	Trhlovca	xx	xx	x	x	*		
11	2003	Trhlovca	xx		x	x			x
12	2003	Trhlovca	xx	x	x	x	*	*	*
13	2003	Trhlovca	xx	x	x	x	*		
14	2003	Trhlovca	xx	xx		x	*		x
15	2003	Trhlovca	xx	xx	x	x			

Tab. 3. The results of the X-ray diffraction analysis (xx – major quantity; x – minor quantity; * – trace).

SAMPLES	SITE	DESCRIPTION	MACROSCOPIC DESCRIPTION	quartz	calcite	muscovite	biotite	feldspars	orthoclase	chlorite	clay minerals	gibbsite	hematite	goethite	pyrithe
1	Trhlovca	cave sediment	brown colour; calcite; bones	X	X	X	X	X		X		X	X		X
2	Divaška jama	cave sediment	yellow colour	X	X	X		*		X	*	X	*	*	
3	Dolina Radvanj	cave sediment	brown red colour	X		X		X		X			X		X
4	Lipove doline	cave sediment	brown red colour	X		X	X	X		X			X		
5	Dane (Globoki potok)	river sediment	grey brown colour; shells	X	X	X		X		X					
6	Reka	river sediment	grey colour; quartz sand	X	X	X		X	X	X					

Tab. 4. The mineralogical composition of the sediment samples according to the optical microscopy and X-ray diffraction method (X – major component; * – trace quantity).

The analysis of the *rhyton* from Edera/Stenašca has demonstrated its local production as well as the analysis of the *rhyton* from Mala Triglavca. These vessels are found in numerous caves and rock shelters on the Triestine Karst and have typological similarities with the Danilo Culture in Dalmatia and the Kakanj Culture in central Bosnia (*Montagnari Kokelj and Crismani 1993*). Chapman has proposed that these were salt containers and argued that their symbolic meaning could be transferred between different groups not as whole pots, but only as fragments (*Chapman 2000.65–68*). Nevertheless, the *rhyta* were probably transported as ideas, not as real vessels or parts of vessels to the northern parts of the Adriatic, the Caput Adriae, since most of the rhyta found in this region were produced locally (*Spataro 2002.199*).

Spataro analysed the mineralogical composition of potsherds from Neolithic and Eneolithic sites on both sites of the Adriatic coast. Samples were taken from 13 sites according to their stratigraphic sequence and typology, but no preliminary macroscopic studies of all the pottery assemblage were undertaken. As the results show, most of the pottery was made from locally available material. Calcite grains and rare organic material, were used as temper in the pottery from the eastern Adriatic coast sites, mostly in the middle Neolithic period; in one sample from Vela Špilja on the island Korčula grog temper was also found in the pottery. (*Spataro 2002.193–199*).

In this study Spataro sampled local clays for her provenience study, but mostly used only one sample in the proximity of a given archaeological site. The potsherds were selected according to typology and ornamentation techniques characteristic of the Impresso and Danilo cultures on the eastern Adriatic coast. So our main criticism is of sampling techniques, which could not include all the possible clay matrixes within a site, since no technological observations were made beforehand.

Some mineralogical and chemical analyses of pottery samples from this region were also carried out in Slovenia. The best example is the scientific study of Roman amphorae from Sermin near Koper on the Adriatic coast, beneath the Karst plateau. The samples were analysed for their chemical and mineralogical composition using similar techniques – inductively coupled plasma emission spectrometry, X-ray powder diffraction, and optical mineralogy. For the analysed amphorae the authors proposed an Adriatic origin on the basis of the mineralogical composition of the samples and their comparison to the geological structure in the eastern Adriatic, namely the composition of flysch rocks (*Zupančič, Bole 1997.98–99*). The mineralogical composition of the pottery and flysch rocks is indeed similar on the general level, but in our opinion for a thorough provenience study, locally available clays should have been sampled.

CONCLUSIONS

Within the different pottery groups we were able to identify three 'recipes' employed by the Neolithic potters: one had no artificially added temper (Fig. 4); the predominant group had calcite grains added as temper (Fig. 3); and one possible group had grains of lime sandstone with micritic calcite cement added as temper (sample 5/2000 from Trhlovca; Fig. 5). Even potsherds that have a clear cultural reference to the Dalmatian coast, in the Danilo culture, such as the rython (Fig. 2:3; Fig. 7), or others with

SAMPLE	YEAR OF SAMPLING	SITE	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Cr_2O_3 (%)
1	2000	Trhlovca	49,8	12,6	6,22	1,5	12,4	0,72	2,21	0,65	0,39	0,12	0,026
2	2000	Trhlovca	34,9	11,41	5,33	1,02	23,2	0,13	1,78	0,53	0,49	0,11	0,019
3	2000	Trhlovca	45,7	11,44	2,15	0,52	18,1	0,03	1,33	0,73	0,47	0,02	0,026
4	2000	Trhlovca	43,9	13,28	5,18	1,13	15,3	0,18	2,22	0,71	0,42	0,14	0,024
5	2000	Trhlovca	58,5	12,2	5,12	1,41	9,72	0,81	1,99	0,67	0,17	0,16	0,018
6	2000	Trhlovca	38,6	9,42	2,13	0,52	25,3	0,05	1,29	0,57	0,09	0,02	0,024
8	2000	Trhlovca	33	12,48	5,69	0,98	23,2	0,06	1,85	0,51	0,38	0,13	0,015
9	2000	Trhlovca	62,6	14,94	6,79	1,69	1,85	0,7	2,77	0,79	0,71	0,18	0,031
10	2000	Trhlovca	60	15,48	8,25	0,91	2,25	0,43	1,79	1,01	0,71	1,58	0,021
11	2000	Trhlovca	30,1	13,56	5,42	1,12	21,4	0,11	1,42	0,57	1,09	0,08	0,015
13	2000	Mala Triglavca	44,6	12,52	4,88	0,83	15,4	0,16	1,58	0,72	0,97	0,15	0,025
14	2000	Mala Triglavca	28,2	11,46	5,56	0,5	23,5	0,15	0,64	0,55	0,9	0,1	0,018
15	2000	Mala Triglavca	60,7	12,95	5,84	1,04	7,14	0,87	1,71	0,79	0,55	0,1	0,03
16	2000	Mala Triglavca	36,8	11,06	4,86	0,5	22,6	0,2	1,27	0,58	0,49	0,06	0,024
17	2000	Mala Triglavca	44,1	12,59	5,11	0,85	14,8	0,19	1,54	0,77	1,66	0,14	0,029
18	2000	Mala Triglavca	51,9	13,27	5,89	0,77	9,22	0,23	0,89	0,84	1,37	0,05	0,029
19	2000	Mala Triglavca	42,9	8,72	4,36	1,18	20,2	0,78	1,36	0,52	0,24	0,14	0,018
21	2000	Mala Triglavca	48,9	11,15	4,77	1,04	13,1	0,41	1,59	0,63	0,49	0,1	0,021
22	2000	Mala Triglavca	43,2	13,2	6,83	0,89	13,6	0,16	1,73	0,7	0,88	0,21	0,026
24	2000	Mala Triglavca	35,1	11,61	5,02	1,17	22,7	0,15	1,6	0,5	0,33	0,21	0,013
1	2004	Trhlovca	42,5	15,48	6,01	1,28	9,94	0,55	1,58	0,89	1,08	0,25	0,02
2	2004	Diva_ka jama	65,6	15,38	6,64	0,77	0,9	0,19	1,27	0,89	0,12	0,16	0,038
3	2004	Dolina Radvanj	56,9	18,28	7,81	1,3	0,85	0,52	1,64	1,02	0,05	0,12	0,03
4	2004	Lipove doline	76,4	9,93	4,18	0,67	0,44	0,17	1,12	0,67	0,04	0,06	0,036
5	2004	Pared	62,8	10,35	5,68	1,26	6,22	0,58	1,77	0,56	0,07	0,65	0,024
6	2004	Reka	82,6	6,29	2,97	0,82	1,03	0,79	0,94	0,41	0,05	0,06	0,024

Tab. 5. The results of the chemical analysis for the pottery and sediment samples. Only the major oxides are presented in form of percentage of mass.

a reference to the Balkans, namely barbotine (Fig. 2:2,6; Fig. 6), were made of local clays and tempering materials.

Some potsherds contained grains of lime sandstone with micritic calcite cement[12] (Fig. 5) in the fabric, and this type of rocks can be found over a very limited area on the plateau. The nearest location of these lime sandstones is near Tomaj, a town located northwest ofthe Divača region and only 15 km from our two archaeological sites (*Otoničar 1999.32–33*). These sandstone grains were probably naturally present in the clay matrix of the pottery from Mala Triglavca and Trhlovca, but could have been added as temper according to the size and angularity of these grains[13]. Nevertheless, these materials point to the possibility of transhumance on the Karst plateau and the gathering of material for the vessels in different places, not just around the two rock shelters. Mala Triglavca and Trhlovca are located some 15 km away from the coastline near Trieste/Trst in Italy. Hence the distance between the coast and the plateau and the distances around the plateau rarely reach more than 30 km. All major communications in this region can be carried out over short distances. Therefore, the lime sandstone temper could have been used in pottery manufacture near the geological area of these rocks, and the finished products transported by herders to the caves around modern-day Divača, with other goods and the herds. Transhumance, i.e. the seasonal transfer of grazing animals to different pastures, often over substantial distances, can be an interpretative postulate for these groups as was shown by other studies (*Sterud 1978. 381–384; Halstead 1996.21–26*).

By using the scanning electron microscope for some of our pottery samples we also found a phosphorite grain in one of the pottery samples from Trhlovca. Phosphorite is a sedimentary rock with a high con-

12 Lime sandstone is composed of quartz, chert and limestone grains, which are combined with micritic calcite cement.

13 The angularity of the grains can be a result of the overall hardness of such grains due to quartz inclusions.

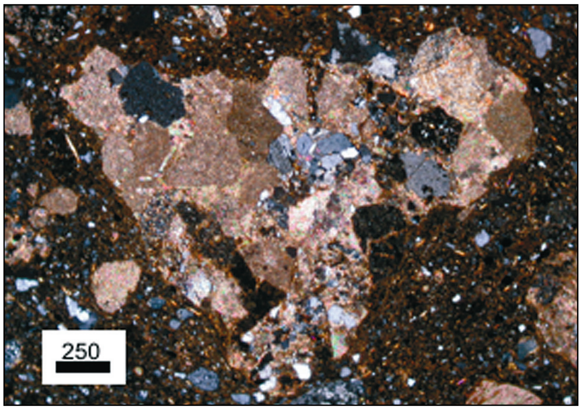

Fig. 5. Thin section photomicrograph of sample 5 (2000) from Trhlovca. In the middle is a grain of lime sandstone with micritic calcite cement (x40; + N; the black line is 250µm wide).

centration of phosphates in nodular or compact masses; one type of phosphorite is coprolites, fossilised animal or fish excrement. Phosphorite can be formed inside pottery in the sediment post-deposition, or may be naturally present in the clay that the potters used for their manufacture. In some potsherds from Mala Triglavca chemical analysis revealed a higher phosphorous content and similarly, in the clay sample from the deposit in Trhlovca. Phosphorus is closely associated with animal and human activity, because bones and teeth contain large amounts of this element. High concentrations of phosphorous in the soil often accumulate where humans have congregated and have discarded the bones of wild or domestic animals (*Brady, Weil 1999.540*). The presence of phosphorous minerals and the element itself in our samples links the potsherds to human and animal activities that took place after the deposition of the material in the caves and rock shelters, or indicates that the clay used for the manufacture of this potsherd was perhaps taken from a place in which these activities took place, for example from Trhlovca.

New soil micromorphological data from four rock shelters in the Trieste Karst (Grotta Azzurra/Pečina na Leskovcu, Edera/Stenašca, Caterina/Katrna pejca and Lonza) show that all post-Mesolithic deposits were coprolitic; that is, they are made up of thoroughly disaggregated and burned herbivore droppings, mostly of sheep and goat dung. The authors' suggestion is that shepherds in the Karst would have used the rock shelters in a system of transhumance pasturage almost exclusively as stables. The low number of remains of material culture (mainly pottery) in the layers offers some evidence for such behaviour. Furthermore, if the specialized use of rock shelters is assumed, it might be reasonable to believe that people moved around (*Boschian and Montagnari-Kokelj 2000.345–350*). The presence of phosphorite, of which coprolites are one of the varieties, in one of the pottery samples links our results with those made in Italy. Although detailed soil micromorphological research has not as yet been carried out in the Slovene Karst region, we may assume that results similar to those from Mala Triglavca and Trhlovca can be expected, since they both contain many animal bones and fewer artefacts, of which mainly pottery was found. Also, many white to grey ash layers are found in the stratigraphic sequence of these sites, which could contain phytoliths and coprolitic aggregates (coprolitic deposits have been proven for Mala Triglavca according to the preliminary results of the soil micromorphological data; Budja, pers.comm.).

The detailed study of the mineralogical and chemical composition of the Neolithic and Eneolithic pottery from two sites around Divača on the Karst plateau has shown that we have very uniform vessel pastes used in the pottery technology. We could find almost no difference in pottery composition within one of the sites or between the two sites, by using tempering material, at least not in the Neolithic and Eneolithic pottery from this micro-region. The use of calcite grains as the predominant temper seems to be not only a technology typical of the Neolithic period in the Karst plateau, but also typical for a wider area in this period. Calcite grains are a common temper in pottery also on the Triestine Karst in layers with the so-called Vlaška group pottery (*Spataro 1999.70–72*) and along the Adriatic coast in the context of the Danilo culture (*Spataro 2002.197*).

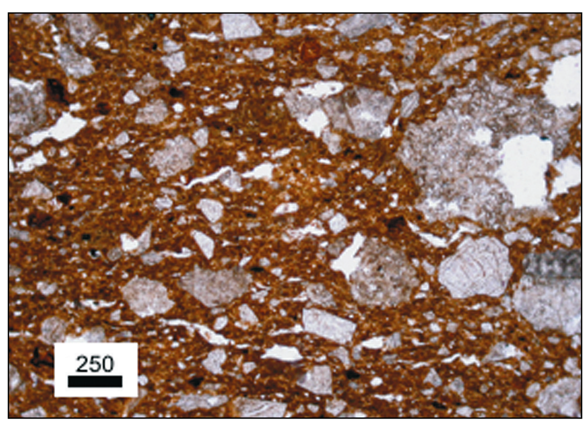

Fig. 6. Thin section photomicrograph of the sample 24 (2000) from Mala Triglavca. The potsherd is decorated with barbotine, The clay matrix includes calcite and few quartz grains (x40; || N; the black line is 250µm wide).

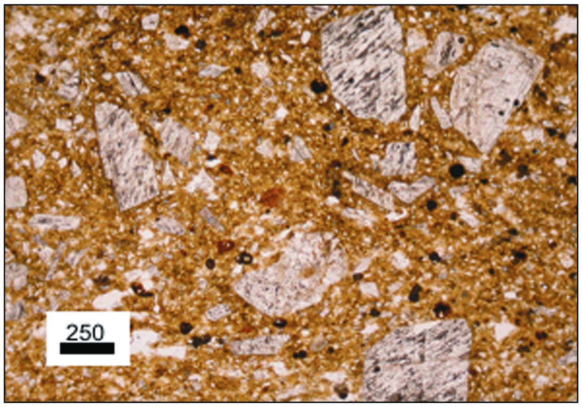

Fig. 7. Thin section photomicrograph of sample 24 (2003) from Mala Triglavca. The **rhyton** *includes calcite and quartz grains and clay pellets (x40; || N; the black line is 250µm wide).*

Pottery from Mala Triglavca and Trhlovca from the Neolithic period was made from local clays that were taken from cave sediments, but not from the deposits near the river as shown by our investigation. The main tempering material was calcite, a mineral that is abundantly available on the Karst and can be easily removed from cave walls and crushed. The clay already contained a lot of mica (muscovite) flakes that added significantly to the overall strength of the pots. The materials were locally available, calcite is abundant in caves, and the clay pastes were also taken from cave deposits as shown by our provenience study. The content of phosphorous in some samples and a phosphorite grain in one of the samples from Trhlovca also show that the rock shelters could have been used as stables for animals by Neolithic shepherds. Thus we conclude that most of the Neolithic pottery was produced on a local scale and from locally available materials on the Karst plateau. On the other hand, some of the pots have lime sandstone with chert grains, which proves that people were mobile, and with them went materials around the Karst plateau. Clays from the region around Tomaj will have to be sampled in the future to establish the original location of this material. Since one of the potsherds from Trhlovca (i.e. sample 10/2000; Tab.1; 5) has a different chemical composition than the other analysed pottery and sediment samples, a different natural clay source has to be assumed. For this reason sediment samples from the Slovene coast region, which is not far the two archaeological sites, would also have too be sampled. New sediment samples and analyses will therefore be needed to produce a more accurate picture of Neolithic pottery technology, mobility, and transhumance in this area.

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