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Karakterizacija lončarske smjese – makroskopska analiza keramike iz brončanog doba

Characterization of ceramic pastes – a macroanalysis of Bronze Age pottery

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U radu se predstavljaju metoda i postupak makroskopske analize, analiza digitalne makrofotografije svježega loma keramičkog uzorka i načela karakterizacije keramičkih struktura, odnosno lončarskih smjesa. Iznose se prednosti i nedostaci makorskopske metode i daju smjernice za njezinu praktičnu, ali i teorijsku primjenu. Metoda je primijenjena na uzorcima keramike iz brončanog doba s prostora sjeverne Hrvatske, a rezultati su dopunjeni prethodno provedenim mikroskopskim analizama. Utvrđeno je da se sirovinski materijal vjerojatno prikupljao u neposrednoj blizini pretpovijesnih naselja i da su lončari koristili različite vrste primjesa: mineralna zrna, litoklaste, grog, glinovite pelete i primjese organskog podrijetla. Analiza je makrofotografija pokazala varijabilnost u odabiru smjese koju je, prema preliminarnim rezultatima istraživanja, moguće povezati s kronološko-kulturološkim karakteristikama keramičkih posuda.

Ključne riječi: *keramika, tehnologija, metodologija, digitalni mikroskop, lončarska smjesa, glinoviti materijal, primjese, brončano doba*

The paper presents the methods and procedures of macroanalysis, the analysis of digital macrophotography of fresh breakage on pottery samples, and the principles of characterizing the ceramic fabric, that is, ceramic pastes. The advantages and disadvantages of the method were noted, and guidelines for its practical, as well as theoretical application are provided below. This method was applied to Bronze Age pottery samples from northern Croatia and the results are supplemented by previously conducted microscopic analyses. It was established that the raw materials were probably gathered in the immediate vicinity of prehistoric sites, and that potters used various temper materials: mineral inclusions, lithoclast, grog, clay pelets (argillaceous rock fragments) and organic material. The analysis of macrophotographs revealed variability in the potters recipe that, according to preliminary research results, can be associated with cultural and chronological features of ceramic vessels.

Key words: *pottery, technology, methodology, digital microscope, ceramic paste, clayey material, temper, Bronze Age*

1. UVOD

Keramika je jedan od najvažnijih izvora informacija za arheologe, poglavito zbog strukture materijala, što je čini gotovo neuništivom. Osim toga, ulomci su keramičkih posuda jedan od najbrojnijih i najučestalijih nalaza na arheološkim nalazištima u svim razdobljima ljudske prošlosti. Lončarija je nemjerljivo vrijedan kronološki indikator, a mnoge relativne kronologije zasnivaju se upravo na tipovima keramičkih posuda. Jedan od osnovnih i najčešćih ciljeva analize keramičkih ulomaka prisutan u domaćim publikacijama je morfološko klasificiranje posuda i njihovih dijelova, a njihova je konačna svrha tipološko-kronološka analiza nalaza i nalazišta te komparacija u odnosu na, prema istim kriterijima klasificirana, nalazišta iz bliže, odnosno dalje okolice. Ipak, u suvremenom razvoju arheološke znanosti brojnost dostupnih analitičkih metoda i tehnološko-društveni oblici interpretacija omogućavaju nemjerljivo složeniji i prije svega znanstveniji način razmatranja rezultata tako postavljene studije, što često podrazumijeva interdisciplinarnost. Posljednjih desetljeća publicirana su brojna monografska izdanja, stručni i znanstveni radovi na temu metodologije obrade arheoloških artefakata, posebice tehnologije proizvodnje keramičkih posuda.[1] Rani je interes za tehnologiju proizvodnje keramičkih posuda bio usmjeren na pitanje "Kako?", međutim, razvojem teorije i metoda iz prirodnih znanosti pitanja su usmjerena na podrijetlo materijala i njihov širi društveno-tehnološki kontekst, odnosno fokus istraživanja nije više samo predmet nego i onaj tko stoji iza njega. U posljednje je vrijeme naglasak stavljen na vezu između tehnologije i društva, odnosno tehnologija prije svega predstavlja integrirani dio kulturnih procesa.[2] Na taj način razmatra se veza između teh-

[1] Rye 1981; Shepard 1985; Rice 1987; Gibson, Woods 1990; Sinopoli 1991; Orton, Tyers, Vince 1993; Albero Santacreu 2014.

[2] Pfaffenberger 1992; Tite 1999; Gosselain 2011.

1. INTRODUCTION

Pottery is one of the most important sources of information for archaeologists, mostly due to its material structure, which makes it almost indestructible. Apart from that, fragments of pottery are one of the most numerous and frequent finds on archaeological sites dated to all periods of human history. Pottery is an immeasurably valuable indicator of chronology, and many relative chronologies are based on types of pottery vessels. One of the basic and most common goals of pottery analysis present in Croatian publications is the morphological classification of vessels and their fragments with the final aim of producing a typological-chronological analysis of both the finds and the site, as well as making comparisons with close-by and distant sites which have been classified according to the same criteria. However, following contemporary developments in archaeological science, the number of available analytical methods, as well as the technological and social modes of interpretations, allow for an immeasurably more complex and, primarily, a more scientific way of looking at the results of such studies, which often includes an interdisciplinary approach.

In the last few decades, many monographs, as well as expert and scientific papers were published on the methodology of processing archaeological artifacts, especially on the technology of pottery production.[1] Early interest in the technology of pottery production focused on the "how". However, following the development of theory and scientific methods applied in natural sciences, questions now focus on the origin of material and the wider socio-technological context, meaning that the focal point of research is no longer only the artifact, but also the person who made it. In recent years, emphasis is put on the link between technology and society, i.e. technology, above all, represents an integral part of cultural processes.[2] This way, we can study the link between the

[1] Rye 1981; Shepard 1985; Rice 1987; Gibson, Woods 1990; Sinopoli 1991; Orton, Tyers, Vince 1993; Albero Santacreu 2014.

[2] Pfaffenberger 1992; Tite 1999; Gosselain 2011.

nološkog odabira,[3] sirovine, okoliša, rituala i društvenih ideologija. Pojedine segmente takvoga složenog odnosa između tehnološkog odabira, lončara i zajednice moguće je identificirati u keramičkom materijalu, a kontinuitet, odnosno promjene u odabiru, mogu biti pokazatelj složenih društvenih odnosa i promjena u kulturnoj tradiciji.

Upravo bi ove smjernice trebale biti pozadina istraživanja keramike, neovisno o metodi analize koja se primjenjuje. Proučavanjem keramičkog materijala, a to se posebno odnosi na posude iz najstarijih razdoblja prošlosti (pretpovijest), promatraju se njihove fizičke karakteristike koje su značajan pokazatelj tehnoloških postupaka onih majstora koji su izrađivali takve uporabne predmete. Cilj je analize lončarske tehnologije identificirati segmente tehnološkog postupka u svrhu rekonstrukcije čitavog procesa stoga je od velikog značaja utvrditi vrstu, podrijetlo i način pripreme sirovinskog materijala (glinoviti materijal i primjese). Keramičke su posude napravljene od lončarske smjese, a zapisi u strukturi keramike sadrže informacije o postupku njezine pripreme koji je u izravnoj vezi s lončarevim odlukama o odabiru specifične sirovine za izradu određene vrste posuda. Stoga se u ovome radu predstavlja relativno jednostavna makroskopska metoda, a pomoću digitalnog mikroskopa sistematizirano se bilježe i prikupljaju podaci o sastavu lončarske smjese, zapisani u strukturi keramike. Rezultati karakterizacije i klasifikacije keramičkih struktura, dokumentirani pomoću digitalnog mikroskopa, mogu biti dobar temelj za odabir uzoraka koji će biti podvrgnuti mikroskopskoj analizi (npr. optičkoj mikroskopiji).[4]

Jedan je od ciljeva ovoga rada potaknuti one koji se bave, i one koji će se tek baviti nekom vrstom analize keramičkog materijala, na razmatranje mogućnosti i svrha njihove obrade. Cilj je također podsjetiti da bi pozadina svake analize morala imati unaprijed određene parametre, smjerni-

[3] Više u Gosselain, Livingstone Smith 1995; Silar, Tite 2000.

[4] Druc 2015.

technological choice,[3] raw materials, the environment, rituals, and social ideologies. Individual segments of the complex relations between the technological choice, the potter, and the community can be identified in the ceramic material, and the continuity and/or changes in these choices can serve as an indicator of social relations and changes in cultural traditions.

These guidelines should be in the background of studies on pottery, regardless of the applied analytical method. By studying pottery, and this especially refers to vessels from the earliest periods of the past (prehistory), we observe its physical characteristics, which are a significant indicator of techniques applied by the artisans who made such every-day objects. The aim of pottery technology analysis is to identify segments of the technological process with the purpose of reconstructing the entire process, so it is very important to determine the kind, origin, and mode in which the raw material was prepared (matrix / clayey material). Pottery vessels were made out of ceramic pastes, and records in the ceramic fabric contain data about the way they were prepared, which is directly connected to the potter's choice of specific raw materials used to produce a certain kind of vessel. Consequently, this paper brings a relatively simple macroscopic method, using a digital microscope to systematically record and collect data on the composition of ceramic pastes preserved in the ceramic structure. The results of characterization and classification of ceramic fabrics defined by using a digital microscope represent a good basis for the selection of samples that will be subjected to microscopic analysis (e.g. optical microscopy).[4]

One of the goals of this paper is to encourage those who currently apply, as well as those who will apply some type of pottery analysis in the future to consider the possibilities and the purpose of such studies. The aim is also to remind others that each analysis should have predetermined parameters and guidelines, i.e. purpose.

[3] For more, see Gosselain, Livingstone Smith 1995; Silar, Tite 2000.

[4] Druc 2015.

ce, odnosno svrhu. S obzirom na to da se u domaćim publikacijama,[5] znanstvenim i stručnim radovima do sada nije značajnije posvetila pozornost analizi tehnologije proizvodnje keramičkih posuda, a radovi se oslanjaju uglavnom na deskriptivnu metodu kojom su nesistematizirano prikupljene informacije o sastavu lončarske smjese, često prenesene s nerazumijevanjem, prepisanim, šturim i ponekad netočnim podacima o tome aspektu proizvodnje, u ovom će radu biti objašnjeno značenje lončarske smjese, istaknut će se svrha primjene ove metode i predstaviti postupak sistematizirane makroskopske analize keramičkih struktura na primjeru posuda iz brončanog doba s prostora sjeverne Hrvatske.

1.1. LONČARSKA SMJESA

Budući da je rad usmjeren na karakterizaciju sastava lončarske smjese, u ovome će se poglavlju pojasniti određeni pojmovi i termini vezani upravo uz taj segmet proizvodnje, odnosno uz njezinu pripremu. Jedan od najčešćih ciljeva provođenja znanstvenih analiza na keramici je utvrditi sastav i podrijetlo sirovine i primjesa kako bi se ustanovila i bolje razumijela njihova svojstva, što u konačnici omogućava rekonstrukciju dijela tehnološkog postupka proizvodnje. Relevantne informacije o podrijetlu i izvorištu sirovine proizlaze iz rezultata mineraloško-petrografskih i geokemijskih analiza, a interpretativno one mogu odgovoriti na pitanja vezana uz razinu ili stupanj organizacije proizvodnje, trgovine i razmjene gotovih predmeta. Određene pokazatelje podrijetla, odnosno izvorišta sirovinskog materijala moguće je djelomično identificirati makroskopski, uz

[5] U posljednjem desetljeću na temu brončanodobne lončarije napravljeno je nekoliko opsežnijih studija i analiza s nizom novih informacija dobivenih primjenom netradicionalnih analitičkih metoda (Michelaki 2006; Kreiter 2007; Sofaer, Budden 2012, 117–127). Na našem prostoru nije bilo tako opsežnih analiza i može se izdvojiti jedino rad S. Karavanić, koja je još devedestih godina primijenila analize na keramici (rendgenska difrakcija, petrografsko-mineraloška analiza, termalna analiza) u sklopu tipološke klasifikacije kasnobrončanodobne keramike s lokaliteta Kalnik-Igrišče, no analize su bile manjeg opsega (Vrdoljak 1995).

Seeing as Croatian publications,[5] scientific and expert papers have, so far, not focused on the analysis of pottery production technology and mostly rely on descriptive methods that contain non-systematically collected data about the composition of the ceramic pastes, which is presented with little to no understanding and often with copied, scant, and sometimes incorrect data about this aspect of production, this paper will explain the significance of ceramic pastes, point out the purpose of applying this method, and present the process of a systematic macroanalysis of Bronze Age ceramic fabrics from northern Croatia.

1.1. CERAMIC PASTE

Considering the fact that this paper focuses on the characterization of raw material composition, this chapter brings explanations of certain concepts and terms connected to that segment of production, i.e. ceramic paste preparation. One of the most common goals of conducting scientific analyses on pottery is to determine the composition and origin of both the raw material and the inclusions in order to establish and better understand their properties, which in turn allows for the reconstruction of a part of the technological production process. Relevant information about the origin and source of raw material is obtained from the results of mineralogical, petrographic, and chemical analyses, and, interpretation-wise, this can answer questions about the level or degree of production organization, as well as about the trade and exchange of finished products. Certain indicators of the origin, i.e. the source of raw material, can be partially identified mac-

[5] Several comprehensive studies and analyses of Bronze Age pottery were published in the last decade, providing a series of new information obtained by applying non-traditional research methods (Michelaki 2006; Kreiter 2007; Sofaer, Budden 2012, 117–127). In Croatia, there have been no such studies, with the exception of S. Karavanić, who conducted such pottery analyses during the 1990s (X-ray diffraction, petrographic-mineralogical analysis, thermal analysis) as part of the typological classification of Late Bronze Age pottery from the site of Kalnik-Igrišče. However, these were small-scale analyses (Vrdoljak 1995).

pomoć digitalnog mikroskopa pri manjim uvećanjima, a na isti način može se identificirati i sastav lončarske smjese.[6]

Lončarska smjesa je materijal za izradu posuda sastavljen od glinovitog materijala (engl. *matrix*) i raznih primjesa (engl. *temper*) koje lončar namjerno dodaje glini. Receptura lončarske smjese produkt je složenih mehanizama odabira i predstavlja jedinstven zapis o tehnologiji proizvodnje, funkciji posuda i njhovim kulturološko-ideološkim aspektima, stoga je njezino proučavanje od velikog značaja za bolje razumijevanje društva koje ih je proizvodilo i koristilo. Postupak pripreme smjese polazi od nabave gline odgovarajuće kvalitete. Takvoj smjesi lončari ponekad dodaju razne vrste primjesa koje također predstavljaju sirovinski materijal koji je potrebno nabaviti i pripremiti. Namjerno dodana primjesa (engl. *temper*) svaki je materijal koji se dodaje glini da bi se povećala viskoznost smjese. Najčešće se dodaju različiti neplastični materijali, kao što su pijesak, litoklasti (kvarcit, vapnenac, rožnjak itd.), grog (usitnjena keramika) ili primjese od organskog materijala (suha trava, pljeva, dlaka, suha kravlja balega, kosti, školjke i sl.). Dodavanjem primjesa u glinoviti materijal pospješuje se oblikovanje i pečenje keramike, pojačava čvrstoća i termička izdržljivost posude, a one utječu i na poroznost.[7] Stoga je odabir primjesa često povezan sa znanjima o njihovu utjecaju na tijek proizvodnje, a često je odabir podložan i tradiciji. Iz tih razloga jedan od osnovnih preduvjeta za kvalitetnu analizu lončarske tehnologije je bilježenje i analiza karakteristika lončarske smjese. Prije svega cilj je utvrditi vrstu i karakteristike neplastičnih materijala, odnosno primjesa koje je lončar dodao smjesi. Njihov je odabir uglavnom u izravnoj vezi s funkcijom posuda, ali odabir sirovine također ovisi o dostupnosti materijala i postojanosti tradicije kod odabira recepture.[8] Međutim, pretpovijesne zajednice iz različitih razdoblja, koje se koriste

[6] Druc 2015.

[7] Rice 1987, 408; Velde, Druc 1999.

[8] Shepard 1985, 163.

roscopically by using a digital microscope with smaller magnification, and the same method can be applied to identify the composition of the ceramic paste.[6]

Ceramic paste is the material used to make vessels, composed of a clayey material (*matrix*) and different kinds of temper material, which the potter intentionally adds to the clay. The recipe of the ceramic paste is a product of complex mechanisms and is a unique record of production technology, vessel function, and cultural and ideological aspects. Therefore, studying it is very significant for the better understanding of society that produced and used the vessels. The ceramic paste preparation procedure starts with obtaining clay of the right quality. Potters sometimes add different kinds of temper material to such a paste, which also represent raw materials that have to be obtained and prepared. Intentionally added inclusions (temper) are all materials that are added to the clay in order to increase the viscosity of the paste. Most commonly, these include nonplastic materials like sand, lithoclasts (quartz, limestone, and chert), grog (fragmented pottery), or organic material temper (dry grass, chaff, animal hair, dry dung, bones, shells and so forth). Adding temper to the clayey material enhances the forming and firing of pottery, increases its hardness and thermal shock resistance, and affects its porosity.[7] Therefore, the selection of temper material is often connected to knowing how it affects the final product, as well as to tradition. Hence, one of the main preconditions for study of pottery production technology is to record and analyze the characteristics of the ceramic pastes. The primary goal is to determine the type and characteristics of non-plastic materials, i.e. temper material that the potter added to the paste. This selection is directly connected to vessel functions, but the choice of raw material also depends on the availability of material and tradition when it comes to choosing the recipe.[8] However, prehistoric communities from different periods that settled the same area did not always use

[6] Druc 2015.

[7] Rice 1987, 408; Velde, Druc 1999.

[8] Shepard 1985, 163.

istim prostorom, ne koriste uvijek istu vrstu primjesa, bez obzira na njihovu, na primjer, laku dostupnost. Jedno od pitanja vezano uz primjese je i kolika je dosljednost lonačara pri uporabi određene vrste primjese. Kada ne bi postojala dosljednost u praksi ili odabiru primjesa, analiza lončarskih smjesa ne bi imala nikakav značaj, odnosno ne bi imalo smisla identificirati ih niti pokušati utvrditi njihovo podrijetlo. Ako pretpostavimo da dosljednost u odabiru postoji i da je ona povezana s funkcionalnim karakteristikama posude ili pak s tradicijom, primarna je zadaća utvrditi sličnosti, odnosno različitosti u lončarskim smjesama. Jednake ili slično pripremljene smjese pokazatelj su ustaljenih odabira lončara odnosno zajednice, a manje razlike u količini specifične primjese mogu biti posljedica individualnih razlika u mjerenju količine takvih primjesa. Veće razlike u recepturi, odnosno vrsti i količini primjesa, pokazatelji su različitih stilova, a kada se razlike mogu dovesti u korelaciju s različitim tipovima posuda, drugačijom obradom površine, različitim dekorativnim stilom, a u arheološkom smislu i drugačijom kulturom, govorimo o različitim praksama i tradicijama.[9] Izrazitiji je konzervativizam u odabiru primjesa zabilježen na mnogim etnografskim[10] i arheološkim[11] primjerima, što se uglavnom povezuje s tradicijom određene populacije, dok je povećana varijabilnost sastava lončarske smjese dobar indikator vanjskih utjecaja, promjena tradicije ili populacije.[12]

Mehanizmi odabira sirovina za izradu lončarske smjese pod utjecajem su različith faktora stoga za njihovo tumačenje valja zasebno i u međusobnoj korelaciji razmotriti prirodno-geološke, tehnološke, morfološke i društvene aspekte. Karakterizacija keramičkih struktura makroskopskom metodom dobar je početni korak na tome putu.

[9] Shepard 1985, 164.

[10] Shepard 1985, 164; Rice 1987, 118; Gosselain, Livingstone Smith 1995; 2005; Gosselain 2008.

[11] Shepard 1985; Michelaki, Minc, O'Shea 2002; Kreiter 2007; Albero Santacreu, García Rosselló, Calvo Trias 2014.

[12] Stark 1991; Stark, Longacre 1997.

the same kinds of temper regardless of, for example, its availability. One of the questions concerning inclusions pertains to the potter's consistency in selecting a certain kind of temper. If there was no consistency in practice or temper selection, the analysis of ceramic paste would be insignificant, i.e. it would be pointless to identify the temper or try to determine its origin. If we assume that there is a consistency in this selection, and that it is connected to the functional characteristics of vessels or tradition, the primary task is to determine similarities or differences in ceramic pastes. Equally or similarly prepared ceramic pastes are an indicator of established choices of the potter and/or the community, while minor differences in, for example, the amount of specific temper, can be a result of individual divergences in, for example, measuring the amount of such inclusions. Greater differences in recipes, that is, the kind and amount of temper, are indicators of different styles, and when these differences can be related to different types of vessels, surface treatment, decorative styles, and, in an archaeological sense, cultures, then we are dealing with different practices and traditions.[9] A more pronounced conservatism was noted in many ethnographic[10] and archaeological[11] examples, which is mostly connected with the tradition of a certain population, while greater variability in the composition of the ceramic structure is a good indicator of outside influences and changes in tradition or population.[12]

The mechanisms of selecting raw material for making pottery are affected by many different factors, so when interpreting them, one should consider natural and geological, technological, morphological, and social aspects individually, and in comparison to each other. Characterization of ceramic fabric using a macroscopic method is a good step in that direction.

[9] Shepard 1985, 164.

[10] Shepard 1985, 164; Rice 1987, 118; Gosselain, Livingstone Smith 1995; 2005; Gosselain 2008.

[11] Shepard 1985; Michelaki, Minc, O'Shea 2002; Kreiter 2007; Albero Santacreu, García Rosselló, Calvo Trias 2014.

[12] Stark 1991; Stark, Longacre 1997.

1.2. METODE I MOGUĆNOSTI KARAKTERIZACIJE STRUKTURE KERAMIKE

Da bismo prikupili podatke relevantne za proučavanje tehnologije proizvodnje posuda u prošlosti, potrebno je provesti karakterizaciju strukture keramike u svrhu identifikacije sastava lončarske smjese. Karakterizacija je keramike kvalitativna i kvantitativna deskripcija kompozicije, odnosno strukture keramike kako bi se vrednovala njezina svojstva. Za provođenje takvih analiza koristi se nekoliko metoda kojima se može pristupiti na dva načina: makroskopski i mikroskopski. Mikroskopska analiza provodi se promatranjem materijala pri znatnim uvećenjima i pomoću svjetlosnog (mikroskop s polarizacijskim svjetlom) i elektronskog mikroskopa. Takva analiza omogućuje promatranje fizičkih karakteristika materijala, posebice onih koji se odnose na njegovo podrijetlo. Takve petrografske i mineraloške analize dvije su osnovne arheometrijske metode analize keramike i glina.[13] Optička metoda na keramičkom izbrusku (engl. *thin section*) omogućava promatranje: prirode i karakteristika neplastičnih inkluzija (mineralni sastav i veličina, distribucija i orijentacija različitih čestica), teksture i optičkih karakteristika glinovitog materijala (dvolom i boja), oblika, količine i orijentacije šupljina i pora.[14] Jedan je od glavnih ciljeva petrologije utvrditi podrijetlo glinovitog materijala i primjesa koje su korištene u proizvodnji keramike.[15] Mineraloški sastav keramike i glina obično se analizira rendgenskom difrakcijom na prahu (XRPD) koja omogućava identifikaciju glavnih minerala u uzorku, kao i razinu njihove zastupljenosti. Metoda se koristi i za utvrđivanje kristalne faze minerala gline koje nije moguće zabilježiti pomoću petrografskog mikroskopa, a od iznimne su važnosti za interpretaciju metode pečenja posuda.[16]

[13] Shepard 1985, 138; Rice 1987, 375.

[14] Quinn 2013.

[15] Rice 1987; Quinn 2013.

[16] Shepard 1985, 93–98; Rice 1987, 382; Albero Santacreu 2014, 20.

1.2. METHODS AND POSSIBILITIES OF CERAMIC FABRIC CHARACTERIZATION

In order to collect data relevant for conducting study of pottery production technology, it is necessary to conduct the characterization of ceramic fabric with the purpose of identifying the composition of the ceramic paste. The characterization of pottery is the qualitative and quantitative description of the ceramic paste composition, i.e. ceramic fabric, done in order to assess its properties and methods of use. In order to carry out such analyses, several methods that can be approached in two ways are applicable: macroscopic and microscopic. Microscopic analysis is conducted by studying material under greater magnification by using a petrographic microscope (a microscope with polarized light) or electronic microscopes. This analysis enables studying numerous physical characteristics of the material, especially those related to its origin. Such petrographic and mineralogical analyses are the two basic archaeometric methods of analyzing pottery and clay.[13] The optical method, applied to ceramic thin sections, allows one to study: the nature and characteristics of non-plastic inclusions (mineral composition and size, the distribution and orientation of different particles), the texture and optical characteristics of the matrix (birefringence and color), and the shape, amount, and orientation of voids and pores.[14] One of the main objectives of petrography is to establish the origin of the clayey material and inclusions used in pottery production.[15] The mineral composition of pottery and clays is mostly determined through X-ray powder diffraction (XRPD), which enables the identification of the main minerals in a sample, as well as their respective quantity within the paste. The method is also used to define the phase of crystallization of the clay minerals that cannot be recorded by using a petrographic microscope, and which are of utmost importance for interpreting the firing techniques.[16]

[13] Shepard 1985, 138; Rice 1987, 375.

[14] Quinn 2013.

[15] Rice 1987; Quinn 2013.

[16] Shepard 1985, 93–98; Rice 1987, 382; Albero Santacreu 2014, 20.

Makroskopska metoda podrazumijeva analizu ulomka prostim okom i uvećanjem pomoću povećala, binokularnog ili digitalnog mikroskopa te analizu makrofotografije uzorka. Prednost je metode pristupačnost što nam omogućava istražiti veću količinu keramičkih uzoraka. Na taj način promatra se površina uzorka i keramička struktura te se karakterizira i sistematizirano bilježi sastav lončarske smjese. Tako provedenom klasifikacijom smjesa može se provesti analitički ispravan odabir uzoraka za buduće analize primjenom mikroskopskih metoda. Uz to, kod lončarskih smjesa izrazitijega heterogenog sastava te onih koje sadrže mnogo primjesa, kakve se često javljaju kod prapovijesne keramike, metoda omogućuje prikupljanje relevantnih podataka koji se mogu koristiti i neovisno o provedenim arheometrijskim analizama. Analizom makrofotografija, napravljenih digitalnim mikroskopom, omogućeno je promatranje fizičkih[17] te djelomično mineraloških[18] svojstava keramičkog materijala uz određena ograničenja.

Optimalni rezultati mogu se dobiti primjenom kombinirane makroskopske i mikroskopske analize. Tako prikupljeni podaci o tehnologiji neovisni su od ostalih uobičajenih kategorija kod arheološke analize keramike, poput stila ili klasifikacije oblika, premda se oni mogu koristiti i za usporedbu tih kategorija ili stvaranje novih.[19] Set prikupljenih podataka pruža dobar temelj za razumijevanje mnogih pitanja o tehnologiji proizvodnje, njezinoj organizaciji, vezi između specifičnih izvora, obrascima lo-

The macroscopic method includes the analysis of a fragment with the naked eye and by using a magnifying glass, a binocular or digital microscope, as well as the analysis of the sample's macrophotography. The advantage of such a method is its accessibility and the fact that it enables one to study a larger amount of pottery samples. In this way, sample surface and ceramic fabric can be observed which allows us to systematically characterize and document composition of ceramic paste. Such a classification can be the basis for an analytically accurate selection of samples for future analyses using microscopic methods. Additionally, for ceramic pastes with more pronounced heterogeneous compositions and ones that contain abundant temper material, which often occur in prehistoric ceramics, such a method allows us to collect relevant data that can be used independently of the conducted archaeometric analysis. The analysis of macrophotography made by a digital microscope allows us to study the physical[17] and, partially, mineralogical[18] properties of pottery with certain limitations.

Optimal results can be achieved by applying a combination of macroscopic and microscopic methods. Technological data gathered in this way is free from the usual categories applied in archaeological analyses of pottery such as style and form classification, although it can be used for comparing these categories or for creating new ones.[19] The set of obtained data provides one with a good foundation for understanding many issues with regard to production processes and their organization, the relation between specific sources, the patterns of local, regional and inter-regional pottery

[17] Fizička su svojstva vrlo značajna deskriptivna karakteristika glinovitog materijala, a uključuju: boju, teksturu, plasticitet, skupljanje i čvrstoću, dok fizičke krakteristike keramičkog materijala pružaju informacije o proizvodnom postupku (obrada površine, tehnika i režim pečenja i sl.) i funkcionalnim karakteristikama, što uključuje: poroznost, tvrdoću, strukturu, mikrostrukturu, čvrstoću i otpornost na termalni stres.

[18] Mineraloška svojstva podrazumijevaju analizu mineralnog sastava sirovine i pečenog proizvoda, odnosno keramike. Karakteristike minerala, poput vrste, oblika i veličine, značajni su zbog određivanja izvora produkcije i u izravnoj su vezi s fizičkim svojstvima, teksturom, poroznošću, tvrdoćom, bojom i čvrstoćom sirovinskog i pečenog materijala (Rice 1987, 313).

[19] Rice 1987, 308.

[17] Physical properties are a very important descriptive feature of clayey materials, and include: color, texture, plasticity, shrinkage, and firmness. The physical characteristics of ceramic materials provide information about the production process (surface processing, firing technique, firing conditions and so forth) and about functional characteristics, which include: porosity, hardness, structure, microstructure, firmness, and resistance to thermal stress.

[18] Mineralogical properties include the analysis of the mineral composition of raw material and the fired product, i.e. pottery. Characteristics of minerals, such as type, shape, and size are significant for determining the source of production and are directly related to physical properties, texture, porosity, hardness, color, and firmness of the raw and fired material (Rice 1987, 313).

[19] Rice 1987, 308.

kalne, regionalne i izvanregionalne distribucije keramike, pojedinačnim i društveno uvjetovanim odabirima, društvenim ideologijama, ritualu i sl., a ovo su samo neka od temeljnih istraživačkih pitanja prilikom proučavanja keramičke tehnologije.[20]

2. POSTUPAK MAKROSKOPSKE ANALIZE LONČARSKE SMJESE

Makroskopska analiza tehnologije proizvodnje keramike podrazumijeva identifikaciju i interpretaciju tragova izrade keramičkih posuda koji su zapisani na njihovoj površini (unutarnja i vanjska stijenka) i u keramičkoj strukturi. S obzirom na to da su gotovo sve metode karakterizacije keramike usmjerene prema analizi keramičke strukture, tj. lončarske smjese, u ovome će se poglavlju predstaviti analitički postupak na uzorcima keramike iz brončanog doba s prostora sjeverne Hrvatske.

Za makroskopsku analizu keramike, odnosno karakterizaciju smjesa, primjenjuje se metodologija koja se upotrebljava i u petrografiji keramike.[21] Međutim, makroskopska analiza sastava lončarske smjese provodi se s određenim ograničenjima, poput nemogućnosti identifikacije pojedinih vrsta mineralnih inkluzija ili identifikacije minerala glina, što je od velike važnosti pri interpretaciji podrijetla materijala. Analizom makrofotografija mogu se prikupiti podaci o veličini i obliku zrna, distribuciji i dimenzijama inkluzija i primjesa, boji i teksturi lončarske smjese te obliku, veličini i količini pora i šupljina u keramičkoj strukturi. Takve informacije pružaju dobru osnovu za sistematizirano prikupljanje podataka pomoću kojih će se karakterizirati uzorci. Cilj je identificirati pojedine minerale, osobine teksture i sastav lončarske smjese, što omogućava grupiranje keramike sličnih karakteristika i identificiranje atipičnih uzoraka. Na taj način radi se se-

[20] Rye 1981; Schiffer, Skibo 1987; Pfaffenberger 1992; Stark, Longacre 1997; Schiffer *et al.* 2001; Miller 2007; Schiffer 2010; Gosselain 2011.

[21] Shepard 1985; Quinn 2013; Druc 2015.

distribution, the individual and socially-conditioned choices, social ideologies, ritual and so forth. These are only some of the fundamental research issues when conducting an analysis of pottery production technology.[20]

2. THE PROCEDURE OF THE MACROANALYSIS OF CERAMIC PASTE

Macroanalysis of pottery production technology includes the identification and interpretation of traces pertaining to pottery production, which are preserved on its surface (inner and outer walls) and in the ceramic structure. Seeing as almost all methods of ceramic characterization focus on analyzing ceramic structure, i.e. ceramic pastes, this chapter presents the analytical procedure applied to samples of Bronze Age pottery from northern Croatia.

Macroanalysis regarding characterization of ceramic fabric uses the same methodology as petrographic studies of pottery.[21] However, the macroanalysis of ceramic paste composition is conducted with certain limitations, including the impossibility of identifying certain kinds of mineral inclusions or identifying clay minerals that are very important when interpreting the origin of the material. By analyzing macrophotographs, one can collect data on the size and shape of grains, the distribution and dimensions of inclusions and temper, the color and texture of the matrix, and the shape, size, and amount of pores and voids in the structure. Such information creates a good basis for the systematic collection of data, which can be used to characterize fabric groups. The goal is to identify specific minerals, features of texture, and the composition of the ceramic paste in order to group together pottery that has similar characteristics and to identify atypical samples. This is used to make a selection and to determine groups of ceramic fabrics from which samples can later be extracted for more precise petrographic, mineralogical, and

[20] Rye 1981; Schiffer, Skibo 1987; Pfaffenberger 1992; Stark, Longacre 1997; Schiffer *et al.* 2001; Miller 2007; Schiffer 2010; Gosselain 2011.

[21] Shepard 1985; Quinn 2013; Druc 2015.

lekcija i određuju grupe keramičkih struktura iz kojih se kasnije mogu izdvojiti uzorci za preciznije, petrografske i mineraloške te kemijske analize. U osnovi, cilj primjene ove metode je što bolje upoznati materijal koji se obrađuje i naučiti prepoznati i dokumentirati karakteristike lončarske smjese.

Da bi se takva analiza provela, keramički uzorak promatra se i dokumentira uz pomoć binokularnog ili digitalnog mikroskopa. Za potrebe ovog rada korišten je digitalni mikroskop *Dino Lite 2.0*, a uzorak je promatran na uvećanjima od 20 do 60 puta i uvećanjima od 200 do 250 puta (sl. 1). Mikroskop je povezan s računalom putem USB priključka, a pomoću softvera izrađuju se digitalne fotografije uzorka. Makrofotografije, napravljene pomoću mikroskopa, predstavljaju dokument svakoga pojedinog uzorka te se njihovom analizom stvara arhiva tzv. karakterističnih grupa keramičkih struktura. Treba naglasiti da digitalni mikroskop ne može zamijeniti specijalizirani petrografski mikroskop.

chemical analyses. Basically, the goal of using this method is to become more familiar with the pottery, as well as to learn to identify and document the characteristics of ceramic structure.

In order to conduct such an analysis, the sample is studied and documented by using a binocular or digital microscope. In this study, the *Dino Lite 2.0* digital microscope was used, and the sample was studied under a magnification between 20 – 60 and 200 – 250 (Fig. 1). The microscope was connected to a computer via USB port, and software was used to make digital photographs of the samples. Macrophotographs made using the microscope document each individual sample and their analysis produces an archive, the so-called characteristic group of ceramic structures. It should be pointed out that a digital microscope cannot replace a specialized petrographic microscope.

Slika / Figure 1. Digitalni mikroskop spojen s računalom i oprema potrebna za rad: kliješta, pomično mjerilo, zip-vrećice, otopina solne kiseline, keramički uzorci i sitni alat (snimila: A. Kudelić). / Digital microscope connected to a computer, and the equipment necessary for work: pliers, caliper, zip-lock bags, hydrochloric acid solution, pottery samples, and small tools (photo by: A. Kudelić).

2.1. ODABIR I PRIPREMA UZORAKA

Odabir uzoraka prije svega ovisi o pitanjima koja analitičar postavlja o materijalu tijekom ili prije istraživanja. Pretpostavlja se da je prije odabira uzoraka analitičar do neke mjere upoznat s materijalom i njegovim kronološkim te fizičkim karakteristikama (relativna / apsolutna datacija, tip posude, boja, debljina stijenke posude, obrada površine, tvrdoća i sl.). Stoga prije uzorkovanja analitičar treba provesti inicijalnu klasifikaciju keramičkih struktura na osnovi iskustva i preliminarnog pregleda materijala te na temelju vizualnog doživljaja i taktilnog osjeta zbog lakšeg snalaženja pri početnoj klasifikaciji. Na taj način materijal se može klasificirati na finu, prijelaznu ili srednje finu strukturu te na ulomke grube strukture. Na početku inicijalne klasifikacije struktura analitičar mora jasno odrediti kriterije prema kojima ih je definirao, na primjer količina primjesa vidljiva prostim okom, debljina stijenke i sl. Valja voditi računa da za svaku skupinu koja se definira treba izdvojiti jednaku količinu uzoraka radi kasnijih usporedbi i statističke analize. Nakon provedene makroskopske klasifikacije keramičkih struktura, njihova će varijabilnost vjerojatno biti mnogo složenija nego nakon rezultata inicijalne klasifikacije.

Također, poželjno je da su uzorci kronološki sigurno određeni, što omogućava pristup analizi keramičke proizvodnje u različitim razdobljima, bilježeći tako promjene i kontinuitet određenih aspekata proizvodnje kroz vrijeme. S tim u vezi je i usporedba tehnologije, ovisno o prostoru, odnosno regiji odakle materijal potječe. Keramički uzorci s različitih arheoloških nalazišta, smještenih na određenom području (mikroregija), odabiru se kako bi se odgovorilo na pitanja o načinu na koji je keramička proizvodnja povezana s različitim izvorima resursa u krajoliku tijekom vremena, ili u specifičnome vremenskom razdoblju. Jedan od osnovnih kriterija pri odabiru uzoraka u izravnoj je vezi s morfologijom posuda. Ako znamo kojem tipu posude uzorak

2.1. SAMPLE SELECTION & PREPARATION

The selection of samples primarily depends on the questions asked by the researcher about the material during and prior to research. The assumption is that the researcher is familiar with the material and its chronological and physical characteristics (relative/absolute dates, vessel type, color, wall thickness, surface treatment, hardness and so forth) to a certain extent before they make the selection. Hence, before selecting samples, the researcher must conduct an initial classification of ceramic structures based on experience and a preliminary overview of the material, as well as based on their visual impressions and touch, all in order to make it easier to keep track of the material during initial classification. Thus the material can be classified into fine, transitional or semi-fine, and fragments that have a coarse structure. At the beginning of the initial classification of the fabrics, the researcher must clearly determine the criteria used for defining them, e.g. the amount of inclusions/temper visible to the naked eye, wall thickness and so forth. They should also note that there should be an equal amount of samples for each defined group because of subsequent comparisons and statistical analyses. After conducting a macroscopic classification of ceramic structures, their variability will probably be more complex than after the initial classification.

It is preferred that the selected samples have been chronologically determined in order to approach the analysis of pottery production in different periods noting changes and continuity of specific aspects of production through time. Comparisons of technology are also connected to this, depending on the region where the material originated from. In that sense, pottery samples from different archaeological sites situated across a certain area (microregion) are selected with the aim of answering questions about the way pottery production is connected to, for example, the availability of different resources in the landscape over time. One of the main criteria when choosing samples is directly connected to vessel morphology. If the type of vessel the sample was part of is known, one has more options in the sense

pripada, onda su otvorene mnogo veće mogućnosti u interpretativnom smislu. Međutim, u arheološkom, osobito naseobinskom kontekstu fragmentacija posuda je izrazito velika. Prednost provođenja analize na amorfnim ulomcima je i njihova količina, za razliku od količine cjelovitih posuda, stoga se njihovom klasifikacijom može prikupiti veća količina podataka. Još je jedna prednost analize ulomaka neovisnost o ostalim varijablama, poput tipologije ili kronologije, što analitičaru osigurava višu razinu objektivnosti.

Nakon odabira uzoraka, potrebno je fotografirati i inventarizirati ulomak, veći dio posude kojoj uzorak pripada ili cijelu posudu (tip posude) te opisati fizičke karakteristike vanjske i unutarnje površine (obrada i boja površine), boju presjeka na svježem lomu uzorka te dodatne napomene ako se procijeni da za to postoji potreba (zabilježiti kategoriju određenu inicijalnom klasifikacijom). Ovi podaci unose se u ranije kreiranu bazu podataka u npr. *Excell Microsoft Office* programu. Nakon promatranja i bilježenja informacija o fizičkim karakteristikama ulomka keramičke posude, kliještima se lomi dio koji će se promatrati pomoću digitalnog mikroskopa. Važno je napomenuti da se mikroskopom promatra svježi lom uzorka koji omogućava jasnu sliku presjeka i bolji uvid u keramičku strukturu za razliku od tzv. starog loma koji je prekriven svojevrsnom patinom, zbog čega je ograničen izravan vizualni pristup keramičkoj strukturi. Keramički uzorci, koji ne sadrže mnogo primjesa, lome se relativno pravilno, odnosno površina na mjestu loma je ravna za razliku od uzoraka tzv. grube keramičke strukture čiji lom ostavlja nepravilnu površinu stoga i makrofotografija može biti slabije kvalitete. Ravan lom može se postići rezanjem ulomka pilom, međutim, pila može ostaviti horizontalne tragove u presjeku, što također nepovoljno utječe na vidljvost. Osim presjeka, dokumentira se vanjska i unutarnja površina uzorka posude. Prilikom promatranja uzoraka trebalo bi obuhvatiti više mjesta na svježem

of interpretation. However, in archaeological, especially settlement contexts, vessel fragmentation is very pronounced. An advantage of conducting the analysis on amorphous fragments is their number, unlike the number of whole vessels. Hence, by classifying them, one can collect a greater amount of data. Another advantage of analyzing fragments is the non-dependency on other variables like typology and chronology, which ensures a higher level of objectiveness.

After the samples have been selected, one must photograph and document the fragment, the larger part of a vessel from which the sample was obtained, or the entire vessel (type of vessel), and must describe the physical characteristics of the outer and inner surfaces (surface treatment and color), the color in the cross section on fresh breakage, and must make additional remarks if they are necessary (take down the category determined by initial classification). The data is then entered into a previously created data base in, e.g. *Excel Microsoft Office*. After studying and recording information about the physical characteristics of a pottery vessel fragment, pliers are used to break off the piece that will be studied under the digital microscope. It is important to note that the microscope is used to study fresh breakage on the sample, which allows for a clear image of the cross section and gives better insight into the ceramic fabric, unlike the so-called old breakage, which is covered by a sort of patina that limits the ability to visually study the structure. Pottery samples that do not contain many inclusions/temper break in a relatively regular way, i.e. breakage is straight, unlike samples of so-called coarse pottery, where breakage leaves an irregular surface, meaning that macrophotographs can be of lower quality. Straight breakage can be achieved by sawing the sample. However, saws can leave horizontal traces in the cross section which also negatively affect visibility. Apart from the cross section, one must document both the outer and the inner surface of a vessel sample. Sample observation should include as many spots on the fresh breakage as possible. It is also important to accompany each

lomu. Također, važno je uz svaku makrofotografiju navesti uvećanje pomoću kojega je snimljena i napomena o zapažanjima. Uvećanje se uglavnom prilagođava debljini stijenke uzorka koji se promatra i ono iznosi između 20 i 60 puta. Ako se obrađuje standardizirani materijal (stijenke ujednačene debljine), preporučuje se isto uvećanje za sve uzorke. Digitalni mikroskop ima mogućnost većih uvećanja do 250 puta, ali kvaliteta fotografije bit će smanjena, što je posljedica načina pripreme uzroka (prelomljeni uzorak) koji nije prilagođen za veća uvećanja (nepravilna površina uzorka). Ipak, veća uvećanja mogu se ponekad koristiti za npr. identifikaciju sitnih čestica minerala, što ovisi o njihovoj vrsti i stupnju vidljivosti. Digitalni mikroskop povezan je s računalom jednostavno kreiranim sučeljem koje pruža mogućnost korištenja alata poput mjerke, umetanja teksta, strelica ili kružnica, kao i alat za crtanje, a omogućena je i manipulacija fotografijama, npr. promjena orijentacije, negativ snimke i dr.[22] Maksimalna razlučljivost iznosi 300 dpi. Kako bi se postigla bolja vidljivost presjeka keramičkog ulomka i naglasio kontrast, makrofotografije mogu se dodatno urediti u programima za obradu fotografija ili se u tu svrhu koristi funkcija softvera za postizanje negativa snimke.

[22] Uz digitalni mikroskop dolazi i softver s osnovnim programom koji se koristi za analizu makrofotografija, međutim, takvi programi nemaju mogućnost kvantitativne analize. Za takav sofisticiraniji pristup mogu se nabaviti programi sa slobodnim pristupom putem interneta. Programi za sedimentologiju i petrologiju su dovoljno prilagođeni da se mogu koristiti i za analizu keramičkih struktura (Druc 2015, 96). Takvi programi omogućavaju mnogo objektivniji pristup analizi, ali jedan od nedostataka jest potpuna automatizacija. Više o takvom tipu kvantitativne analize makrofotografija vidjeti u Reedy, Kamboj 2004; Livingood, Cordell 2009.

macrophotograph with information about the magnification used, and remarks on observations. The magnification is mostly adjusted to the wall thickness of the sample under study, and it is usually between 20 and 60 times. If working with standardized material (walls of similar thickness), it is recommended to use the same magnification for all samples. The digital microscope can produce magnification larger than 250 times, but the image quality will be reduced as a result of preparation methods (breaking/cutting the sample), which are not suited for higher magnification (irregular sample surface). However, larger magnification is sometimes used to, for example, identify small mineral particles, which depends on their type and the level of visibility. The digital microscope is connected to a computer via a simple interface which allows one to use tools like measuring tapes, insert text, pointers, or circles, as well as use drawing tools and manipulate the photographs, e.g. change their orientation, produce a negative of the image, and so forth.[22] The maximum resolution is 300 dpi. In order to achieve better visibility of the cross section of a pottery fragment, and to enhance contrast, macrophotographs can additionally be edited in programs for photo editing, or they can be turned into negatives by using a feature of the software.

[22] The digital microscope comes with accompanying software used to analyze macrophotographs. However, such programs do not allow for a high-quality analysis. For such a sophisticated approach, one can use freeware found on the internet. Programs used in sedimentology and petrology are adapted to a level where they can also be used for analyzing pottery structures (Druc 2015, 96). Such programs allow for an objective approach to the analysis, but complete automatization is one of their bad sides. For more on this type of quantitative analysis of macrophotographs, see Reedy, Kamboj 2004; Livingood, Cordell 2009.

2.2. KARAKTERIZACIJA GLINOVITOG MATERIJALA I PRIMJESA

Glinoviti materijal i inkluzije u petrografiji se tretiraju zasebno,[23] a isti način primjenjuje se i pri makroskopskoj analizi. Promatranjem presjeka keramičkog uzorka cilj je zabilježiti značajke glinovitog materijala i ustanoviti eventualne primjese koje je lončar dodao smjesi. Međutim, makroskopskom metodom glinoviti materijal može se karakterizirati s određenim ograničenjima. Naime, glinoviti materijal (sirovina koju lončar koristi za izradu posuda) sastoji se od vrlo sitnih zrna veličine glina (< 2 mikrometra) i praha (2 – 60 mikrometara) te mineralnih inkluzija uglavnom dimenzija pijeska (60 – 2000 mikrometara). Glina je glavna komponenta svake keramičke strukture i čini uglavnom više od 50% volumena uzorka.[24] Pojedinačni minerali glina uglavnom su manji od 2 μm stoga ni jača uvećanja, ili korištenje petrografskog mikroskopa s polarizacijskim svjetlom, nisu dovoljna za njihovu karakterizaciju.[25] Minerali glina vidljivi su kao homogena masa koju je moguće karakterizirati samo prema kriteriju boje, no premda subjektivan, boja može biti dobar kriterij pri preliminarnom određivanju grupa keramičkih struktura. Boja glinovitog materijala ovisi o nekoliko faktora: vrsti minerala glina, količini organskih primjesa, prisutnosti željezovitih minerala te oksidacijskom stanju željeza unutar njih, prisutnosti ostalih finih čestica, npr. kalcita, i metodi te atmosferi pečenja.[26] S obzirom na to da je određivanje boje podložno subjektivnom doživljaju, preporučuje se korištenje atlasa boja *Munsell color system* ili definiranje nekoliko njih koje su najučestalije, odnosno korištenje ograničene količine boja i njihovih kombinacija radi veće objektivnosti.[27]

[23] Quinn 2013, 42.

[24] Quinn 2013, 42.

[25] Quinn 2013, 39.

[26] Rice 1987, 331–346; Quinn 2013, 42.

[27] S obzirom na to da je boja značajan pokazatelj atmosfere pečenja, što je vrlo važan segment proizvodnje, njezino je bilježenje nešto kompleksnije. Preporučuje se bilježiti sve boje u presjeku, počevši od unutarnje prema vanjskoj sti-

2.2. CHARACTERIZATION OF CLAYEY MATERIAL AND TEMPER

Clayey material and temper material are treated separately in petrography,[23] and the same approach is used in macroanalysis. When studying the ceramic cross section, the goal is to note all features of the clayey material and to establish possible temper material added to the paste by the potter. However, the clayey material can be characterized only to a certain extent by using macroanalysis. Namely, clayey material (raw material used to make vessels) consists of tiny grains the size of clay (< 2 micrometers) and dust (2 – 60 micrometers), and mineral inclusions mostly the size of sand (60 – 2000 micrometers). Clay is the main component of every ceramic fabric and mostly comprises over 50% of sample volume.[24] Individual clay minerals are mostly smaller than 2 μm, so they cannot be characterized even by using larger magnification or petrographic microscope with polarized light.[25] Clay minerals are visible as a homogenous mass which can only be characterized by color, which can be, albeit subjective, a good criterion used for defining groups of ceramic structures during preliminary determinations. The color of clayey material depends on several factors: the type of mineral clay, the amount of organic temper, the presence of iron oxides and the oxidation state of iron within them, the presence of other fine particles like calcite, as well as the firing method.[26] Seeing as color definition depends on subjective experience, using the *Munsell color system* color chart or defining several most frequent colors - using a restricted amount of colors and their combinations to achieve a greater level of objectivity - is recommended.[27]

[23] Quinn 2013, 42.

[24] Quinn 2013, 42.

[25] Quinn 2013, 39.

[26] Rice 1987, 331–346; Quinn 2013, 42.

[27] Seeing as color is a significant indicator of the firing method, a very important segment of production, noting it down is somewhat more complex. It is recommended to record all colors which appear in the cross section, starting from the inner surface of the vessel towards the outside or vice versa, i.e. to systematically record always using the same criteria (e.g. dark gray/dark gray/brown-yellow or dark grey/dark grey/dark grey/brown-yellow/dark grey). Apart from recording the colors, it is important to document their intensity and sharpness, i.e. the clarity of the border between the

Glinoviti materijal u sebi sadrži i minerale (kvarc, tinjci, kalcit i sl.), tj. inkluzije kao prirodnu sastavnicu sirovine, koje mogu biti i pokazatelj njezina podrijetla. Takve su čestice većih dimenzija vidljive prostim okom. Primjena optičke mikroskopije pomoću polarizacijskog svjetla uz stručnjaka geologa najbolji je načina karakterizacije navedenih minerala. Međutim, kod slabijih uvećanja nije uvijek moguće identificirati minerale. Ako su zrna jasno vidljiva, opisuju se njihove karakteristike (boja, oblik, veličina, zastupljenost itd.), ali ne preporučuje se imenovati, odnosno determinirati vrstu stijene ili minerala, osim ako analitičar dobro poznaje osnove petrologije i mineralogije. U suprotnome, valja konzultirati geologe ili iskusnije analitičare. Za identifikaciju željeza u smjesi može se koristiti magnet, a za identifikaciju karbonatnih minerala koristi se razrijeđena solna kiselina (otopina 5 – 10%). Kiselinu kapnemo na zrno koje želimo testirati i, ako se dogodi reakcija (otpuštanje plina ugljičnog dioksida u obliku mjehurića), to je pokazatelj da je u uzorku prisutan karbonatni mineral, kao što je npr. kalcit,[28] ili stijena poput vapnenca. Osim inkluzija u glinovitom materijalu, valja opisati i matriks u cjelini, tj. pokušati izmjeriti veličinu zrna minerala od kojih je matriks prirodno sastavljen (sitna zrna pjeskovitog materijala). Takva zrna uglavnom nisu veća od 0,06 mm i mogu se izmjeriti pomoću digitalnog mikroskopa pri uvećanjima od približno 200 puta. Kako bi karakterizacija glinovitog materijala bila sistematizirana i što preciznija, koriste se geološke granulometrijske tablice (tab. 1) s unaprijed definiranim vrijednostima i na-

Clayey material also contains minerals (quartz, mica, calcite etc.), that is, inclusions as natural components of raw material that can indicate its place of origin. Such larger particles are visible to the naked eye. Applying optical microscopy using a polarized light with an expert geologist present is the best way to characterize the listed minerals. However, if the grains are well visible, their characteristics can be described (color, shape, size, quantity etc.), but it is not recommended to name or determine the type of rock or mineral, unless the researcher is familiar with the basics of petrology and mineralogy. If that is not the case, one should consult with geologists or more proficient researchers. The presence of iron in a paste can be identified by using a magnet, and carbonate minerals by using a hydrochloric acid solution (5 – 10% solution). The acid is dripped onto the grain and if there is a reaction (releasing carbon dioxide in the form of bubbles), it is an indication that the sample contains a carbonate mineral like, e.g. calcite,[28] or a rock such as limestone. Apart from inclusions in the clayey material, one should also describe the entire matrix, i.e. try to measure the size of minerals which the matrix naturally contains (tiny grains of sandy material). Such grains are usually not larger than 0.06 mm and can be measured using a digital microscope with a magnification of approximately 200. In order for the characterization of clayey material to be systematic and as precise as possible, one should use geological granulometric tables (Tab. 1) with previously defined values and terms for the type of paste.[29] Researchers can create and make their own tables with criteria of values and names of specific groups and should, in that case, use them consistently. Apart from

jenci posude ili obrnuto, odnosno sustavno bilježiti uvijek prema istim kriterijima (npr. tamnosiva/tamnosiva/smeđe-žuta ili tamnosiva/tamnosiva/tamnosiva/smeđe-žuta /tamnosiva). Osim bilježenja boja, važno je dokumentirati i njihov intenzitet ili oštrinu granice između boje vanjske, odnosno unutarnje stijenke i boje jezgre, što se može razraditi u sklopu zasebne tehnološke analize koja je usmjerena interpretaciji tehnike i uvjeta pečenja keramike.

[28] Karbonatni materijal u uzorku keramike može biti posljedica nekih sekundarnih pojava, poput taloženja kalcita koji nastaje djelovanjem voda u tlu. Takvi talozi uglavnom se nalaze na površini ulomka ili u njegovim pukotinama, a njihova pojava u tome slučaju nema veze s podrijetlom materijala.

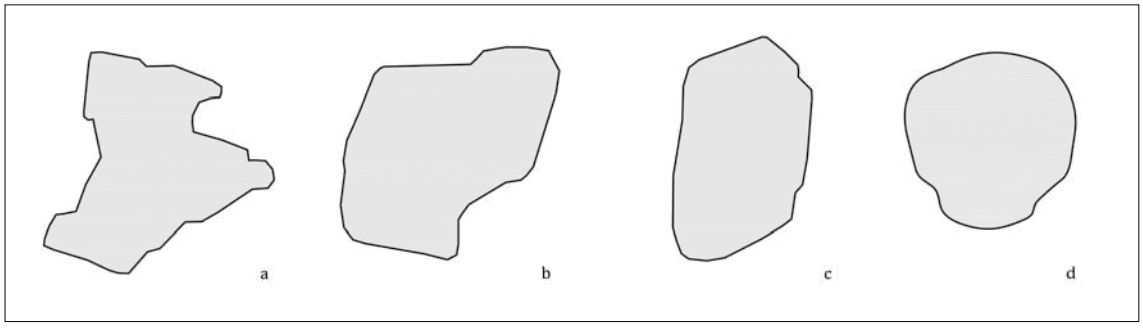
outer and inner surface color and the color of the core, all of which can be additionally defined within a separate technological analysis focused on interpreting the firing method and firing conditions.

[28] Carbonaceous material in a pottery sample can be the result of some secondary phenomena such as precipitation of calcite, which is a result of water in the soil. Such precipitates are mostly located on the surface of a fragment or in its crevices, and their appearance in those cases has nothing to do with the origin of the material.

[29] Rice 1987, 38; Prehistoric Ceramics Research Group 1997; Druc 2015, 16.

OPIS / DESCRIPTION	VELIČINA ČESTICA / PARTICLE SIZE
VRLO GRUB PIJESAK / VERY COARSE SAND	1 – 2 mm
GRUBI PIJESAK / COARSE SAND	0,63 – 1 mm
SREDNJI PIJESAK / MEDIUM SAND	0,2 – 0,63 mm
FINI PIJESAK / FINE SAND	0,125 – 0,2 mm
VRLO FINI PIJESAK / VERY FINE SAND	0,063 – 0,125 mm
PRAH / SILT	2 – 63 μm
GLINA / CLAY	< 2 μm

Tablica / Table 1. Standardi za klasifikaciju veličine čestica (Rice 1987, 38; Druc 2015, 16). / Standards for particle size classification (Rice 1987, 38; Druc 2015, 16).



Slika / Figure 2. Prikaz stupnjeva zaobljenosti zrna: uglata, djelomično uglata, djelomično zaobljena i zaobljena (Druc 2015, 17). / Representation of the degrees of grain roundness: angular, subangular, subrounded and rounded (Druc 2015, 17).

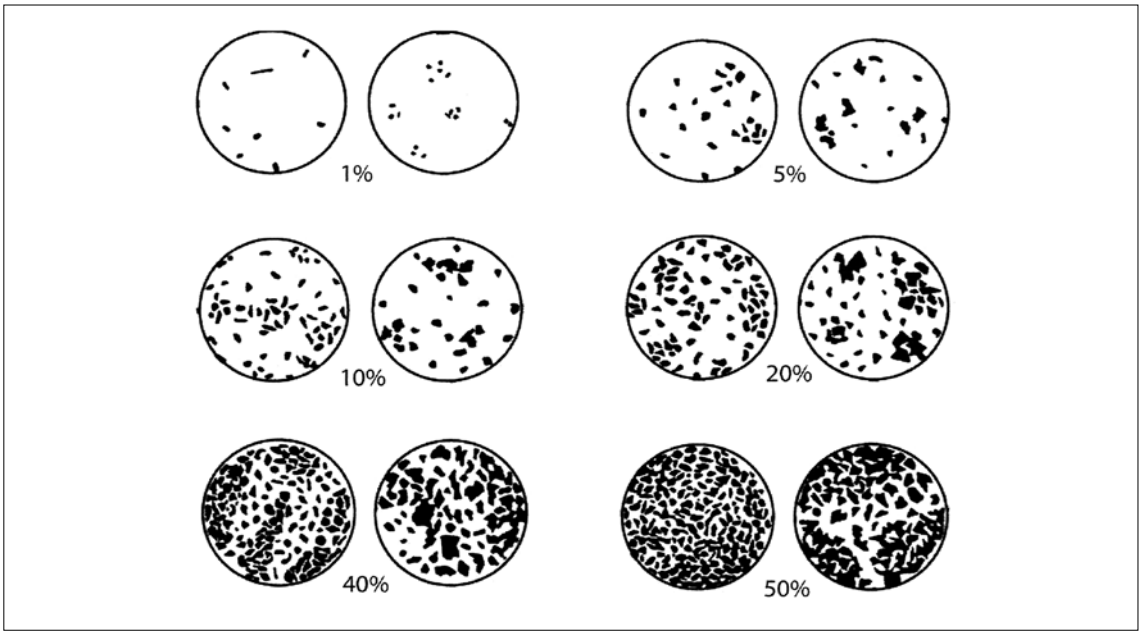
zivima za vrstu smjese.[29] Analitičar može osmisliti i izraditi vlastitu tablicu s kriterijima vrijednosti i nazivima pojedinih grupa i u tome slučaju dosljedno se njome koristiti. Osim veličine, potrebno je opisati i oblik zrna, bilo da se radi o inkluzijama ili primjesama. Oblik zrna definira se prema također unaprijed određenim kriterijima oblika, a ona mogu biti zaobljena, djelomično zaobljena, uglata i djelomično uglata (sl. 2).[30] Geološki, stupanj uglatosti/zaobljenothe size, one should describe the shape of the grain of both the temper and the inclusions in the paste. Grain shape is also defined based on previously defined criteria, and can be rounded, subrounded, angular, and subangular (Fig. 2).[30] Geologically speaking, the degree of angularity/roundedness of mineral/rock particles and their size are connected to transporting (via wind and/or water), i.e. to the distance of mineral grains from their source.[31] In that sense, they can be an indicator of the location of sedi-

[29] Rice 1987, 38; Prehistoric Ceramics Research Group 1997; Druc 2015, 16.

[30] Whitbread 1986; Quinn 2013, 84

[30] Whitbread 1986; Quinn 2013, 84

[31] Velde, Druc 1999, 26, 67–68.



Slika / Figure 3. Grafikon za određivanje gustoće zrna (Quinn 2013, 82). / Chart for determining grain density (Quinn 2013, 82).

sti čestica minerala/stijena i njihova veličina povezani su s transportom (vjetrom i/ili vodom), odnosno udaljenošću zrna minerala od njihova izvora.[31] U tome smislu, oni mogu biti indikator lokacije izvorišta sedimentnih glina, a navedeni parametri značajni su i za identifikaciju primjesa u lončarskoj smjesi.[32]

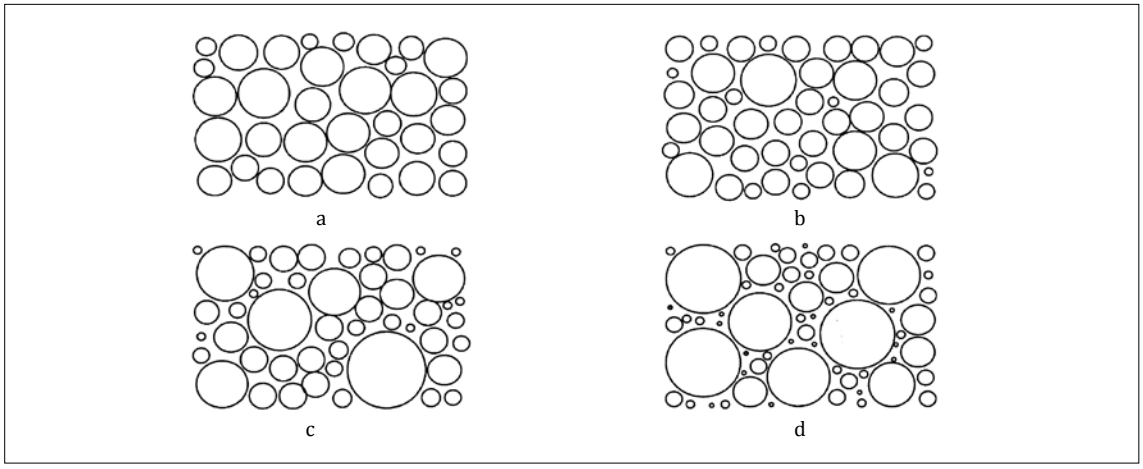
Bilježenjem gustoće zrna određuje se udio određene vrste zrna u keramičkoj strukturi, što može omogućiti, npr. određivanje količine primjesa koje lončar dodaje smjesi iz tehnoloških ili nekih drugih razloga. Gustoća zrna određuje se pomoću već oblikovanih tablica i izražena je u postocima (sl. 3). Promatranjem keramičkog uzorka pri slabijim uvećanjima moguće je procijeniti i zabilježiti relativnu gustoću primjesa, odnosno inkluzija u keramičkoj strukturi. Iako je i ovaj kriterij podložan subjektivnom doživljaju, bit će smanjen ako analizu većeg broja uzoraka provodi jedna osoba, prihvaćajući uvijek iste kriterije za procjenu.

mentary clays, and the listed parameters are also important for identifying inclusions in the ceramic paste.[32]

Recording the grain density allows us to determine the share and kind of grains in the ceramic structure, which can enable us, for example, to determine the amount of temper added to the paste by the potter for technological or some other reasons. The simplest way to determine grain density is by using premade tables, and expressing it in percentages (Fig. 3). By observing ceramic samples at lower magnifications it is possible to estimate and record the relative density of temper and inclusion grains in the ceramic structure. Even though this criterion is subject to individual interpretation, subjectivity can be reduced if large numbers of samples are analyzed by the same person always using the same evaluation criteria.

[31] Velde, Druc 1999, 26, 67–68.

[32] Quinn 2013, 83.



Slika / Figure 4. Grafikon za određivanje rasporeda zrna: (a) vrlo dobro raspoređena, (b) dobro raspoređena, (c) loše raspoređena, (d) vrlo loše raspoređena (Quinn 2013, 87). / Chart for determining grain distribution: (a) very well sorted, (b) moderately sorted, (c) poorly sorted, (d) very poorly sorted (Quinn 2013, 87).

Raspored inkluzija ili primjesa u smjesi pokazatelj su postupka pripreme smjese ili načina oblikovanja posude.[33] Prema kriterijima distribucije zrna mogu biti vrlo dobro, dobro, loše i vrlo loše raspoređena. U tu svrhu koriste se unaprijed određeni kriteriji iskazani u tablici (sl. 4). U istu svrhu koristi se i karakterizacija orijentacije zrna i praznina u odnosu na orijentaciju stijenke posude, a tzv. preferirana orijentacija odnosi se na položaj inkluzija i šupljina/pora u keramičkoj strukturi i na površini posude, ovisno o smjeru sile koja se na površinu vrši pri oblikovanju posude ili obrade površine.[34] Njihova orijentacija može biti paralelna, djelomično paralelna i nepravilna (sl. 5). Međutim, prisutnost pora može biti pokazatelj nekih drugih pojava. Na primjer, izdužene, paralelno orijentirane pore u strukturi upućuju na sekundarnu poroznost, a njihov nastanak može biti rezultat migracije plinova tijekom procesa pečenja keramike. Pore koje ne pokazuju preferiranu orijentaciju i pravilan oblik mogu ukazivati na lošu kvalitetu izrade keramičkih predmeta.[35] Oblik i orijentacija pora mogu ovisiti i o tehnici izrade keramičkih posuda pa izdužene i paralelno orijentirane pore mogu biti pokazatelj oblikovanja posude na

[33] Rye 1981, 61–88.

[34] Rye 1981, 61.

[35] Velde, Druc, 1999.

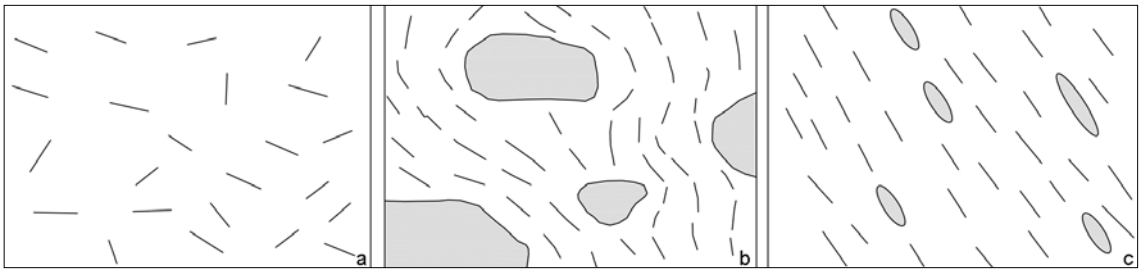
Distribution of temper or inclusion grains in the ceramic paste is an indicator of procedures in paste preparation, or of the vessel forming technique.[33] Based on distribution criteria, grains can be very well, moderately, poorly, or very poorly distributed. This is determined by predefined criteria shown in a table (Fig. 4). The characterization of grain and void orientation in relation to the orientation of the vessel walls is used for the same reason, i.e. the preferred orientation refers to the position of temper and voids/pores in vessel structure and on its surface depending on the direction of the force applied to the surface during vessel shaping or surface treatment.[34] Their orientation can be parallel, partially parallel and irregular (Fig. 5). However, the presence of pores can be an indicator of other phenomena, for example, elongated parallel pores indicate secondary porosity, and their emergence can be the result of gas migration during the process of firing. Pores which do not have the preferred orientation and regular shape can point to poor-quality production of ceramic objects.[35] Pore shape and orientation can also depend on the vessel forming techniques, so elongated and parallel pores can be an indicator of shaping the vessel on a potter's wheel, and round pores are an indicator of hand-made vessels.[36] Parallel ori-

[33] Rye 1981, 61–88.

[34] Rye 1981, 61.

[35] Velde, Druc, 1999.

[36] Cuomo di Caprio 2007.



Slika / Figure 5. Orijentacija zrna i pora/šupljina: (a) nepravilna, (b) djelomično orijentirana, (c) paralelno orijentirana (modificirano prema: Rye 1981, 61; Grzunov 2014). / Grain and pore/void orientation: (a) irregular orientation, (b) partially parallel orientation, (c) parallel orientation (modified after: Rye 1981, 61; Grzunov 2014).

kolu, a zaobljene pore pokazatelj su ručnog oblikovanja posude.[36] Paralelna orijentacija u pojedinim uzorcima može biti posljedica izrade posude uz pomoć rotacije, ali isto tako može biti i posljedica ručne izrade, stoga se interpretacije ovog tipa ne mogu izvoditi s potpunom sigurnošću.

Osim neplastičnih materijala (mineralnih zrna, litoklasta, groga), koje lončari obično dodaju smjesi, u strukturi pretpovijesne keramike često se nalaze i glinoviti peleti (engl. *argillaceous rock fragments*). Mikrostruktura je takvih primjesa slična strukturi glinovitog materijala stoga je njihova vidljivost na svježem lomu uzorka često smanjena. Međutim, postoje smjernice uz pomoć kojih je moguće razlikovati pelet od matriksa uz pomoć petrografskog mikroskopa s polarizirajućim svjetlom.[37] Glinoviti peleti mogu imati različiti karakter: mogu biti sastavni dio glinovitog materijala, kao posljedica nedovoljno izmiješane smjese, mogu biti namjerno dodane različite vrste glinovitog materijala da bi se poboljšala svojstva gline ili peleti mogu biti pripremljeni i dodani smjesi poput groga.[38] Definiranje karaktera glinovitih peleta nije uvijek jednostavno, ali njegova identifikacija predstavlja značajnu informaciju za rekonstrukciju proizvodnog postupka.

Osim različitih neplastičnih materijala, koje lončar dodaje smjesi, primjese mogu biti i organskog podrijetla, poput trave,

[36] Cuomo di Caprio 2007.

[37] Više u Withbread 1986; Cuomo di Caprio, Vaughan 1993.

[38] Whitbread 1986; Cuomo di Caprio, Vaughan 1993; Quinn 2013, 84; Albero Santacreu 2014, 62; Kudelić 2016.

entation can, in some samples, be the result of shaping the vessel using rotation, but can also be the result of shaping the vessel by hand, so interpretations of this sort cannot be completely accurate.

In addition to non-plastic minerals (mineral grains, lithoclasts, and grog) that the potters usually added to the paste, the ceramic fabirc usually includes argillaceous rock fragments. The microstructure of such inclusions is similar to that of clayey material, so it is often very difficult to see them in the cross section. However, there are guidelines which can be used to help differentiate between argillaceous rock fragments and the matrix by using a petrographic microscope with polarized light.[37] Argillaceous rock fragments can differ in character: they can be a constituent part of the clayey material as a result of insufficiently mixed pottery clay, they can be intentionally added to different kinds of clayey material to improve its properties, or they can be prepared and added like grog.[38] Determining the characteristics of argillaceous rock fragments is not always simple but its identification can provide very important data for reconstructing the pottery production process.

Apart from different non-plastic materials added to the paste by the potter, temper can also be organic, e.g. grass, chaff, hay, dung and so forth, and it can appear intentionally or unintentionally. Organic temper materials as well as non-plastic temper materials are added to

[37] For more, see Withbread 1986; Cuomo di Caprio, Vaughan 1993.

[38] Whitbread 1986; Cuomo di Caprio, Vaughan 1993; Quinn 2013, 84; Albero Santacreu 2014, 62; Kudelić 2016.

pljeve, slame, kravlje balege i sl. Njihova pojava također može biti slučajna i namjerna. Primjese od organskog materijala smjesi se dodaju u svrhu poboljšanja svojstava glina koje su vrlo plastične, kako bi se olakšalo oblikovanje i sušenje glinene posude te da bi se osigurala visoka razina otpornosti na termalni stres tijekom postupka pečenja i tijekom uporabe predmeta.[39] Organski materijal tijekom pečenja izgori, a u keramičkoj strukturi manifestira se u obliku šupljina i pora. Osim na takav način, njihov zapis manifestira se i u obliku tamnih mrlja nastalih uslijed njihova izgaranja i oslobađanja ugljika u strukturi keramike, a veće količine vrlo usitnjene primjese u smjesi mogu znatno utjecati na boju presjeka keramike. Prilikom promatranja svježeg loma uzorka treba navesti postoje li pokazatelji prisutnosti organskih primjesa te opisati oblik i orijentaciju pora, odnosno šupljina, ako se pretpostavlja da su nastale izgaranjem primjesa organskog podrijetla.

Dakle, veličina čestica, vrsta, oblik, raspored, gustoća, orijentacija i boja bilježe se za glinoviti materijal ako za to postoje pokazatelji. Ograničenja primjene makroskopske metode onemogućavaju potpunu karakterizaciju glinovitog materijala stoga je za potpunu analizu neophodno provesti i petrografsko-mineraloške analize. Međutim, promatranjem uzorka na prikazani način omogućeno je bilježenje boje presjeka te, ako je riječ o vrlo homogenoj smjesi bez krupnih primjesa, što omogućava bolju vidljivost matriksa, bilježi se i veličina čestica, vrsta, oblik, raspored, gustoća i orijentacija mineralnih zrna. Veličina čestica, vrsta, oblik, raspored, gustoća i orijentacija bilježe se za primjese identificirane u glinovitu materijalu poput kvarca, pjeskovitog materijala, groga i sl. Ako je zabilježeno korištenje više vrsta primjesa, za svaku posebno bilježi se oblik, a zajednički se bilježi veličina čestica, raspored, gustoća i orijentacija. Oblik, raspored i orijentacija bilježe se za pore i šupljine u keramičkoj strukturi.

[39] Skibo, Schiffer, Reed 1989; Gibson, Woods 1990, 27; Velde, Druc 1999, 83; Quinn 2013, 156, 158.

the ceramic paste in order to reduce the plasticity of the clayey material, to facilitate the forming and drying of the vessel, to ensure a good level of heat resistance during the firing process, and while the vessel is being used.[39] Organic material is burned off during firing, and appears in the ceramic structure in the form of voids and pores. It is also visible as small dark spots caused by the burning of the organic material and oxygen release within the pottery structure. Larger amounts of very finely shredded inclusions in the ceramic paste can significantly affect the color of pottery cross sections. When observing the cross section of a sample, one should record indicators of organic temper material presence, and should describe the shape and orientation of pores and voids if one assumes they are present due to organic inclusion burning.

Finally, grain size, type, shape, distribution, density, orientation, and color for the clayey material are recorded if there is a need to do so. Certain limitations of applying the macroscopic method do not allow for a complete characterization of the clayey material. Therefore, it is necessary to conduct a complete petrographic and mineralogical analysis. However, by observing the sample in the presented manner we are able to record the color of the cross section and, in case of working with a very homogenous paste without large inclusions which make studying the matrix easier, to record grain size, kind, shape, distribution, density and orientation, as well as the orientation of mineral grains. Grain size, kind, shape, distribution, density and orientation are recorded for those inclusions identified in the clayey material such as quartz, sandy material or grog. If more kinds of inclusions were used, the shape of each is recorded separately for each kind, and size, distribution, density, and orientation are recorded together. The shape, distribution, and orientation are also recorded for pores and voids in the ceramic structure.

[39] Skibo, Schiffer, Reed 1989; Gibson, Woods 1990, 27; Velde, Druc 1999, 83; Quinn 2013, 156, 158.

3. KARAKTERISTIKE LONČARSKIH SMJESA IZ BRONČANOG DOBA

Predstavljena metoda primijenjena je na uzorcima keramičkih posuda različitih kultura i kulturnih grupa brončanog doba s prostora sjeverne Hrvatske. Keramički je materijal otkriven tijekom arheoloških istraživanjima i definiran je relativno te apsolutno kronološki. Makrofotografijom je dokumentirano i analizirano ukupno 246 uzoraka keramike. Od toga 12 uzoraka pripada keramici vinkovačke kulture (nalazište: Donji Miholjac), 15 uzoraka keramici kulture Kisapostag i licenskoj keramici s područja Turopolja i Podravine (nalazišta: Đelekovec-Log, Vratnec, Kurilovec, Selnica Ščitarjevska), 13 uzoraka panonskoj inkrustiranoj keramici (nalazište: Jagodnjak-Krčevine), 182 uzorka pripada keramičkim posudama grupe Virovitica s područja Turopolja (nalazišta: Kurilovec-Belinščica, Selnica Ščitarjevska) i Podravine (nalazišta: Vratnec, Podvratnec, Podgorica, Podpanje, Jablanec, Močvar) i 24 uzorka kasnobrončanodobnoj keramici (nalazišta: Kalnik-Igrišče, Dubovac-Stari grad). Karakterizacija i opis sastava lončarske smjese, a to se posebno odnosi na glinoviti materijal i neplastične mineralne sirovine, bit će mnogo kvalitetniji ako analitičar do neke mjere poznaje geološki sastav tla područja koje istražuje.

3.1. KARAKTERIZACIJA GLINOVITOG MATERIJALA

Radi potpunije i kvalitetnije interpretacije, korišteni su rezultati već provedenih arheometrijskih analiza keramike i glina[40] kako bi se stekao bolji uvid u sastav sirovinskog materijala i njegovo podrijetlo. Rezultati provedenih arheometrijskih analiza keramike i glinovitog materijala, koji je prikupljen u blizini pretpovijesnih naselja na području Podravine i dijela Posavine (Tu-

[40] Petrografsko-mineraloške analize provedene su na ukupno 64 uzorka, od toga na 49 uzoraka keramike grupe Virovitica, 3 uzorka licenske keramike te 9 uzoraka kasnobrončanodobne keramike s nalazišta Kalnik-Igrišče.

3. CHARACTERISTICS OF BRONZE AGE CERAMIC PASTES

The presented method was applied to samples of pottery vessels ascribed to different Bronze Age cultures and cultural groups from the territory of northern Croatia. The pottery was discovered in archaeological excavations and was chronologically dated both relatively and absolutely. Macrophotography was used to document and analyze a total of 246 pottery samples. A total of 12 samples belong to the Early Bronze Age Vinkovci Culture (site: Donji Miholjac), 15 samples to the Kisapostag Culture and Litzen pottery from Turopolje and the Podravina region (sites: Đelekovec-Log, Vratnec, Kurilovec, Selnica Ščitarjevska), 13 samples to Pannonian Encrusted Ware (site: Jagodnjak-Krčevine), 182 samples belong to pottery vessels of the Virovitica group from the Turopolje region (sites: Kurilovec-Belinščica, Selnica Ščitarjevska) and Podravina (sites: Vratnec, Podvratnec, Podgorica, Podpanje, Jablanec, Močvar), and 24 samples are Late Bronze Age pottery vessels (sites: Kalnik-Igrišče, Dubovac-Stari grad). The characterization and description of the ceramic paste, which especially refers to clayey material and non-plastic mineral raw materials, will be of higher-quality if the researcher is familiar with the geological composition of soil across the studied territory.

3.1. CHARACTERIZATION OF CLAYEY MATERIAL

In order for the interpretation to be more complete and of higher quality, the results of previously conducted archaeometric analyses (optical microscopy, XRD) conducted on pottery and clayey material samples were used primarily to gain better insight into the composition of the raw material and its origin.[40] The results of the conducted archaeometric analyses of pottery and samples of clayey material collected

[40] Petrographic and mineralogical analyses were conducted on a total of 64 samples, on 49 pottery samples of the Virovitica group, 3 samples of Litzen pottery, and 9 samples of Late Bronze Age pottery from the site of Kalnik-Igrišče.

Slika / Figure 6. Makrofotografije keramičkih struktura brončanodobne keramike načinjene od gline s finim do vrlo finim zrnima kvarcnog pijeska: (a) vinkovačka kultura – Donji Miholjac, uvećanje 45 x; (b) licenska keramika – Đelekovec-Log, uvećanje 60 x; (c) panonska inkrustirana keramika – Jagodnjak-Krčevine, uvećanje 35 x (snimila: A. Kudelić). / Macrophotographs of Bronze Age pottery made of clay with fine and very fine grains of quartz sand: (a) the Vinkovci Culture – Donji Miholjac, magnification 45 x; (b) Litzen pottery – Đelekovec-Log, magnification 60 x; (c) Pannonian Encrusted Ware – Jagodnjak-Krčevine, magnification 35 x (photo by: A. Kudelić).

ropolje), pokazuju da je za izradu posuda u brončano doba korišten sirovinski materijal lokalnog podrijetla.[41] Niz je provedenih istraživanja pokazao da udaljenost od mjesta eksploatacije sirovine do mjesta na kojem se izrađuju posude može iznositi od 1 do 10 km, međutim, najčešće se glina nabavlja u radijusu od 1 km od mjesta izrade posuda.[42] Većina je analiziranih keramičkih uzoraka pronađena u naseljima nizinskog tipa, smještenih uz veće ili manje vodotoke, stoga se pretpostavlja da je aluvijalni tip glina bio dovoljno kvalitetan i lako dostupan. Na osnovi iznesenih rezultata istraživanja i pretpostavki slično se može zaključiti i za nalaze na kojima nisu provedene arheometrijske analize iako su za dio uzoraka one u postupku obrade.

Promatranjem svježeg loma keramičkih uzoraka pomoću digitalnog mikroskopa zabilježena su i izmjerena vidljiva zrna u matriksu te je struktura okarakterizirana kao fina do vrlo fina, sastavljena od relativno sitnih zrna, veličine od 0,03 mm do 0,25 mm, djelomično uglatih i dobro raspoređenih (sl. 6). S obzirom na to da glinovito tlo aluvijalnog podrijetla sadrži samo određeni udio minerala glina, a preostali je dio sačinjen od praha i pjeskovitog materijala,[43]

in the vicinity of prehistoric sites in Podravina and part of Posavina (Turopolje) show that raw material of local origin was used to produce vessels in the Bronze Age.[41] A series of studies has shown that the distance between the place of raw material exploitation and the location where vessels were produced can vary from 1 to 10 km, but that clay is most often collected in a radius of 1 km from the place of production.[42] Most of the analyzed pottery samples were found in lowland types of settlements that were situated near larger or smaller watercourses. Hence, the assumption is that alluvial clays were of good enough quality and easily available. Based on the presented research results and assumptions, the same can also be concluded for the finds which have not been microscopically studied, although some sample analyses are currently being conducted.

By observing the cross sections of ceramic samples using a digital microscope, visible grains in the matrix were recorded measuring between 0.03 mm to 0.25 mm in size, subangular and well distributed, so the fabric was defined as varying from fine to very fine (Fig. 6). Considering the fact that clayey soil of alluvial origin contains only a certain amount of clay minerals, and the rest is made up of powder and sandy material,[43] it is assumed that

[41] Kudelić 2015; Kudelić *et al.* 2018.

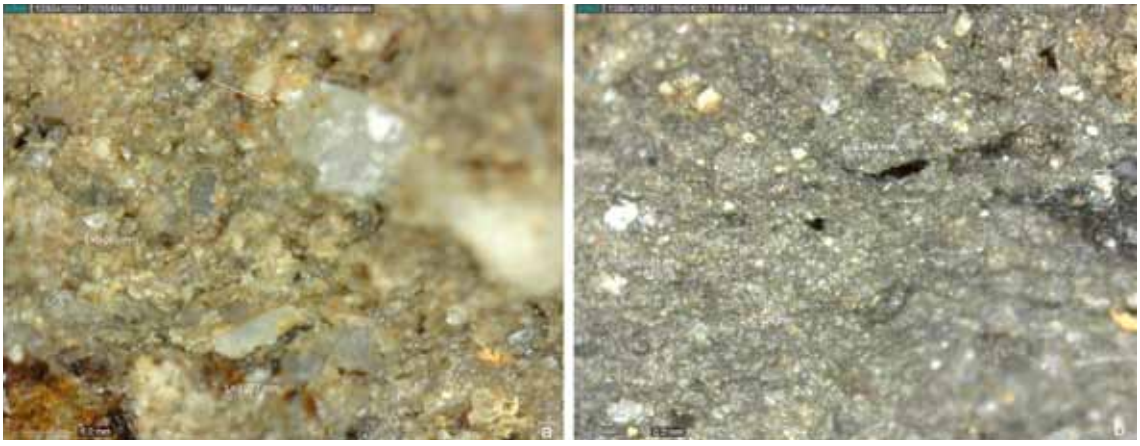
[42] Rice 1987, 116; Arnold 2000, 343.

[43] Pijesak je prirodni granularni materijal, sačinjen od fino razdijeljenih čestica stijena i minerala. Ako se odnosi na ter-

[41] Kudelić 2015; Kudelić *et al.* 2018.

[42] Rice 1987, 116; Arnold 2000, 343.

[43] Sand is a natural granulated material made up of finely dispersed rock particles and minerals. In geology, it is mate-



Slika / Figure 7. Makrofotografije kvarcnog pijeska u keramičkoj strukturi posuda vinkovačke kulture – Donji Miholjac: (a) uvećanje 230 x, (b) uvećanje 230 x (snimila: A. Kudelić). / Macrophotographs of quartz sand in the structure of Vinkovci Culture pottery vessels – Donji Miholjac: (a) magnification 230 x, (b) magnification 230 x (photo by: A. Kudelić).

pretpostavlja se da je riječ o prirodnoj sastavnici sirovine i da je riječ o sitnom pijesku koji se sastoji od više vrsta silikatnih minerala, poput kvarca, feldspata, tinjaca i dr. S obzirom na mogućnosti makroskopske analize, o podrijetlu materijala ne može se reći mnogo više. Ipak, postoje minerali koji se mogu identificirati pomoću digitalnog mikroskopa, odnosno promatranjem svježeg loma uzorka pri manjim uvećanjima.

Najučestaliji i najprepoznatljiviji mineral je kvarc (sl. 7). Pripada skupini silikatnih minerala, a razlikuje se nekoliko varijeteta. Kvarc kristalizira heksagonski, svijetle je boje i staklastog sjaja te vrlo visoke tvrdoće. Sličan petrogeni mineral, svijetle boje te jednako učestao (tvori više od 60% Zemljine kore) je feldspat koji, za razliku od kvarca, mijenja svojstva pod utjecajem vode, a nalazi se u sedimentnim, magmatskim i metamorfnim stijenama. Predstavlja skupinu minerala (alkalne feldspate, kao npr. ortoklas, i plagioklase, kao npr. albiti) koje nije moguće razlikovati uporabom samo digitalnog mikroskopa pa su za identifikaciju potrebne petrografske ili kemijske

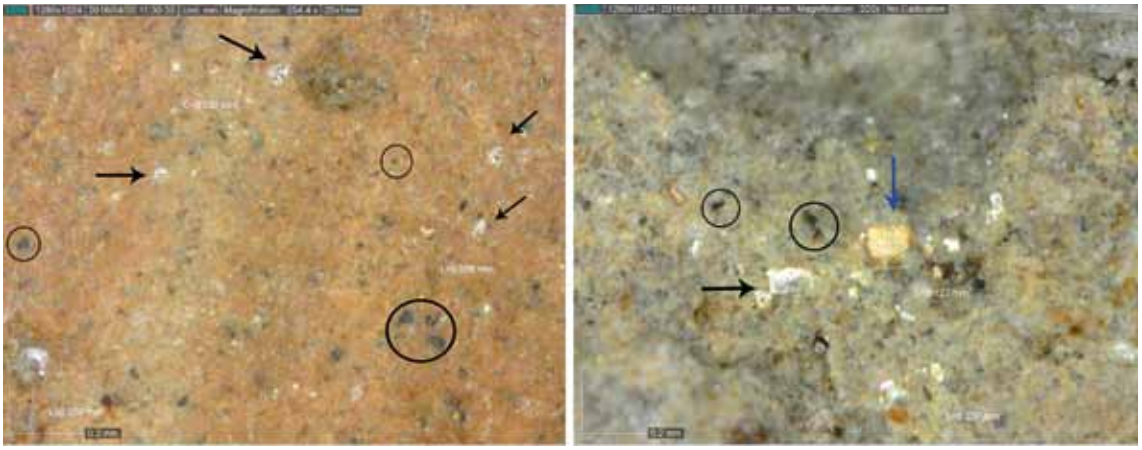
the grains are a natural component of the raw material, and that they are grains of fine sand comprised of more kinds of silicate minerals such as quartz, feldspar, mica etc. Regarding the limitations of macroanalysis we cannot say much more about the origin of the raw material. However, there are minerals which can be identified using a digital microscope, i.e. by studying cross sections under lower magnifications.

The most common and recognizable mineral is quartz (Fig. 7). It falls under the group of silicate minerals, and appears in several variants. Quartz crystallizes in a hexagonal pattern, is light in color, has a glassy sheen, and is very hard. Feldspar is a similar rock-forming mineral, light in color, is equally frequent (makes up over 60% of the Earth's crust) and, unlike quartz, changes its properties under the influence of water and can be found in sedimentary, igneous, and metamorphic rocks. It represents a group of minerals (alkaline feldspar such as orthoclase and plagioclase like albite) that cannot be discerned by using a digital microscope, but requires petrographic or chemical analyses.[44] This way, we can study the physi-

min u geologiji, riječ je o materijalu čiji je promjer od 60 do 200 mikrometara. Pijesak je najvećim dijelom sačinjen od silicijeva dioksida, SiO_2, najčešće u formi kvarca. Sastav je pijeska varijabilan i može sadržavati: muskovit, cirkon, rutil, apatit, granat, magnetit, turmalin itd.

rial measuring 60 – 200 micrometers in diameter. Sand is mostly comprised of silica SiO2, mostly in the form of quartz. The composition of sand varies and can contain: muscovite, zircon, rutile, apatite, garnet, magnetite, tourmaline, etc.

[44] Druc 2015, 24.



Slika / Figure 8. Makrofotografije minerala iz skupine tinjaca u keramičkoj strukturi; crni krugovi označavaju biotit i/ili amfibole, crne strelice označavaju muskovit, a plava flogopit; panonska inkrustirana keramika – Jagodnjak-Krčevine: (a) uvećanje 250 x, (b) uvećanje 220 x (snimila: A. Kudelić). / Macrophotographs of minerals from the mica group in the pottery fabric; black circles denote biotite and/or amphibolites, black arrows denote muscovite, and the blue one denotes phlogopite; Pannonian Encrusted Ware – Jagodnjak-Krčevine: (a) magnification 250 x, (b) magnification 220 x (photo by: A. Kudelić).

analize.[44] Na taj način promatraju se fizička svojstva pojedinih minerala i lom svjetla s njihove površine koji manifestira razlike u građi minerala, odnosno uređenost njihove kristalne rešetke. Pomoću digitalnog mikroskopa, razliku između feldspata i kvarca nije moguće sa sigurnošću utvrditi na temelju njihovih fizičkih karakteristika,[45] jer ovi minerali mogu biti izrazito slični.

Velik je broj posuda izrađen od smjese koja sadrži izrazito svjetlucavi pijesak. Riječ je o sitnim zrnima minerala iz skupine tinjaca ili liskuna (muskovit), slojevitih silikata koji se lome u listićima. Oni također pripadaju skupini silikatnih minerala koji su vrlo učestala sastavnica glinovitog materijala koji se koristio za izradu posuda u brončano doba, odnosno prirodna su sastavnica tala na prostoru sjeverne Hrvatske, posebice pijeska. Najzastupljeniji minerali iz skupine tinjaca su muskovit i biotit (sl. 8). Biotit je mineral tamnozelene do crne boje i vrlo je sličan mineralu amfibolu. Muskovit je uglavnom bezbojan, odnosno bijeli tinjac, ponekad žutih i smeđih tonova, dok je flogopit zlatne boje.

[44] Druc 2015, 24.

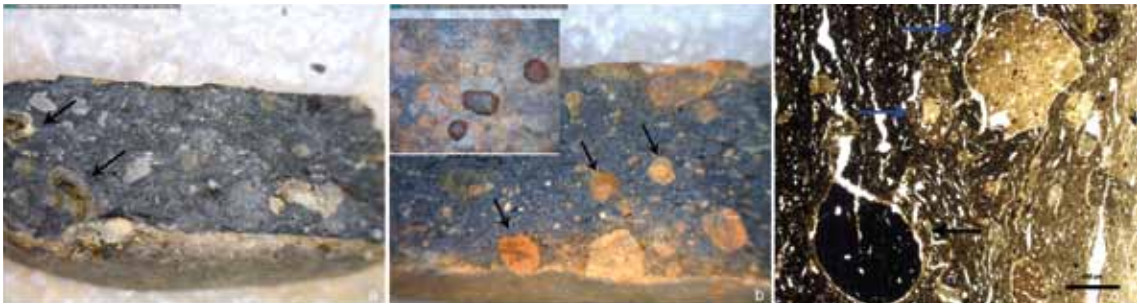
[45] Druc 2015, 24.

cal properties of individual minerals and the way light reflects from their surface, which is affected by differences in mineral composition, i.e. the organization of their crystalline grid. It is not completely possible to identify differences between feldspar and quartz based on the physical characteristics of each mineral by using a digital microscope,[45] because they can be very similar.

A large number of vessels is made from paste that contains highly reflective sand. The sand is comprised of tiny mineral grains from the group of mica (muscovite), layered silicates that break off in thin sheets. The group of minerals is a very common compound in clayey material used to produce Bronze Age vessels as it is a natural component of northern Croatian soils, especially sand. The most represented minerals from the mica group are muscovite and biotite (Fig. 8). Biotite is a dark green-black mineral and is very similar to amphibolites. Muscovite is mostly colorless, that is, a white kind of mica that sometimes appears in yellow and brown tones, while phlogopite is golden.

Oxides and hydroxides are also natural soil components, which make up a large portion of the Earth's crust, and many of them are im-

[45] Druc 2015, 24.



Slika / Figure 9. Makrofotografije oksida i hidroksida u keramičkoj strukturi; crne strelice označavaju željezovite granule i okside iz tla, a plave strelice grog: (a) Kurilovec-Belinščica, uvećanje 50 x; (b) Podgorica, uvećanje 35 x; manja makrofotografija prikazuje granule na površini posude, uvećanje 30 x; (c) Podgorica, mikrofotografija keramičkog preparata s vidljivim crnim zrnom željezova oksida, možda getita (snimile: A. Kudelić, M. Mileusnić). / Macrophotographs of oxides and hydroxides in the pottery fabric; black arrows denote ferrous granules and oxides from the soil, and blue ones denote grog: (a) Kurilovec-Belinščica, magnification 50 x; (b) Podgorica, magnification 35 x; the smaller macrophotograph shows granules on the vessel surface, magnification 30 x; (c) Podgorica, microphotograph of a pottery thin section sample with a visible black grain of an iron oxide, possibly goethite (photo by: A. Kudelić, M. Mileusnić).

Prirodna su sastavnica tla i oksidi i hidroksidi koji čine velik dio Zemljine kore i mnogi su od njih važni minerali, npr. hematit, magnetit i getit (željezovi oksidi / hidroksidi). U glinovitome materijalu manifestiraju se kao oksidirana zrna zaobljena ili djelomično zaobljena, crveno-smeđih, smeđih ili tamnijih, crnih tonova.[46] Tla sjeverne Hrvatske bogata su željezovim oksidima koji se vrlo lako primjećuju na keramici (sl. 9a). Hematit i ostali željezovi oksidi mogu se koristiti za pripremu pigmenata i glinovitih suspenzija za premaze koji se ponekad nanose na površinu posude u dekorativne svrhe. Iako su oksidi prisutni u gotovo svim analiziranim uzorcima, na keramičkim uzorcima iz srednjeg i kasnoga brončanog doba s prostora Podravine zabilježena je izrazitija pojava ovalnih oksidiranih granula promjera i do 3 mm (sl. 9: b, c). Takva su zrna pronađena i u uzorcima tla u blizini arheoloških nalazišta iste mikroregije.[47]

Uvidom u makrofotografije uzoraka keramičkih posuda brončanog doba s prostora sjeverne Hrvatske, kao i na osnovi rezultata provedenih petrografsko-mineraloških analiza,[48] može se zaključiti da je glinoviti

[46] Druc 2015.

[47] Kudelić *et al.* 2018.

[48] Kudelić 2015; Kudelić *et al.* 2018.

portant minerals, e.g. hematite, magnetite, and goethite (iron oxides / hydroxides). In the clayey material, they appear as rounded or subrounded oxidized grains, which vary in color from red-brown to brown or darker, black tones.[46] Northern Croatian soils are rich in iron oxides, which are easily identified in pottery sample cross sections (Fig. 9a). Hematite and other iron oxides can be used in preparing pigments and clayey suspensions for coating, which are sometimes applied to the surfaces of vessels for decorative purposes. Although oxides are present in almost all of the analyzed samples, Middle and Late Bronze Age samples from Podravina more frequently include oval oxidized granules measuring up to 3 mm in diameter (Fig. 9: b, c). Such grains were also found in soil samples collected in the vicinity of the archaeological sites in the same region.[47]

By studying macrophotographs of Bronze Age pottery vessel samples from northern Croatia, and on the basis of the previously conducted petrographic and mineralogical analyses,[48] we can conclude that the clayey material contained silicate minerals (quartz, muscovite, biotite, amphibole, pyroxene), iron oxides and, less frequently, carbonates (calcite, dolomite). The listed minerals are natural components of the

[46] Druc 2015.

[47] Kudelić *et al.* 2018.

[48] Kudelić 2015; Kudelić *et al.* 2018.

materijal sastavljen od silikatnih minerala (kvarca, muskovita, biotita, amfibola, piroksena), željeznih oksida i hidroksida te rjeđe karbonata (kalcit, dolomit). Navedeni su minerali prirodna sastavnica glinovitog materijala koji se koristio za izradu keramičkih posuda. Njihova zrna često nisu veća od 0,15 mm i imaju mali utjecaj na uporabna svojstva gotovog proizvoda.

clayey material used for pottery production. The mineral grains are often no larger than 0.15 mm, and they have little effect on the characteristics of the finished product.

3.2. KARAKTERIZACIJA PRIMJESA

U strukturi keramike iz brončanog doba često se nalaze veća zrna različith stijena i minerala, uglavnom pjeskovitog materijala (litoklasti), ili neke druge vrste neplastičnih materijala (grog) veličine od 0,1 do otprilike 3 mm. Takva zrna u lončarskoj smjesi mogu biti prirodna sastavnica glinovitog materijala, ali mogu biti pokazatelj uporabe posebno prikupljenog ili pripremljenoga sirovinskog materijala koji je lončar namjerno dodao smjesi (usitnjena stijena, pijesak, šljunak ili grog). Međutim, kako razlikovati zrna litoklasta ili minerala, koji su prirodna sastavnica tla (inkluzije), od namjerno dodanih primjesa minerala i stijena na svježem lomu uzorka pri manjim uvećanjima? Neplastični materijali, koji nisu prirodna sastavnica glinovitog materijala, npr. grog, razna zrna metamorfnih, sedimentnih i magmatskih stijena, i šljunak mogu se identificirati kao primjese. Iz ovih bi razloga bilo dobro da analitičar poznaje geologiju područja koje istražuje. Osim toga, vrlo je dobar pokazatelj veličina zrna i njihova zastupljenost/gustoća.[49] Ako je na svježem lomu uzorka zabilježeno jedno krupnije zrno, može se pretpostaviti da je riječ o prirodnoj inkluziji iz glinovitog materijala ili slučajnoj inkluziji koja nije uklonjena tijekom postupka pripreme smjese. Međutim, ako se krupna zrna litoklasta ili neke druge vrste mineralnih, organskih ili antropogenih materijala učestalo nalaze u keramičkoj strukturi te ako se takva tzv. gruba keramička struktura povezuje s određenim tipom posude, onda je riječ o namjerno dodanoj pri-

[49] Više u Shepard 1985, 161–165; Quinn 2013, 159–161.

3.2. CHARACTERIZATION OF TEMPER MATERIAL

The ceramic fabric of Bronze Age pottery often contains larger grains of different kinds of rocks and minerals, mostly sandy material (lithoclasts), or other kinds of non-plastic materials (grog), which vary in size from 0.1 to approximately 3 mm. Such grains in ceramic pastes can be natural components of clayey material, but can indicate specially collected or prepared raw material intentionally added to the paste by the potter (ground rock, sand, gravel, or grog). Still, how does one differentiate between grains of lithoclasts or minerals that are a natural component of soil (inclusions) and intentionally added temper of minerals and rocks on sample cross sections of fresh breakage when using smaller magnification? Non-plastic materials that are not a natural component of the clayey material, e.g. grog, different grains of metamorphous, sedimentary, and magmatic rocks and gravel can be identified as temper. This is why it is good for the researcher to know the geology of the area under study. Apart from that, grain size and distribution are very good indicators.[49] If one larger grain is visible on fresh breakage of a sample, one can assume that it is a natural inclusion in the clayey material or that it is a chance inclusion which was not removed in the from the clay paste during the preparation process. However, if larger grains of lithoclasts or some other kind of mineral, organic or anthropogenic materials are frequently found in the pottery structure, and if such a coarse ceramic fabric is connected to, for example, specific types of vessels, then we are dealing with an intentionally

[49] For more, see Shepard 1985, 161–165; Quinn 2013, 159–161.

mjesi.[50] S obzirom na to da je receptura lončarske smjese u izravnoj vezi s lončarevim odlukama, praksom, tradicijom i funkcijom konačnog proizvoda, ovaj segement analize od velike je važnosti za rekonstrukciju postupka proizvodnje posuda.

Analizom makrofotografija keramike vinkovačke kulture (26 – 22. st. pr. Kr.) s nalazišta Donji Miholjac primijećena je velika raznolikost lončarskih smjesa (12 uzoraka). Budući da uzorke nije bilo moguće povezati s tipom posude, zbog fragmentiranosti materijala napravljena je analiza ulomaka vidljivo različitih struktura kako bi se bolje upoznao materijal i stekao uvid u recepturu, kao i identificirale vrste primjesa. Stijenke su svih uzoraka relativno tanke, a vrijednosti njihove debljine kreću se od 0,35 do 0,6 cm. Primijećene su smjese kojima nisu dodavane primjese, a takvi su uzorci uglavnom okarakterizirani kao fina keramička struktura. Smjesa nakon pečenja poprimila je tamnosivu boju, a sastavljena je od vrlo finog do finog pijeska, djelomično uglatih i djelomično zaobljenih, vrlo dobro raspoređenih zrna silikatnih minerala. Od takve sitnozrnate smjese izrađene su posude glatke površine bez ukrasa, sive i tamnosive boje (sl. 10). Identificirana je i smjesa prirodne sitnozrnate strukture koja sadrži veće pore, odnosno šupljine, koje su vjerojatno posljedica pripreme smjese. Osim toga, primijećena su zrna pijeska i groga u malim količinama, do 1%. (sl. 11). Treća identificirana vrsta smjese sadrži 20% mineralnih primjesa, poput kvarcnog pijeska i litoklaste (kvarcit) maksimalne veličine 1,7 mm (sl. 12a). Zrna su djelomično uglata do djelomično zaobljena, loše su raspoređena i nemaju preferiranu orijentaciju. Na makrofotografiji svježeg loma uzorka primijećena je i promjena u boji koja se povezuje s izgaranjem organskog materijala, ali nema dovoljno pokazatelja pomoću kojih bi se organska primjesa mogla okarakterizirati. Međutim, zabilježen je i uzorak koji sadrži organski materijal, vidljiv na makrofotografiji svježeg loma uzorka, kao i na njegovoj

[50] Više u Shepard 1985, 161–165; Quinn 2013, 165.

added temper.[50] Seeing as ceramic paste composition is in direct connection with the potter's decisions, practice, tradition, and the function of the finished product, this segment of analysis is very important for reconstructing the process of pottery production.

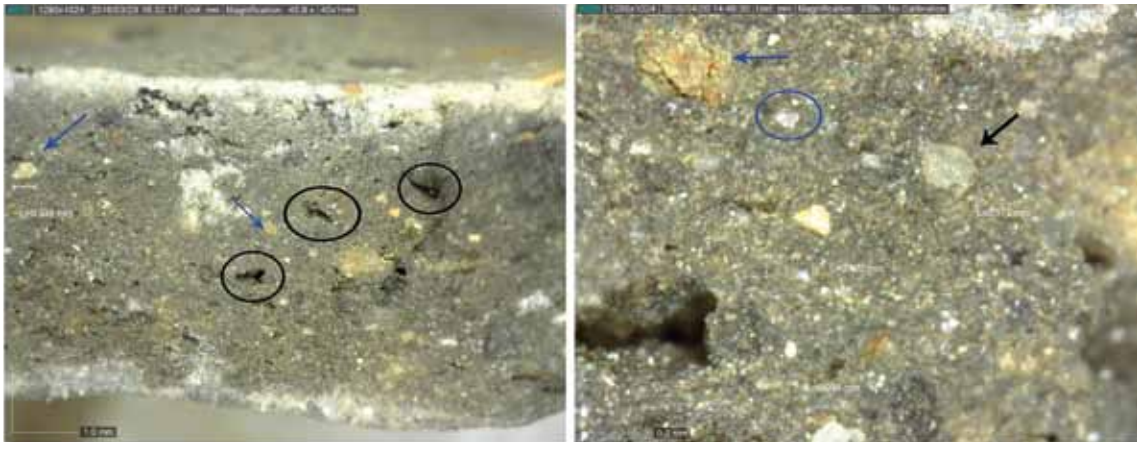
The analysis of macrophotographs of pottery material ascribed to the Early Bronze Age Vinkovci Culture (26th – 22nd cent. BC) from the site of Donji Miholjac revealed a high diversity of ceramic pastes (12 samples). Seeing as the samples could not be linked to specific types of vessels due to their fragmentation, the analysis was conducted on fragments with various visible fabrics in order to gain an insight into the recipe and to identify the type of temper. The walls of all the samples are relatively thin, and their thickness varies between 0.35 and 0.6 cm. Certain non-tempered pastes were noted, and such samples were mostly characterized as fine-grained fabric. Such ceramic pastes turned dark gray after firing, and are composed of very fine to fine sand composed of subangular and subrounded, very well distributed grains of silicate minerals. These fine-grained pastes were used to make vessels with smooth, undecorated surfaces, varying in color from gray to dark gray (Fig. 10). Another paste was identified that is also composed of naturally fine-grained clay with visible larger pores, that is, voids that are probably the result of clay paste preparation. In addition, tiny grains of sand and grog were noted in small amounts, up to 1% (Fig. 11). The third identified paste contains 20% of mineral inclusions such as quartz sand and lithoclasts (quartzite) of up to 1.7 mm in size (Fig. 12a). The grains are subangular to subrounded and are poorly sorted without a preferred orientation. A macrophotograph of a cross section showed a change in color that is associated with organic material burning, but there are not enough indicators that could help characterize the type of organic temper. However, a sample containing organic material visible on a macrophotograph of the sample cross section, as well as on its surface, was also noted (Fig. 13). Considering the density and relatively well distributed traces of burned organic material, we

[50] For more, see Shepard 1985, 161–165; Quinn 2013, 165.

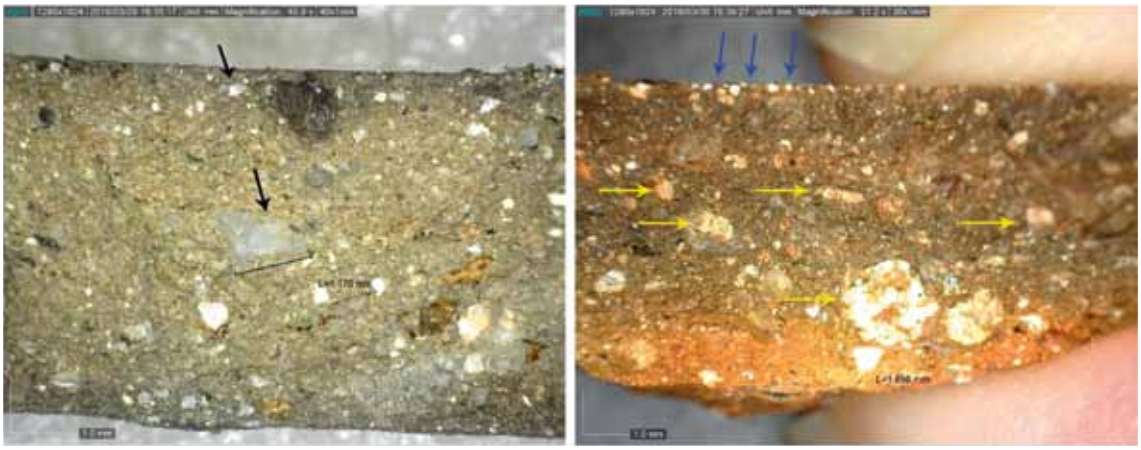
Slika / Figure 10. Makrofotografije vinkovačke keramike sastavljene od finih do vrlo finih zrna kvarcnog pijeska – Donji Miholjac: (a) uvećanje 36 x, (b) uvećanje 240 x (snimila: A. Kudelić). / Macrophotographs of Vinkovci Culture pottery comprised of fine to very fine grains of quartz sand – Donji Miholjac: (a) magnification 36 x, (b) magnification 240 x (photo by: A. Kudelić).

površini (sl. 13). S obzirom na gustoću i relativno dobro raspoređene tragove izgorenoga organskog materijala, može se zaključiti da organska primjesa, vrlo vjerojatno napravljena od suhe trave, slame ili pljeve u smjesi, nije slučajna. U istoj su smjesi zabilježena sitna zrna kvarcnog pijeska te veća zrna litoklasta od kojih se prepoznaje kvarcit i nedefinirana vrsta veličine dimenzija 1,5 mm u količni do 5% (sl. 13a). Lončarska smjesa uzorka broj osam pripremljena je slično kao i smjesa uzorka broj šest s jedna-

can conclude that the organic temper, probably made from dry grass, hay, or chaff, was not unintentional. The same paste also has tiny grains of quartz sand and larger grains of lithoclasts that contain quartzite and an unidentified kind of rock which is 1.5 mm in diameter and appears in amounts of up to 5% (Fig. 13a). The paste of sample 8 is prepared similarly to that of sample 6, has the same amount of temper material (20%), grain size, and wall thickness (0.55 cm), but a different kind of temper. The paste contains lithoclasts, quartz sand, and grains



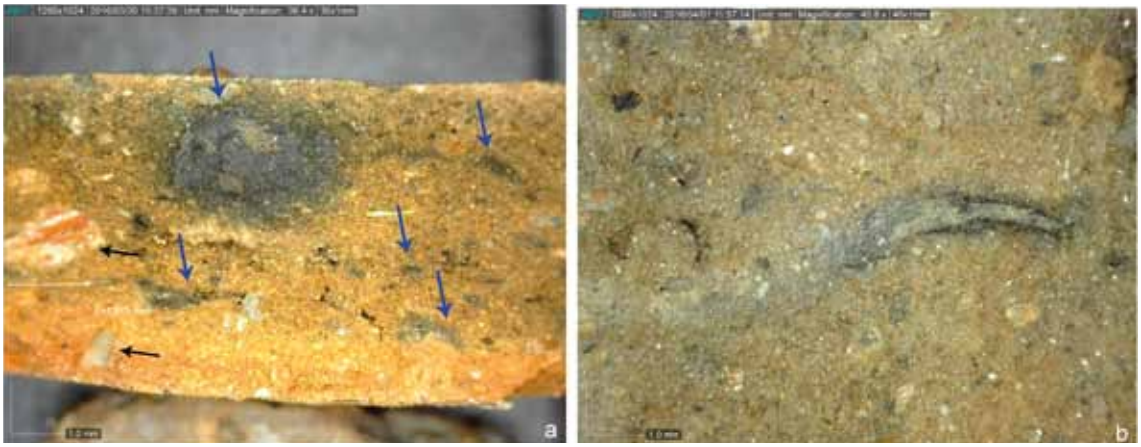
Slika / Figure 11. Makrofotografije vinkovačke keramike sastavljene od finih do vrlo finih zrna kvarcnog pijeska (plavi krug) koja sadrži i vrlo malu količinu sitnih zrna groga (plave strelice). Crni krugovi označavaju praznine u keramičkoj strukturi – Donji Miholjac: (a) uvećanje 45 x, (b) uvećanje 240 x (snimila: A. Kudelić). / Macrophotographs of Vinkovci Culture pottery comprised of fine to very fine grains of quartz sand (blue circle), which also contains a very small amount of tiny grains of grog (blue arrows); black circles denote voids in the ceramic fabric – Donji Miholjac: (a) magnification 45 x, (b) magnification 240 x (photo by: A. Kudelić).



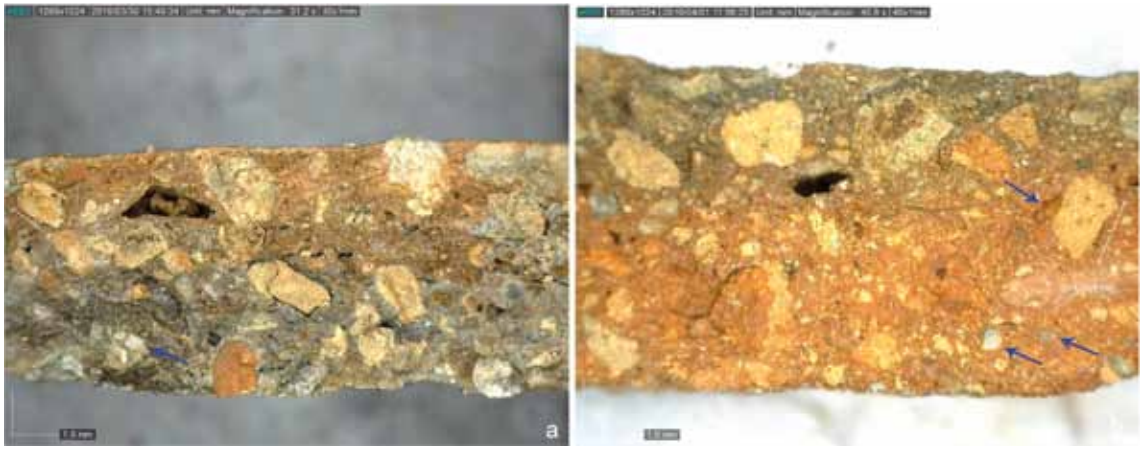
Slika / Figure 12. Makrofotografije vinkovačke keramike sastavljene od srednje finih do finih zrna kvarcnog pijeska – Donji Miholjac: (a) smjesa sadrži 20% primjesa kvarcnog pijeska i litoklasta (kvarcit je označen crnom strelicom), uvećanje 45 x; (b) smjesa sadrži 20% groga (označen žutim strelicama) i nekoliko zrna litoklasta, dok plave strelice označavaju paralelan raspored primjesa s unutarnjom stijenkom posude, uvećanje 36 x (snimila: A. Kudelić). / Macrophotographs of Vinkovci Culture pottery comprised of medium-fine to fine grains of quartz sand – Donji Miholjac: (a) the paste is tempered with 20% of quartzite sand and lithoclast (quartzite is marked by a black arrow), magnification 45 x; (b) the paste contains 20% of grog (marked by yellow arrows) and several grains of lithoclasts, while blue arrows denote the parallel distribution of inclusions in relation to the inner surface of the vessel, magnification 36 x (photo by: A. Kudelić).

kom količinom primjesa (20%), veličinom zrna i debljinom stijenki (0,55 cm), međutim, vrsta je primjese drugačija. Smjesa sadrži zrna litoklasta, kvarcni pijesak i zrna groga (sl. 12b). Zrna su djelomično uglata do djelomično zaobljena, loše raspoređena i nemaju preferiranu orijentaciju. Osim navedenih karakteristika, smjese se mogu okarakterizirati kao fine do srednje fine, a može se primijetiti da su neke smjese sadržavale i do 40% primjesa koje je lončar namjerno dodao - najčešće

of grog (Fig. 12b). The grains are subangular to subrounded, poorly sorted, and do not have preferred orientation. In addition to the listed characteristics, the pastes can be characterized as fine to medium-fine, and it can be noted that some pastes contained up to 40% of temper material added intentionally by the potter - mostly



Slika / Figure 13. Makrofotografije vinkovačke keramike s tragovima primjesa od organskog materijala u keramičkoj strukturi i na površini posude vinkovačke kulture – Donji Miholjac: (a) plave strelice pokazuju tragove izgorenog organskog materijala, a crne strelice pokazuju primjese većih zrna litoklasta, uvećanje 40 x; (b) makrofotografija površine posude s tragom izgorenog materijala organskog podrijetla, uvećanje 40 x (snimila: A. Kudelić). / Macrophotographs of Vinkovci Culture pottery with traces of organic material temper in the ceramic fabric and on the surface of the vessel – Donji Miholjac: (a) blue arrows denote traces of burned-up material, and black arrows denote inclusions of larger grains of lithoclasts, magnification 40 x; (b) a macrophotograph of a vessel surface with traces of burned-up material of organic origin, magnification 40 x (photo by: A. Kudelić).



Slika / Figure 14. Makrofotografije svježeg loma keramike vinkovačke kulture sa 40% primjesa groga i/ili glinovitih peleta – Donji Miholjac: (a) uvećanje 30 x, (b) uvećanje 40 x (snimila: A. Kudelić). / Macrophotographs of Vinkovci Culture pottery tempered with 40% of grog and/or argillaceous rock fragments – Donji Miholjac: (a) magnification 30 x, (b) magnification 40 x (photo by: A. Kudelić).

denih karakteristika smjesa, koje se mogu okarakterizirati kao fine i srednje fine, zabilježene su i smjese kojima je lončar dodao čak 40% primjesa uglavnom krupnih, djelomično uglatih do djelomično zaobljenih zrna groga, i/ili glinovitih peleta veličine do 1,5 mm (sl. 14: a, b) te s obzirom na relativno tanku stijenku, krupna su zrna vrlo loše raspoređena.

Ranobrončanodobna kultura Kisapostag (22. – 19. st. pr. Kr.), čiji se materijalni ostaci nalaze uglavnom na prostoru zapadnog dijela savsko-dravskog međurječja, na našim prostorima još uvijek nije u potpunosti istražena, kao ni njezina veza sa srednjobrončanodobnom licenskom keramikom (18. – 15. st. pr. Kr.).[51] Osnovna razlika između kulture Kisapostag i licenske keramike način je ukrašavanja posuda (lončari kulture Kisapostag na površinu su posude utiskivali namotanu uzicu, a na površinu licenske keramike utiskivala se pletena vrpca). Kultura Kisapostag tumači se kao protolicenska faza, a na prostoru Transdanubije predstavlja prethodnicu kultura inkrustirane keramike[52] koja se na prostoru sjeverne Hrvatske pojavljuje na području Baranje. Preliminarno su pregledani uzroci

large, subangular to subrounded grains of grog and/or argillaceous rock fragments up to 1.5 mm in size (Fig. 14: a, b). Considering the relatively thin vessel walls, the large grains are very poorly sorted.

The Early Bronze Age Kisapostag Culture (22nd – 19th cent. BC), the material remains of which can mostly be found on the territory of the western part of the Sava-Drava river plains, has still not been fully researched, just like its relation to the Middle Bronze Age Litzen pottery (18th – 15th cent. BC).[51] The basic difference between Kisapostag and Litzen pottery is in decoration (potters of the Kisapostag Culture pressed string into the clay, and those producing Litzen pottery used braided ribbons). The Kisapostag Culture is seen as a pre-Litzen phase, and, in the area around the Danube, it is the predecessor of the Encrusted Ware Culture,[52] which appears in northern Croatia on the territory of Baranja. A preliminary analysis was conducted on pottery ascribed to both cultural occurrences, but, seeing as only a small number of samples was available (15) from several different sites, we only bring general remarks in this paper. The analysis of fresh breakage conducted on samples from sites in Podravina (Đelekovec-Log I, Vratnec I) and Turopolje (Kurilovec, Selnica

[51] Više u Marković 2002; Črešnar 2010; Teržan, Črešnar 2014, 667.

[52] Torma 1972.

[51] For more, see Marković 2002; Teržan, Črešnar 2014, 667; Črešnar 2010.

[52] Torma 1972.

keramičkih posuda obiju kulturnih pojava, a s obzirom na to da je dostupan bio samo manji broj uzoraka (15), ovdje se donose opća zapažanja s nekoliko različitih nalazišta. Analiza svježeg loma uzoraka, napravljena na keramici s nalazišta u Podravini (Đelekovec-Log I, Vratnec I) i Turopolju (Kurilovec, Selnica Ščitarjevska), pokazala je neke zajedničke elemente u odabiru recepture lončarskih smjesa. Naime, sličnosti se najviše primjećuju pri odabiru primjesa za izradu posuda debljih stijenki, odnosno tzv. grube strukture, međutim, količina uzoraka keramike kulture Kisapostag znatno je manja pa je karakterizacija temeljena uglavnom na uzorcima koji se sa sigurnošću pripisuju licenskoj keramici. U keramičkoj su strukturi zabilježena zaobljena zrna čestica veličine šljunka[53] i kvarcit, a zbog njihove veličine i količine pretpostavlja se da je riječ o primjesama. S obzirom na to da analizirani uzorci potječu iz ostataka naselja, koja su smještena u nizinskom dijelu sjeverne Hrvatske, neposredno uz manje i veće vodotoke (rijeka Sava i Drava), pretpostavlja se lokalno podrijetlo sirovinskog materijala. Uporaba znatnije količine takvih litoklasta (20 – 40%), vrlo loše raspoređenih, osnovna je karakteristika smjese (sl. 15) za izradu posuda koje su vjerojatno bile korištene za pripremu, pohranu hrane i njezinu termalnu obradu. Premda u smjesi dominiraju zaobljena zrna litoklasta (čestice veličine šljunka i kvarcit) do 4 mm veličine, u znatno su manjem omjeru prisutna i zrna groga (do 1 mm) manjih dimenzija (sl. 15). Takav je sastav smjese zabilježen na uzrocima licenske keramike i posuda kulture Kisapostag. Varijabilnost receptura uglavnom se odnosi na količinu litoklasta u odnosu na količinu groga ili glinovitih peleta, a na temelju preliminarnih analiza može se zaključiti da su zrna litoklasta u smjesi uvijek zastupljenija. Među dostupnim uzorcima nije zabilježena pojava organskih primjesa koje ostavljaju trag u svježem lomu uzorka. Pojava izduženih pora i šupljina, koje se

[53] Šljunak je prirodni granulirani materijal, sačinjen od razdijeljenih čestica stijena i minerala određene veličine. U geologiji, šljunak je bilo koja rastresita stijena sa zaobljenim zrnima koja su veća od 2 i manja od 75 milimetara.

Ščitarjevska) revealed some common elements in the choice of clay paste recipe. Namely, similarities are most notable in the choice of temper material for pottery production with thicker walls, i.e. coarse ceramic fabric. However, the amount of pottery samples of the Kisapostag Culture is significantly lower, so the characterization was mostly based on samples which could be ascribed to Litzen pottery with certainty. In the ceramic fabric, rounded grains of particles the size of gravel[53] and quartzite were recorded, and because of their size and amount, it is assumed that these are temper material. Seeing as the analyzed samples originated from the remains of settlements situated in lowland parts of northern Croatia right next to smaller and larger watercourses (the Sava and Drava rivers), it is assumed that the raw material was of local origin. Using more significant amounts of such lithoclasts (20 – 40%), which are very poorly sorted, is the main characteristic of the paste (Fig. 15) used to make vessels that were probably used for preparing, storing, and thermally processing food. Although the paste is dominated by rounded grains of lithoclasts (particles the size of gravel and quartzite) up to 4 mm in size, smaller amounts of grog or clay pelets (up to 1 mm) of smaller size (Fig. 15) were also noted. This type of ceramic fabric was noted on samples of Litzen pottery and Kisapostag Culture vessels. The variability of recipes mostly pertains to the amount of lithoclasts in relation to amounts of grog or clay pelets, and, based on preliminary analyses, it can be concluded that the paste always contains more grains of lithoclasts. The available samples did not have traces of organic materials that leave traces visible in the ceramic cross section. The presence of elongated pores and voids, mostly found in pastes which contain notably larger grains of mineral temper may be an indication of paste preparation and vessel production techniques (Fig. 15).

[53] Gravel is a natural granulated material made up of separate rock particles and minerals of certain sizes. In geology, gravel is any friable rock with round grains larger than 2 and smaller than 75 millimeters.

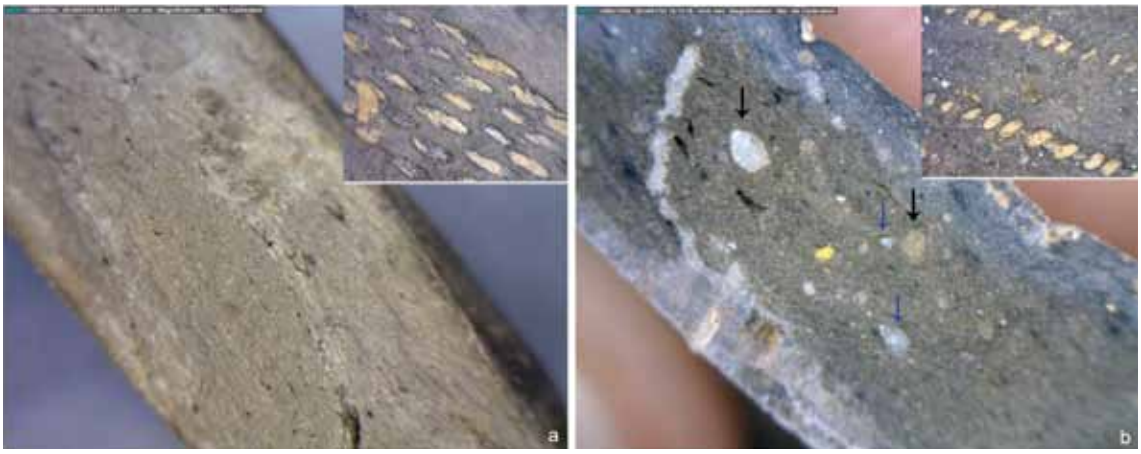
Slika / Figure 15. Makrofotografije licenske keramike i keramike kulture Kisapostag koja sadrži između 20 i 40% primjesa litoklasta zaobljenih i djelomično zaobljenih zrna te nekoliko zrna groga označenih crnim strelicama: (a) Vratnec I, uvećanje 30 x; (b) Kurilovec-Belinščica, uvećanje 30 x; (c) Đelekovec-Log, uvećanje 30 x; (d) Kurilovec-Belinščica, uvećanje 35 x (snimila: A. Kudelić). / Macrophotographs of Litzen pottery and pottery of the Kisapostag Culture which contains between 20 and 40% of rounded lithoclast grains and several grains of grog marked with black arrows: (a) Vratnec I, magnification 30 x; (b) Kurilovec-Belinščica, magnification 30 x; (c) Đelekovec-Log, magnification 30 x; (d) Kurilovec-Belinščica, magnification 35 x (photo by: A. Kudelić).

uglavnom nalaze u smjesi što sadrži izrazito velika zrna mineralnih primjesa, mogu biti pokazatelj pripreme smjese i tehnika izrade posude (sl. 15).

Posuda licenskih karakteristika i tankih stijenki (vrčić) izrađena je od izrazito fine sitnozrnate glinovite smjese koja sadrži zrna kvarcnog pijeska manja od 0,03 mm (sl. 16a). Smjesa za izradu ove posude nabavljena je na posebnom izvoru vrlo homogenoga glinovitog materijala ili je sirovinu lončar sekundarno pročistio. Svijetlosiva boja svježeg loma uzorka razlikuje se od ostalih keramičkih ulomaka, a to može biti posljedica sirovine koja sadrži vrlo mali postotak željeznih oksida ili je riječ o izra-

A vessel of Litzen characteristics and thin walls (small pot) was made out of notably fine-grained clayey material which contains grains of quartz sand smaller than 0.03 mm (Fig. 16a). The clay for making this kind of vessel was acquired at a particular source of very homogenous clayey material, or the raw material was secondarily refined by the potter. The light gray color of the sample cross section differs from the other samples, which can be a consequence of using raw material with a very low percentage of iron oxide, or of using an exceptionally carbonate-rich material.[54] On the other hand, the fresh breakage of a vessel decorated with ribbon imprints, associated with the Kisapostag Culture, shows

[54] Shepard 1985, 104.



Slika / Figure 16. Makrofotografije licenske keramike i keramike kulture Kisapostag i makrofotografije ukrašene površine istih uzoraka: (a) Đelekovec-Log, uvećanje 60 x; (b) Vratnec I, crnim su strelicama označena zrna groga ili glinovitih peleta, a plavima kvarcit, uvećanje 60 x (snimila: A. Kudelić). / Macrophotographs of fresh breakage on Litzen pottery and pottery of the Kisapostag Culture and macrophotographs of decorated surfaces of the same samples: (a) Đelekovec-Log, magnification 60 x; (b) Vratnec I, black arrows mark grains of grog or clay pelets, and blue ones mark quartz, magnification 60 x (photo by: A. Kudelić).

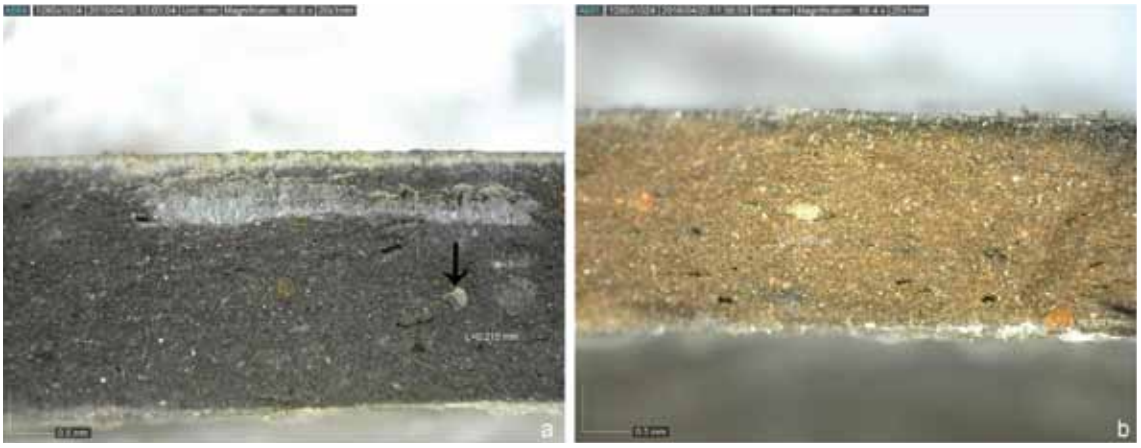
zito karbonatnoj sirovini.[54] S druge strane, na svježem lomu uzorka posude ukrašene tehnikom namotane niti, koja se povezuje s kulturom Kisapostag, glinoviti je materijal sastavljen od srednje finih zrna pijeska, a zabilježena je i pojava zrna groga i litoklasta veličine do 1 mm u količini do 2% (sl. 16b).

Panonska inkrustirana keramika relativno kronološki pripada srednjem brončanom dobu (19. – 17. st. pr. Kr.), a karakteristična je po razvedenim i raznolikim oblicima posuda, načinu ukrašavanja i atraktivnom stilu. Na osnovi skromnog broja uzoraka (13) napravljena je preliminarna analiza lončarskih smjesa s nalazišta Jagodnjak-Krčevine koje je smješteno u Baranji. Odabrani su uzorci inicijalno klasificirani u dvije skupine, finu i grubu strukturu, a oblik posuda kojima pripadaju nije bio poznat. Dio keramičkih uzoraka izrađen je od sitnozrnatoga glinovitog materijala, fine i vrlo fine strukture, sastavljene od kvarcnog pijeska, posebice tinjaca poput muskovita (sl. 6b, 8, 17). Stijenke su posuda vrlo tanke, debljine između 0,2 i 0,3 cm. Pojedini uzroci sadrže oko 1% primjesa sitnoga groga (sl. 17a) za koji se pretpostavlja da je slučajno u smjesi, uzimajući u obzir da je lončar koristio grog

that the clayey material contains medium-fine grains of sand, and grains of grog and lithoclasts up to 1 mm in size in amounts of up to 2% (Fig. 16b).

Pannonian Encrusted Ware, in the sense of relative chronology, is mostly ascribed to the Middle Bronze Age (19th – 17th cent. BC) and is characterized by indented and diverse vessel forms, decorations, and its attractive style. Based on a small number of samples (13), a preliminary analysis of ceramic fabric was conducted on samples from the site of Jagodnjak-Krčevine in Baranja. The selected samples were initially classified into two groups, fine and coarse ware, but the shape of the vessels could not be determined. A part of the pottery samples is composed of fine clayey material with fine and very fine quartz sand, and especially mica such as muscovite (Fig. 6b, 8, 17). The vessel walls are very thin, between 0.2 and 0.3 cm. Individual samples contain about 1% of tiny grog grains (Fig. 17a), for which we assume got into the paste by chance, seeing as the potter used large amounts of grog in the composition of the paste for vessels with thick walls. However, several samples of thin-walled vessels (0.2 cm) contain between 5 and 10% of grog, with grain size up to 0.5 mm. The paste used to produce such ves-

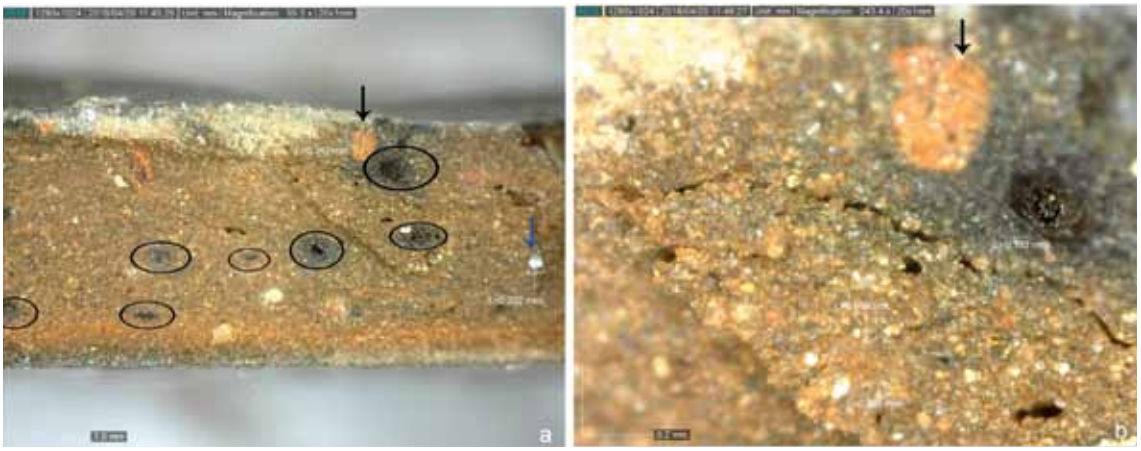
[54] Shepard 1985, 104.



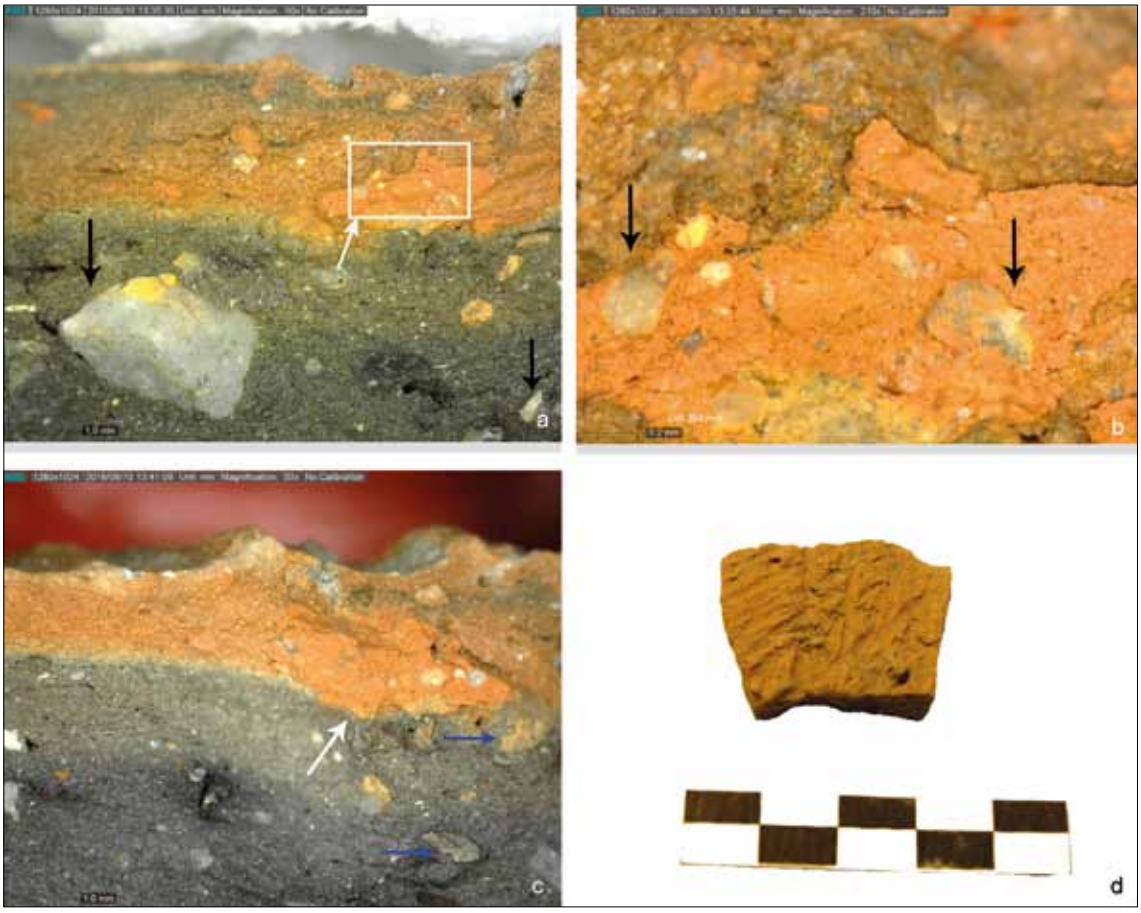
Slika / Figure 17. Makrofotografije panonske inkrustirane keramike sastavljene od finih i srednje finih zrna kvarcnog pijeska – Jagodnjak-Krčevine: (a) crna strelica označava zrno groga ili glinoviti pelet, uvećanje 60 x; (b) uvećanje 65 x (snimila: A. Kudelić). / Macrophotographs of the Pannonian Encrusted Ware comprised of fine and medium fine grains of quartz sand – Jagodnjak-Krčevine: (a) the black arrow denotes the grain of grog or clay pelet, magnification 60 x; (b) magnification 65 x (photo by: A. Kudelić).

u većim količinama, što je vidljivo iz sastava smjese za izradu posuda debljih stijenki. Ipak, nekoliko keramičkih ulomaka tankih stijenki (0,2 cm) sadrži između 5 i 10% groga, veličine zrna do 0,5 mm. Smjesa za izradu takvih posuda sadrži i organski materijal, a zabilježen je i ostatak sitnog, zaobljenog organskog materijala, vjerojatno neka vrste sjemenke (sl. 18). Uzorci posuda debljih stijenki (0,5 – 1,2 cm), čija je površina često prošarana metličastim urezima, pred-

sels also contains organic material, sometimes in the shape of tiny, round black residue, probably some sort of seed. (Fig. 18). Samples of thick-walled vessels (0.5 – 1.2 cm), which often have combed incisions on the surface, belong to the so-called coarse ware, which is assumed to have been used for storing, preparing and thermally processing food. This paste is made from fine clayey material with added high amounts of large grains of grog which are sometimes accompanied by equally-sized grains of litho-



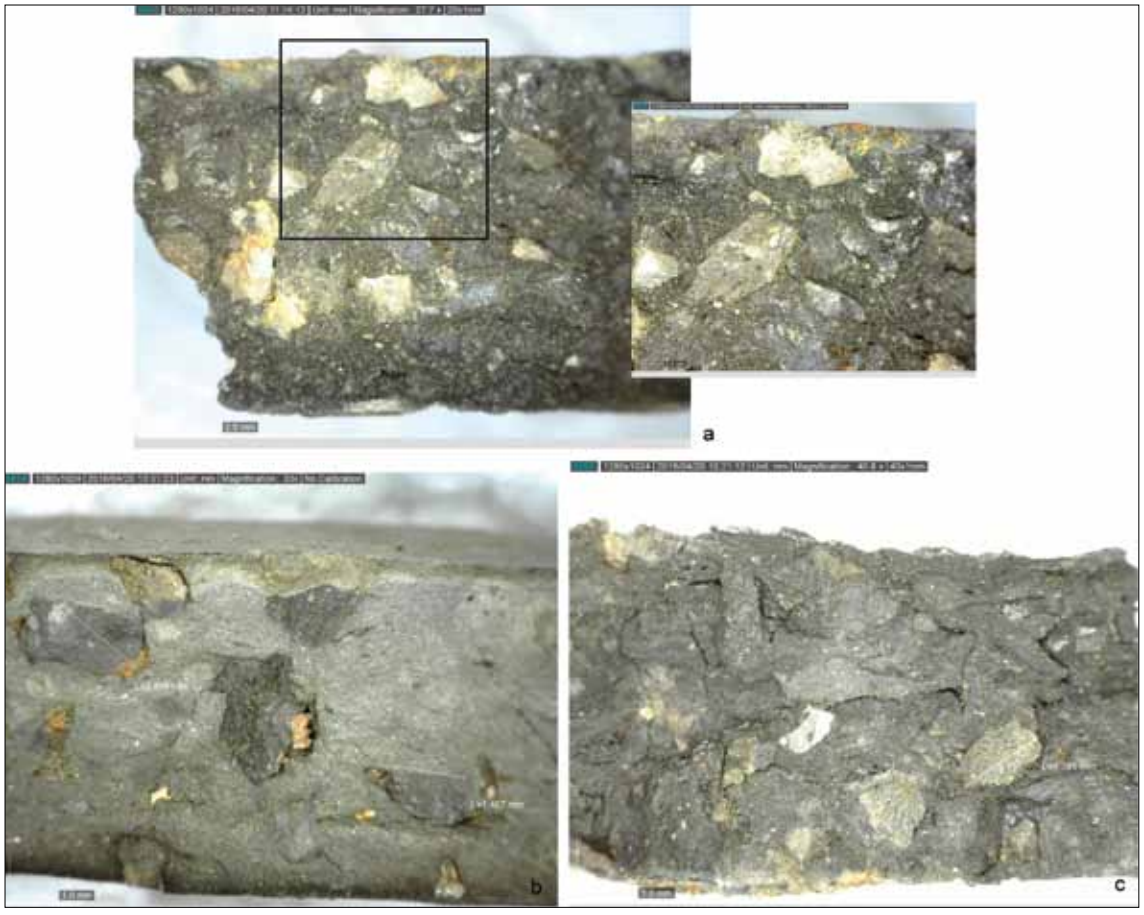
Slika / Figure 18. Makrofotografije panonske inkrustirane keramike sastavljene od srednje finih do finih zrna kvarcnog pijeska, primjesa organskog podrijetla, označenih crnim krugovima, i zrno groga/glinovitog peleta ili granula željezovitog oksida, označeno crnom strelicom – Jagodnjak-Krčevine: (a) uvećanje 55 x, (b) uvećanje 243 x (snimila: A. Kudelić). / Macrophotographs of the Pannonian Encrusted Ware comprised of medium fine and fine grains of quartz sand, inclusions or temper of organic origin are marked by black circles, and grog/clay pelet grain or iron-oxide granules are marked by black arrows – Jagodnjak-Krčevine: (a) magnification 55 x, (b) magnification 243 x (photo by: A. Kudelić).



Slika / Figure 19. Makrofotografije panonske inkrustirane keramike s primjesama litoklasta i groga – Jagodnjak-Krčevine: (a) bijelom strelicom i bijelim okvirom označeno je zrno groga, dok crna strelica prikazuje veliko zrno kvarcita, uvećanje 50 x; (b) uvećani prikaz zrna groga u čijoj strukturi se vide zrna litoklasta i kvarcnog pijeska, uvećanje 210 x; (c) prikaz drugog dijela istog uzorka s vidljivom površinom istog zrna groga (bijela strelica) i još nekoliko manjih zrna istaknutih plavom strelicom, uvećanje 50 x; (d) uvećanje 240 x, (e) fotografija vanjske stijenke ulomka, čija je površina metličasto izbrazdana (snimila: A. Kudelić). / Macrophotographs of Pannonian Encrusted Ware tempered with lithoclasts and grog – Jagodnjak-Krčevine: (a) the white arrow and the white frame denote the grain of grog, and the black arrow denotes the large grain of quartzite, magnification 50 x; (b) enlarged photograph of grains of grog with grains of lithoclasts and quartz sand, magnification 210 x; (c) a photograph of a second part of the same sample with a visible surface of the same grain of grog (white arrow) and several smaller grains marked by the blue arrow, magnification 50 x; (d) magnification 240 x, (e) a photograph of the outside wall of a fragment with combed decorations (photo by: A. Kudelić).

stavljaju dijelove tzv. grubog posuđa za koje se pretpostavlja da je moglo biti korišteno za skladištenje, pripremu hrane ili njezinu termalnu obradu. Takva je smjesa izrađena od finog glinovitog materijala kojemu je dodana veća količina krupnih zrna groga uz koja se ponekad nalaze i zrna litoklasta jednake veličine (sl. 19a). Prema tablici za mjerenje gustoće zrna u matriksu, zabilježeno je između 10 i čak 50% primjesa (sl. 20). U velikim zrnima groga ponekad se nalaze starija zrna, odnosno grog druge ge-

clasts (Fig. 19a). Based on grain density tables, the matrix contains between 10 and even 50% of temper in the paste (Fig. 20). Large grains of grog sometimes contain older grains, i.e. second-generation grog (Fig. 20). Grog grains were prepared from pottery with the same physical characteristics, as is clearly visible in the cross section of a sample which contains a grain of grog made following a similar recipe and from a vessel with a similarly treated surface (Fig. 19). The grog is a chunk from the outer wall of an older vessel and has visible traces of combed



Slika / Figure 20. Makrofotografije panonske inkrustirane keramike s primjesama groga – Jagodnjak-Krčevine: (a) crni okvir prikazuje uvećano zrno groga u kojemu su vidljiva zrna kvarcnog pijeska i zrno groga druge generacije, uvećanje 30 x i 60 x; (b) uvećanje 30 x, (c) uvećanje 40 x (snimila: A. Kudelić). / Macrophotographs of Pannonian Encrusted Ware tempered with grog – Jagodnjak-Krčevine: (a) the black frame denotes the enlarged grain of grog with visible grains of quartz sand and the grain of second-generation grog, magnification 30 x and 60 x; (b) magnification 30 x, (c) magnification 40 x (photo by: A. Kudelić).

neracije (sl. 20). Zrna groga pripremala su se od keramičkih posuda jednakih fizičkih karakteristika, što se dobro vidi na uzorku u čijem se presjeku nalazi zrno groga načinjeno prema sličnoj recepturi i na isti način obrađene površine posude (sl. 19). Grog predstavlja krhotinu vanjske stijenke starije posude. Na zrnu groga vidljivi su tragovi metličastog urezivanja, a na takav je način obrađena i površina ulomka posude. Zrno groga također u sebi sadrži kvarcit ili neku drugu vrstu litoklasta, što znači da je smjesa za izradu starije posude bila pripremljena od zrna litoklasta, slično kao i posuda čiji je ulomak analiziran.

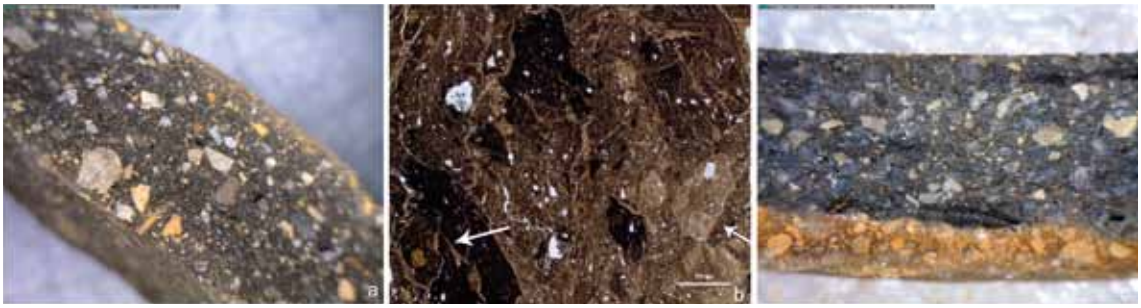
incisions, the same surface treatment as on the surface of the analyzed vessel fragment. The grain of grog also contains quartzite or some other kind of lithoclast, which means that the paste for the production of the older vessel was made out of grains of lithoclasts, similar to the vessel under study.

Kulturna grupa Virovitica (15. – 12. st. pr. Kr.) relativo kronološki datira se u kraj srednjeg i početak kasnoga brončanog doba te predstavlja dio kulture polja sa žarama. Na keramici virovitičke grupe napravljene su opsežne petrografsko-mineraloške analize na relativno velikom uzorku, a na još većem je uzorku napravljena i makroskopska analiza.[55] Stoga se ovdje predstavljeni rezultati makroskopskih analiza nadovezuju na rezultate arheometrijskih analiza. Za potrebe tih istraživanja prikupljeni su i uzorci glinovitog materijala iz neposredne blizine brončanodobnih nalazišta te je usporedbom s keramičkim materijalom utvrđeno da su posude izrađivane od lokalne sirovine. Glinoviti je materijal aluvijalnog podrijetla i uglavnom su to prahovite gline i glinoviti prah koji sadrže kvarc, zatim plagioklase, feldspate, željezove okside i rjeđe karbonate te sporadično muskovit. Makroskopskom metodom na većem uzroku ustanovljeno je da 99% uzoraka sadrži grog koji je lončar dodavao smjesi za izradu svih oblika keramičkih posuda, neovisno o njihovoj funkciji i veličini (sl. 21). Značajka virovitičke keramike, osobito one iz Turopolja, vrlo je visoka razina lomljivosti uslijed vrlo porozne strukture. Upravo se ova karakteristika dobro vidi na svježem lomu uzorka. Keramika se vrlo lako lomi kliještima, pri čemu se intenzivno mrvi. Promatranjem karakteristika matriksa na svježem lomu uzorka pomoću digitalnog mikroskopa (pri uvećanjima iznad 200 puta), zbog poroznosti, veće količine sitnih pora i pukotina, nije uvijek moguće zabilježiti karakteristike glinovitog materijala, osim u slučajevima kada je smjesi dodano vrlo malo primjesa, što omogućava bolju vidljivost matriksa. Neki od čimbenika koji su mogli utjecati na takvo stanje uzoraka niske su temperature pečenja i uporaba usitnjenih primjesa organskog materijala, a oba razloga vidno su utjecala na stanje keramike. U uzrocima iz Turopolja mineralna zrna iz matriksa su vrlo fina, veličine od 0,02 – 0,05 mm dok uzorci iz Podravine sadrže više tinjaca veličine i do 0,09 mm. Razlike u sastavu glinovitog materijala

[55] Kudelić 2015; Kudelić *et al.* 2018.

The Virovitica cultural group (15th – 12th cent. BC) is by relative chronology dated to the end of the Middle and beginning of the Late Bronze Age, and belongs to the wider cultural horizon of the early period of the Central European Urnfield Culture. Extensive petrographic and mineralogical studies have been conducted on a relatively large number of samples of Virovitica pottery, and a macroanalysis was done on an even larger number of samples.[55] Hence, the results of macroscopic analyses presented in this paper are complemented by the results of the conducted archaeometric analysis. For research purposes, clayey material samples were collected from the immediate vicinity of Bronze Age sites, and it was concluded, after comparisons with pottery material, that pottery was produced out of locally available raw material. The clayey material is of alluvial origin and mostly includes silty clays and clayey silt which contain quartz, plagioclase, feldspar, iron oxides, less often carbonates, and sporadically muscovite. The analysis of the pottery material revealed grog, which was added to the paste for making all forms of vessels, regardless of their function and size (Fig. 21), in 99% of the samples. A feature of Virovitica pottery, especially from the Turopolje region, is a very high level of fragility due to its highly porous structure. Precisely this characteristic is clearly visible on the cross section of the samples. The pottery is very easily broken off with pliers and crumbles intensely. When studying matrix characteristics on fresh breakage on samples using a digital microscope (magnification over 200), it was not always possible to record the characteristics of the clayey material due to porosity, large amounts of tiny pores and cracks, except in cases when very few inclusions were added to the paste allowing better visibility of the matrix. Some of the factors that could have affected the state of the samples are usage of minced organic temper, and low firing temperatures - both visibly affecting the state of the pottery. Mineral grains from the matrix of the Turopolje region samples are very fine, between 0.02 and 0.05 mm in size, and the samples from the Podravina region contain more mica, measuring up to even 0.09 mm. The differences in clayey material composition

[55] Kudelić 2015; Kudelić *et al.* 2018.



Slika / Figure 21. Makorfotografija keramike kulturne grupe Virovitica s primjesama groga: (a) Podgorica, uvećanje 50 x; (b) Selnica Ščitarjevska, mikrofotografija preparata s prikazom groga prve i druge generacije; (c) Kurilovec-Belinščica, uvećanje 55 x (snimile: M. Mileusnić, A. Kudelić). / Macrophotograph of the Virovitica cultural group grog-tempered pottery (a) Podgorica, magnification 50 x, (b) Selnica Ščitarjevska, a microphotograph of a specimen displaying first-generation and second-generation grog, (c) Kurilovec-Belinščica, magnification 55 x (photo by: M. Mileusnić, A. Kudelić).

prije svega su posljedica prirodnog sastava tla pojedinog područja, što se dobro vidi i prema izrazitijoj zastupljenosti željezovih oksida u keramici iz Podravine.

Grog koji je vjerojatno pripremljen od ulomaka starijih keramičkih posuda dodavao se u količini od 2 – 40%, a veličina zrna iznosi između 0,1 i 3 mm. Na osnovi gustoće zrna zabilježenih makrofotografijom svježeg loma uzorka, identificirane su četiri skupine lončarskih smjesa od kojih je najzastupljenija smjesa koja sadrži oko 7% primjesa. Istraživanje nije u potpunosti ukazalo na eventualne obrasce ili pravilnosti u odabiru pojedine lončarske smjese u odnosu na npr. tip posude, međutim, smjesa koja sadrži oko 25% primjese groga najviše se koristila za izradu posuda u Turopolju, i to uglavnom za tipove posuda 3, 4, 8 i 18 (lonci, duboke zdjele – posude koje su mogle biti korištene za termalnu obradu hrane na vatri i šalice). Na području Podravine slična smjesa koristila se za izradu posuda tip 5 i 19 (duboke zdjele, šalice i plitke zdjele, odnosno posude koje ne pokazuju tragove uporabe na vatri). Statistički je na cjelokupnom uzorku utvrđeno da se količina primjesa povećava s prosječnom debljinom stijenke posude.[56] U većim zrnima groga također su primijećena manja, starija zrna, načinjena od istog materijala, odnosno riječ je o drugoj generaciji groga (sl.21b).

[56] Kudelić 2015.

are primarily the result of the natural composition of soil in specific areas, as is clearly visible through a more notable presence of iron oxides in the pottery from Podravina.

Grog, which was probably prepared from fragments of older pottery vessels, was added in amounts from 2 to 40%, and the size of grains is between 0.1 and 3 mm. Based on the density of grains recorded on macrophotographs of fresh breakage on samples, we identified 4 groups of clay pastes, and the pastes which has about 7% of grog grains is the most common. Research has not fully revealed potential patterns or regularities in choosing specific clay paste in relation to, e.g. vessel type. However, the fabric which contains about 25% of grog grains was most frequent for vessel production in Turopolje, and mostly for vessel types 3, 4, 8, and 18 (pots and deep bowls - vessels which were mostly used for thermal processing of food, and cups). In Podravina, a similar paste was used to make type 5 and 19 vessels (deep bowls, cups, and shallow bowls, that is, vessels which do not display traces of exposure to fire). Statistically, the complete number of samples shows that the amount of temper increases in correlation with wall thickness.[56] Smaller, older grains made from the same material were recorded in grog grains, indicating second-generation grog (Fig. 21b).

[56] Kudelić 2015.

Slika / Figure 22. Makorfotografija keramike kulturne grupe Virovitica s vidljivim glinovitim peletima označenima crnim strelicama – Kurilovec-Belinščica: (a) glinoviti peleti zaobljenih rubova (plava strelica), uvećanje 500 x; (b) glinoviti pelet zaobljenih rubova i željezoviti oksidi (plava strelica), uvećanje 50 x; (c) glinoviti peleti difuznih i zaobljenih rubova, uvećanje 50 x (snimila: A. Kudelić). / Macrophotograph of Virovitica cultural group pottery with visible argillaceous rock fragments marked with black arrows – Kurilovec-Belinščica: (a) argillaceous rock fragments with round edges (blue arrow), magnification 500 x; (b) an argillaceous rock fragment with round edges and iron oxides (blue arrow) magnification 50 x; (c) argillaceous rock fragments with diffused and round edges, magnification 50 x (photo by: A. Kudelić).

Osim primjesa groga, u brončanodobnoj je keramici zabilježena i pojava glinovitih peleta (sl. 22). U uzrocima keramike s nalazišta u Kurilovcu zabilježene su zaobljene granule, čiji sastav odgovara sastavu matriksa, međutim, razlika se manifestira u boji (sl. 22a, 22b). Dokumentirani su peleti difuznih rubova i nepravilnih oblika koji se vjerojatno slučajno nalaze u smjesi (sl. 22a, 22c). Tragovi izgorenoga organskog materijala na svježem lomu keramike zabilježeni su samo na jednom uzorku, a na osnovi provedenih eksperimenata ustanovljeno je da je smjesi vjerojatno dodana suha trava, slama i pljeva.[57] Preostali keramički materijal ima presjek ujednačene tamnosive boje i izrazito poroznu strukturu, a to su neki od pokazatelja uporabe vrlo usitnjene organske primjese. Pretpostavlja se da je u tu svrhu korištena balega preživača.

Kasno brončano doba (11. – 9. st. pr. Kr.) i razdoblje prijelaza na željezno doba obilježilo je sve očitije društveno raslojavanje. Jedno od najznačajnijih nalazišta s kraja kasnoga brončanog doba u sjevernoj Hrvatskoj je Kalnik-Igrišče. Petrografsko-mineraloške analize na manjem broju keramičkih uzoraka, kao i analize lokalnih glina, napravljene su još devedesetih godina prošlog

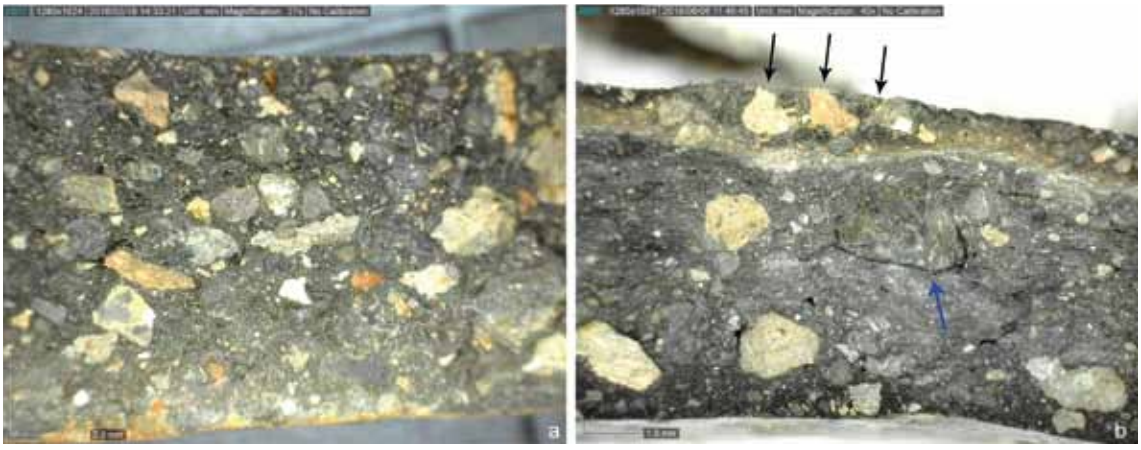
[57] Kudelić 2015; Kudelić 2016.

In addition to grog, Bronze Age pottery samples also included clay pelets (argillaceous rock fragments) (Fig. 22). Pottery samples from the site at Kurilovec have rounded granules of the same composition as the matrix, but of different color (Fig. 22a, 22b). We also recorded clayey inclusions with diffuse edges and irregular shapes that are probably accidentally in the clay paste (Fig. 22a, 22c). Traces of burned-up organic material in the cross section are only visible on one sample, and, based on the conducted experiments, it was established that dry grass, hay, and chaff were probably added to the paste.[57] The rest of the material is of equal dark gray color and has a porous structure, and these features are some of the indicators of using very small organic temper. It is assumed that dry dung of ruminants was used for that purpose.

The Late Bronze Age (11th – 9th cent. BC) and the transition into the Iron Age were marked by increasingly notable social stratification. One of the most significant sites dated to the end of the Late Bronze Age in northern Croatia is Kalnik-Igrišče. Petrographic and mineralogical analyses were done on a smaller number of samples, analyses of local clays were done back in the 1990s,[58] and technological and macrophotograph analyses of pottery samples are still underway. All of these studies have increased the

[57] Kudelić 2015; Kudelić 2016.

[58] Vrdoljak 1995.



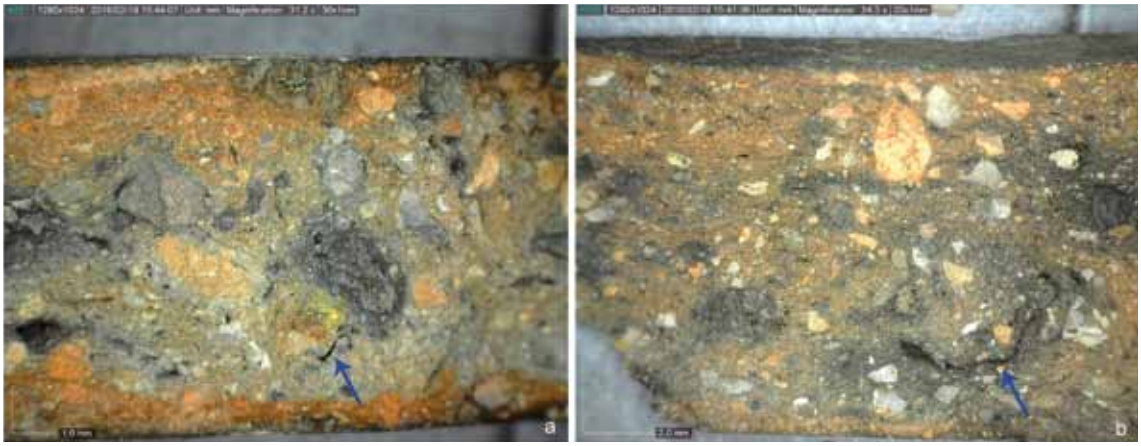
Slika / Figure 23. Makrofotografija keramike iz kasnoga brončanog doba s primjesama groga – Kalnik-Igrišče: (a) uvećanje 30 x, (b) crne strelice označavaju paralelan raspored primjesa s unutarnjom stijenkom posude, uvećanje 40 x (snimila: A. Kudelić). / Macrophotograph of Late Bronze Age grog tempered pottery – Kalnik-Igrišče: (a) magnification 30 x, (b) black arrows denote the parallel distribution of inclusions with the inner vessel wall, magnification 40 x (photo by: A. Kudelić).

stoljeća,[58] a tehnološka analiza i analiza makrofotografija uzoraka keramike, koja se i dalje provodi, nadopunila je postojeću bazu podataka. Uz uzorke s nalazišta na Kalniku provedena je i preliminarna makroanaliza uzoraka keramike s nalazišta Dubovac pokraj Karlovca koji potječu iz istovremenog naselja. Oba nalazišta smještena su na povišenim lokacijama (do 500 metara nadmorske visine), za razliku od lokacija ranije spomenutih prapovijesnih naselja koja se nalaze u izrazito nizinskim područjima. Tipološko-morfološka analiza keramičkih posuda s nalazišta na Kalniku ima jasne pokazatelje standardizacije oblika. Drugim riječima, posude određenog tipa istih su dimenzija ili se izrađuju u nekoliko veličina, a na njima se koriste ujednačene tehnike oblikovanja i obrade površine. To se posebno primjećuje na oblicima zdjela s uvučenim rubom, loncima sa suženim vratom i izrazito ljevkastim otvorom te kod lonaca izduženog, zaobljenog tijela, blago izvučenog otvora, na čijoj se površini često nalazi horizontalno postavljena glinena traka u kojoj su kružni otisci. Zbog dobro očuvanih posuda omogućena je analiza i usporedba tipa posude i lončarske

[58] Vrdoljak 1995.

existing database. Along with the samples from Kalnik, a preliminary macroanalysis of pottery samples from the contemporaneous settlement of Dubovac near Karlovac was conducted. Both sites are situated on elevated positions (up to 500 meters above sea level), unlike previously discussed prehistoric settlements, which are mostly situated in lowland areas. The typological and morphological analysis of pottery from Kalnik clearly indicates standardization of vessel forms. In other words, certain vessel types have the same dimensions or are made in several sizes, and they are formed and processed in the same manner. This is especially visible on bowl forms with an inward-facing rim, pots with a narrowed neck and a notably funnel-shaped opening, and pots with an elongated round body and a slightly outward-facing rim decorated with horizontal plastic application with circular impressions. Well-preserved vessels allowed us to analyze and compare vessel types and clay pastes they were made from.[59] Considering the fact that the research is still in progress, only the basic characteristics of the ceramic fabric are presented. Just like in the earlier period, the basic temper material added to the paste by

[59] Karavanić 2009; Karavanić, Kudelić 2011; Karavanić *et al.* 2015.



Slika / Figure 24. Makrofotografije keramičke strukture zdjela s uvučenim rubom iz kasnoga brončanog doba s tragovima izgorenih primjesa od organskog materijala (plave strelice označavaju moguće tragove organskog materijala) i groga – Kalnik-Igrišče: (a) uvećanje 30 x, (b) uvećanje 25 x (snimila: A. Kudelić). / Macrophotographs of the pottery structure of a bowl with an inward-facing rim from the Late Bronze Age with traces of burned-up organic temper (blue arrows denote possible traces of organic material) and grog – Kalnik-Igrišče: (a) magnification 30 x, (b) magnification 25 x (photo by: A. Kudelić).

smjese od koje su napravljene.[59] S obzirom na to da se istraživanja još provode, ovdje će biti predstavljene samo osnovne karakteristike keramičke strukture.

Kao i u razdoblju koje je prethodilo ovome, osnovna primjesa koju je lončar dodavao smjesi je grog (sl. 23), a varijabilnost receptura uglavnom se odnosi na količinu i veličinu dodanih zrna. Na makrofotografijama uzoraka koji pripadaju zdjelama uvučenog ruba zabilježena su uglavnom zrna groga (20%), međutim, u smjesi su primijećeni i tragovi izgorenoga organskog materijala koji se povezuje sa zdjelama koje su pečene u drugačijim uvjetima od ostalih posuda. Naime, tragovi izgorenoga organskog materijala, koji je u uzorku relativno dobro raspoređen, nema preferiranu orijentaciju i mogu se povezati s primjesama poput pljeve ili suhe trave, pripadaju posudi koja je pečena u oksidacijskim uvjetima, stoga je presjek uzorka smeđe-narančaste boje (sl. 24). Nakon inicijalnog pečenja posude su podvrgnute sekundarnoj redukciji pa su vanjska i unutarnja stijenka uzoraka tamnosive boje. Smjesa kojoj je lonačar dodavao velika zrna

the potter is grog (Fig. 23), and the variability of recipes mostly refers to the size and amount of added temper grains. Macrophotographs of samples of bowls with inward-facing rims mostly recorded grains of grog (20%). However, the paste also contained traces of burned-up organic material that is linked to bowls, which were fired under different conditions than other vessels. Namely, traces of burned-up organic material, which is relatively well distributed, do not have preferred orientation, and can be connected to inclusions such as chaff or dry grass. They were part of a vessel which was fired in an oxidation atmosphere and, consequently, the sample has a brown-orange cross section (Fig. 24). After the initial firing, the vessels were fired again in a reduction atmosphere, so the outer and inner surfaces of the samples are dark gray. The potter added large grains of grog to the paste that was used in the production of pots which do not have notable surface treatment, and which were used at the hearth for thermal processing of food. Large, subangular grains of grog sometimes exceed the size of 5 mm, and were added in amounts of around 20% (Fig. 23a). The grains of grog which are 0.2 – 2 mm in size, and appear in amounts of 10 – 20%, are poorly sorted and were added to the paste used

[59] Karavanić 2009; Karavanić, Kudelić 2011; Karavanić *et al.* 2015.

groga koristila se za izradu lonaca čija površina nije posebno tretirana, a korištene su na ognjištu za termalnu obradu hrane. Velika, djelomično uglata zrna groga, ponekad prelaze veličinu od 5 mm, a dodavala su se u količini oko 20% (sl. 23a). Za izradu šalica i manjih zdjela tankih stijenki (0,35 cm) i glačane površine, lončar je smjesi dodavao između 10 i 20% groga veličine zrna od 0,2 do 2 mm (sl. 23b).

Vrlo sličan sastav lončarskih smjesa zabilježen je i na uzorcima s nalazišta Dubovac-Stari grad, smještenog uz rijeku Kupu pokraj Karlovca. Uzorci su odabrani prema inicijalnoj karakterizaciji materijala na tzv. finu, srednju i grubu keramičku strukturu. Gotovo sve analizirane smjese sadrže zrna groga. Zrna su djelomično uglata i djelomično zaobljena, dobro i umjereno raspoređena, veličine između 0,3 i 3 mm. Lončar je smjesi dodavao od 2 do 40% groga. Na svježem lomu triju uzoraka primijećeni su tragovi izgorenoga organskog materijala (sl. 25) koji se mogu povezati s primjesama poput pljeve, suhe trave ili sjemenki. Posuda tankih stijenki također sadrži grog, ali i dobro raspoređeni organski materijal, a pripada posudi pečenoj u oksidacijskim uvjetima (sl. 25). Ručka koja pripada posudi glatkih stijenki izrađena je od vrlo fine smjese, bez većih mineralnih inkluzija, međutim, u strukturi je zabilježen vrlo usitnjen organski materijal, dobro raspoređen u matriksu (sl. 25).

for producing thin-walled vessels averaging 0.35 cm in thickness, and were discovered in a cup and a small decorated bowl with a polished surface (Fig. 23b).

A very similar composition of clay paste was noted in samples from the site of Dubovac-Stari grad, situated next to the Kupa River near Karlovac. Samples were selected based on the initial characterization of ceramic material as being of fine, medium-fine, and coarse fabric. Almost all analyzed pastes contain grains of grog. The grains are subangular and subrounded, well and fairly well distributed, and vary in size from 0.3 to 3 mm. The potter added 2 – 40% of grog to the paste. The fresh breakage on three samples have traces of burned-up organic material (Fig. 25), which can be linked to temper such as chaff, dry grass, or seeds. A vessel with thinner walls, fired in an oxidation atmosphere, contains grog, but also well distributed organic material (Fig. 25). A handle fragment from a thin-walled vessel from the site of Dubovac was made out of very fine paste without larger mineral inclusions, but it also contains very tiny organic material which is well distributed in the matrix (Fig. 25).

Slika / Figure 25. Makrofotografija keramike iz kasnoga brončanog doba s primjesama groga – Dubovac-Stari grad: (a) uvećanje 30 x, (b) primjese groga i tragovi primjesa od organskog materijala, uvećanje 45 x; (c) dio ručke izrađene od vrlo finog, sitnozrnatoga glinovitog materijala s tragovima izgorenoga organskog materijala, uvećanje 45 x (snimila: A. Kudelić). / Macrophotograph of the Late Bronze Age grog tempered pottery – Dubovac-Stari grad: (a) magnification 30 x, (b) inclusions of grog and traces of organic inclusions, magnification 45 x; (c) fragment of a handle made out of very fine, fine-grained clayey material with traces of burned-up organic material, magnification 45 x (photo by: A. Kudelić).

4. TUMAČENJE ODABIRA LONČARSKE SMJESE

Prema rezultatima ranije provedenih istraživanja[60] i preliminarno provedenih analiza makrofotografija uzoraka keramike iz brončanog doba na prostoru sjeverne Hrvatske, utvrđeno je da su lončarske smjese raznolike te da se njihova varijabilnost uglavnom može razmatrati u kulturno-kronološkim okvirima karakteristika keramičkog materijala. Ipak, nekoliko je značajnih informacija utvrđeno na razini odabira vrste i količine primjesa. Odabir glinovitog materijala za pripremu smjese kroz čitavo razdoblje brončanog doba bio je ograničen na neposrednu okolicu naselja, odnosno podrijetlo sirovinskog materijala bilo je vjerojatno lokalno. Razlog je prije svega laka dostupnost kvalitetnog aluvijalnog tipa sedimenta i primjesa. Općenitim uvidom u keramičke strukture brončanodobne keramike može se reći da su posude malih dimenzija i tankih stijenki, poput šalica, vrčeva i zdjela bile izrađene od relativno finoga glinovitog materijala, s vrlo malo primjesa ili bez njih. S obzirom na to da su sitnozrnate inkluzije silikatnih minerala vrlo dobro raspoređene u glinovitome materijalu, pretpostavlja se da smjesi nisu dodavane kao primjese te da su sastavni dio sedimenta.[61] To se posebno odnosi na muskovit koji je vidljiv na površini keramičkih posuda, kao svjetlucavi pijesak, i koji se u objavama često pogrešno tumači kao glina s primjesama muskovita (engl. *mica-tempered*). Izrazitija je zastupljenost ove vrste silikata zabilježena u uzorcima inkrustirane keramike na prostoru Baranje (sl. 8) i uzorcima keramike vinkovačke kulture iz Donjeg Miholjca iako se u manjem omjeru nalazi i u keramičkim uzorcima s ostalih nalazišta koja su ovdje obrađena. Dobra vidljivost listića muskovita na površini keramičkih posuda, osobito onih tamne boje, može biti posljedica glačanja ili poliranja površine posude jer se na taj način mijenja orijentacija listića koji postaju paralelni s površinom posude te postaju vidljivi čitavom svojom površinom.

[60] Kudelić 2015; Kudelić *et al.* 2018.

[61] Više u Shepard 1985, 162.

4. INTERPRETING CERAMIC PASTE SELECTION

Based on the results of previously conducted research,[60] as well as preliminary analyses of macrophotographs of Bronze Age pottery samples from northern Croatia, it was determined that the clay paste recipes are different, and that this variability can mostly be considered in the cultural and chronological framework of the pottery material characteristics. However, several important pieces of information were gathered on the level of choosing the kind and amount of temper. The selection of clayey material used for paste preparation throughout the entire Bronze Age was limited to the immediate vicinity of a settlement, i.e. the raw material is probably of local origin. The primary reason for this was the availability of high-quality alluvial type sediments and temper material. By studying the general overview of Bronze Age ceramic fabric, we can say that smaller vessels with thin walls, such as cups, jugs, and bowls, were made out of relatively fine non-tempered clayey material or material with a very small amount of temper. Seeing as fine-grained and silicate mineral inclusions are very well distributed in the clayey material, it can be assumed that they were not added to the paste as temper, but were a constituent part of the sediment.[61] This especially refers to muscovite, which is visible on the vessel surface as shiny sand and which is often misinterpreted in publications as mica-tempered clay. A more notable representation of this kind of silicate was noted in samples of incrusted ware from Baranja (Fig. 8) and samples of Vinkovci Culture pottery from Donji Miholjac, although smaller amounts of muscovite were also noted in samples from other sites discussed in this paper as well. Good visibility of muscovite on the surface of pottery vessels, especially those of darker color, can be the result of polishing the vessel surface, because it changes the orientation of particles, making them parallel to the vessel surface and causing the entire surface of these particles to be visible.

[60] Kudelić 2015; Kudelić *et al.* 2018.

[61] For more, see Shepard 1985, 162.

Mnogo više informacija o odabiru može se prikupiti identifikacijom i analizom primjesa koje lončar koristi za izradu smjese. Bez obzira na vrstu primjese, one u keramičkoj strukturi mogu biti obilne ili pak sporadične. Primijećeno je obilno korištenje (20 – 40%) primjesa groga (i glinovitih peleta) ili litoklasta u smjesi iz svih kulturnih skupina. Ta je količina zabilježena na posudama koje sadrže tragove sekundarne oksidacije vanjske stijenke, što je dobar pokazatelj da je posuda korištena na vatri (sl. 12b, 14, 15d). U osnovi neplastične primjese (mineralna zrna, litoklasti ili grog) glini se dodaju kako bi se pospješilo oblikovanje i pečenje keramike, pojačala čvrstoća i termička izdržljivost, što u konačnici utječe i na poroznost posude.[62] Takvi neplastični materijali dodaju se smjesi da bi se pojačala otpornost na termalni stres (pri pečenju ili za posude koje se koriste na vatri). Termalni je stres pojava širenja i skupljanja materijala u kontaktu s visokom temperaturom, pri čemu je napeta forma stijenke posude podložna pucanju. Iz tih se razloga u smjesu gline dodaju primjese otporne na visoke temperature, oko kojih se pri pečenju posude stvaraju mikropukotine te one kasnijom upotrebom na vatri omogućavaju slobodan prostor za nesmetano stezanje. U tu svrhu često se koristi kvarc. Toplinska je otpornost složen parametar i pod utjecajem je prijenosa topline, toplinskog širenja, čvrstoće i otpornosti, a na njega utječe i oblik posude, stoga se moraju razmotriti svi navedeni parametri.[63]

Zabilježene su i lončarske smjese koje također sadrže veće količine primjese, međutim, ne povezuju se s posudama namijenjenima korištenju na vatri. Stoga je tumačenje odabira količine primjesa u funkcionalnom smislu do neke mjere upitna. Upravo se ova pojava uglavnom povezuje s primjesama groga čija količina (1 – 7%) nije dovoljna da pozitivno utječe na fizička svojstva posude (npr. termalna svojstva). U sklopu kulturne grupe Virovitica, i u kasnom brončanom dobu, lončari koriste isključivo grog za izra-

A lot more data on this selection can be gathered by identifying and analyzing the temper material used by the potter in the paste preparation process. Regardless of the type, temper material can appear in the ceramic structure in abundance or sporadically. Large amounts (20 – 40%) of grog (and clay pelets) and lithoclasts in pastes were used by all cultural groups. These amounts were noted in vessels that had traces of secondary firing in an oxidation atmosphere on the outer surface, which is a good indicator of the vessel having been used in fireplaces (Fig. 12b, 14, 15d). Basically, non-plastic inclusions (mineral grains, lithoclasts, or grog) were added to the pastes in order to improve the shaping and firing of the vessel, to increase its firmness and thermal resistance, which also affected the porosity of the vessel.[62] Such non-plastic materials were added to the paste in order to improve the resistance to thermal stress (during firing or during use). Thermal stress is an occurrence where material expands and shrinks in contact with higher temperatures, whereby the tense vessel wall is prone to breaking. That is why temper resistant to high temperatures is added to the paste. Microcracks appear around these temper grains during firing that enable stress-free shrinkage during subsequent exposure to fire. Quartz is often used for that purpose. Thermal resistance is a complex parameter affected by the transfer of heat, thermal expansion, firmness and resistance, and by the shape of the vessel, which is why all listed parameters must be considered.[63]

Ceramic pastes that contained higher amounts of temper material, but which cannot be associated with vessels that were exposed to fire were also noted. Therefore, explaining the choice of temper amounts in terms of functionality is somewhat questionable. Precisely this occurrence is most often connected with grog, the amount of which (1 – 7%) is not enough to positively affect the physical properties of the vessel (e.g. thermal properties). In the framework of the cultural group Virovitica and the Late Bronze Age, potters exclusively used grog in the production of all vessel types, and larger amounts (10 – 30%) of such temper were often used in

[62] Rye 1981, 39; Shepard 1985, 25; Velde, Druc 1999.

[63] Schiffer *et al.* 1994; Hein, Müller, Kilikoglou 2007, 15.

[62] Rye 1981, 39; Shepard 1985, 25; Velde, Druc 1999.

[63] Schiffer *et al.* 1994; Hein, Müller, Kilikoglou 2007, 15.

du svih oblika posuda, a veće količine (10 – 30%) takve primjese često se koriste i za izradu posuda tankih stijenki (sl. 21a, 23b). Prevladavajuće je mišljenje da je uporaba groga tehno-funkcionalna, a prema nekim istraživanjima za postizanje optimalne kvalitete kaolinske gline u smjesu je potrebno dodati između 20 i 50% neplastičnih materijala.[64] Prednost groga prije svega je njegova dostupnost, zatim relativno jednostavna priprema i funkcionalne karakteristike koje mogu osigurati posudi otpornost na termalni stres i razna mehanička oštećenja.[65] Međutim, korištenje groga može se tumačiti i na drugačiji način. Podaci iz arheoloških i etnoarheoloških izvora govore o sustavnom recikliranju keramike i snažnim elementima tradicije u odabiru primjesa.[66] U tome smislu ovaj fenomen može se smatrati kao simbolički aspekt ugradnje starijih posuda u nove, a takvo recikliranje materijala i njegova transformacija predstavljaju simbolično održavanje kontinuiteta i identiteta unutar zajednice.[67]

Organski materijal (suha trava, slama, pljeva, sjemenke, kravlja balega i sl.) zastupljen je u pojedinim uzorcima gotovo svih kulturnih grupa, a iznimka je licenska keramika. Prisutnost organskih materijala u smjesi može poboljšati svojstva glina koje su vrlo plastične, a s obzirom na to da većina primjesa izgori tijekom pečenja te u strukturi keramike ostaju manje ili veće šupljine/pore, one smanjuju i utjecaj termalnog stresa na stijenke posude.[68] Premda je analiziran mali broj uzoraka, postoje pokazatelji da je takva vrsta materijala korištena kao primjesa za izradu samo nekih tipova posuda, npr. zdjela s uvučenim rubom. U ovom slučaju, razlozi uporabe organskih primjesa ne mogu se tumačiti termalnom otpornošću tijekom uporabe jer zdjele ne sadrže tragove izlaganja vatri, a slično se pretpostavlja i

[64] Rye 1981, 39.

[65] Rice 1987, 229; Spindel 1989, 69 (prema Kreiter 2007, 117); Velde, Druc 1999, 116.

[66] Sterner 1989, 458 (prema Deal, Hagstrum 1995, 122); Kreiter 2007; Gosselain 2011.

[67] De Boer 1974, 336; Smith 1989, 61; Chapman 2000; Brück 2006.

[68] Skibo, Schiffer, Reed 1989.

the production of thin-walled vessels (Fig. 21a, 23b). The prevailing opinion is that using grog was techno-functional, and some research has shown that, in order to achieve the optimal quality of kaolin clay, one must add between 20 and 50% of non-plastic materials.[64] The advantage of grog is primarily its availability, and another is the relatively simple preparation and functional characteristics, which can make the vessel resistant to thermal stress and diverse mechanical damage.[65] However, using grog can also be interpreted in a different way. Data from archaeological and ethnological sources speaks in favor of systematic pottery recycling, pointing to strong elements of tradition in temper selection.[66] In that sense, this phenomenon can be seen as a symbolic aspect of incorporating older vessels into new ones, meaning that such recycling and transformation of the material are a symbolic act of keeping the continuity and identity within a community.[67]

Organic material (dry grass, hay, chaff, seeds, cow dung and so forth) is present in individual samples of almost all cultural groups, with the exception of Litzen pottery. The presence of organic temper materials in a paste enhances the properties of plastic clays and, seeing as most inclusions burn up during firing, leaving smaller or larger voids/pores in the structure of the pottery, they reduce the effect of thermal stress on the vessel walls.[68] Even though the number of analyzed samples is small, there are indicators that such material was used as temper in the production of only some types of vessels, e.g. bowls with inward-facing rims. In this case, the reasons for using organic temper cannot be interpreted through, e.g. thermal resistance during vessel use, seeing as the bowls do not have

[64] Rye 1981, 39.

[65] Rice 1987, 229; Spindel 1989, 69 (after Kreiter 2007, 117); Velde, Druc 1999, 116.

[66] Sterner 1989, 458 (after Deal, Hagstrum 1995, 122); Kreiter 2007; Gosselain 2011.

[67] De Boer 1974, 336; Smith 1989, 61; Chapman 2000; Brück 2006.

[68] Skibo, Schiffer, Reed 1989.

za panonsku inkrustiranu keramiku te posude vinkovačke kulture. Tumačenje odabira organske primjese moglo bi biti u vezi s termalnom otpornošću tijekom postupka proizvodnje, odnosno pečenja keramike.

Glineni peleti za sada su zabilježeni u uzorcima panonske inkrustirane keramike i keramike virovitičke grupe, međutim, preciznija karakterizacija nije moguća jer ova metoda ne dopušta jasno razlikovanje između groga i peleta.

Na uzorcima vinkovačke kulture primijećena je velika raznolikost lončarskih smjesa, vrste primjesa i recepture, stoga je za bolje razumijevanje njihova odabira potrebno provesti opsežnije analize. Ipak, primjećeni su uzorci kojima nije dodavana primjesa i oni u kojima se nalazi i nekoliko različitih vrsta primjesa, dok je debljina stijenke svih uzoraka prilično ujednačena (oko 0,5 cm). Velika varijabilnost lončarskih smjesa može biti pokazatelj suživota različitih tehno-kulturnih praksa, ali ona predstavlja i dobar indikator vanjskih utjecaja, promjena tradicije ili populacije.[69]

Bez obzira na kronološku diskrepanciju između kulture Kisapostag i licenske keramike, lončarske smjese s izrazitijom količinom litoklasta, često vrlo krupnih zaobljenih zrna (do 5 mm), tek preliminarno, predstavljaju dobre pokazatelje smanjene varijabilnosti, odnosno visoke razine sličnosti u pripremi smjese. Pojava neznatne količine groga, uz obilnije prisutne primjese litoklasta, za sada se može tumačiti u okvirima dostupnosti sirovine. Zaobljena zrna litoklasta mogu se vrlo lako nabaviti u prirodi u obliku šljunka i predstavljaju gotovu petrogenu primjesu, za razliku od groga koji zahtijeva posebnu pripremu. S druge strane, analiza makrofotografija svježeg loma panonske inkrustirane keramike pokazala je drugačiju praksu. Osnovna je vrsta primjesa grog (i/ili glinoviti peleti) koji se smjesi dodavao u većim količinama, i to za izradu određene vrste posuda, a količina litoklasta, iako prisutna gotovo je zanemariva. Ipak, za sada

[69] Stark 1991; Stark, Longacre 1997; Arnold 2000; Gosselain 2000.

traces of fire exposure, and a similar thing is suggested for Pannonian Encrusted Ware and vessels of the Vinkovci Culture. Interpretation of organic temper selection may be related to thermal resistance during the manufacturing process or firing.

Clay pelets (argillaceous rock fragments) have, so far, only been noted in samples of Pannonian Encrusted Ware and pottery of the Virovitica group. However, more precise characterization has been prevented due to the difficulty of distinguishing pellets from grog by using this method.

Samples of the Vinkovci Culture display a wide variety of clay pastes, type of temper, and recipes, so in order to better understand their selection, it is necessary to conduct more-encompassing analyses. However, samples which had a pretty even vessel wall thickness (about 0.5 cm) without added temper and those which had several types were also noted. The large variability in ceramic pastes can be an indicator of the cohabitation of several different technological and cultural practices, but also of outside influences, changes in tradition or population.[69]

Regardless of the chronological discrepancy between the Kisapostag Culture and Litzen pottery, ceramic pastes with more pronounced amounts of very often large and rounded lithoclast grains (up to 5 mm) represent, albeit preliminarily, indicators of reduced variability, that is, of a high level of similarity in paste preparation. The presence of insignificant amounts of grog, along with lithoclasts, can be interpreted in terms of the availability of raw materials. Rounded grains of lithoclasts can easily be obtained from the environment, in the form of gravel, and represent a natural rock-forming temper, unlike grog, which requires special preparation. On the other hand, the analysis of macrophotographs of Pannonian Encrusted Ware ceramic fabric revealed a different practice. The basic temper is grog (and/or clay pelets), which was added to the paste in larger amounts, and only to produce certain kinds of vessels, and the amount of lithoclasts, although noted, is almost negligible. However, for now, there are good indicators for

[69] Stark 1991, Stark, Longacre 1997; Arnold 2000; Gosselain 2000.

postoje dobri pokazatelji vrlo ujednačenih recepata, smjese bez groga i one s velikom količinom većih zrna groga uz koje se rjeđe nalaze i zrna litoklasta. Takav je odabir čini se povezan s debljinom stijenke, obradom površine te vjerojatno i funkcijom posuda. Miješanje različitih vrsta primjesa u arheološkoj, ali i etnološkoj praksi nije neuobičajeno.[70]

Odabir lončarske smjese može biti povezan s tehnikom ukrašavanja njihove površine. Licenski ukras, odnosno tehnika utiskivanja tkane uzice ili namotane niti na površinu glinene posude, izvodi se s lakoćom i izgleda urednije ako se utiskuje u smjesu koja ne sadrži krupne primjese, a jednak odabir smjese povezuje se i s tehnikom rovašenja, žljebljenja i urezivanja, kakva se koristila za dekoriranje posuda s inkrustacijom (panonska inkrustirana keramika). S druge strane, posude vinkovačke kulture jednakih karakteristika izrađene su od sitnozrnatoga glinovitog materijala, međutim, površina takvih posuda uglavnom je neukrašena.

Tragovi tehnika izrade i obrade površine keramičkih posuda, koji mogu biti vidljivi u keramičkoj strukturi, posebna su tematika koja do neke mjere prelazi okvire ovog rada. Međutim, upravo su pojedini elementi koji se promatraju u keramičkoj strukturi, poput orijentacije i rasporeda pora/šupljina, čestica minerala ili neplastičnih zrna, jedan od pokazatelja tog dijela keramičke proizvodnje.[71] Tehnike oblikovanja posuda dijele se na primarne, koje podrazumijevaju izradu posude, i sekundarne, koje se odnose na završnu obradu kao što je stanjivanje stijenke, glačanje površine i sl. Raspored zrna groga, koji se nalaze paralelno uz vanjsku stijenku posude (sl. 26a, 23b, 12b), mogu biti pokazatelj uporabe kalupa, odnosno zrna groga, a predstavljaju materijal koji je služio za oblaganje kalupa i njegovo lakše odvajanje od posude.[72] Takav raspored groga u keramičkoj strukturi, osim primarnih metoda izrade posuda, vjerojatniji je po-

[70] Quinn 2013, 168; Albero Santacreu 2014, 70.

[71] Rye 1981, 67–72.

[72] Quinn 2013, 174, Fig. 6.33.

similar recipes for pastes without grog, and for those with larger amounts of grog grains which are seldom accompanied by grains of lithoclasts. Such a choice is connected to vessel wall thickness, surface processing, and, probably, vessel function. The mixing of different kinds of temper is not unusual in archaeological, as well as ethnological practice.[70]

The selection of ceramic paste can be connected to, e.g. decorative techniques. Litzen decorations, i.e. impressing a braided ribbon or thread onto the surface of a pottery vessel, are easily done and look more orderly if impressed onto a paste with fewer inclusions, and the same selection of paste is connected to gauging, grooving, and incising used to decorate incrusted vessels (Pannonian Encrusted Ware). On the other hand, the mostly undecorated vessels of the Vinkovci Culture with the same characteristics are made out of fine-grained clayey material.

Traces of forming techniques and surface treatment that may be visible in ceramic fabrics are a separate topic that falls within the scope of this paper to a certain extent. Still, certain elements studied in the pottery fabric, such as orientation and the distribution of voids/pores, mineral particles, or non-plastic grains, are one of the indicators of that aspect of pottery production.[71] Techniques of vessel shaping are divided into primary, including forming the vessel, and secondary, including final processing such as thinning of the vessel walls and so forth. The distribution of grog grains that are parallel to the outer vessel wall (Fig. 26a, 23b, 12b) can be an indicator of using a cast, i.e. the grains of grog are the remains of material used to cover the cast in order to enable the separation of the vessel from the cast.[72] Such a distribution of grog in the ceramic structure, apart from primary techniques of vessel production, is a more probable indicator of secondary techniques such as surface polishing.[73] The category of secondary techniques of pottery production, that is, final processing, includes slip, a liquid suspension of clayey material and minerals (and/or other ma-

[70] Quinn 2013, 168; Albero Santacreu 2014, 70.

[71] Rye 1981, 67–72.

[72] Quinn 2013, 174, Fig. 6.33.

[73] Albero Santacreu 2014, 85–86.

Slika / Figure 26. Makrofotografije brončanodobne keramike s tragovima tehnika izrade posuda: (a) crne strelice označavaju paralelan raspored primjesa s unutarnjom stijenkom posude i pokazatelj su primjene tehnike glačanja površine posude – Jagodnjak-Krčevine, uvećanje 36 x; (b) koncentričan raspored i orijentacija zrna neplastičnih materijala u keramičkoj strukturi mogu biti pokazatelj tehnike izrade posude pomoću glinenih traka ovalnog presjeka – Kurilovec-Belinščica, uvećanje 25 x (snimila: A. Kudelić). / Macrophotographs of Bronze Age pottery with traces of surface treatment and forming techniques: (a) black arrows denote the parallel distribution of inclusions and the inner vessel wall, which is an indicator of applying the technique of polishing the vessel surface – Jagodnjak-Krčevine, magnification 36 x; (b) the concentric distribution and orientation of grains of non-plastic materials in the structure of pottery can be an indicator of using a specific forming technique, coiling – Kurilovec-Belinščica, magnification 25 x (photo by: A. Kudelić).

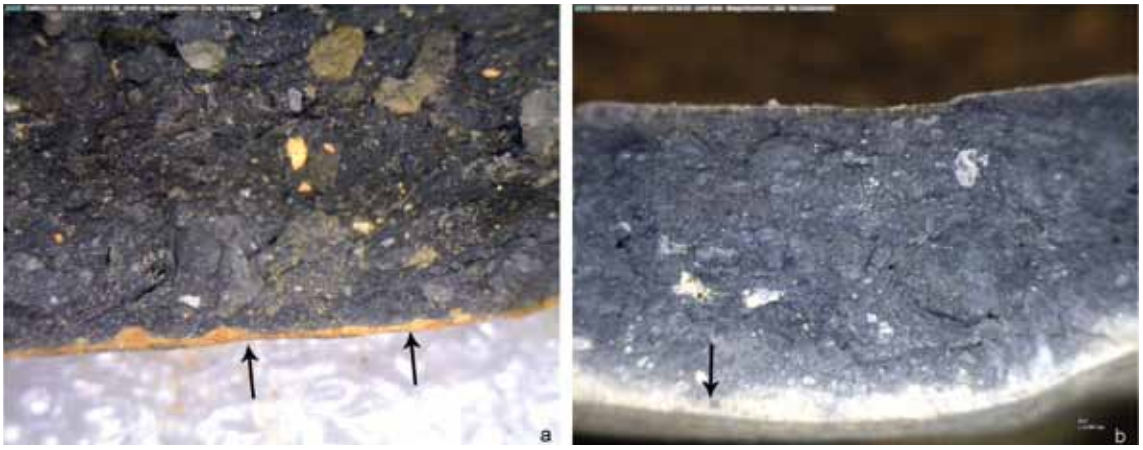
kazatelj sekundarnih tehnika, poput glačanja površine.[73] U kategoriju sekundarnih tehnika izrade posuda, odnosno finalnoj obradi, pripada slip, tekuća suspenzija glinovitog materijala i minerala (i/ili drugih materijala) koja se prije pečenja u tankom sloju nanosi na čitavu površinu posude. Slip uglavnom sadrži manju količinu inkluzija sitnijih čestica u odnosu na sastav smjese i često je drukčije boje. Njegova debljina ovisi o tehnici i sastavu suspenzije, a kada je sloj premaza deblji, može se zabilježiti i makrofotografijom (sl. 27). Šupljine i pore, paralelne sa stijenkom posude, zabilježene su u gruboj keramičkoj strukturi kulture Kisapostag i licenske keramike na svim uzorcima, neovisno o području odakle potječu, stoga su dobar pokazatelj ujednačenih tehnika izrade posuda (sl. 15). Orijentacija zrna neplastičnih materijala i pora u keramičkoj strukturi, poput koncentričnog ili izrazito zakrivljenog smijera orijentacije, mogu biti pokazatelj tehnike izrade posude pomoću glinenih traka ovalnog presjeka (sl. 26, 22c).

Provedenim istraživanjem ustanovljeno je da lončarski odabiri u sklopu brončanodobnih zajednica na prostoru sjeverne

terial), which is used to thinly cover the entire vessel surface before firing. Slip mostly contains smaller amounts of inclusions of particles that are smaller than those in the paste composition, and are often of a different color. Its thickness depends on the technique and composition of the suspension, and, when the coating is thicker, it can also be recorded on macrophotographs (Fig. 27). Voids and pores that are parallel to vessel walls were noted on coarse ware of the Kisapostag Culture and Litzen pottery on all samples, regardless of where they came from, and are a good indicator of very similar pottery production techniques (Fig. 15). The orientation of non-plastic grains and pores in the ceramic structure, such as concentric or notably curved orientation, can be an indicator of the coiling pottery technique of forming vessels (Fig. 26, 22c).

The conducted research has shown that the potter's choices within Bronze Age communities in northern Croatia reflect certain variability and specific similarities (Tab. 2), which are a good foundation for developing a systematic analy-

[73] Albero Santacreu 2014, 85–86.



Slika / Figure 27. Makrofotografije brončanodobne keramike s tragovima uporabe debelog sloja premaza ili slipa, a od matriksa se razlikuje sitnijim sastavnim česticama i drugačijom bojom – Kurilovec-Belinščica: (a) uvećanje 35 x, (b) premaz izrazito svijetle, bež boje, uvećanje 35 x (snimila: A. Kudelić). / Macrophotographs of Bronze Age pottery with traces of using a thick layer of coating or slip which differs from the matrix due to very tiny particle components and color – Kurilovec-Belinščica: (a) magnification 35 x, (b) the notably light, beige-colored coating, magnification 35 x (photo by: A. Kudelić).

Hrvatske odražavaju složenu varijabilnost i specifične sličnosti (tab. 2) koje predstavljaju dobar temelj za razvoj sistematizirane analize lončarskih smjesa svake pojedine kulturološki određene grupe/zajednice te da je njihova analiza ukazala na izraziti potencijal budućih proširenih istraživanja.

sis of ceramic fabrics in order to determine the composition of clay pastes for every cultural group/community, and this analysis expressed the potential of future, more-encompassing research.

	LITOKLASTI / LITHOCLAST	GROG–GLINOVITI PELETI / GROG–CLAY PELETS	ORGANSKI MATERIJAL / ORGANIC MATERIAL
Vinkovačka kultura / Vinkovci–Somogyvár culture (Donji Miholjac)	+	+	
Kisapostag kultura i licenska keramika / Kisapostag culture and Licen pottery (Turopolje i/and Podravina)	++	+	
Panonska inkrustirana keramika / Pannonian Encrusted Ware (Jagodnjak-Krčevine)	+	++	+
Kulturna grupa Virovitica / Virovitica cultural group (Turopolje i/and Podravina)		+	+
Kasno brončano doba / Late Bronze Age (Kalnik-Igrišče i/and Dubovac-Stari grad)		+	+

Tablica / Table 2. Korištene vrste primjesa za pripremu lončarskih smjesa u brončano doba na području sjeverne Hrvatske (++ – učestalije korištena vrsta primjese). / Types of temper material used for preparing Bronze Age ceramic pastes in northern Croatia (++ – more frequently used type of temper).

5. ZAKLJUČAK

Da bi se ustanovili složeni mehanizmi odabira lončarskih smjesa u okviru i između kulturnih grupa / zajednica iz brončanog doba sjeverne Hrvatske, valja provesti mnogo opsežnije istraživanje. Ipak, ovdje su predstavljeni osnovni kriteriji za njihovu karakterizaciju u okviru mogućnosti manjih uvećanja uzoraka, kao i preliminarni rezultati provedenih makroskopskih analiza koje čine dobre smjernice za odabir novih uzoraka i buduća istraživanja. Pretpostavka je da brončanodobni lončari svojstva primjesa koje dodaju u smjesu od kojih izrađuju predmete dobro poznaju te da njihov odabir nije slučajan. Pretpostavka je također da je njihov odabir djelomično povezan s dostupnošću pojedinog materijala, a prema rezultatima provedenih analiza zabilježene vrste primjesa i glinoviti materijal mogli su se nabaviti u neposrednoj okolici naselja ili u samom naselju. Zabilježene su i velike različitosti u odabiru recepata za pripremu lončarskih smjesa, a to se posebice odnosi na odabir vrste primjesa. Pretpostavka je da su različitosti produkt društvenih zbivanja na prostoru savsko-dravskog međurječja, odnosno da su odabiri uvjetovani kulturološkim čimbenicima.

Desetljećima su razvijane teorije, a provedena su i brojna ekstenzivna arheološka i etnoarheološka istraživanja koja se bave tehnologijom, tehnikom, tehnološkim odabirima i njihovim odnosom s društvenim i kulturno uvjetovanim naslijeđem i ritualom. Rezultati takvih istraživanja ukazuju na to da su u lončarskoj praksi pretpovijesnih zajednica najznačajniji pokazatelji tehnoloških odabira, tradicije ili varijabilnosti skriveni u dubokim kulturološko-ideološkim vrijednostima zajednice. Tehnički izbori najbolje se mogu tumačiti kao kulturno naučeno ponašanje, a ne usvojena strategija.[74] Iako lončari načelno imaju mogućnost

[74] Gosselain, Livingstone Smith 1995, 158.

5. CONCLUSION

Future research is required in order to understand the complex mechanisms of ceramic paste selection among and between Bronze Age cultural groups/communities in northern Croatia. However, the basic criteria for their characterization within the possibilities of smaller magnifications, as well as preliminary results of conducted macroscopic analyses which give good guidelines for new sample selection and future research were presented in this paper. The assumption is that Bronze Age potters knew the properties of temper added to the paste and that their selection was not accidental, and that this selection was partially connected to the availability of certain material. The conducted analyses revealed that temper and clayey material could have been obtained in the immediate vicinity of settlements or within the settlements themselves. Differences in the selection of recipes for ceramic paste preparation, which especially refers to the choice of temper material, were also noted. It is assumed that the differences are a result of social conditions in the Sava-Drava river valley, that is, that the selection was affected by cultural factors.

Theories have been evolving for decades, and numerous extensive archaeological and ethnoarchaeological studies have been conducted on the questions of technology, technique, technological choices, and their relation to socially and culturally conditioned heritage and ritual. The results of such research show that the most significant indicators of technological choices, tradition, and variability in the pottery-making practices of prehistoric communities are hidden in the deeply-rooted cultural and ideological values of a community. Technological choices can best be explained as culturally-learned behavior, and not as an adopted strategy.[74] Although potters generally could make different technological choices, they were greatly influenced by technological traditions which

[74] Gosselain, Livingstone Smith 1995, 158.

različitih tehnoloških odabira, oni su uvelike diktirani tehnološkom tradicijom u sklopu koje djeluju.[75] Naša je zadaća u ulomcima keramičkih posuda pokušati pronaći pokazatelje tradicije i pokazatelje promjena u lončarskim praksama te ih sistematizirano bilježiti kako bismo pokušali bolje razumijeti te procese.

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[75] Gosselain, Livingstone Smith 1995, 158.

surrounded them.[75] Our task is to try and find indicators of tradition, as well as changes in pottery production practices, and to systematically record them in order to gain insight into these processes.

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[75] Gosselain, Livingstone Smith 1995, 158.

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