

Most na Soči

Razprave
Treatises

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ŽELEZNODOBNO NASELJE MOST NA SOČI. RAZPRAVE
THE IRON AGE SETTLEMENT AT MOST NA SOČI. TREATISES

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**ŽELEZNODOBNO NASELJE MOST NA SOČI
RAZPRAVE**

**THE IRON AGE SETTLEMENT AT MOST NA SOČI
TREATISES**

Uredila / Editors:

Janez Dular, Sneža Tecco Hvala



LJUBLJANA 2018

VSEBINA

Janez DULAR, Sneža TECCO HVALA: <i>Most na Soči v železni dobi</i>	9
Janez DULAR: <i>Kronološka slika železnodobne naselbine Most na Soči</i>	147
Drago SVOLJŠAK: <i>Posoško železnodobno stavbarstvo</i>	167
Boštjan LAHARNAR: <i>Kovinske in steklene najdbe ter kamniti kalupi iz železnodobne naselbine na Mostu na Soči</i>	195
Lucija GRAHEK: <i>Naselbinska keramika z Mosta na Soči</i>	249
Lucija GRAHEK, Adrijan KOŠIR: <i>Analiza naselbinske keramike z Mosta na Soči z vrstičnim elektronskim mikroskopom</i>	307
Žiga ŠMIT, Boštjan LAHARNAR: <i>Analiza bronastih surovcev iz železnodobne naselbine na Mostu na Soči in grobnih najdb z Mosta na Soči in iz Bohinja</i>	321
Jakob LAMUT: <i>Analiza železove žlindre in železnega kvadra iz naselbine na Mostu na Soči</i>	333
Aleksander HORVAT: <i>Petrološke analize in provenienca kamnitih artefaktov iz železnodobne naselbine Most na Soči</i>	349
Sila MOTELLA DE CARLO: <i>Arheobotanične raziskave z najdišča Most na Soči: uporaba lesa, pokrajina in gospodarstvo med 6. in 1. stoletjem pr. Kr.</i>	361
Tjaša TOLAR: <i>Ostanki prehranskih rastlin iz hiš 6 in 15A z Mosta na Soči</i>	445
Karina GRÖMER, Klara KOSTAJNŠEK, Tjaša TOLAR, Gojka PAJAGIČ BREGAR: <i>Tekstilna najdba iz železnodobne naselbine Most na Soči: konservacija, analiza, primerjava</i>	453
Borut TOŠKAN, László BARTOSIEWICZ: <i>Živalski ostanki iz naselbine na Mostu na Soči: vpogled v družbeno kompleksnost železnodobne skupnosti v jugovzhodnoalpskem prostoru</i>	467
<i>Seznam avtorjev</i>	511

CONTENTS

Janez DULAR, Sneža TECCO HVALA: <i>Most na Soči in the Iron Age</i>	9
Janez DULAR: <i>Chronology of the Iron Age settlement at Most na Soči</i>	147
Drago SVOLJŠAK: <i>Iron Age architecture in Posočje</i>	167
Boštjan LAHARNAR: <i>Metal finds, glass finds and stone moulds from the Iron Age settlement at Most na Soči</i>	195
Lucija GRAHEK: <i>Pottery from the settlement at Most na Soči</i>	249
Lucija GRAHEK, Adrijan KOŠIR: <i>Scanning electron microscopy analysis of the pottery from the settlement at Most na Soči</i>	307
Žiga ŠMIT, Boštjan LAHARNAR: <i>Analysis of raw bronze from the Iron Age settlement Most na Soči and of grave finds from Most na Soči and Bohinj</i>	321
Jakob LAMUT: <i>Analysis of ferrous slag and a metal block from the settlement at Most na Soči</i>	333
Aleksander HORVAT: <i>Petrology and provenance of the raw material of stone artefacts from the Most na Soči Iron Age settlement</i>	349
Sila MOTELLA DE CARLO: <i>Indagini archeobotaniche a Most na Soči: tecnologia del legno, paesaggio ed economia tra VI sec. e I sec. a. C.</i>	361
Tjaša TOLAR: <i>Edible plant remains from Houses 6 and 15A at Most na Soči</i>	445
Karina GRÖMER, Klara KOSTAJNŠEK, Tjaša TOLAR, Gojka PAJAGIČ BREGAR: <i>Textile find from the Iron Age settlement at Most na Soči: conservation, analysis and comparisons</i>	453
Borut TOŠKAN, László BARTOSIEWICZ: <i>Animal remains from the settlement at Most na Soči: insights into the social complexity of an Iron Age community in south-eastern Alps</i>	467
<i>List of contributors</i>	511

ANALIZA NASELBINSKE KERAMIKE Z MOSTA NA SOČI Z VRSTIČNIM ELEKTRONSKIM MIKROSKOPOM

SCANNING ELECTRON MICROSCOPY ANALYSIS OF THE POTTERY FROM THE SETTLEMENT AT MOST NA SOČI

Lucija GRAHEK, Adrijan KOŠIR

ANALIZE SESTAVE KERAMIKE

Ena glavnih značilnosti naselbinske keramike z Mosta na Soči je sestava lončarske gline (mase), za katero je bilo že z makroskopsko analizo celotne zbirke najdb ugotovljeno, da vsebuje veliko primešanega karbonatnega peska. Te rezultate smo podkreplili z mikroskopsko analizo osmih vzorcev keramike. Poleg vzorcev značilne drobnozrnate in bolj finozrnate ter grafitne keramike smo iz celotne zbirke keramičnih najdb izbrali in analizirali še nekaj fragmentov rdeče-črno barvanih pitosov in loncev z metličenim okrasom (sl. 1).¹

FABRIC ANALYSIS

One of the main characteristics of the ceramics from the settlement at Most na Soči is the fabric with a high amount of carbonate sand temper. This has first been observed macroscopically and confirmed by the results of microscopic analyses. More specifically, it has been confirmed by scanning electron microscopy (SEM) analyses, which have been applied to examine eight samples taken from shards of the characteristic medium-grained, fine-grained and graphite ware fabrics. Apart from these, we also selected and analysed several unprocessed shards of black-on-red painted pithoi and brushed jars (Fig. 1).¹

¹ Vsi citati tabel se nanašajo na objavo gradbenih izvidov naselja z Mosta na Soči (Svoljšak, Dular 2016).

¹ The drawings of all ceramic finds have been published in the first volume of the publication of the Iron Age settlement at Most na Soči (Svoljšak, Dular 2016).

Vzorec / sample	Inv. št. / Inv. No.	Objava / drawing	Opis / description
MNS A	-		fragment značilne drobnozrnate keramike (hiša 15A) / frg. of characteristic medium-grained fabric (House 15A)
MNS B	-		fragment značilne bolj finozrnate keramike (hiša 15A) / frg. of characteristic more fine-grained fabric (House 15A)
MNS C	P 4602		fragment grafitne keramike iz hiše 11(2) / frg. of graphite ware fabric from House 11(2)
MNS D	P 4007		frag. finozrnatega rdeče-črno barvanega lonca (L 21) iz hiše 16(2) / frg. of fine-grained, black on red painted jug (L21) from House 16 (2)
MNS E	P 4776		frag. drobnozrnatega ostenja z metličenim okrasom (O 7) iz hiše 14(2) / medium-grained frg. with brushed decoration (O 7) from House 14(2)
MNS F	P 5382		frag. finozrnatega pitosa (Pi) iz hiše 15A(1) / frg. of fine-grained pithoi (Pi) from House 15A(1)
MNS G	P 4240	t. 23: 21	frag. drobnozrnatega pitosa (Pi) iz hiše 3(2) / frg. of medium-grained pithoi (Pi) from House 3(2)
MNS H	P 2332		frag. drobnozrnatega lonca z metličenim okrasom (L 17) iz hiše 1(2) / frg. of medium-grained jug with brushed decoration (L 17) from House 1(2)

Sl. 1: Seznam vzorcev keramike za analizo sestave lončarske mase.

Fig. 1: List of samples subjected to fabric analyses.

MATERIAL IN METODE

Za mikroskopsko analizo smo vzorce keramike s precizno žago Buehler IsoMet nažagali na približno centimeter debele rezine, ki smo jih v vakuumski komori impregnirali in zalili z nizkoviskozno epoksidno smolo Epo-Tek 301-1. Iz zalitih primerkov smo izrezali planparalelne ploščice (*sl. 2*), ki smo jih na eni strani strojno izravnali ter suksesivno obrusili in polirali na papirnih ploščah Kemet z abrazivom iz silicijevega karbida zrnavosti F1200, F2500 in F4000.

Vzorce smo proučili na vrstičnem elektronskem mikroskopu JEOL JSM-IT100 v laboratoriju za mikroskopijo na Paleontološkem inštitutu ZRC SAZU v Ljubljani. Fragmente in obruse smo opazovali nenapršene (to je brez nanosa tanke prevodne plasti zlata ali ogljika) in fotografirali v grobovakuumskem načinu (od 20 do 40 Pa) s pospeševalno napetostjo 15 ali 20 kV in pri delovni razdalji od 9 do 11 mm. Vzorce smo fotografirali s signalom detektorja odbitih elektronov (BED) v senčnem (BES) načinu.

Kvalitativno in semikvantativno elementno analizo z energijsko disperzijsko spektroskopijo rentgenskih žarkov (EDS) smo izvedli pri enakih grobovakuumskih pogojih. Elementne spektre smo posneli točkovno ali ploskovno s prednastavljenim časom 100 sekund z avtomatskimi načinom identifikacije elementov. Na vsakem vzorcu smo opravili vsaj tri analize celotnega vidnega polja reprezentativnih delov obrusa pri enaki povečavi (približno 3,5 x 2,5 mm pri povečavi 40x; *pril. 1*).

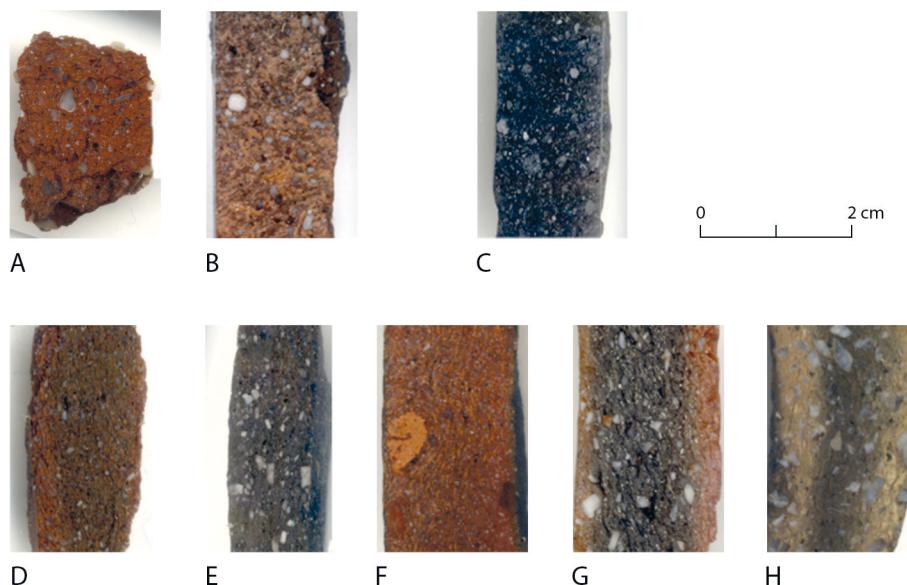
Poroznost keramike smo ocenili na podlagi vsebnosti klora v spektrih analiziranih površin, kar odraža delež smole, ki vsebuje približno 1,4 % Cl.

MATERIAL AND METHODS

Samples were prepared by cutting approximately one-centimetre thick slabs (*Fig. 2*) from the selected pottery shards using a Buehler IsoMet precise saw. The slabs were impregnated and embedded with a low-viscosity Epo-Tek 301-1 epoxy resin in a vacuum chamber. The embedded slabs were trimmed parallel and machine-lapped on one side, which was followed by manual fine lapping and polishing using Kemet silicon carbide abrasive pads of F1200, F2500 and F4000 grit size.

Each sample was examined under a JEOL JSM-IT100 LA scanning electron microscope at the microscopy lab of the Institute of Palaeontology ZRC SAZU in Ljubljana. We also examined unprocessed pottery shards. Both the unprocessed shards and the polished samples were observed uncoated, with elemental analysis and imaging performed in a low vacuum mode (20–40 Pa) at an accelerating voltage of 15 and 20 kV, and a working distance from 9 to 11 mm. Images were taken in topographic and shadow backscattered electron imaging (BED-T and BED-T) modes.

A qualitative and semi-quantitative Energy Dispersive X-ray Spectroscopy elemental analysis (EDS) was performed in the same low-vacuum conditions. Elemental spectra were obtained from uncoated specimens using point or small area analysis with 100 seconds preset (live) time and an automatic element identification mode. At least three whole-view elemental analyses were done on representative parts of each polished slab at the same magnification (at 40x showing approx. 3.5 x 2.5 mm large area; *App. 1*) and in constant operating conditions.



Sl. 2: Obrusi vzorcev keramike.

Fig. 2: Polished slabs.

SESTAVA IN STRUKTURA LONČARSKE GLINE

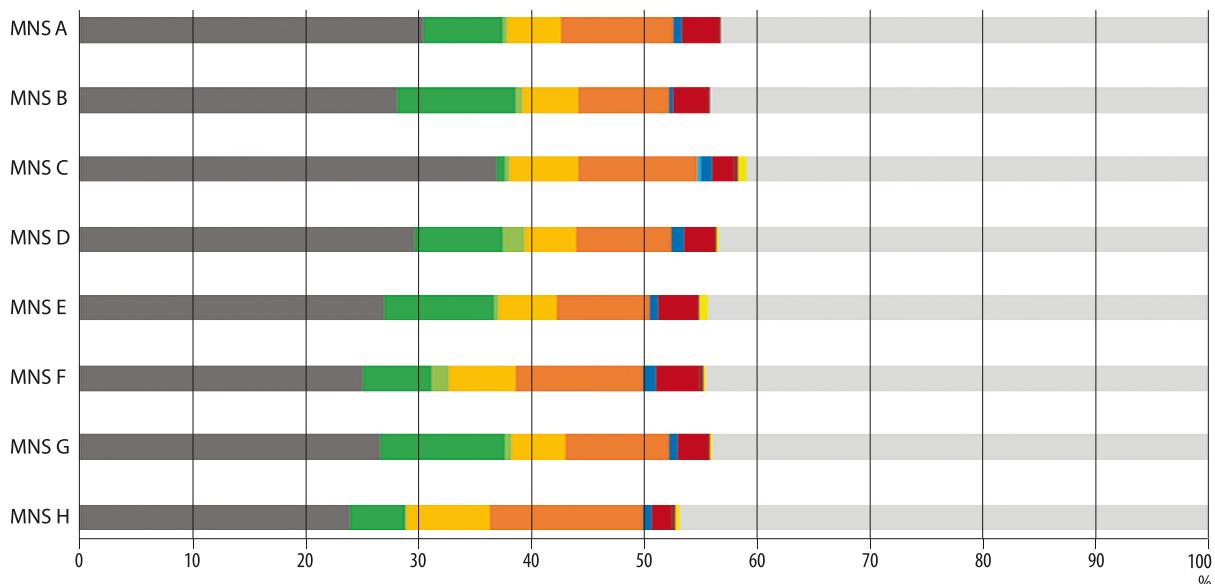
Iz rezultatov ploskovnih meritev na posameznih vzorcih (*sl. 3*) je razvidno, da je sestava naselbinske keramike z Mosta na Soči razmeroma enotna. Tako pri drobnozrnati kot pri bolj finozrnati lončarski glini zasledimo 5 do 11 % kalcija (Ca), ki je večinoma vezan na karbonatna zrna v velikosti peska in melja, kar pomeni od 10 do 25 % kalcijevega karbonata (CaCO_3) v celotni masi. Kot je razvidno iz mikroskopskih fotografij (*pril. 1*), v lončarsko glico ni bil primešan le apnenčev pesek, pač pa pogosto predvsem evhedralna in subhedralna zrna kristalnega kalcita (*pril. 1: A, G, H; sl. 4: b*). V vseh vzorcih smo zasledili le manjšo količino kremenovih zrn² (SiO_2), ki so praviloma velikosti melja (<63 µm)

² Deloma gre za verjetno za roženec ali delno silificirana karbonatna zrna.

Porosity of the pottery has been roughly estimated by the chlorine content in the analysed spectra, corresponding to the proportion of the resin impregnation in the sample (pure hardened resin contains approximately 1.4 wt% of Cl).

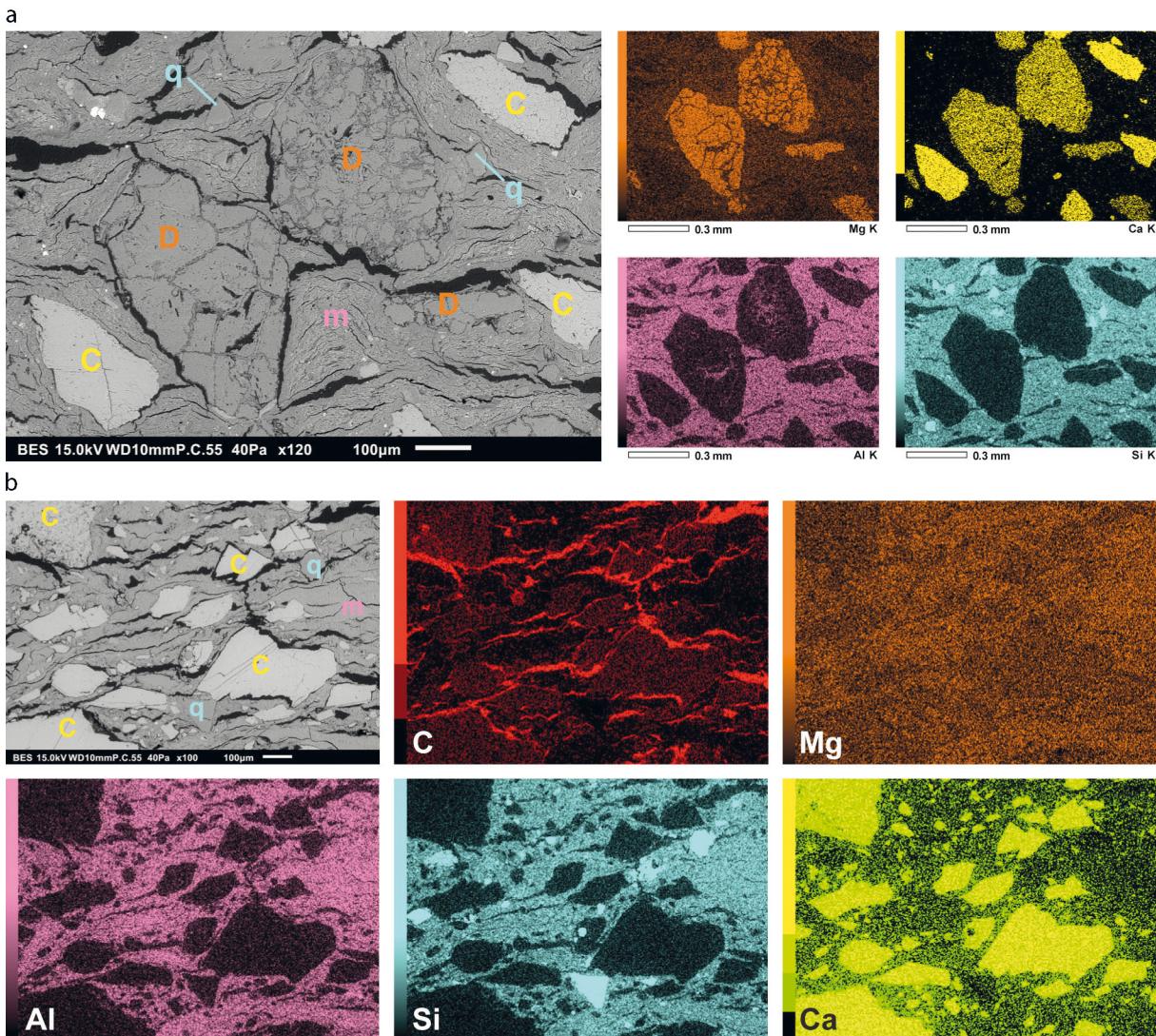
COMPOSITION AND STRUCTURE OF THE FABRIC

The results of the EDS analysis of individual samples (*Fig. 3*) indicate a relatively uniform composition of the pottery from Most na Soči. Both medium-grained and fine-grained fabrics contain from 5 to 11 wt% of calcium (Ca), which is generally associated with sand- and silt-size carbonate grains, corresponding to 10–25% of calcium carbonate (CaCO_3) in the total mass.



Sl. 3: Povprečje rezultatov ploskovnih analiz sestave vzorcev keramike (masni %).

Fig. 3: Mean results of the full image fabric analyses of pottery samples (mass %).



Sl. 4: (a) Levo: polirana površina vzorca MNS D, posneta z detektorjem odbitih elektronov v senčnem (BES) načinu. Desno: ustrezače karte elementov Mg, Ca, Al in Si. (b) BES slika polirane površine vzorca MNS E (levo zgoraj) in ustrezače karte elementov C, Mg, Al, Si in Ca.

Fig. 4: (a) Left: Backscattered shadow (BES) image of a polished surface of sample MNS D. Right: corresponding elemental maps of Mg, Ca, Al and Si. (b) BES image of a polished surface of sample MNS E (upper left) and corresponding elemental maps of C, Mg, Al, Si and Ca.

C – kalcit / calcite, D – dolomit / dolomite, q – kremen / quartz, m – osnova / matrix

(sl. 4). Znatnejša količina dolomitnih zrn je le v vzorcu MNS-D (sl. 4: a), sicer pa je količina magnezija (Mg) v drobnozrnnati osnovi keramiki <1% (sl. 3; sl. 4: b). Tako pri kremenu kot dolomitu gre za majhne količine, sploh v primerjavi s kalcitnim peskom, zatorej se postavlja vprašanje, ali v njunem primeru sploh lahko govorimo o namenskem dodajanju pustil v lončarsko glico ali gre zgolj za nečistoči v surovini. Enako velja za delež železa (Fe), ki je bilo v obliki oksidih ali hidroksidnih mineralov prisotno v sami ilovici. Ker sta aluminij (Al) in kalij (K) vezana na minerale glin, bi bila s prihodnjimi analizami vzorcev ilovnatih sedimentov iz okolice možna identifikacija železnodobnega glinokopa.

Photomicrographs of many samples (App. 1) reveal that the admixture in the fabric is not only limestone sand, but also calcite euhedral and subhedral crystal particles (App. 1: A, G, H; Fig. 4b). Silt-size quartz grains are present in all samples, but only in small amounts (Fig. 4a). A substantial amount of dolomite grains is present in Sample MNS-D (Fig. 4a), whereas the magnesium content of the fine-grained clay matrix is generally <1% (Figs. 3 and 4b). Both quartz and dolomite occur in relatively small amounts, particularly in comparison with calcite grains, it is therefore not certain if they were added on purpose or merely represent natural impurities in the source clay. Similarly, the iron (Fe) content reflects

Vzorec / sample	Inv. št. / Inv. No.	Objava / drawing	Opis / description
Most 1	P 4602		frag. dna grafitnega lonca iz hiše 11(2) / base frg. of graphite jug from House 11(2)
Most 2	P 4168		frag. ustja grafitnega lonca iz hiše 3(2) / rim frg. of graphite jug from House 3(2)
Most 3	P 8241	t. 91: 6	frag. noge rdeče(-črno) barvane situle (Si) iz hiše 29 (1) / pedestal frg. of (black-on-) red painted situlae (Si) from House 29(1)
Most 4	P 4007		frag. ustja (rdeče-)črno barvanega lonca (L 21) iz hiše 16(2) / rim frg. of black (-on-red) painted jug (L 21) from House 16(2)
Most 5	P 2352	t. 1: 2	frag. ustja rdeče barvanega lonca (L 13) iz hiše 1 (1) / rim frg. of red painted jug (L 13) from House 1(1)
Most 6	P 5499	(t. 59: 1)	frag. ostenja rdeče barvanega lonca (L 14) iz hiše 19 / frg. of red painted jug (L 14) from House 19
Most 7	P 5882	t. 80: 14	frag. ostenja narebrene situle (O 1a) z rdeče slikanim okrasom iz hiše 23(2) / frg. of ribbed and red painted situlae (O1a) from House 23(2)
Most 8	P 5383	t. 41: 1	frag. črno premazanega ustja pitosa (Pi b) iz hiše 15A(1) / black painted rim frg. of pithoi (Pi b) from House 15A(1)
Most 9	P 2566	t. 98: 5	frag. skodele (Sk 1) s črnim premazom iz hiše 35(2) / frg. of black painted bowl (Sk 1) from House 35(2)
Most 10	P 5380		frag. ostenja (rdeče-)črno barvanega pitosa (Pi) iz hiše 15A(1) / frg. of black (-on-red) painted pithoi (Pi) from House 15A(1)
Most 11	P 5437	t. 58: 1	frag. dna sklede s črnim premazom (LT-Rim) iz hiše 17 (2) / base frg. of black painted dish (LT-Rim) from House 17(2)
Most 12	*33/1	t. 97: 12	frag. ustja sklede s črnim premazom (LT-Rim) iz hiše 33 / base frg. of black painted dish (LT-Rim) from House 17(2)

Sl. 5: Seznam vzorcev keramike za analizo zunanje površine in barvnih premazov.

Fig. 5: List of samples subjected to exterior surface and paint analyses.

Analiza rezultatov primerljivih vzorcev nakazuje, da lahko z elementno mikroskopsko analizo prepoznamo tudi domnevno različne proizvodnje keramike. To kažejo rezultati analiz vzorcev MNS F in G (sl. 1–3; pril. 1: F, G), ki oba pripadata narebrem, rdeče-črno barvanim pitosom (Pi). Ker se pitos z vzorcem MNS F od preostalih razlikuje že po prelomu, nekoliko pa tudi po kemijski sestavi (zlasti delež Ca, Si, Fe in Mg), domnevamo, da gre za estenski primerek.³ Tudi petrografska analiza keramike z območja estenske kulture je namreč pokazala več lastnosti podobnih značilni naselbinski keramiki z Mosta na Soči. Analize sestave lončarske gline, ki so bile opravljene na vzorcih keramike iz Oppeana (Verona), so pokazale, da pride do večjih sprememb v sestavi nekje v 6. do 5. stol. pr. n. št., ko se tudi pri tamkajšnji keramiki občutno poveča delež primešanega apnenčevega peska oziroma kristalnega kalcita.⁴

the presence of Fe oxide and hydroxy-oxide minerals in the clay. As aluminum (Al) and potassium (K) are associated with clay minerals, it would be possible to identify the potential Iron Age clay pits if we were to analyse the clay deposits in the area of Most na Soči.

A comparative analysis indicates that the elemental microanalysis also enables the identification of different pottery productions. This is demonstrated by the composition of Samples MNS F and G (Figs. 1–3; App. 1: F, G) both taken from cordoned black-on-red painted pithoi (Pi). The pithos of Sample MNS F differs from other pithoi in the appearance of the fracture, but slightly also in its chemical composition (particularly the Ca, Si, Fe and Mg contents), which leads us to see the pithos as an import, presumably from Este.² Petrographic analyses of the pottery from the Este area has, in fact, shown several characteristics that are similar to those of the pottery from the settlement at Most na Soči. The fabric composition analyses performed on the sampled pottery from Oppeano (Verona), for example, have revealed that the significant changes in the fabric occurring sometime in the 6th–5th centuries BC involved an increased share of added limestone sand or calcite crystal particles.³

³ Prim. Saracino 2014, 131, 132.⁴ Saracino 2014, 144. Prim. Boschian, Floreano 2007.² Cf. Saracino 2014, 131, 132.³ Saracino 2014, 144. Cf. Boschian, Floreano 2007.

GRAFITNA KERAMIKA

Med mikroskopsko analiziranimi obrusi vzorcev keramike pričakovano najbolj izstopa vzorec MNS C, ki pripada grafitni keramiki (*sl. 1–4; pril. 1: C*).⁵ Na istem vzorcu je bila opravljena tudi analiza zunanje površine (*sl. 5: Most 1*). Četudi rezultati meritev površine in obrusa vzorca grafitne keramike niso neposredno primerljivi⁶, pa je pomenljiva primerjava s prav tako na površini analiziranim drugim vzorcem grafitne posode (*sl. 5: Most 2*). Za slednjega je bilo že pri makroskopski analizi ugotovljeno, da bržkone vsebuje več grafita, saj je keramika bolj mastna. Večja vsebnost grafita, to je mehkega ogljikovega minerala (C), ki se najpogosteje pojavlja v luskastih in lističastih agregatih, potrjuje mnogo večja vrednost ogljika v primerjavi z vzorcem 1 (*sl. 7*).

POROZNOST KERAMIKE

Mikroskopska analiza prepariranih vzorcev omogoča tudi oceno poroznosti keramike. Vzorci so bili impregnirani z nizkoviskozno smolo, ki učinkovito prodre tudi v najmanjše pore keramike. Delež por in njihova oblika sta lepo vidna na elementni karti ogljika (*sl. 4: b C*), saj pore, zalite s smolo, ki jo sestavlja več kot 70 % ogljika, izrazito izstopajo. Semikvantitativno smo poroznost izračunali iz deleža klora, ki ima v epoksidni smoli enakomeren delež (približno 1,4 %), v neimpregnirani keramiki pa ga nismo zaznali. Videti je, da poroznost keramike ni odvisna od zrnavosti gline in primesi.

ANALIZE BARVNIH PREMAZOV

Ker še nimamo opravljenih kemijskih analiz barvnih premazov na prazgodovinski keramiki iz našega prostora, smo na izbranih vzorcih skušali premaze analizirati z elementno mikroskopsko analizo (SEM-EDS), čeprav se pri nas v restavratorstvu za analize pigmentov in glazur na keramiki uporablja predvsem metoda rentgenske fluorescenčne spektrometrije (XRF-EDS).⁷ Z enako metodo kot v primeru pripravljenih zbruskov prelomov keramike smo na površini analizirali neobdelane fragmente (grafitne in) keramike z barvnimi premazi (*sl. 5, 6*). Ker smo pri vsakem vzorcu opravili ploskovne meritve tako površine s premazom kot brez njega, so rezultati opravljenih meritev⁸ med seboj primerljivi.

⁵ Prim. Friederich 2013, Abb. 4.

⁶ Rezultati meritev na površini neobdelanih vzorcev keramike so kvalitativni in zaradi velikih napak ne omogočajo zanesljive primerjave z rezultati analiz na poliranih vzorcih.

⁷ Nemeček 2011, 3–6, 13, 30; Menart et al. 2017, 158. Prim. Łaciak, Stoksik 2010.

⁸ Cf. op. 4.

GRAPHITE WARE

The microscopically analysed samples include one (Sample MNS C) that stands out from the others, which is an expected result as it was taken from a graphite ware vessel (*Figs. 1–4; App. 1: C*).⁴ The sample was also subjected to an exterior surface analysis (*Fig. 5: Most 1*). The results of the surface measurements are not directly comparable with those of the fabric analysis on the fracture,⁵ but they are comparable with the surface measurements of another graphite ware sample (*Fig. 5: Most 2*). This shard has a greasy surface that suggests a higher amount of graphite, and has already been determined as graphite ware during macroscopic observation. The microscopic analysis revealed a considerably higher carbon content in comparison with Sample Most 1 (*Fig. 7*) and consequently confirmed a higher graphite content (graphite is a soft carbon (C) mineral that most commonly occurs in flaky aggregates).

POROSITY

As a result of sample impregnation with low-viscosity epoxy resin that effectively penetrated even the smallest pores of the ceramics, the SEM analysis also enabled us to estimate the porosity of the pottery. The proportion and geometry of the pores are distinguishable on the element concentration map of carbon (*Fig. 4b: C*) due to the resin containing more than 70% carbon. Porosity was semi-quantitatively determined from the total Cl content in the analysed area, assuming a uniform 1.4% Cl concentration in the pure resin and its apparent absence in the ceramics. There is no significant correlation between porosity and grain size.

PAINT ANALYSES

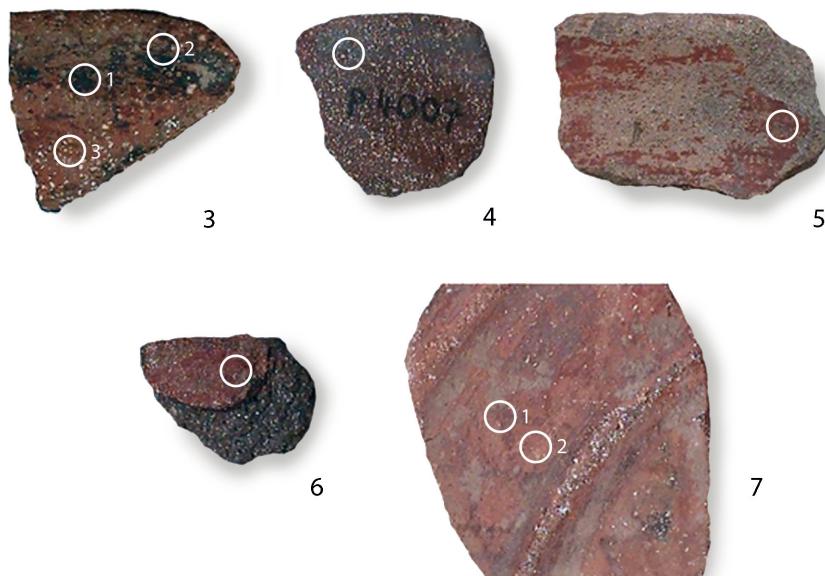
In Slovenia, the most commonly used method for analysing pigments and glazes on pottery is that of X-ray fluorescent spectrometry (XRF-EDS),⁶ but it has never been applied to chemically analyse prehistoric pottery. For the shards from the prehistoric Most na Soči, a chemical analysis was performed using the SEM-EDS method to examine unprocessed shards of (graphite ware and) painted pottery (*Figs. 5, 6*). To obtain comparable results on the painted and non-painted parts a full image analysis was carried out on each sample.⁷

⁴ Cf. Friederich 2013, Fig. 4.

⁵ The elemental analyses done on unprocessed surfaces are merely qualitative and cannot be reliably used for a comparison with the results obtained from the polished samples.

⁶ Nemeček 2011, 3–6, 13, 30; Menart et al. 2017, 158. Cf. Łaciak, Stoksik 2010.

⁷ Cf. Fn. 4.



Sl. 6: Vzorci keramike Most 3–7 z označenim mestom analize.

Fig. 6: Samples Most 3–7 with marked paint analysis.

ČRNI PREMAZI

Pri črnih premazih razlikujemo med črno grafitno barvo (Čg), ki ima kovinski sijaj, in črno smolnato barvo (Č), ki je domnevno organske sestave.⁹ Črna premaza na vzorcih Most 3 in 4 smo na makroskopskem nivoju opredelili kot grafitna, mikroskopska analiza pa je pričakovano pokazala večjo vsebnost ogljika (C) na premazu kot na neobarvanem delu površine (sl. 6: 3, 4). Še mnogo večji vrednosti ogljika (več kot 65 %) sta bili izmerjeni na črno (Č) premazanih vzorcih Most 8 in 9 (sl. 7; pril. 2: e). Ker pri njima vrednosti fosforja (P) in kalija (K) ne presegajo meritev na preostalih analiziranih vzorcev, z opravljenou analizo ne moremo potrditi, da so črni smolnati premazi domnevno izdelani iz oglja. Na Poljskem opravljene kemijske analize barvnih premazov na keramiki namreč kažejo, da so alkalni oksidi (K_2O , P_2O_5 in tudi CaO) lahko povezani tudi z uporabo v prah zdrobljenega lesnega oglja (listavcev), ki pa ni služil le kot barvilo, temveč za boljši oprijem barvnih nanosov na posodje.¹⁰

BLACK PAINTS

We distinguish between a black graphite paint (Čg), which has a metallic shine, and a black resinous paint (Č), which is presumably organic in origin.⁸ The black paint on Samples Most 3 and 4 has been macroscopically determined as graphite. For both, microscopic analysis revealed a higher carbon (C) content in the painted part as opposed to the non-painted parts of the surface (Fig. 6: 3, 4). An even higher carbon content (more than 65%) has been measured on the black (Č) painted Samples Most 8 and 9 (Fig. 7; App. 2: e). The analysis showed that the phosphorus (P) and potassium (K) content in these samples does not exceed the measurements on other analysed samples, hence it is not possible to determine whether the black resinous paints are charcoal-based. Chemical analyses of paints carried out in Poland revealed that the alkali oxides (K_2O , P_2O_5 and also CaO) may be associated with the use of powdered wood charcoal (of deciduous trees), which served not only as a pigment, but also to ensure better adhesion of the paints onto the ceramic surface.⁹

⁹ Prim. Grahek 2016, 216 s; Łaciak, Stoksik 2010, 145.¹⁰ Łaciak, Stoksik 2010, 145.⁸ Cf. Grahek 2016, 216 f; Łaciak, Stoksik 2010, 145.⁹ Łaciak, Stoksik 2010, 145.

Vzorec / Sample	Masa / Fabric	C	O	Na	Mg	Al	Si	P	S	K	Ca	Ti	Mn	Fe
Most 01	grafitna ker. / graphite ware	14,93	60,35		0,68	6,26	10,33	0,40		1,59	1,54	0,52		3,40
Most 02	grafitna ker. / graphite ware	34,41	41,26		0,87	4,30	7,47	1,19	0,16	0,86	4,62	0,31		4,56
Most 02*	zrno grafita / graphite-grain	83,52	13,08			1,00	1,13	0,53		0,14				

Barva / Paint

Most 03	Čg	18,92	44,41		0,99	8,28	8,17	1,33		2,00	2,73	0,82	1,18	11,17
Most 03	R	12,29	45,15		0,94	10,28	9,81	1,83		3,62	4,10	0,51	3,50	10,49
Most 03	brez / without	8,00	48,53		1,76	7,27	16,02	0,77		2,35	4,67	0,74		9,89
Most 04-2	Čg	72,85	20,87		0,21	1,44	1,91	0,24		0,31	0,77			1,39
Most 04-1	brez / without	34,84	40,67		0,86	5,58	8,78	0,51		1,24	2,40	0,35		4,77
Most 05	R	14,02	52,08	0,08	0,78	10,07	13,70	2,82		0,51	1,65	0,71		3,48
Most 06	R	6,62	56,77		0,92	10,23	15,51	0,00		0,98	2,60	0,57		5,79
Most 07	R-temna / dark	6,31	48,96		1,76	10,04	12,98	0,87		2,50	2,95	0,76	0,56	12,30
Most 07	R-svetla / light	5,28	49,70		1,80	10,08	13,72	0,81		2,61	3,02	0,67	0,43	11,88
Most 08	Č	68,56	27,18		0,17	0,71	1,17	0,20		0,30	1,73			
Most 09	Č	66,79	28,64			0,85	1,01	0,17		0,31	0,99			1,24
Most 10	Č	59,10	33,65		0,30	1,34	2,04	0,19		0,34	1,78			1,25
Most 11	Č	7,08	43,64		1,25	15,44	13,03			1,76	0,86	0,73	16,22	
Most 12-1	Č	7,30	43,20	0,77	1,53	12,71	16,40			4,70	1,54		11,52	
Most 12-2	brez / without	5,84	45,63	0,42	3,15	6,19	18,90			1,42	7,37		10,30	

Sl. 7: Rezultati ploskovnih analiz na zunanji površini grafitne keramike in keramike z barvnimi premazi.

Fig. 7: Results of the full image exterior surface analyses on graphite ware and painted pottery.

R – rdeča / red; Č – črna / black; Čg – črna grafitna barva / black graphite paint.

RDEČI PREMAZI**RED PAINTS**

Rdeči premazi temeljijo na kovinskih, predvsem železovih oksidih, pri čemer pa je barvi odtenek premaza zelo odvisen tudi od temperature žganja.¹¹ Ker sta železo in titan običajno prisotna že v glini, smo vse izmerjene vrednosti železa (Fe) najprej primerjali z izmerami na neobarvani površini. Izkazalo se je, da se pri rdeče obarvanih vzorcih (sl. 6: 3, 5–7) delež železa dejansko poveča, pri čemer so izmere na vzorcu Most 7 pokazale, da vsebuje temnejši, iz več nanosov sestavljen okras večjo vsebnost (sl. 7). Po naslikanem motivu ima ta vzorec najboljše primerjave med estensko keramiko,¹² zato se zdi pomenljiva tudi izmerjena vsebnost mangana (Mn).

Red paints are based on metal, primarily iron oxides, with their hue greatly influenced by the firing temperature.¹⁰ As iron and titanium are usually present in the source clay, all the measurements of iron (Fe) were first compared with the measurements on the non-painted surface. The results showed an increased quantity of iron in the red paint samples (Fig. 6: 3, 5–7), of which Sample Most 7 with a darker painted decoration applied in several layers revealed an even higher quantity of iron (Fig. 7). The closest parallels for the decorative motif can be found among the pottery from Este;¹¹ in this respect it is also worth mentioning that the sample showed the presence of manganese (Mn).

¹¹ Horvat 1999, 42.¹² Capuis, Chieco Bianchi 2006, t. 94: 38; 136: 4; 210: 2; prim. XLVIII: d.¹⁰ Horvat 1999, 42.¹¹ Capuis, Chieco Bianchi 2006, Pl. 94: 38; 136: 4; 210: 2; cf. XLVIII: d.

UVOŽENA KERAMIKA

Kot kažejo rezultati meritev na prelomih keramike manganovi oksidi v surovini niso bili prisotni, vsaj ne v izmerljivih količinah (*sl. 3*), zato lahko na površini keramike izmerjen mangan pripišemo sestavi barvnih premazov. Največji delež mangana je bil izmerjen na vzorcih črno barvane, uvožene rimske keramike (*sl. 6–7, pril. 2: f*). Ti premazi očitno temeljijo na manganovih oksidih kot je hausmanit (Mn_2O_4) in ne železovih kot so hercinit ($FeAl_2O_4$), magnetit (Fe_3O_4) ali hematit (Fe_2O_3), ki sestavlajo črne poslikave na atiški keramiki.¹³ Rimska keramika s črnim premazom je na Most na Soči najverjetnejše prišla iz severno italijanskih produkcijskih središč, zatorej lahko tudi za vzorca rdeče(-črno) barvane halštatske keramike (*sl. 6: 3,7*), pri katerih smo izmerili vsebnost mangana, domnevamo, da sta bila izdelana v estenskih delavnicih.

SKLEP

Mikroskopska analiza keramike iz Mosta na Soči je pokazala enotno sestavo lončarske gline, od katere pričakovano odstopa le vzorec grafitne keramike. Za sestavo halštatske keramike je najbolj značilno, da je bil lončarski masi dodan, verjetno skrbno izbran, kalcitni pesek. Podobna struktura lončarske gline s kalcitom je znana z območja estenske kulture. Z analizo kemijske sestave pa smo ugotovili pomenljiva odstopanja, ki omogočajo prepoznavanje izdelkov estenskih delavnic (vzorec MnS F).

Rezultati analiz površine grafitne keramike potrjujejo opažanja na makroskopskem nivoju. Spodbudne rezultate pa smo pridobili z elementno analizo barvnih premazov. Ta na eni strani podpira opažanja na makroskopskem nivoju, na drugi strani pa omogoča zaznavanje domnevno različnih načinov proizvodnje na osnovi različne sestave premazov. Kemijska sestava rdeče-črnih premazov z manganeseom (Mn) na halštatski keramiki (vzorca Most 3 in 7) namreč govori v prid estenskih delavnic, saj je bila prisotnost mangana izmerjena le še pri vzorcih rimske keramike s črnim premazom, ki je bila uvožena iz severnoitalijanskih delavnic.

Rezultati opravljenih analiz z vrstičnim elektronskim mikroskopom na naselbinski keramiki z Mosta na Soči so vzpodbudni. Ker pa je bil analiziran zelo majhen vzorec keramike, bomo za tehtnejše zaključke nadaljevali s sistematičnim vzorčenjem in analiziranjem večjega števila vzorcev, in sicer tako samih keramičnih izdelkov kot tudi vzorcev iz domnevno izvornih glinokopov.

IMPORTED POTTERY

The results of the measurements on the pottery fractures show that manganese oxides were not present in the clay, at least not in detectable amounts (*Fig. 3*); the manganese measured on the surface may therefore be seen as an ingredient of the paint. The highest manganese content has been measured on the black-slipped samples of imported Roman pottery (*Figs. 6–7, App. 2: f*). These slips are apparently based on manganese oxides such as hausmannite (Mn_2O_4) and not on iron oxides such as hercynite ($FeAl_2O_4$), magnetite (Fe_3O_4) or hematite (Fe_2O_3) that are to be found in the black paints of the Attic pottery.¹² The Roman black-slipped pottery most probably came to Most na Soči from north Italian production centres; in parallel, we suggest that the pottery of the two samples of red (black-on-red) painted Hallstatt pottery (*Fig. 6: 3,7*) with a high manganese content also came from northern Italy, from the workshops at Este.

CONCLUSION

The microscopic analysis has shown a uniform fabric composition of the pottery from Most na Soči with only the graphite ware sample standing apart. The characteristic feature of the pottery dating to the Hallstatt period is the admixture of probably carefully selected calcite sand to the fabric. A similar structure of the fabric with added calcite is also known from the area of the Este culture and the analysis of the chemical composition of the fabric of Sample MNS F, which revealed significant deviations, allow us to identify a product of an Este workshop.

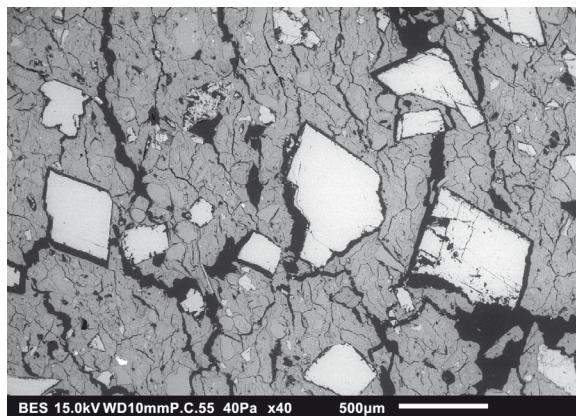
The results of the surface analysis of the graphite ware samples have confirmed the macroscopic observations. The results of the elemental analysis of the paints on these samples also support the macroscopic observations, but in addition indicate potentially different production manners based on the different compositions of the paints. The chemical composition of the black-on-red paints containing manganese (Mn) on the Hallstatt pottery (Samples Most 3 and 7) speaks in favour of production in the workshops at Este because, apart from these two samples, the presence of manganese has only been detected in the samples of the Roman black-slipped ware imported from northern Italy.

The results of the scanning electron microscopy analyses of the pottery from the settlement at Most na Soči are encouraging. Having said that, only a small portion of the recovered pottery has been sampled and systematic sampling coupled with a higher number of samples, both of the ceramic artefacts and the potential clay pits, is needed to be able to draw more relevant conclusion.

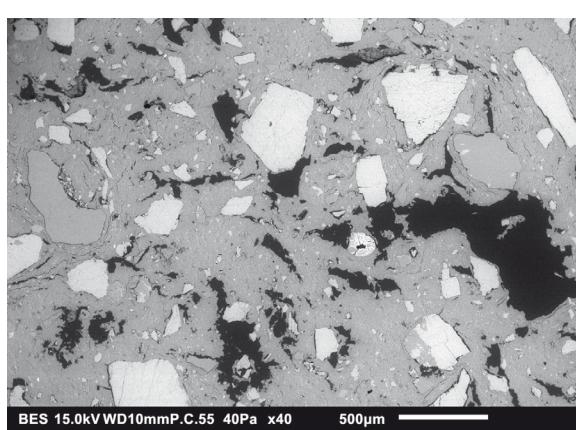
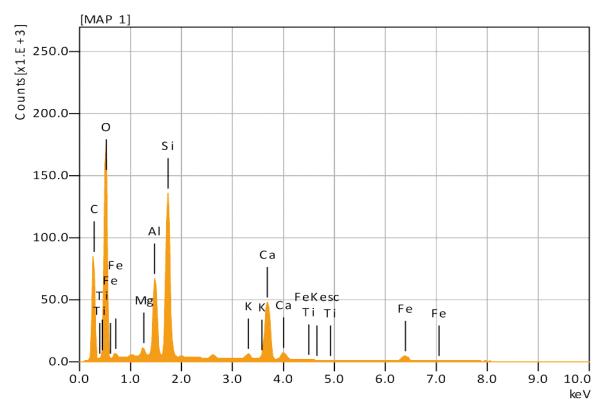
¹³ Prim. Bente, Sobott, Berthold 2013, tab. 1.

¹² Cf. Bente, Sobott, Berthold 2013, Pl. 1.

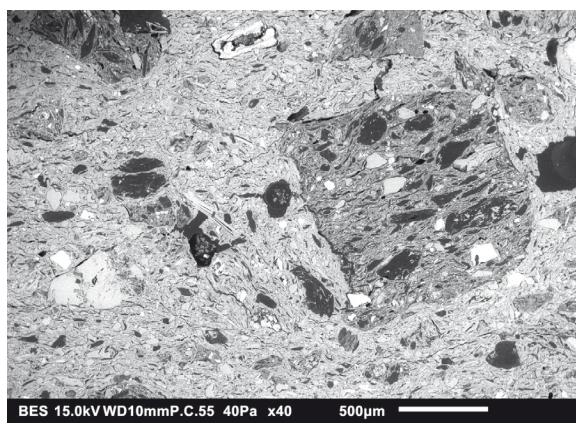
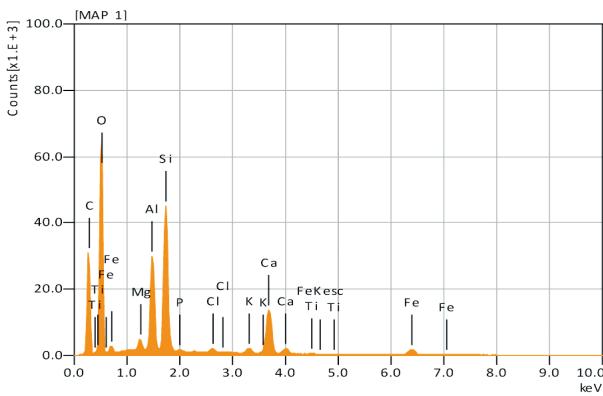
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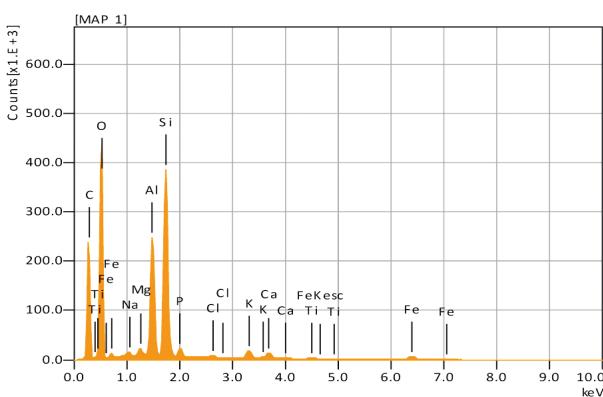
A



B

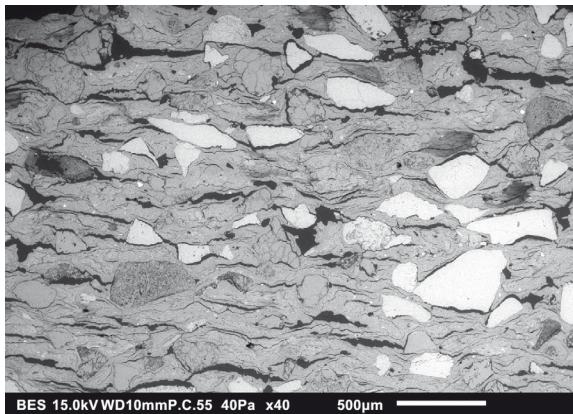


C

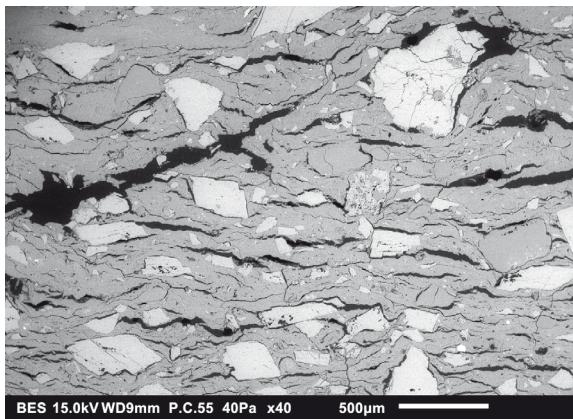


Pril. 1a: Obrusi vzorcev, posneti z detektorjem odbitih elektronov v senčnem (BES) načinu pri enaki povečavi, in ustrezajoč elementni spektri, posneti z EDS ploskovno analizo celotnega vidnega dela vzorca. Vzorci MNS A-C.

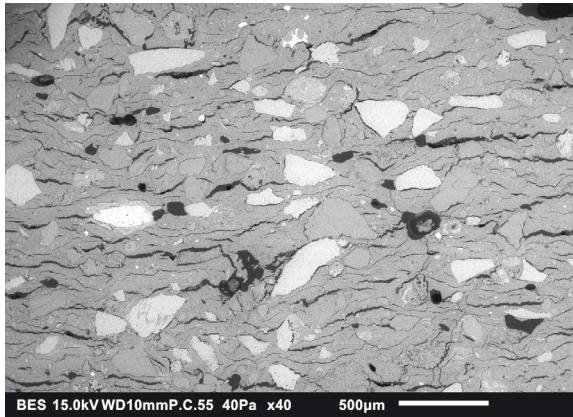
App. 1a: Backscattered shadow (BES) images of polished slabs, taken at the same magnification (40x) and corresponding elemental spectra obtained from whole-view EDS analyses. Samples MNS A-C.



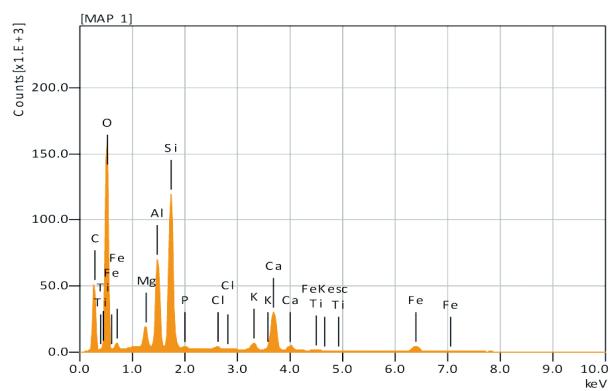
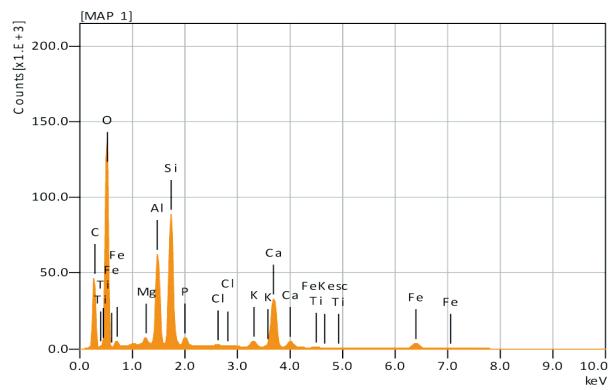
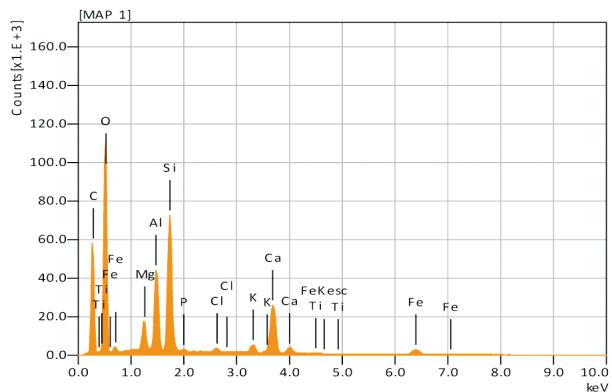
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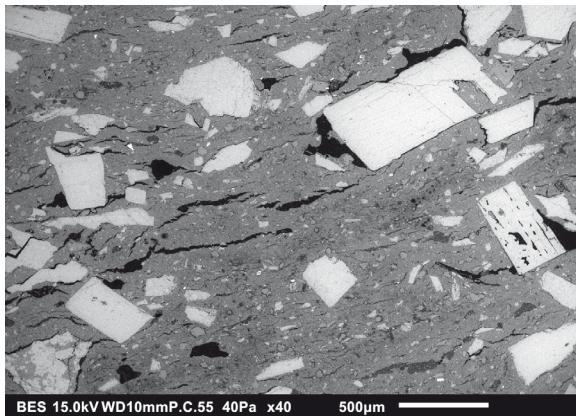
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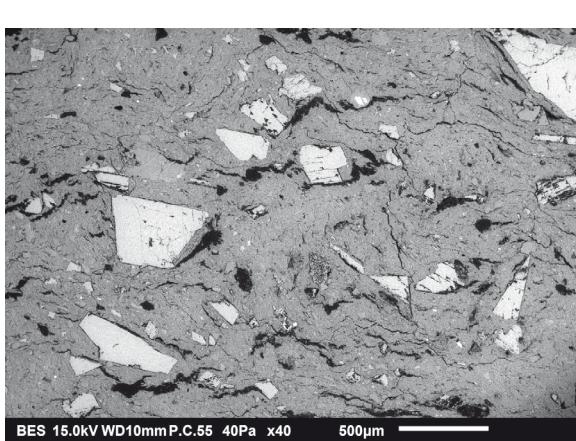
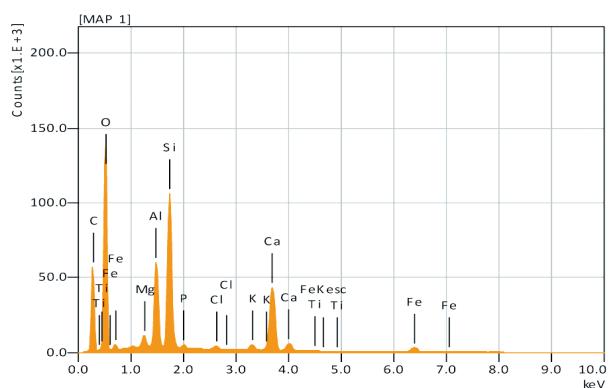
F



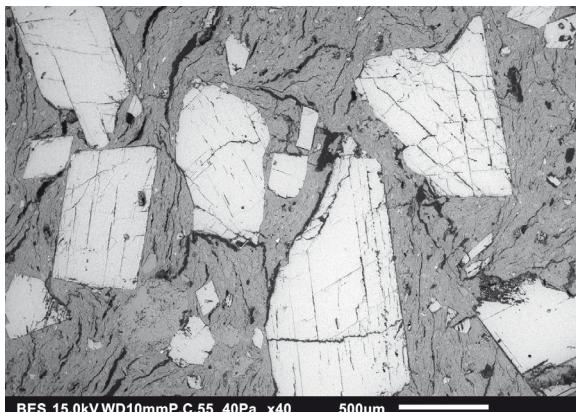
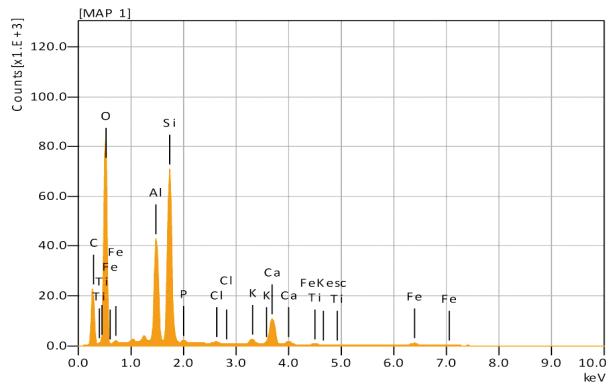
Pril. 1b: Obrusi vzorcev, posneti z detektorjem odbitih elektronov v senčnem (BES) načinu pri enaki povečavi in ustrezajoči elementni spektrovi, posneti z EDS ploskovno analizo celotnega vidnega dela vzorca. Vzorci MNS D–F.
App. 1b: Backscattered shadow (BES) images of polished slabs, taken at the same magnification (40x) and corresponding elemental spectra obtained from whole-view EDS analyses. Samples MNS D–F.



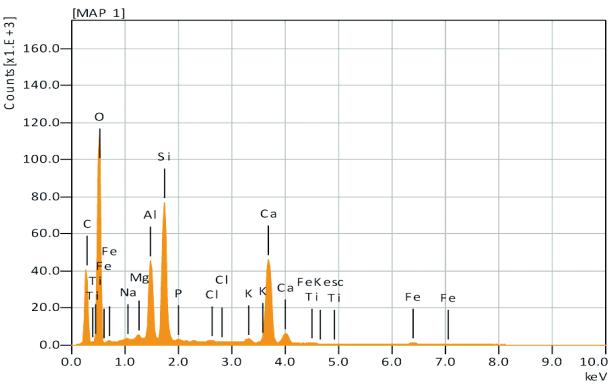
G



H 1

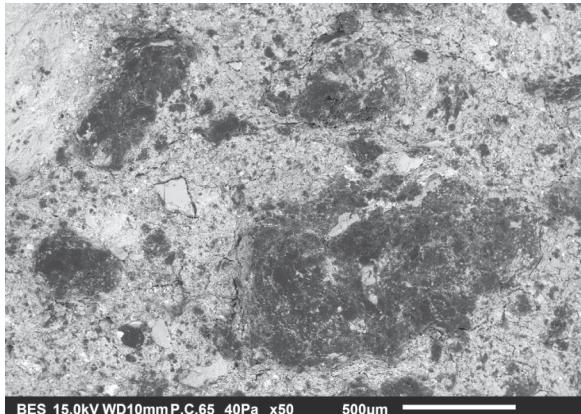


H 2

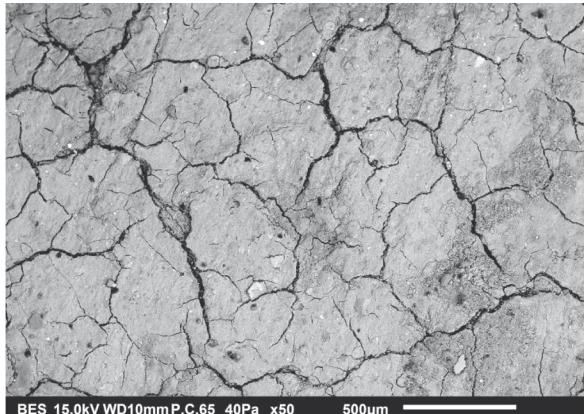


Pril. 1c: Obrusi vzorcev, posneti z detektorjem odbitih elektronov v senčnem (BES) načinu pri enaki povečavi, in ustrezajoči elementni spektri, posneti z EDS ploskovno analizo celotnega vidnega dela vzorca. Vzorci MNS G–H.

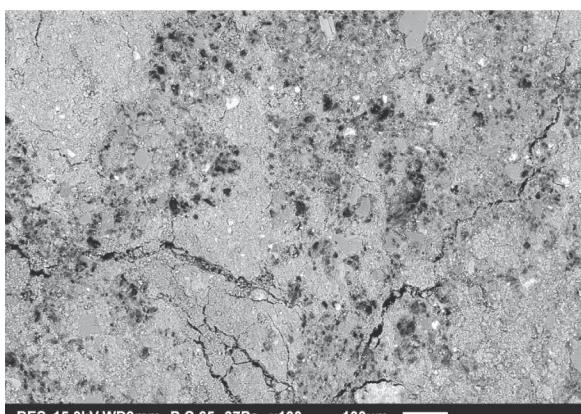
App. 1c: Backscattered shadow (BES) images of polished slabs, taken at the same magnification (40x) and corresponding elemental spectra obtained from whole-view EDS analyses. Samples MNS G–H.



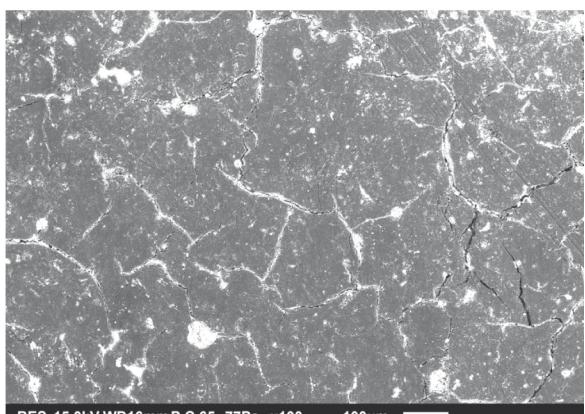
a: Most 2



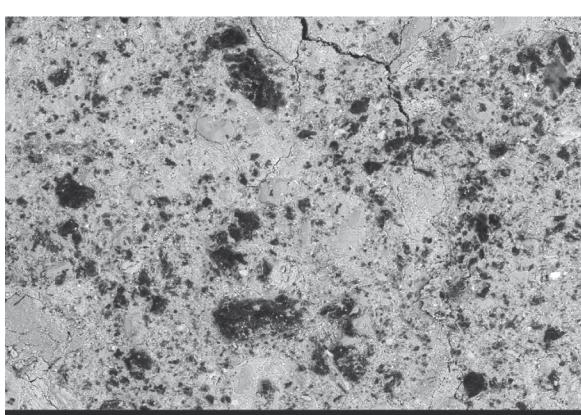
d: Most 5



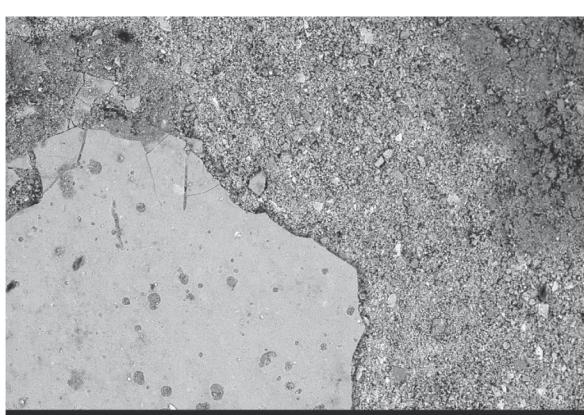
b: Most 3



e: Most 9



c: Most 4



f: Most 12

Pril. 2: BES slike površine vzorcev keramike Most 2–5, 9 in 12.
App. 2: BES images of surface of samples Most 2–5, 9 and 12.