Sara MOČINIĆ, Tea ZUBIN FERRI

FT-IR SPEKTROSKOPSKA ANALIZA PRAPOVIJESNE KERAMIKE IZ OSORA

FT-IR SPECTROSCOPIC ANALYSIS OF PREHISTORIC POTTERY FROM OSOR

Sara Močinić
Palisina 6, 52100 Pula
sara.mocinic@yahoo.it

Tea Zubin Ferri
METRIS, Zagrebačka 30, Pula
tea.zubin@ida.hr, www.metris-research.com

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U ovom radu predstavljamo rezultate analize kemijskog sastava prapovijesne keramike iz Osora metodom infracrvene spektroskopije s Fourierovom transformacijom (FT-IR). Infracrvena spektroskopija pokazala se vrlo korisnom za razvrstavanje velikog broja uzoraka prema sličnosti u kemijskom sastavu, što se kod arheološke keramike može koristiti za razlikovanje porijekla ulomaka slične izrade. Cilj ovog istraživanja bio je otkriti može li infracrvena spektroskopija pomoći u relativnoj dataciji keramike. U tu su svrhu uzeti uzorci iskopani na tri različite dubine s lokaliteta Kaštel u Osoru. Odabrane su tri skupine od dvadeset međusobno vrlo različitih uzoraka, ne bi li se izbjegao utjecaj fakture i drugih strukturnih karakteristika keramike na konačan rezultat analize. Nakon provedbe spektroskopske analize uz pomoć dendrograma istražene su sličnosti ispitanih uzoraka. Osim usporedbe triju skupina analizirana je i svaka skupina posebno. Rezultati istraživanja upućuju na činjenicu da nije prisutna uvozna keramika te da se na temelju njihovog sastava uzorci s dna iskopa i oni iz sredine jasno razlikuju, dok su uzorci s površine vjerojatno miješanog podrijetla.

KLJUČNE RIJEČI: *infracrvena spektroskopija, klaster analiza, sastav keramike, arheološka istraživanja u Osoru, prapovijesna keramika, relativna datacija keramike, provjera stratigrafije*

Sara Močinić
Palisina 6, 52100 Pula
sara.mocinic@yahoo.it

Tea Zubin Ferri
METRIS, Zagrebačka 30, Pula
tea.zubin@ida.hr, www.metris-research.com

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In this paper we present the results of an analysis of the chemical composition of prehistoric pottery from Osor, obtained by means of Fourier transform infrared spectroscopy (FT-IR). Infrared spectroscopy has proven to be very useful in the classification of a large number of samples according to similarities in the chemical composition, which can be used on archaeological pottery in order to distinguish the origin of fragments of similar make. The scope of this study was to discover whether infrared spectroscopy can assist with the relative dating of pottery. With this in mind we took samples that were unearthed on three different depths on the site of "Kaštel" at Osor. We selected three groups of twenty mutually very different samples in order to avoid any influences caused by fabric and other structural characteristics of pottery, which may affect the end results of the analysis. After making the spectroscopic analysis with the help of a dendrogram, we explored the similarities of the samples tested. In addition to comparing the three groups, we likewise analyzed each group separately. The research results indicate an absence of imported pottery. And furthermore, based on their composition, the samples from the bottom of the excavation and those from the middle clearly differ, whereas those samples from the surface are probably of mixed origin.

KEY WORDS: *infrared spectroscopy, cluster analysis, pottery composition, archaeological excavations at Osor, prehistoric pottery, relative dating of pottery, stratigraphy check*

UVOD

Spektroskopska analiza keramike koristi se u arheologiji barem od druge polovice 20. stoljeća (Shepard 1985, 143-145). Infracrvena (IR) spektroskopija vrlo je raširena i učestalo korištena metoda analize kemijskog sastava različitih vrsta materijala. Rezultat analize prikazan je u obliku spektra u kojem se očitavaju podaci o strukturi spojeva prisutnih u uzorku. Razlike u količini određenih elemenata koriste se za razdvajanje materijala prema sličnosti u sastavu. Zbog osjetljivosti u razlikovanju materijala i brzine primjene, infracrvena spektroskopija idealna je metoda za obrađivanje velikih količina uzoraka, pogotovo u odnosu na analizu mikroskopom, koja oduzima daleko više vremena.

Gore navedene karakteristike (brzina, mogućnost obrade serije uzoraka) uvjetovale su odabir infracrvene spektroskopije kao metodu za analizu prapovijesne keramike iz Osora, na otoku Cresu. Materijal potječe iz iskopavanja na lokalitetu Kaštel, koje su proveli 1953. godine Boris Baćić i njegovi suradnici iz Arheološkog muzeja Istre u Puli, a sastoji se od preko četrdeset tisuća ulomaka keramičkih posuda. Lokalitet se nalazi na samo nekoliko metara od kanala Kavanele, koji odvaja otoke Cres i Lošinj. Baćić je na temelju nalaza zaključio da je lokalitet predstavljao *ustrinum*[1] te je bio mišljenja da je pronađen važan keramički materijal iz 6./5. stoljeća pr. Kr.[2] Nalazi su naknadno odvezeni u Pulu, gdje su uskladišteni bez daljnje obrade.

Do sada se spektroskopska analiza koristila najčešće za razlikovanje podrijetla keramike i drugih materijala (Antonelli, Bernardini, Capedri, Lazzarini i Montagnari Kokelj 2004, 540-545, za kamen; Barone, Lo Giudice, Mazzoleni, Pezzino, Barilaro, Crupi i Triscari 2005, 745, 753-759, 762 i Shepard 1985, IV, za keramiku; Renfrew, Bahn 2002, 325, za jantar), ali u slučaju prapovijesne keramike iz Osora pretpostavlja se da je većina keramike proizvedena lokalno i da će uvozna keramika biti prepoznatljiva na pogled. Zbog toga je istraživanje usmjereno uglavnom prema drugim ciljevima. Prvi cilj je ispitati razliku u sastavu keramike iskopane na različitim dubinama, ne bi li se ustanovilo postoji li takva razlika i može li potkrijepiti kronološki integritet stratigrafskog slijeda. Taj podatak je posebno važan s obzirom na mnoge nedostatke u dokumentaciji iskopavanja, tijekom kojeg nisu definirani kulturni slojevi. Ne bi li se odgovorilo na ovo pitanje istražen je sastav triju skupina uzoraka: prva skupina preuzeta

1 Prostor za spaljivanje pokojnika.

2 Navedeni podaci nalaze se u pismu sačuvanom u datoteci Dokumentacijskog odjela Arheološkog muzeja Istre u Puli. Broj dokumenta u datoteci je 713/53.

INTRODUCTION

Spectroscopic analyses of pottery have been used in archeology since at least the second half of the 20th century (Shepard 1985, 143-145). Infrared (IR) spectroscopy is a widespread and frequently used method of analysis of the chemical composition of different types of materials. The analysis result is shown in the form of a spectrum in which data are shown, which regard the structure of the components present in the sample. Differences in the amount of certain elements are used to classify these materials according to similarities in their composition. Due to the sensitivity when distinguishing materials, and the velocity of application, infrared spectroscopy represents an ideal method for processing large quantities of samples, especially in relation to microscopic analyses, which take a much longer period of time.

The above characteristics (speed, ability to process a series of samples) conditioned the choice of infrared spectroscopy as a method to analyze the prehistoric pottery from Osor on the island of Cres. The material stems from excavations conducted on the site of Kaštel, which were carried out in 1953 by Boris Baćić and his associates from the Archaeological Museum of Istria, and consists of more than forty thousand pottery vessel fragments. The site is located only a few meters away from Kavanela Channel that separates the islands of Cres and Lošinj. Based on these finds, Baćić concluded that the site represents an *ustrinum*[1], and he also believed that an important discovery of pottery material from the 6th/5th century BCE was made[2]. The finds were later taken to Pula, where they were stored without being further processed.

Spectroscopic analysis was to date most often used to differentiate the origins of pottery and other materials (Antonelli, Bernardini, Capedri, Lazzarini and Montagnari Kokelj 2004, 540-545, for stone; Barone, Lo Giudice, Mazzoleni, Pezzino, Barilaro, Crupi and Triscari 2005, 745, 753-759, 762, and, Shepard 1985, IV, for pottery; Renfrew, Bahn 2002, 325, for amber), but in the case of prehistoric pottery from Osor it was assumed that most of the pottery was produced locally, and that imported pottery will be recognizable at a glance. That is why research was to a large extent focused towards other goals. The first objective was to examine the differences in the composition of pottery unearthed at different depths, in order to determine whether such a difference exists, and whether it can support the chronological integrity

1 An area where the deceased were cremated.

2 The mentioned data are from a letter that is kept in the data pool of the Documentation Department of the Archaeological Museum of Istria at Pula. The document number in the data pool is 713/53.

je s dna iskopavanja (~4,5 m), druga iz sredine (~2,5) a treća iz površinskih slojeva. Svaka skupina uzoraka broji po dvadeset ulomaka keramike, odabranih tako da po svojim fizičkim karakteristikama budu što raznovrsniji odnosno reprezentativni za slojeve iz kojih su uzeti. Potrebno je napomenuti da je tradicionalna obrada tog materijala tek u početnoj fazi i da je spektroskopsko ispitivanje provedeno u trenutku kad je mali dio keramike bio pregledan i datiran.

Usporedba kemijskog sastava uzoraka odrađena je uz pomoć programa, a rezultate analize i interpretaciju rezultata iznosimo u ovom radu.

MATERIJALI I METODE

Infracrvena spektroskopija s Fourierovom transformacijom

Pojedine spektroskopske metode analize temelje se na elektromagnetskom zračenju koje molekule (uzorak) apsorbiraju do njihovog pobuđenog stanja. Prijelaz u odgovarajuće pobuđeno stanje ovisi o energiji elektromagnetskog zračenja. Infracrvena (IR) spektroskopija najčešće koristi područje elektromagnetskog spektra između 2,5 μm i 25 μm. Infracrveno zračenje uzrokuje u molekuli vibracijsko gibanje atoma oko ravnotežnih položaja (Guenzler, Gremlich 2006, 12-16). Energijska stanja u molekuli su kvantizirana pa se za svaku molekulu vibracije događaju pri određenim karakterističnim frekvencijama, koje je instrument u mogućnosti snimiti te prikazati u obliku grafa apsorbiranog zračenja. Takav graf, koji se naziva infracrveni spektar, u cijelosti je karakterističan za svaku molekulu, odnosno određenu supstancu. Sastoji se od područja *skupinskih vibracija*, u kojem apsorpcija infracrvenih zraka potječe od vibracija skupina atoma (takozvanih funkcionalnih skupina), na koje ostatak molekule slabo može utjecati, te od područja koje se naziva *otisak prsta* molekule, a što je posljedica vibracija molekulske okosnice i svojstveno je molekuli (Guenzler, Gremlich 2006, 12-15). Interpretacija spektara složenih molekula ili smjesa nekoliko tvari može biti komplicirana.

Infracrvena spektroskopija s Fourierovom transformacijom (FT-IR) vrlo je raširena analitička tehnika kemijske karakterizacije, koja ima važne primjene u području kulturne baštine. Veliko značenje IR spektroskopije temelji se na visokoj informacijskoj vrijednosti i na raznovrsnim mogućnostima mjerenja uzoraka, što predstavlja veliku prednost u istraživanju materijala kulturne baštine jer su oni vrlo raznoliki, a često se sastoje od smjesa različitih tvari koje nisu pripravljene pod standardiziranim uvjetima. IR

of the stratigraphic sequence. This piece of information is particularly important given the many shortcomings in the documentation related to the excavations, in the course of which the cultural layers were not defined. In order to answer this question, we investigated the composition of three groups of samples: the first group includes samples taken from the bottom of the excavation (~4.5 m), the second from the middle (~2.5 m), and the third from the surface layers. Each group of samples consists of twenty pottery fragments that were selected so as to be, on account of their physical characteristics, as diverse and representative of the strata from which they were taken. It should be mentioned that the traditional processing of this material is at an early stage, and that the spectroscopic analysis was performed at a time, when only a small portion of the pottery was examined and dated.

The comparison of the chemical composition of the samples was performed with the help of software. The results of the analysis and the interpretation of the results are presented in this paper.

MATERIALS AND METHODS

Fourier transform infrared spectroscopy

Individual spectroscopic methods of analysis are based on the absorption of electromagnetic radiation by molecules (of the sample), up to their state of excitation. The transition to the corresponding excited state depends on the energy of the electromagnetic radiation applied. Infrared (IR) spectroscopy for the most part uses an area of the electromagnetic spectrum between 2.5 μm and 25 μm. Infrared radiation causes a vibratory movement of atoms around their balanced positions in a molecule (Guenzler, Gremlich 2006, 12-16). At the molecular level, energy is quantized, and for each molecule vibrations occur at certain characteristic frequencies that the instrument is able to record and display in the form of a graph of absorbed radiation. Such a graph, called the infrared spectrum, is in its entirety characteristic for each molecule or certain substance. It consists of an area of *group vibrations*, in which the absorption of infrared rays originates from vibrations of clusters of atoms (so-called functional groups) onto which the rest of the molecule exerts only a weak influence, and an area that is called the *fingerprint* of a molecule, which stems from vibrations of the molecular skeleton and is characteristic for the molecule (Guenzler, Gremlich 2006, 12-15). The interpretation of spectra of complex molecules, or mixtures of several substances, can be complicated.

Fourier transform infrared spectroscopy (FT-IR) represents a very widely spread analytical technique spektroskopija ima i druge prednosti osim široke primjene, a to su prvenstveno preciznost, dobra senzibilnost, brzina i jednostavnost provođenja analize te relativno niski troškovi instrumenata, potrošnog materijala i održavanja. U zadnjih nekoliko godina, zahvaljujući intenzivnoj primjeni ove metode na materijalima kulturne baštine (kamen, keramika, boje na slikama te freskama i drugo), dostupne su brojne i sve potpunije zbirke spektara, odnosno digitalne biblioteke, u kojima je s vremenom broj izmjerenih spektara za usporedbu sve veći i precizniji. Tehničko napredovanje i mnoga poboljšanja na spektrometrima, kao i uvođenje mikroskopa koji omogućavaju snimanje IR spektara vrlo tankih slojeva i površina, omogućuje nam da danas na potpuno nedestruktivan način karakteriziramo kemijski sastav velikog broja međusobno vrlo različitih materijala iz kulturne baštine (Guenzler, Gremlich 2006, 14; Madejova 2003, 1).

Sl. 1 FT-IR spektrometar u METRIS-u (snimila T. Zubin Ferri)
Fig. 1 The FT-IR spectrometer at METRIS (photo by T. Zubin Ferri)

Za analizu uzoraka keramike korišten je IR spektrometar koji za mjerenje zahtijeva pripremu uzorka u obliku tanke pastile. Za spravljanje pastile potrebno je usitniti u tarioniku malu količinu uzorka i pomiješati je s kalijevim bromidom (KBr) u određenom omjeru. Pastile za analizu keramike pripremljene su miješajući 5 mg uzorka sa 150 mg kalijevog bromida. KBr je sol koja služi kao pomoćna tvar, odnosno supstrat za pripremu pastila, a "nevidljiva" je infracrvenim zrakama. Nakon miješanja KBr-a i uzorka smjesa se dodatno homogenizira u tarioniku te uz pomoć preše pretvara u tanku pastilu, koja se potom podvrgava analizi.

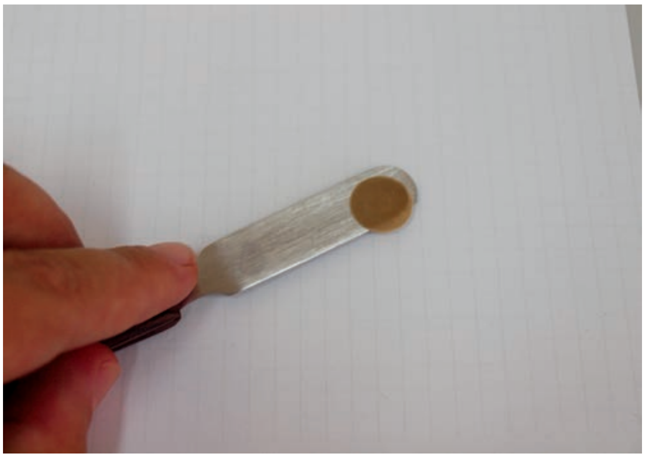
Takva metoda pripreme nepovratno mijenja uzorak, no s obzirom na male količine uzorka koje su potrebne (nekoliko miligrama), smatra se mikrodestruktivnom.

of chemical characterization, which has important applications in the field of cultural heritage. The great significance of infrared spectroscopy is based on the high information value, and on different possibilities of sample measurement, which is a great advantage in the study of materials associated with cultural heritage because they are very diverse, and often they consist of mixtures of different substances that were not prepared under standardized conditions. Infrared spectroscopy has other advantages besides its wide range of applications, and these are primarily accuracy, good sensitivity, speed and simplicity when carrying out an analysis, and the relatively low costs of instruments, supplies and maintenance. In the past few years, thanks to the intensive application of these methods on cultural heritage materials (stone, pottery, paint on pictures and frescoes, and the like), we have at our disposal numerous and ever more complete collections of spectra, i.e., digital libraries, in which the numbers of measured spectra used for comparison purposes grow larger and more precise with the passage of time. Technical advancements as well as the many improvements made on spectrometers, and the introduction of microscopes that enable the recording of infrared spectra of very thin layers and surfaces, nowadays allow us to characterize the chemical composition of a large number of mutually very different cultural heritage materials in a completely non-destructive manner (Guenzler, Gremlich 2006, 14; Madejova 2003, 1).

For the analysis of the pottery samples, an infrared spectrometer was used, which requires samples prepared in the form of a thin pastille. This pastille is prepared by grinding a small amount of sample in a mortar and adding potassium bromide (KBr) in a specific ratio. The pastilles for pottery analysis were prepared by mixing 5 mg of sample with 150 mg of potassium bromide. Potassium bromide is a salt that serves as an auxiliary substance, or substrate, for the preparation of pastilles, which is "invisible" to infrared rays. After mixing the potassium bromide with the sample, the mixture is additionally homogenized in a mortar, and with the help of a press it is then converted into a thin pastille that is subjected to the analysis.

Such a method of preparation changes the sample in an irreversible manner, but given the small amounts of sample needed (a few milligrams) it is considered micro-destructive.

The instrument used to record spectra of the pottery samples was a TENSOR 27 FT-IR spectrometer manufactured by the German firm Bruker. Infrared



Sl. 2 Gotova KBr pastila uzorka (snimila T. Zubin Ferri)
Fig. 2 The finished potassium bromide pastille of the sample (photo by T. Zubin Ferri)

Za snimanje spektara uzoraka keramike korišten je FT-IR spektrometar TENSOR 27 njemačkog proizvođača Bruker. IR spektri snimljeni su u intervalu spectra were recorded in an interval of 4000 to 400 cm^{-1}, with a resolution of 4 cm^{-1}, and an individual spectrum actually represents the mean value of a total of 32 recorded spectra. On each spectrum, with the help of software, the peak of carbon dioxide was minimized and baseline correction was performed.

Although much more used in the analysis of pigments, binders and painting materials, infrared spectroscopy has for decades been one of the favorite techniques used to investigate the structure, bonding, and chemical properties of clay minerals (Madejova 2003, 1), but in this segment it was not as extensively used (De Benedetto, Laviano, Sabbatini and Zambonin 2002, 177). Infrared spectroscopy at the same time allows the identification of changes that have occurred due to firing in the crystalline and amorphous clay minerals, and it therefore represents a powerful tool for the classification, and in general, the processing of pottery finds. In addition to recording, processing and comparison of the IR spectrum with the

Sl. 3 Postavljanje stalka s pastilom za analizu u IR spektrometar (snimila T. Zubin Ferri)
Fig. 3 Putting the stand with the pastille to be analyzed in the infrared spectrometer (photo by T. Zubin Ferri)

od 4.000 do 400 cm^{-1} uz razlučivanje od 4 cm^{-1}, a pojedini spektar zapravo predstavlja srednju vrijednost ukupno 32 snimljena spektara. Na svakom je spektru programom minimalizirana vrpca ugljikovog dioksida te je obavljena korekcija osnovne linije.

Iako znatnije korištena u analizi pigmenata, veziva i slikarskih materijala, IR spektroskopija već desetljećima predstavlja rado korištenu tehniku i za ispitivanje strukture, vezivanja i kemijskih svojstava glinenih minerala (Madejova 2003, 1), no u tom se segmentu ne primjenjuje tako opsežno (De Benedetto, Laviano, Sabbatini i Zambonin 2002, 177). Infracrvena spektroskopija istovremeno omogućava identifikaciju promjena koje su se dogodile uslijed pečenja u kristalnim i amorfnim glinenim mineralima te zbog toga predstavlja moćan alat u klasifikaciji, ali i općenito u obradi keramičkih nalaza. Osim snimanja, obrade i usporedbe IR spektra s dostupnim digitalnim bibliotekama, programi danas omogućuju i statističku obradu spektara, njihovu međusobnu usporedbu, odnosno identifikaciju numeričke vrijednosti stupnja njihove međusobne sličnosti (De Benedetto, Laviano, Sabbatini i Zambonin 2002, 177-178).

Suvremene statističke metode, poput kemometričkih tehnika, omogućuju obradu i analizu velikog broja podataka te grupiranje rezultata temeljem različitih algoritama. Kemometrika je zapravo grana kemije koja proučava primjenu matematičkih i statističkih metoda na kemijske podatke, i to tako što ekstrahira informacije iz kemijskih sustava i primjenjuje metode obrade podataka kao što su multivarijantna statistika, primijenjena matematika i informatika, s ciljem rješavanja problema u kemiji, biokemiji, medicini, biologiji i kemijskom inženjerstvu (Todeschini 1998, 3-17).

Klaster analiza

Klaster analiza (eng. *cluster* = skupina) predstavlja statističku tehniku kojom se uzorci ili objekti grupiraju na način da oni unutar jedne skupine više nalikuju jedan drugome nego onima u drugim skupinama. Koristi se u različitim granama znanosti za klasifikaciju pojedinih jedinica analize (na primjer uzoraka ili objekata) na temelju njihove sličnosti odnosno različitosti prema nekim njihovim mjerenim obilježjima (Todeschini 1998, 78-79). Za klaster analizu u ovom su se radu koristili parametri vrpca kao mjerena obilježja, odnosno položaj (valni broj) i intenzitet (apsorbancija) vrpci u IR spektrima analiziranih uzoraka keramike. Pri

available digital libraries, software nowadays also renders possible a statistical analysis of spectra, their mutual comparison, or identification of the numerical value of the degree of their mutual similarity (De Benedetto, Laviano, Sabbatini and Zambonin 2002, 177-178).

Modern statistical methods, such as chemometric techniques, allow the processing and analysis of large quantities of data, and the clustering of results based on various algorithms. Chemometrics is actually a branch of chemistry that studies the application of mathematical and statistical methods to chemical data by way of extracting information from chemical systems, and applying data processing methods such as multivariate analysis, applied mathematics, and computer science, in order to solve problems in chemistry, biochemistry, medicine, biology and chemical engineering (Todeschini 1998, 3-17).

Cluster analysis

A cluster analysis (Eng. *cluster* = group) is a statistical technique for grouping samples or objects, so that those within one cluster resemble more to one another with respect to those in other clusters. It is used in various branches of science for the classification of individual units of analysis (e.g., samples or objects) on the basis of their similarities, or differences towards some of their measured characteristics (Todeschini 1998, 78-79). For the cluster analysis in this paper, we used band parameters as measured characteristics, i.e., the position (wavenumber) and intensity (absorbance) of bands in infrared spectra of analyzed pottery samples. For the calculation of similarities, Ward's algorithm was applied and the similarity has been based on the Euclidean distance. Ward's algorithm is used whenever we wish to find the most homogenous groups. This means that the groups that are connected first in the dendrogram, show the smallest increase in the heterogeneity factor (H), whose value is shown on the Y axis. Instead of determining the spectral distance, Ward's algorithm determines the increase of heterogeneity of recorded infrared spectra. Before an analysis, each spectrum was processed by a correction of the baseline, and a compensation of carbon dioxide peaks. The program used for cluster analysis is OPUS 7 (Bruker, Germany).

Dendrograms

The result of a cluster analysis is usually shown in the form of a dendrogram. A dendrogram is a graph showing the grouping sequence of objects, in this case of pottery samples, on the basis of infrared spectra, and their mutual similarities in the composition. A dendrogram is a graph računanju sličnosti korišten je Wardov algoritam, a sličnost je temeljena na euklidskoj udaljenosti. Wardov algoritam se koristi kad se žele pronaći što homogenije grupe, što znači da se u dendrogramu spajaju one grupe koje pokazuju najmanji rast u faktoru heterogenosti (H) čija je vrijednost prikazana na osi Y. Umjesto određivanja spektralne udaljenosti, Wardov algoritam određuje rast heterogenosti snimljenih IR spektara. Prije analize svaki je spektar obrađen korekcijom bazne linije i kompenzacijom pikova ugljikovog dioksida. Program korišten za klaster analizu je OPUS 7 (Bruker, Njemačka).

Dendrogram

Rezultat klaster analize najčešće se prezentira u obliku dendrograma. Dendrogram je graf koji prikazuje redoslijed grupiranja objekata, u ovom slučaju uzoraka keramike, na temelju IR spektara, odnosno njihove međusobne sličnosti u sastavu. Dendrogram je graf koji je vrlo lako iščitati jer vizualno pokazuje koji su objekti, u ovom slučaju uzorci keramike, međusobno najsličniji, a koji najrazličitiji. Na osi X prikazana je logična udaljenost klastera temeljem odabrane metrike, dok je na osi Y prikazana hijerarhijska razina agregacije (Todeschini 1998, 87-96).

Važno je imati na umu da dendrogram ne odgovara na pitanje koliko grupa postoji, već kojim se redoslijedom postojeće grupe spajaju.

Odabir uzoraka

Kako je navedeno u prethodnom poglavlju, za istraživanje je bilo potrebno odabrati tri skupine uzoraka iz različitih dubina iskopa. Određivanje dubina otežavali su nedostaci informacija u dokumentaciji iskopa, u kojoj nisu označeni kulturni slojevi, nego slojevi iskopa, a za pojedine slojeve iskopa nije navedena dubina. Najveće teškoće bile su vezane uz površinske slojeve, za koje ne postoje nikakve koordinate, zbog čega je njihova pozicija tek pretpostavka.

Skupine uzoraka keramike nazvane su skupina 1 (uzorci iz najdubljeg dijela iskopavanja), skupina 2 (uzorci iz središnjeg dijela iskopavanja) i skupina 3 (uzorci iz površinskih slojeva). Zbog lakše međusobne usporedbe uzoraka, njihova su obilježja prikazana u tablicama 1, 2 i 3. Prva karakteristika u tablici je faktura. Druga navedena karakteristika je boja. Zabilježene su boje vanjske i unutrašnje stijenke te boja presjeka. Boje su dane prema Munsellovom sistemu[3]. Kod ulomaka

[3] Munsell 2000.

that is very easy to interpret because it visually shows which objects, in this case pottery samples, are most similar to each other and which differ most from one another. Depicted on the X axis is the logical distance of the cluster based on selected metrics, while the Y axis shows the hierarchical level of aggregation (Todeschini 1998, 87-96).

It is important to note that dendrograms don't give an answer to the question of how many groups exist, but rather, they illustrate the sequence in which existing groups combine.

Selection of samples

As was stated in the previous section, for this study it was necessary to select three clusters of samples from different excavation strata. The determination of depths was made more difficult due to the lack of information in the excavation documentation, in which excavation strata, rather than cultural layers, were marked. Likewise missing are the depths of individual excavation layers. The biggest problems were associated with superficial layers for which there were no coordinates, which means that their position had to be assumed.

Pottery samples were divided into Cluster 1 (samples from the deepest section of the excavation), Cluster 2 (samples from the central section of the excavation, and Cluster 3 (samples from the surface layers). In order to facilitate the comparison of samples between each other, their characteristics are shown in Tables 1, 2 and 3. The first characteristic listed in the tables is fabric. The second characteristic is color. The color of the inner and outer wall was recorded, as well as that of the cross-section. The colors were presented in accordance with the Munsell system[3]. For fragments that featured two dominant colors in section, both of these were listed. Following color is the characterization of the outer surface: here we briefly differentiate between coarse, smooth, burnished and slipped surfaces[4]. Temper is always present in relatively large amounts, and due to difficulties in determining the exact percentage of it, here we only refer to its size. Three categories of size were defined, i.e., fine (up to 0.5 mm), medium (from

[3] Munsell 2000.

[4] After Horvat 1999, 25, a coarse surface is the result of extra treatment by smoothing out, a smooth surface is one that was additionally wiped, while a burnished surface corresponds to a polished one. Slip in this text refers to clayish slips, as defined in Horvat 1999, 26.

koji su u presjeku imali dvije dominantne boje navedene su obje. Nakon boje slijedi karakterizacija vanjske površine: ovdje su ukratko razlikovane gruba, glatka, glačana i premazana površina[4]. Primjese su uvijek prisutne u relativno velikim količinama, a zbog teškoća u određivanju točnog postotka njihove prisutnosti, ovdje se navodi samo njihova veličina. Navedene su tri kategorije veličine - sitne (do 0,5 mm), srednje (od 0,5 do 2 mm) i grube (preko 2 mm)[5]. O sastavu primjesa bit će riječi u poglavlju o sastavu keramike. Zadnja karakteristika uvedena u tablicu je debljina stijenke. Po obrađenim ulomcima određene su tri njezine kategorije: tanka stijenka je ona debljine do 0,5 cm, srednja od 0,5 do 1 cm, a debela je stijenka ona deblja od 1 cm.

Nazivi uzoraka dani su u obliku serije brojki, npr. 414-58, gdje prvi dio broja označava sloj iskopa, a drugi je redni broj ulomka.

Uzorci skupine 1

Skupina 1 sačinjena je od uzoraka iz obrađenih slojeva iskopa - to su slojevi broj 352, 356 i 414, čija zajednička apsolutna dubina ide od 4,3 do 4,5 m (gdje se nalazilo dno iskopavanja). Nakon lijepljenja, ulomaka je iz tih slojeva iskopa na koncu bilo ukupno 253. Među njima izabrano je dvadeset međusobno najrazličitijih po karakteristikama opisanim u prethodnom poglavlju. Premda to još nije sa sigurnošću utvrđeno, keramika ove skupine preliminarno je datirana u kasno brončano doba, to jest u 11. i 10. stoljeće pr. Kr.[6]

Karakteristike uzoraka skupine 1 prikazane su u tablici br. 1. Potrebno je istaknuti uzorak 414-58, koji nije ulomak posude nego grumen slabo pečene gline.

[4] Prema Horvat 1999, 25 - gruba površina je rezultat dorade glađenjem, glatka je površina ona dorađena brisanjem, a glačana površina odgovara kod Horvat poliranoj. Pod premazom se u ovom tekstu podrazumijevaju glineni premazi kako su definirani u Horvat 1999, 26.

[5] Prilagođeno prema Horvat 1999, 16. Kod Horvat se nalaze još dvije kategorije veličine primjesa, vrlo sitne (do 0,25 mm) i vrlo grube (preko 3 mm), koje su izostavljene u ovom radu jer u njih ne spada ni jedan od ovdje ispitanih uzoraka.

[6] Datirano po sličnostima kod istarskih zdjela s uvijenim ušćem i loncima s ukošenim rubom ušća, u Cestnik 2009, 43-52; te po dataciji dekoracije utiskom prsta, u Urem 2012, 94-95.

0.5 to 2 mm) and coarse (over 2 mm)[5]. The section about pottery composition also deals with the composition of temper. The last characteristic that was included in the table is wall thickness. According to the processed fragments, we determined three categories: a thin wall has a thickness up to 0.5 cm, a medium wall from 0.5 to 1 cm, and a thick one surpasses 1 cm in thickness.

The names of the samples are actually a series of numbers, e.g., 414-58, where the first part of the number indicates the layer of the excavation, the other being the ordinal number of the fragment.

Cluster 1 samples

Cluster 1 consists of samples from the processed layers of the excavation. These are layers number 352, 356 and 414, whose mutual absolute depth is in the range from 4.3 to 4.5 m (where the bottom of the excavation was located). After gluing, the total number of fragments from these layers of the excavation numbered 253 pieces. Among them we selected twenty of the most diverse fragments, as judged on the basis of the characteristics described in the preceding chapter. Although it has not yet been determined with certainty, this cluster of pottery was preliminarily dated to the Late Bronze Age, i.e., into the 11th and 10th century BCE[6].

The sample characteristics of Cluster 1 are shown in Table 1. It should be mentioned that sample 414-58 is not a vessel fragment but a lump of poorly fired clay.

[5] Adapted after Horvat 1999, 16. Horvat has two additional categories of temper size, i.e., very fine (up to 0.25 mm), and very coarse (over 3 mm), both of which were left out of this paper because none of the samples analyzed here fits into these two categories.

[6] Dated on the basis of similarities with Istrian bowls with an inverted mouth, and pots with a slanted edge of the mouth, as described in Cestnik 2009, 43-52; and in accordance with the dating of the finger-impressed decoration in Urem 2012, 94-95.

Tablica 1. Podaci o uzorcima iz skupine 1

UZORAK	FAKTURA	BOJA VANI	BOJA UNUTRA	BOJA PRESJEK	POVRŠINA	PRIMJESE	DEBLJINA
352-34	FINA	5YR 5/1 gray	5YR 5/1 gray	5YR 6/4 light reddish brown	GLAČANA	SREDNJE	SREDNJA
352-45	FINA	10YR 4/1 dark gray	10YR 5/4 yellowish brown	7.5YR 7/6 reddish yellow	PREMAZ	SITNE	SREDNJA
352-46	FINA	2.5YR 5/6 red	10YR 6/3 pale brown	10YR 6/1 gray	GLAČANA	SITNE	SREDNJA
352-51	GRUBA	10YR 6/3 pale brown	10YR 4/1 dark gray	2.5YR 5/8 red	GRUBA	SREDNJE	DEBELA
352-53	GRUBA	5PB 4/1 dark bluish gray	2.5YR 4/1 dark gray	2.5YR 5/8 red	GRUBA	SREDNJE	SREDNJA
352-55	GRUBA	10YR 5/2 grayish brown	10R 4/6 red	10R 4/6 red	GRUBA	SREDNJE	DEBELA
356-42	FINA	5YR 5/1 gray	5YR 5/1 gray	5YR 5/1 gray	GLATKA	SITNE	TANKA
356-50	GRUBA	2.5YR 6/8 light red	10YR 4/1 dark gray	2.5YR 6/8 light red; 10YR 4/1 dark gray	GRUBA	SITNE	DEBELA
356-52	GRUBA	5YR 5/3 reddish brown	10YR 3/1 very dark gray	10YR 3/1 very dark gray	GRUBA	GRUBE	DEBELA
356-54	GRUBA	2.5YR 5/8 red	2.5YR 5/8 red	5YR 4/1 dark gray	GRUBA	SREDNJE	SREDNJA
356-56	GRUBA	2.5YR 5/8 red	2.5YR 5/8 red	2.5YR 5/8 red	GRUBA	SREDNJE	DEBELA
357-20	GRUBA	10YR 5/1 gray	10YR 5/1 gray	10YR 4/1 dark gray	GRUBA	SREDNJE	DEBELA
357-21	DOBRA	N 4/1 dark gray	N 3/1 very dark gray	N 3/1 very dark gray	GLATKA	SREDNJE	SREDNJA
357-22	DOBRA	2.5Y 6/1 gray	2.5Y 6/1 gray	2.5Y 6/1 gray	PREMAZ	SREDNJE	SREDNJA
414-58	GRUMEN	5YR 7/8 reddish yellow	/	5YR 7/8 reddish yellow	GRUBA	NEMA	/
414-61	FINA	2.5Y 6/1 gray	2.5Y 6/1 gray	2.5Y 6/1 gray	PREMAZ	SITNE	SREDNJA
414-62	FINA	N 4/1 dark gray	N 3/1 very dark gray	N 3/1 very dark gray	GLAČANA	SITNE	TANKA
414-63	GRUBA	2.5YR 4/3 reddish brown	2.5YR 5/8 red	10YR 3/2 very dark grayish brown	GLAČANA	SREDNJE	SREDNJA
414-64	GRUBA	10R 4/1 dark reddish gray	2.5YR 5/8 red	2.5YR 5/8 red	GRUBA	SREDNJE	SREDNJA
414-65	GRUBA	2.5YR 3/1 dark reddish gray	2.5YR 4/1 dark reddish gray	2.5YR 5/8 red	PREMAZ	GRUBE	SREDNJA

Table 1. Data regarding Cluster 1 samples

SAMPLE	FABRIC	EXTERIOR COLOR	INTERIOR COLOR	CROSS-SECTION COLOR	SURFACE	TEMPER	THICKNESS
352-34	FINE	5YR 5/1 grey	5YR 5/1 grey	5YR 6/4 light reddish brown	BURNISHED	MEDIUM	MEDIUM
352-45	FINE	10YR 4/1 dark grey	10YR 5/4 yellowish brown	7.5YR 7/6 reddish yellow	SLIP	FINE	MEDIUM
352-46	FINE	2.5YR 5/6 red	10YR 6/3 pale brown	10YR 6/1 grey	BURNISHED	FINE	MEDIUM
352-51	COARSE	10YR 6/3 pale brown	10YR 4/1 dark grey	2.5YR 5/8 red	COARSE	MEDIUM	THICK
352-53	COARSE	5PB 4/1 dark bluish grey	2.5YR 4/1 dark grey	2.5YR 5/8 red	COARSE	MEDIUM	MEDIUM
352-55	COARSE	10YR 5/2 greyish brown	10R 4/6 red	10R 4/6 red	COARSE	MEDIUM	THICK
356-42	FINE	5YR 5/1 grey	5YR 5/1 grey	5YR 5/1 grey	SMOOTH	FINE	THIN
356-50	COARSE	2.5YR 6/8 light red	10YR 4/1 dark grey	2.5YR 6/8 light red; 10YR 4/1 dark grey	COARSE	FINE	THICK
356-52	COARSE	5YR 5/3 reddish brown	10YR 3/1 very dark grey	10YR 3/1 very dark grey	COARSE	COARSE	THICK
356-54	COARSE	2.5YR 5/8 red	2.5YR 5/8 red	5YR 4/1 dark grey	COARSE	MEDIUM	MEDIUM
356-56	COARSE	2.5YR 5/8 red	2.5YR 5/8 red	2.5YR 5/8 red	COARSE	MEDIUM	THICK
357-20	COARSE	10YR 5/1 grey	10YR 5/1 grey	10YR 4/1 dark grey	COARSE	MEDIUM	THICK
357-21	GOOD	N 4/1 dark grey	N 3/1 very dark grey	N 3/1 very dark grey	SMOOTH	MEDIUM	MEDIUM
357-22	GOOD	2.5Y 6/1 grey	2.5Y 6/1 grey	2.5Y 6/1 grey	SLIP	MEDIUM	MEDIUM
414-58	LUMP	5YR 7/8 reddish yellow	/	5YR 7/8 reddish yellow	COARSE	NONE	/
414-61	FINE	2.5Y 6/1 grey	2.5Y 6/1 grey	2.5Y 6/1 grey	SLIP	FINE	MEDIUM
414-62	FINE	N 4/1 dark grey	N 3/1 very dark grey	N 3/1 very dark grey	BURNISHED	FINE	THIN
414-63	COARSE	2.5YR 4/3 reddish brown	2.5YR 5/8 red	10YR 3/2 very dark greyish brown	BURNISHED	MEDIUM	MEDIUM
414-64	COARSE	10R 4/1 dark reddish grey	2.5YR 5/8 red	2.5YR 5/8 red	COARSE	MEDIUM	MEDIUM
414-65	COARSE	2.5YR 3/1 dark reddish grey	2.5YR 4/1 dark reddish grey	2.5YR 5/8 red	SLIP	COARSE	MEDIUM

Uzorci skupine 2

Dvadeset uzoraka skupine 2 preuzeto je iz slojeva iskopa koji nose brojeve 48, 226, 288, 289, 397, 398 i 428. Svi su oni iskopani na dubini od 2,0 do 2,5 m. Ukupan broj ulomaka u tim slojevima nije trenutno poznat. Materijal iz tih slojeva iskopa nije obrađen, stoga je odabir reprezentativnih uzoraka postavljao drugačiju problematiku u odnosu na skupinu 1.

Za skupinu 2 nije moguće dati preliminarnu dataciju, ali je na dubini između skupine 1 i 2 (točnije od 3,0 do 3,2 m) pronađeno više ulomaka jednog daunijskog kratera koji je moguće datirati u kraj 7. ili u 6. st. pr. Kr.[7] Ako stratigrafski slijed nije narušen, moguće je pretpostaviti da keramika skupine 2 nije nastala prije kraja 7. st. pr. Kr.

Cluster 2 samples

The twenty samples from Cluster 2 were taken from excavation layers with the numbers 48, 226, 288, 289, 397, 398 and 428. All of them were unearthed at a depth ranging from 2.0 to 2.5 m. The total number of fragments in these layers is not currently known. The materials from these excavation layers have not been processed; hence the selection of representative samples presented a different set of issues in comparison with Cluster 1.

We are not in a position to offer a preliminary dating for Cluster 2. However, at a depth between Clusters 1 and 2 (ranging from 3.0 to 3.2 m, to be more precise), several fragments of a Daunian krater were discovered, which can be dated to the end of the 7th, or into the 6th century BCE[7]. If the stratigraphic sequence was not compromised, it is possible to assume that the pottery in Cluster 2 was not produced prior to the end of the 7th century BCE.

Tablica 2. Podaci o uzorcima skupine 2

UZORAK	FAKTURA	BOJA VANI	BOJA UNUTRA	BOJA PRESJEK	POVRŠINA	PRIMJESE	DEBLJINA
288-1	GRUBA	5YR 5/1 gray	5YR 5/2 reddish gray	5YR 4/6 yellowish red	GLATKA	SITNE	DEBELA
288-2	GRUBA	5YR 4/2 dark reddish gray	2.5YR 4/8 red	2.5YR 4/8 red	GRUBA	GRUBE	DEBELA
289-3	FINA	7.5YR 5/2 brown	7.5YR 5/3 brown	7.5YR 5/1 gray	GRUBA	SREDNJE	TANKA
226-4	GRUBA	7.5YR 7/3 pink	5YR 6/4 light reddish brown	2.5YR 5/6 red	GRUBA	GRUBE	DEBELA
226-5	FINA	10YR 4/1 dark gray	10YR 4/2 dark grayish brown	10YR 4/2 dark grayish brown	GLATKA	SITNE	SREDNJA
226-6	FINA	5YR 6/3 light reddish brown	5YR 5/4 reddish brown	5YR 4/1 dark gray	GLAČANA	SREDNJE	SREDNJA
226-7	GRUBA	10YR 3/1 very dark gray	10YR 4/1 dark gray	10YR 4/2 dark grayish brown	GRUBA	GRUBE	DEBELA

7 Po obliku posude u Yntema 1990, 290-293.

7 In accordance with a vessel form in Yntema 1990, 290-293.

UZORAK	FAKTURA	BOJA VANI	BOJA UNUTRA	BOJA PRESJEK	POVRŠINA	PRIMJESE	DEBLJINA
428-8	GRUBA	10YR 4/2 dark grayish brown	10YR 5/1 gray	10YR 5/1 gray	GRUBA	SITNE	DEBELA
428-9	GRUBA	2.5YR 4/2 weak red	7.5YR 5/1 gray	5YR 4/2 dark reddish gray	GRUBA	SITNE	DEBELA
428-10	GRUBA	10YR 4/1 dark gray	2.5YR 5/1 gray	10YR 3/1 very dark gray	GRUBA	GRUBE	DEBELA
289-11	GRUBA	7.5YR 6/2 pinkish gray	7.5YR 6/2 pinkish gray	5PB 3/1 very dark bluish gray	GRUBA	SREDNJE	SREDNJA
289-12	GRUBA	5PB 4/1 dark bluish gray	10YR 7/3 very pale brown	10YR 6/1 gray	GRUBA	SITNE	DEBELA
289-13	GRUBA	2.5YR 5/6 red	10B 3/1 very dark bluish gray	2.5YR 5/6 red; 10B 3/1 very dark bluish gray	GRUBA	GRUBE	SREDNJA
48-14	FINA	5YR 6/3 light reddish brown	5YR 7/2 pinkish gray	5YR 5/1 gray	PREMAZ	SREDNJE	SREDNJA
48-15	GRUBA	10YR 4/1 dark gray	7.5YR 5/2 brown	7.5YR 5/2 brown	GRUBA	SREDNJE	SREDNJA
48-16	GRUBA	2.5Y 7/1 light gray	2.5Y 7/1 light gray	7.5YR 7/3 pink	GRUBA	SITNE	DEBELA
397-17	GRUBA	5YR 6/2 pinkish gray	5YR 5/3 reddish brown	5YR 5/3 reddish brown	GRUBA	GRUBE	DEBELA
397-18	GRUBA	5PB 3/1 very dark bluish gray	2.5YR 5/4 reddish brown	7.5YR 5/1 gray	GLATKA	SREDNJE	SREDNJA
397-19	GRUBA	10YR 5/2 grayish brown	7.5YR 5/3 brown	5YR 4/2 dark reddish gray	GRUBA	SREDNJE	DEBELA
398-20	FINA	7.5YR 7/4 pink	7.5YR 7/4 pink	7.5YR 7/4 pink	GLATKA	SITNE	SREDNJA

Table 2. Data regarding Cluster 2 samples

SAMPLE	FABRIC	EXTERIOR COLOR	INTERIOR COLOR	CROSS-SECTION COLOR	SURFACE	TEMPER	THICKNESS
288-1	COARSE	5YR 5/1 grey	5YR 5/2 reddish grey	5YR 4/6 yellowish red	SMOOTH	FINE	THICK
288-2	COARSE	5YR 4/2 dark reddish grey	2.5YR 4/8 red	2.5YR 4/8 red	COARSE	COARSE	THICK
289-3	FINE	7.5YR 5/2 brown	7.5YR 5/3 brown	7.5YR 5/1 grey	COARSE	MEDIUM	THIN
226-4	COARSE	7.5YR 7/3 pink	5YR 6/4 light reddish brown	2.5YR 5/6 red	COARSE	COARSE	THICK
226-5	FINE	10YR 4/1 dark grey	10YR 4/2 dark greyish brown	10YR 4/2 dark greyish brown	SMOOTH	FINE	MEDIUM
226-6	FINE	5YR 6/3 light reddish brown	5YR 5/4 reddish brown	5YR 4/1 dark grey	BURNISHED	MEDIUM	MEDIUM
226-7	COARSE	10YR 3/1 very dark grey	10YR 4/1 dark grey	10YR 4/2 dark greyish brown	COARSE	COARSE	THICK
428-8	COARSE	10YR 4/2 dark greyish brown	10YR 5/1 grey	10YR 5/1 grey	COARSE	FINE	THICK
428-9	COARSE	2.5YR 4/2 weak red	7.5YR 5/1 grey	5YR 4/2 dark reddish grey	COARSE	FINE	THICK
428-10	COARSE	10YR 4/1 dark grey	2.5YR 5/1 grey	10YR 3/1 very dark grey	COARSE	COARSE	THICK
289-11	COARSE	7.5YR 6/2 pinkish grey	7.5YR 6/2 pinkish grey	5PB 3/1 very dark bluish grey	COARSE	MEDIUM	MEDIUM
289-12	COARSE	5PB 4/1 dark bluish grey	10YR 7/3 very pale brown	10YR 6/1 grey	COARSE	FINE	THICK
289-13	COARSE	2.5YR 5/6 red	10B 3/1 very dark bluish grey	2.5YR 5/6 red; 10B 3/1 very dark bluish grey	COARSE	COARSE	MEDIUM
48-14	FINE	5YR 6/3 light reddish brown	5YR 7/2 pinkish grey	5YR 5/1 grey	SLIP	MEDIUM	MEDIUM
48-15	COARSE	10YR 4/1 dark grey	7.5YR 5/2 brown	7.5YR 5/2 brown	COARSE	MEDIUM	MEDIUM
48-16	COARSE	2.5Y 7/1 light grey	2.5Y 7/1 light grey	7.5YR 7/3 pink	COARSE	FINE	THICK
397-17	COARSE	5YR 6/2 pinkish grey	5YR 5/3 reddish brown	5YR 5/3 reddish brown	COARSE	COARSE	THICK
397-18	COARSE	5PB 3/1 very dark bluish grey	2.5YR 5/4 reddish brown	7.5YR 5/1 grey	SMOOTH	MEDIUM	MEDIUM
397-19	COARSE	10YR 5/2 greyish brown	7.5YR 5/3 brown	5YR 4/2 dark reddish grey	COARSE	MEDIUM	THICK
398-20	FINE	7.5YR 7/4 pink	7.5YR 7/4 pink	7.5YR 7/4 pink	SMOOTH	FINE	MEDIUM

Sl. 4 Uzorak 352-46 (snimila S. Močinić)
Fig. 4 Sample 352-46 (photo by S. Močinić)

Sl. 5 Uzorak 414-62 (snimila S. Močinić)
Fig. 5 Sample 414-62 (photo by S. Močinić)

Uzorci skupine 3

Skupina 3 predstavljala je posebno problematičnu grupu uzoraka. Ta se skupina trebala sastojati od uzoraka iz površinskih slojeva koji često sadržavaju miješani materijal iz različitih razdoblja. U ovom slučaju, uz očekivane probleme površinskih slojeva pojavio se još jedan: u dokumentaciji iskopa nije navedena dubina najplićih slojeva pa je njihova pozicija u prostoru iskopa bila samo pretpostavka. Po dostupnim informacijama i usporedbom s ostatkom slojeva, dubina slojeva iz kojih su preuzeti uzorci skupine 3 trebala bi biti između 0,00 i 0,70 m.

Uzorci skupine 3 izabrani su iz slojeva iskopa s brojevima 7, 8, 37, 97, 143, 145 i 146. U trenutku pisanja ovog rada materijal iz ove skupine još nije bio obrađen. Što se datacije tiče, ova bi skupina trebala biti kasnija: jedan od uzoraka ima jasan trag izrade lončarskim kolom, a u materijalu iz sloja iskopa broj 97 postoji ulomak rimske *terre sigillate*.

Karakteristike uzoraka skupine 3 prikazane su u tablici 3

Cluster 3 samples

Cluster 3 represents an especially problematic group of samples. This group should have consisted of samples from the surface layers that often contain mixed material from different periods of time. In this case, along with the expected issues related to surface layers, another problem appeared: the excavation documentation had no data regarding the shallowest layers, which means that their position in the area of excavation was only an assumption. According to the available information, and in comparison with the rest of the layers, the depth of the layers from which the samples of Cluster 3 were taken should be in the range from 0.00 and 0.70 m.

Samples from Cluster 3 were selected from excavation layers bearing the numbers 7, 8, 37, 97, 143, 145 and 146. At the time of writing of this paper the materials from this cluster had not been processed yet. As far as dating is concerned, this cluster should be younger: one of the samples shows a clear trace that it was produced on a potter's wheel, in the material from excavation layer number 97 there is a fragment of Roman *terra sigillata*.

The characteristics of Cluster 3 samples are shown in Table 3.

Tablica 3. Podaci o uzorcima skupine 3

UZORAK	FAKTURA	BOJA VANI	BOJA UNUTRA	BOJA PRESJEK	POVRŠINA	PRIMJESE	DEBLJINA
8-1	GRUBA	10YR 5/1 gray	10YR 5/1 gray	7.5YR 4/2 brown	GRUBA	GRUBE	DEBELA
8-2	GRUBA	10YR 4/1 dark gray	2.5YR 5/6 red	10YR 4/1 dark gray; 2.5YR 5/6 red	GRUBA	GRUBE	SREDNJA
8-3	FINA (KOLO)	2.5YR 4/8 red	2.5YR 4/8 red	2.5YR 4/8 red	GRUBA	SITNE	SREDNJA
37-4	FINA	5YR 7/4 pink	5YR 7/4 pink	5YR 7/4 pink	PREMAZ	SREDNJE	SREDNJA
37-5	GRUBA	5YR 5/1 gray	5YR 6/1 gray	2.5YR 6/6 light red	GRUBA	SREDNJE	SREDNJA
37-6	GRUBA	7.5YR 5/2 brown	7.5YR 5/2 brown	10YR 4/1 dark gray	GRUBA	GRUBE	DEBELA
97-7	GRUBA	10B 3/1 very dark bluish gray	10YR 4/2 dark grayish brown	5YR 4/6 yellowish red	GRUBA	GRUBE	SREDNJA
97-8	GRUBA	10YR 4/1 dark gray	10YR 5/1 gray	10YR 5/1 gray	GRUBA	SREDNJE	DEBELA
97-9	GRUBA	10YR 5/2 grayish brown	10YR 5/2 grayish brown	2.5YR 4/8 red	GLATKA	SITNE	SREDNJA
146-10	FINA	2.5YR 6/8 light red	5YR 6/3 light reddish brown	2.5YR 6/8 light red	GLATKA	SITNE	SREDNJA
146-11	GRUBA	5YR 5/1 gray	5YR 6/3 light reddish brown	5YR 5/6 yellowish red	GRUBA	SREDNJE	SREDNJA
146-12	GRUBA	2.5YR 5/4 reddish brown	5PB 4/1 dark bluish gray	2.5YR 5/4 reddish brown; 5PB 4/1 dark bluish gray	GRUBA	SREDNJE	DEBELA
145-13	FINA	10YR 4/1 dark gray	10YR 5/1 gray	5YR 5/8 yellowish red	GLAČANA	SITNE	SREDNJA
145-14	GRUBA	7.5YR 5/1 gray	10YR 3/1 very dark gray	10YR 4/1 dark gray	GRUBA	SREDNJE	DEBELA
145-15	GRUBA	10YR 6/3 pale brown	10YR 6/3 pale brown	10YR 6/3 pale brown	GRUBA	GRUBE	SREDNJA
7-16	GRUBA	10YR 5/1 gray	10YR 4/1 dark gray	7.5YR 3/2 dark brown	PREMAZ	SREDNJE	SREDNJA
7-17	GRUBA	5YR 7/3 pink	5YR 5/1 gray	5YR 5/1 gray	GRUBA	SREDNJE	DEBELA
7-18	GRUBA	5YR 4/3 reddish brown	2.5YR 5/4 reddish brown	2.5YR 4/8 red	GRUBA (UKRAS)	SREDNJE	SREDNJA
143-19	FINA	7.5YR 4/1 dark gray	7.5YR 6/1 gray	7.5YR 5/1 gray	GLATKA	SITNE	SREDNJA
143-20	GRUBA	2.5YR 5/4 reddish brown	2.5YR 6/4 light reddish brown	5YR 6/2 pinkish gray	GRUBA	SREDNJE	DEBELA

Table 3. Data regarding Cluster 3 samples

SAMPLE	FABRIC	EXTERIOR COLOR	INTERIOR COLOR	CROSS-SECTION COLOR	SURFACE	TEMPER	THICKNESS
8-1	COARSE	10YR 5/1 grey	10YR 5/1 grey	7.5YR 4/2 brown	COARSE	COARSE	THICK
8-2	COARSE	10YR 4/1 dark grey	2.5YR 5/6 red	10YR 4/1 dark grey; 2.5YR 5/6 red	COARSE	COARSE	MEDIUM
8-3	FINE (WHEEL)	2.5YR 4/8 red	2.5YR 4/8 red	2.5YR 4/8 red	COARSE	FINE	MEDIUM
37-4	FINE	5YR 7/4 pink	5YR 7/4 pink	5YR 7/4 pink	SLIP	MEDIUM	MEDIUM
37-5	COARSE	5YR 5/1 grey	5YR 6/1 grey	2.5YR 6/6 light red	COARSE	MEDIUM	MEDIUM
37-6	COARSE	7.5YR 5/2 brown	7.5YR 5/2 brown	10YR 4/1 dark grey	COARSE	COARSE	THICK
97-7	COARSE	10B 3/1 very dark bluish grey	10YR 4/2 dark greyish brown	5YR 4/6 yellowish red	COARSE	COARSE	MEDIUM
97-8	COARSE	10YR 4/1 dark grey	10YR 5/1 grey	10YR 5/1 grey	COARSE	MEDIUM	THICK
97-9	COARSE	10YR 5/2 greyish brown	10YR 5/2 greyish brown	2.5YR 4/8 red	SMOOTH	FINE	MEDIUM
146-10	FINE	2.5YR 6/8 light red	5YR 6/3 light reddish brown	2.5YR 6/8 light red	SMOOTH	FINE	MEDIUM
146-11	COARSE	5YR 5/1 grey	5YR 6/3 light reddish brown	5YR 5/6 yellowish red	COARSE	MEDIUM	MEDIUM
146-12	COARSE	2.5YR 5/4 reddish brown	5PB 4/1 dark bluish grey	2.5YR 5/4 reddish brown; 5PB 4/1 dark bluish grey	COARSE	MEDIUM	THICK
145-13	FINE	10YR 4/1 dark grey	10YR 5/1 grey	5YR 5/8 yellowish red	BURNISHED	FINE	MEDIUM
145-14	COARSE	7.5YR 5/1 grey	10YR 3/1 very dark grey	10YR 4/1 dark grey	COARSE	MEDIUM	THICK
145-15	COARSE	10YR 6/3 pale brown	10YR 6/3 pale brown	10YR 6/3 pale brown	COARSE	COARSE	MEDIUM
7-16	COARSE	10YR 5/1 grey	10YR 4/1 dark grey	7.5YR 3/2 dark brown	SLIP	MEDIUM	MEDIUM
7-17	COARSE	5YR 7/3 pink	5YR 5/1 grey	5YR 5/1 grey	COARSE	MEDIUM	THICK
7-18	COARSE	5YR 4/3 reddish brown	2.5YR 5/4 reddish brown	2.5YR 4/8 red	COARSE (DECORATION)	MEDIUM	MEDIUM
143-19	FINE	7.5YR 4/1 dark grey	7.5YR 6/1 grey	7.5YR 5/1 grey	SMOOTH	FINE	MEDIUM
143-20	COARSE	2.5YR 5/4 reddish brown	2.5YR 6/4 light reddish brown	5YR 6/2 pinkish grey	COARSE	MEDIUM	THICK

Sl. 6 Uzorak 356-56 (snimila S. Močinić)
Fig. 6 Sample 356-56 (photo by S. Močinić)

REZULTATI ISTRAŽIVANJA

Interpretacija IR spektara: podaci o sastavu keramike

Svaka vrpca na IR spektru odnosi se na određenu funkcionalnu skupinu jednog ili više spojeva prisutnih u uzorku. Pridruživanjem pojedinih vrpci u spektru odgovarajućim skupinama atoma (asignacijom) moguće je odrediti strukturu, odnosno sastav uzorka. Iako su neprikladni za preciznu kvantitativnu analizu, pri mjerenju infracrvenih spektara utvrđuje se količina apsorbiranog elektromagnetskog zračenja do kojeg dolazi pri interakciji s uzorkom te je moguće donekle odrediti količinu odnosno omjer prisutnih supstanci u uzorku, ako se uzorak sastoji od više tvari.

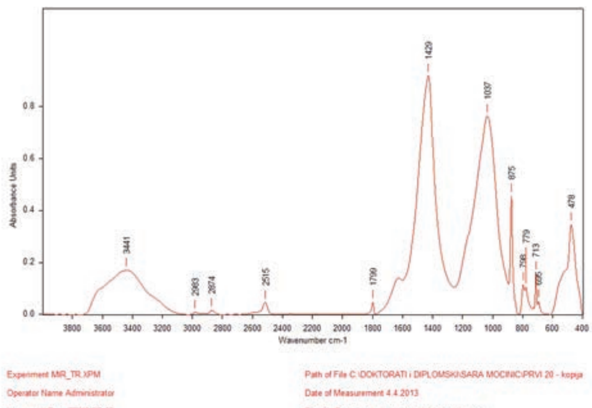
Snimljeni IR spektri uzoraka keramike pokazuju međusobno vrlo slične vrpce, što ukazuje na to da analizirani uzorci sadrže zajedničke supstance te da variraju uglavnom njihovi omjeri.

Najistaknutije vrpce u većini spektara su one kalcijeva karbonata odnosno kalcita (kemijske formule $CaCO_3$). Najintenzivnija vrpca kalcita nalazi se pri približno 1425 cm^{-1} i posljedica je istezanja C-O veza karbonatnog iona, dok vrpce pri 875 i 713 cm^{-1} odgovaraju savijanjima CO_3^{-2} iona. Vrlo intenzivna vrpca pri približno 1040 cm^{-1} te vrpca pri 481 cm^{-1} s ramenom pri 564 cm^{-1} upućuju na prisutnost spojeva sa Si-O i Al-O skupinama u strukturi, odnosno alumosilikata predstavnika glinene komponente keramike. Kako su u gotovo svim spektrima vidljive i vrpce pri 799 i 778 cm^{-1}, koje potječu od kvarca, odnosno silicijevog oksida (SiO_2), moguće je zaključiti da je keramika sastavljena uglavnom od kalcijeva karbonata, glinenih minerala i kvarca (De Benedetto, Laviano, Sabbatini, i Zambonin 2002, 177).

EXPLORATION RESULTS

Interpretation of infrared spectra: pottery composition data

Each band in the infrared spectrum refers to a certain functional group of one or more compounds present in the sample. By conjugating individual bands in the spectrum to the corresponding atom groups (assignment), it is possible to determine the structure and composition of the sample. Although unsuitable for precise quantitative analyses, when measuring infrared spectra we determine the amount of absorbed electromagnetic radiation that occurs during the interaction with the sample, and it is to a certain extent possible to determine the amount and ratio of the substances present in the sample, if the sample is composed of several substances. The recorded infrared spectra of pottery samples show mutually very similar bands, which indicates that the analyzed samples contain common substances, and that it is mainly their ratios that vary. The most emphasized bands in most spectra are those of calcium carbonate or calcite (chemical formula $CaCO_3$). The most intensive calcite band is located at approximately 1425 cm^{-1} and it is the consequence of stretching of the C-O links of the carbonate ion, whereas bands at 875 and 713 cm^{-1} correspond to the bending of CO_3^{-2} ions. The very intensive band at approximately 1040 cm^{-1}, and the band at 481 cm^{-1}, with a shoulder at 564 cm^{-1}, indicate the presence of compounds with Si-O and Al-O clusters in the structure, i.e., aluminosilicates representing the pottery clay components. As in nearly all spectra there are visible bands at 799 and 778 cm^{-1}, which stem from quartz, or silicon oxide (SiO_2), it is possible to conclude that the pottery is composed mainly of calcium carbonate, clay minerals and quartz (De Benedetto, Laviano, Sabbatini and Zambonin 2002, 177).



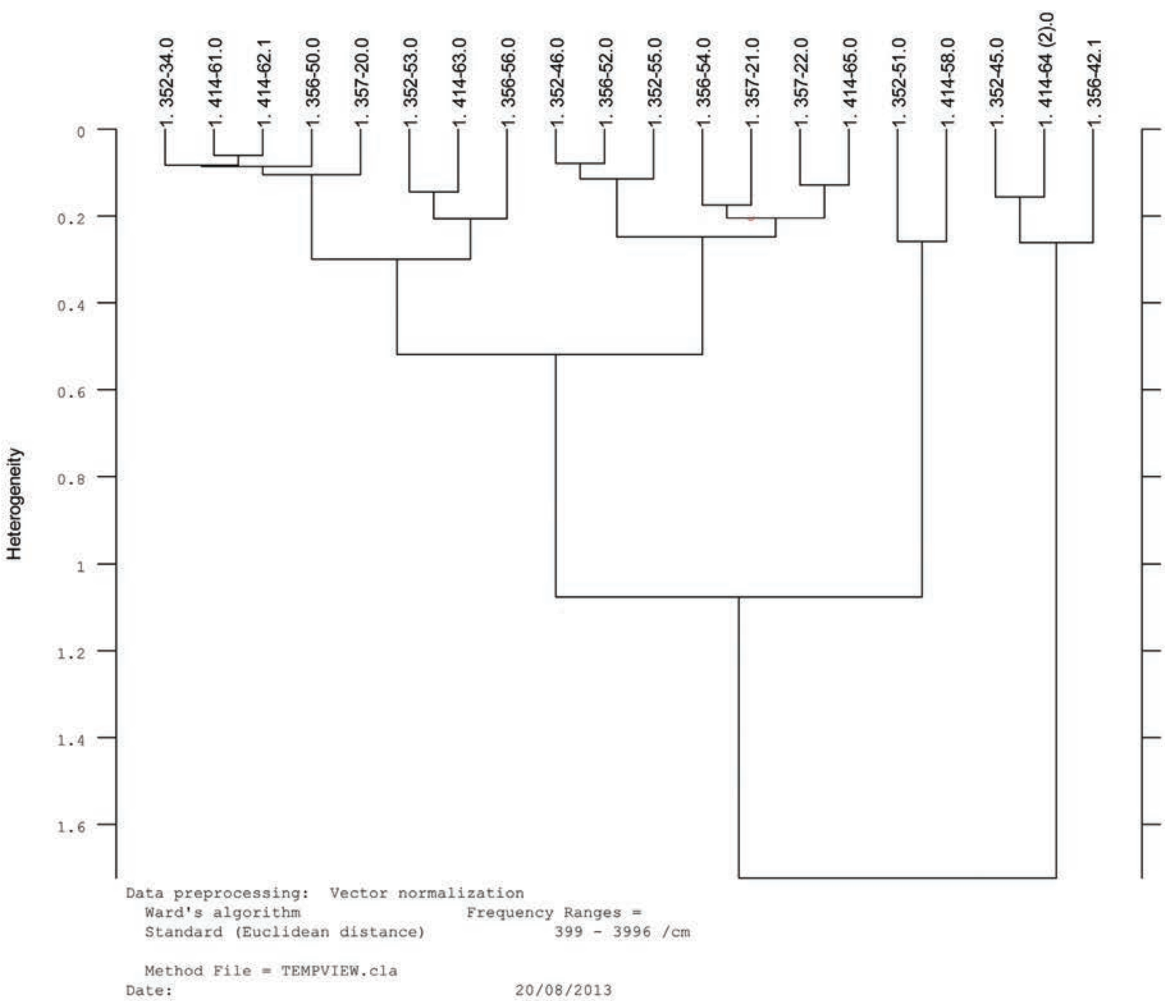
Sl. 7 FT-IR spektar uzorka 414-61
Fig. 7 FT-IR spectrum of sample 414-61

Rezultati klaster analize

Nakon snimanja spektara i njihove osnovne obrade, oni su dalje korišteni za klaster analizu. Klaster analiza provedena je unutar svake skupine te među uzorcima različitih skupina. Na gornjoj strani svakog dendrograma nalaze se oznake uzoraka. Oznake uzorka počinju brojem koji označava skupinu uzorka, zatim je naveden broj sloja iskopa, a nakon povlake broj uzorka (npr. 1.414-65). Oznake uzoraka su u dendrogramu povezane linijama koje grafički prikazuju odnose sličnosti. Razlike među uzorcima u dendrogramima su relativne, što znači da nije toliko važna apsolutna vrijednost na skali, koliko međusobna udaljenost više uzoraka ili grupa uzoraka.

Cluster analysis results

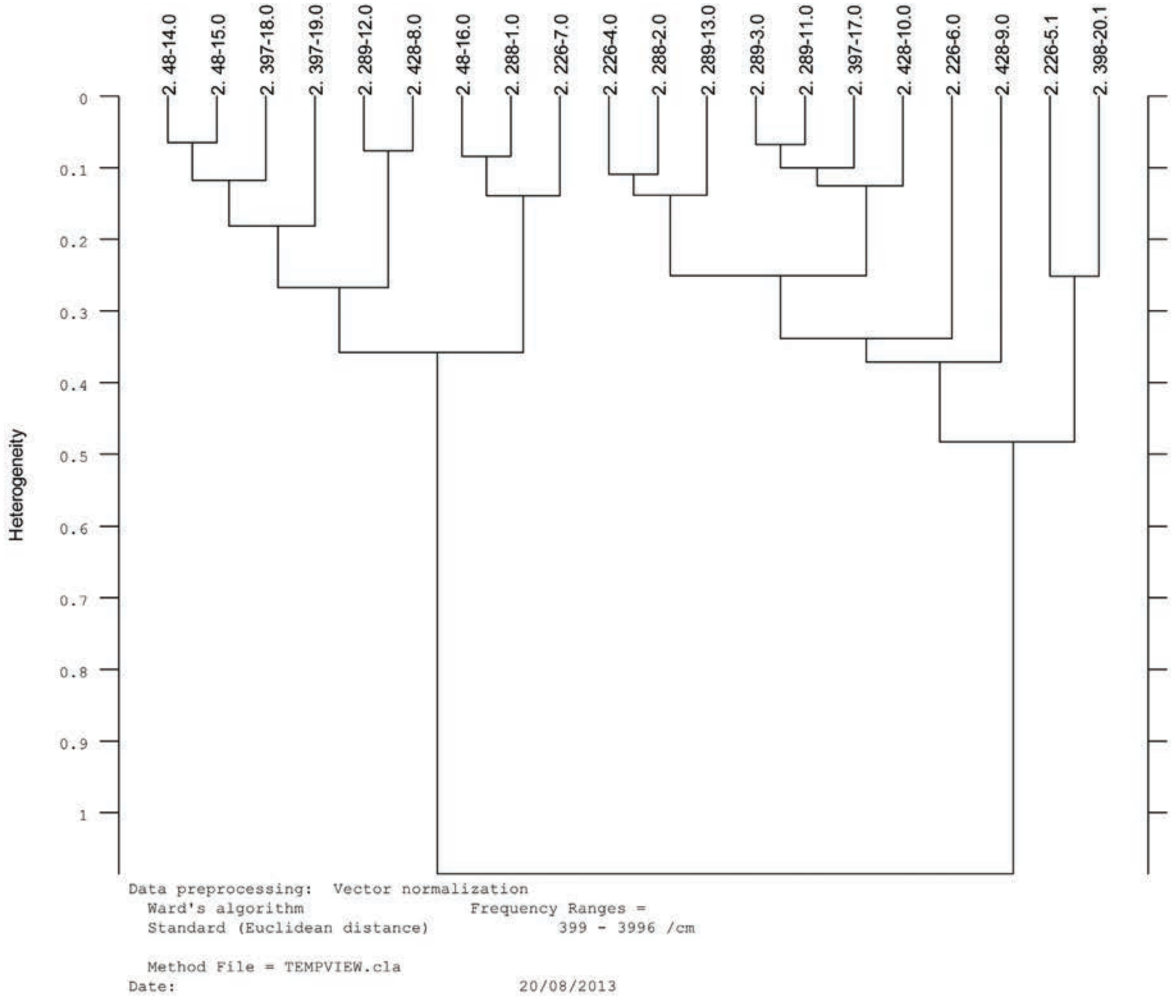
After spectra were recorded, and their basic processing carried out, the same were used for a cluster analysis. A cluster analysis was performed within each cluster and among samples of different clusters. The sample marks are on the upper side of each dendrogram. The marks of each sample begin with a number that denotes the cluster of the sample, followed by the number of the excavation layer, and after the dash, the sample number (e.g., 1.414-65). In a dendrogram, sample marks are connected with lines that graphically illustrate the relationships of similarity. The differences among samples in dendrograms are relative, which means that the absolute value on a scale is not as important as the distance of several samples, or groups of samples, between one another.



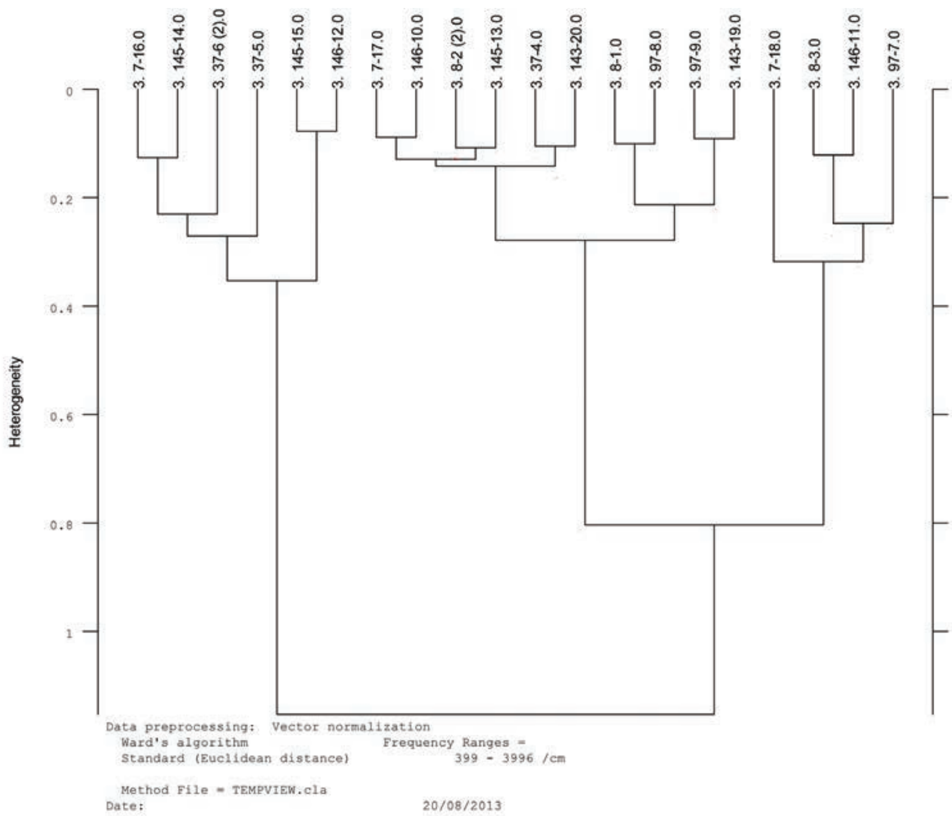
Sl. 8 Dendrogram skupine 1
Fig. 8 Dendrogram of Cluster 1

Dendrogram skupine 1 (sl. 8) pokazuje ukupno 11 klastera. Vidljivo je da se uzorci 352-51, 414-58, 352-45, 414-64 te 356-42 najviše razlikuju od ostatka skupine. Međusobno su uzorci 352-51 i 414-58 slični, kao što su to i uzorci 352-45, 414-64 i 356-42. Ostali uzorci skupine 1 međusobno pokazuju visoku sličnost u sastavu, a dvije grupe u koje su podijeljeni spajaju se već na vrijednosti 0.6 faktora heterogenosti. Grupa uzoraka 352-34, 414-61, 414-62, 356-50 i 357-20 pokazuje vrlo velike sličnosti u sastavu, što vjerojatno ukazuje na njihovo zajedničko porijeklo.

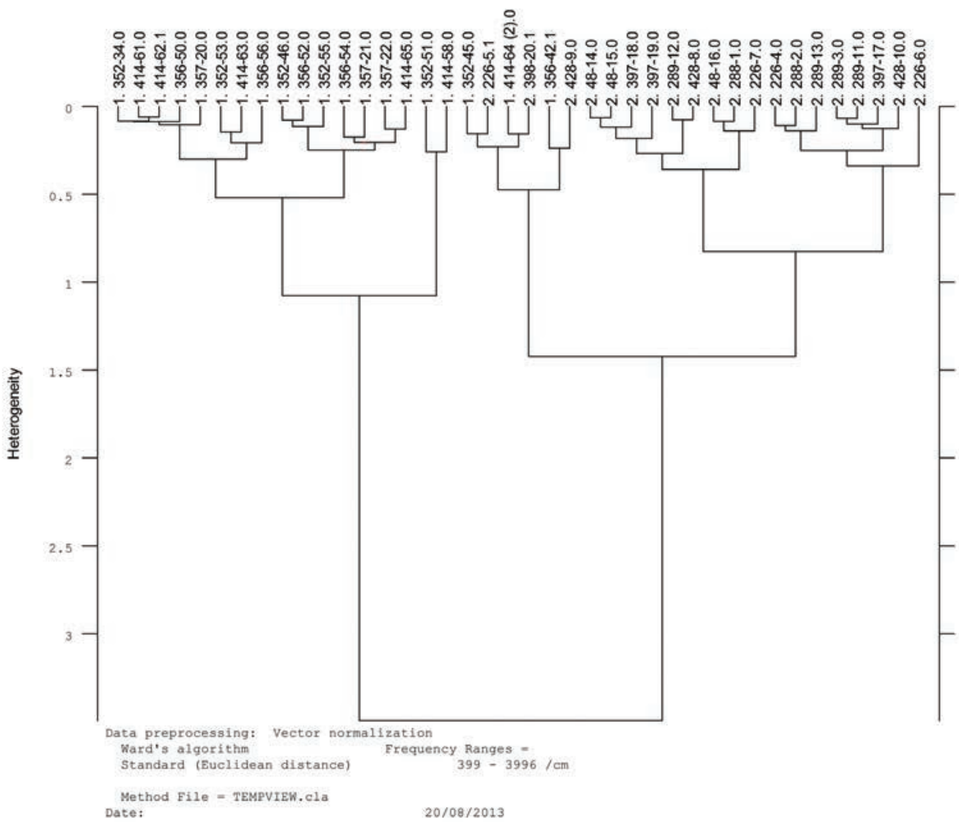
The Cluster 1 dendrogram (Fig. 8) shows a total of 11 clusters. It is readily apparent that samples 352-51, 414-58, 352-45, 414-64 and 356-42 are most dissimilar in comparison with the rest of the cluster. Samples 352-51 and 414-58 are mutually similar, as is the case with samples 352-45, 414-64 and 356-42. Other Cluster 1 samples show a great degree of similarity in their composition when compared to one another, and the two groups into which they branched, merge already on a heterogeneity factor value of 0.6. The group of samples 352-34, 414-61, 414-62, 356-50 and 357-20, shows great similarities in composition, which probably reflects their common origin.



Sl. 9 Dendrogram skupine 2
Fig. 9 Dendrogram of Cluster 2



Sl. 10 Dendrogram skupine 3
Fig. 10 Dendrogram of Cluster 3



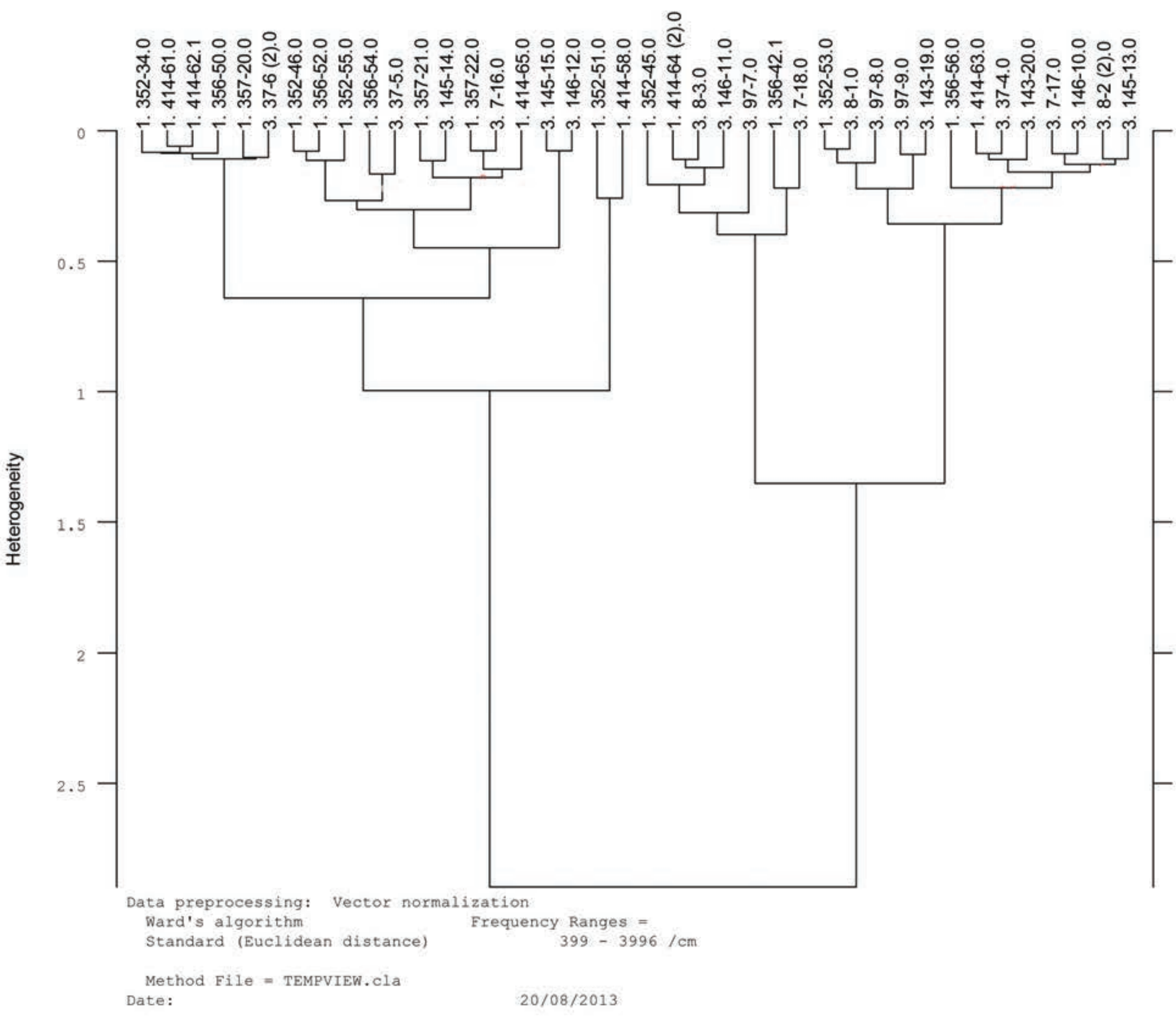
Sl. 11 Dendrogram skupina 1 i 2
Fig. 11 Dendrogram of Clusters 1 and 2

Dendrogram skupina 1 i 2 (sl. 11) ukazuje na to da se po sastavu većina uzoraka iz skupine 1 jasno razlikuje od većine uzoraka iz skupine 2. Uzorci iz skupine 1 i skupine 2 koji su se u dendrogramima pojedinih skupina razlikovali od većine uzoraka u ovom zajedničkom dendrogramu pokazuju međusobne sličnosti, a to su uzorci 352-45, 226-5, 414-64, 398-20, 356-42 te 428-9 .

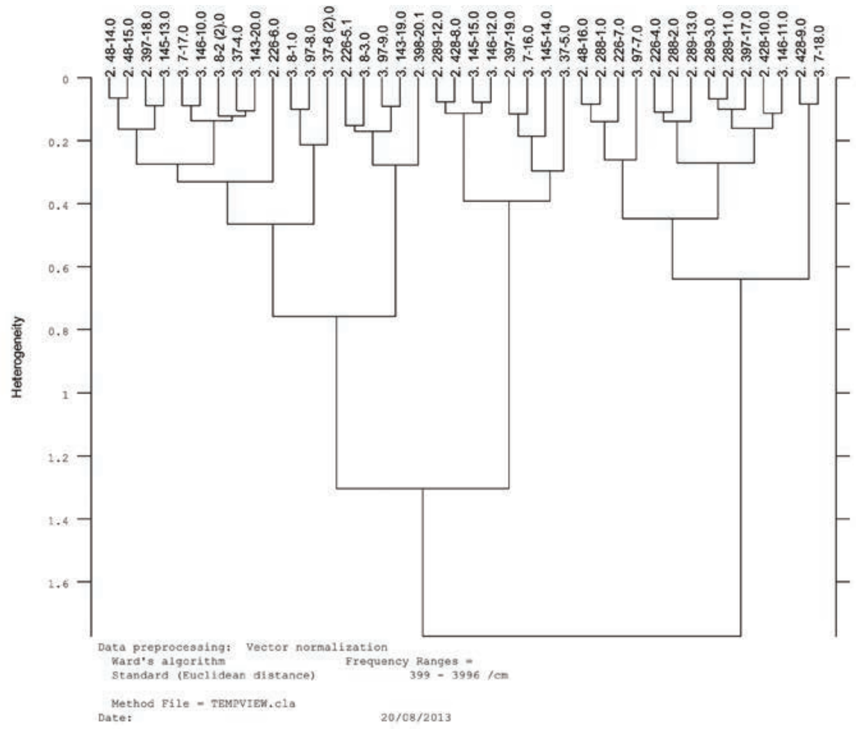
Dendrogram temeljen na vrijednostima IR spektara iz skupina 1 i 2 dokazuje da postoje određene razlike u sastavu keramike skupina 1 i 2: uz pomoć tih razlika moguće je jasno razlikovati, odnosno grupirati keramiku iz iste skupine, što čini ovu metodu klasifikacije pogodnom za pripisivanje novih uzoraka određenoj skupini.

The dendrogram of Clusters 1 and 2 (Fig. 11) shows that the composition of most of the samples from Cluster 1 is clearly dissimilar from most of the samples from Cluster 2. Samples from Cluster 1 and Cluster 2, which in the dendrograms of individual clusters differed from most of the samples in this common dendrogram, show mutual similarities, and these are samples 352-45, 226-5, 414-64, 398-20, 356-42 and 428-9.

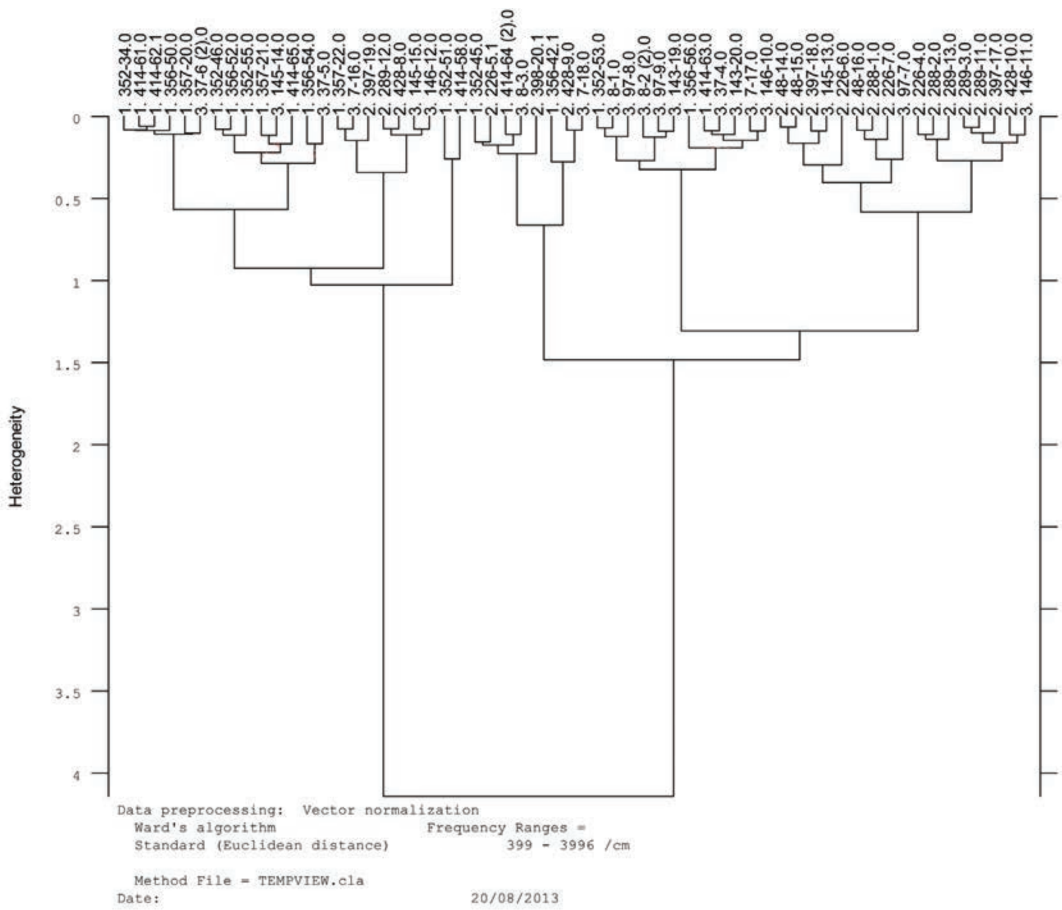
The dendrogram based on values of infrared spectra from Clusters 1 and 2 proves that there are certain differences in the composition of pottery from Clusters 1 and 2: using these differences it is possible to clearly distinguish pottery from these two clusters, i.e., to group pottery coming from the same cluster, which makes this method of classification suitable for assigning new samples to a particular cluster.



Sl. 12: Dendrogram skupina 1 i 3
Fig. 12 Dendrogram of Clusters 1 and 3



Sl. 13 Dendrogram skupina 2 i 3
Fig. 13 Dendrogram of Clusters 2 and 3



Sl. 14 Dendrogram skupina 1, 2 i 3
Fig. 14 Dendrogram of Clusters 1, 2 and 3

Dendrogram na sl. 14 prikazuje usporedbu svih 60 uzoraka. Iako su skupine 1 i 2 pokazale veliku međusobnu različitost, dodavanje skupine 3 je umnogome promijenilo situaciju, stvarajući čak četiri velike miješane grupe. Prema tome, možemo zaključiti da je skupina 3 raznovrsnog podrijetla.

INTERPRETACIJA REZULTATA

U ovom dijelu rada prikazana je usporedba rezultata spektroskopske i klaster analize s podacima o uzorcima koji su predstavljeni u tablicama 1 do 3.

Dendrogram skupine 1 (sl. 8) ukazuje na to da je većina uzoraka međusobno vrlo slična. Osim razlike uzorka 414-58 (grumen slabo pečene gline) u odnosu na druge (dijelovi posuda), nema poveznica između grupa koje su se formirale u dendrogramu i formalnih karakteristika keramike.

Skupina 2 je homogenija od skupine 1. Njezin dendrogram (sl. 9) dijeli uzorke u dvije grupe koje su međusobno relativno homogenog sastava. To se odražava i u njihovim fizičkim karakteristikama, jer dvije grupe nemaju posebnosti ni u fakturi, ni u bojama i načinu pečenja, ni u obradi površine. Mala je razlika u veličini primjesa: u jednoj grupi su primjese u prosjeku veće nego u drugoj. Vjerojatno su sastav primjesa i njihova količina razlog odvajanju dviju grupa.

Kao što je već ranije istaknuto, najraznovrsnija je skupina 3. Grupa uzoraka od 7-16 do 146-12, koja se posebno ističe u odnosu na druge dvije formirane grupe, razlikuje se i po vidljivim karakteristikama. Ona je po svim svojim karakteristikama grublja od ostalih. Ovo je jedina skupina u kojoj se razlika u sastavu očituje u razlici u gore navedenim karakteristikama.

Dendrogram koji međusobno uspoređuje uzorke skupina 1 i 2 (sl. 11) je najzanimljiviji. Prikazuje razdvajanje dviju skupina, osim male miješane grupe od šest uzoraka koja se priklanja skupini 2, ali nije dio nje. Moguće je pretpostaviti da je razlika između keramike iz najdubljih slojeva iskopa i onih iz sredine prouzročena različitom metodom izrade keramike kroz vrijeme te da vrlo vjerojatno označava da je stratigrafija u donjem dijelu iskopavanja vjerodostojna. Tu pretpostavku podržava činjenica da su uzorci pojedine skupine međusobno relativno homogeni, odnosno sličnog sastava.

Razlog postojanja razlika u sastavu mogla bi biti promjena recepture ili omjera gline i primjesa kroz vrijeme, korištenje drugog nalazišta gline ili pak više faktora istovremeno. Pretpostavku će biti moguće potvrditi ili odbaciti tijekom daljnjeg istraživanja.

The dendrogram in Fig. 14 shows a comparison between all 60 samples. Although Clusters 1 and 2 showed a large amount of differences between one another, the addition of Cluster 3 greatly changed the situation, creating four large, mixed groups. We can therefore conclude that Cluster 3 is of diverse origins.

INTERPRETING THE RESULTS

In this section of the paper we compare the results from the spectroscopic and cluster analysis with data regarding samples presented in Tables 1 to 3.

The Cluster 1 dendrogram (Fig. 8) shows that the majority of samples are very similar to each other. Apart from the differences of sample 414-58 (a lump of poorly baked clay), as compared with others (sections of vessels), there are no links between the groups that were formed in the dendrogram and formal pottery characteristics.

Cluster 2 is more homogeneous than Cluster 1. Its dendrogram (Fig. 9) divides the samples into two groups that have a relatively homogenous composition as compared with one another. This is also reflected in their physical characteristics, because the two groups don't have any special features as regards fabric, color and mode of firing, and surface treatment. There is a small difference in temper size: the temper in one group is on average larger than in the other. Temper composition, and quantity, are probably the reasons for the divergence of the two groups.

As was already emphasized, Cluster 3 represents the most differentiated group. The group of samples from 7-16 to 146-12, which stands out in particular when compared with the other two formed groups, also differs on account of visible characteristics. The pottery in this group is coarser with respect to the rest of the samples. This is the only cluster in which the difference in composition reflects itself in differences in the aforementioned characteristics.

The dendrogram that mutually compares samples from Clusters 1 and 2 (Fig. 11) is the most interesting one. It shows the separation of the two clusters, except for the small, mixed group of six samples, which inclines towards Cluster 2 although it is not part of it. We can assume that the differences among pottery from the deepest layers of the excavation, and those from the middle, stem from different methods of making pottery through time, and that they most likely mean that the stratigraphy in the lower section of the excavation is reliable. This assumption is supported by the fact that samples taken from an individual cluster are homogeneous, i.e., they are of similar composition.

Miješana grupa uzoraka sastoji se od uzoraka koji su se u određenoj mjeri razlikovali od vlastitih skupina (vidi sl. 8 i 9). Međusobno ti uzorci nisu ujednačeni po svojim formalnim karakteristikama.

Nakon logične podjele između skupina 1 i 2, podjela skupina 1 i 3 potpuno je nejasna (sl. 12). Nije moguće prepoznati logiku grupiranja, a razlike nema ni u formalnim karakteristikama keramike. Znajući da skupina 3 dolazi iz slojeva iskopa nesigurne stratigrafije, ne smatramo da takvi rezultati mogu pobiti pravilnu podjelu skupina 1 i 2 ili dovesti u pitanje efikasnost metode. Površinski slojevi mogli su sadržavati ulomke keramike s dubine od 4,5 m zbog poremećaja slojeva ili zbog infiltracije.

Dendrogram skupina 2 i 3 (sl. 13) poseban je u odnosu na druge do sada analizirane, zbog razlika u karakteristikama koje je moguće očitati unutar njegovih grupa. Izgleda da se ovdje očitavaju razlike u keramici prema funkciji, jer je sličnost među skupinama 2 i 3 veća nego među skupinama 1 i 2 te 1 i 3.

Treba napomenuti da je razlika u fakturi keramike postojala već unutar same skupine 3. Ukazuje li veća sličnost između skupina 2 i 3 na njihovu veću kronološku blizinu u odnosu na skupine 1 i 2? To će se pokazati kada keramika bude obrađena i datirana.

Dendrogram na slici 14 uspoređuje uzorke svih skupina. Nakon usporedbe po formalnim karakteristikama keramike, zaključeno je da se samo jedna manja grupa uzoraka ističe u odnosu na ostale - uzorci 352-45, 226-5, 414-64, 8-3, 398-20, 356-42, 428-9 i 7-18. U toj grupi ne prevladavaju uzorci niti jedne skupine, već su oni posebni po svojim karakteristikama. Ti su uzorci u prosjeku finiji nego ostatak keramike, a primjese su im u prosjeku sitnije te stijenke tanje. No, ipak većina uzoraka ne pokazuje grupiranje po fakturi.

The reasons for the existence of differences in composition could be attributed to a change in the ingredients used, a ratio of clay and temper that differed through time, the use of clay from another deposit, or else these differences could be the result of more factors acting simultaneously. Further research will be necessary to either confirm or reject this assumption.

A mixed group of samples consists of samples that have, to a certain degree, differed from their own clusters (see Fig. 8 and 9). These samples are mutually not uniform as regards their formal characteristics.

After a logical division between Clusters 1 and 2, the division of Clusters 1 and 3 is completely unclear (Fig. 12). We are unable to recognize the logic behind the grouping, and likewise, there is no difference in the formal characteristics of pottery. Knowing that Cluster 3 comes from excavation layers with an unreliable stratigraphy, we do not believe that such results can refute the correct division of Clusters 1 and 2, or raise doubts about the effectiveness of the method. It is possible that surface layers could have contained pottery fragments from a depth of 4.5 m because of layer disturbances, or conversely, because of infiltration.

The dendrogram of Clusters 2 and 3 (Fig. 13) is specific when compared to the others so far analyzed because of the differences in characteristics that can be read within its groups. It appears that differences in pottery according to function manifest themselves here because the similarities between Clusters 2 and 3 exceed those between Clusters 1 and 2, as well as 1 and 3. It should be mentioned that differences in the fabric of the pottery existed already within Cluster 3 itself. Whether a greater similarity between Clusters 2 and 3 points towards their greater chronological proximity in relation to Clusters 1 and 2 will be shown when the pottery is processed and dated.

The dendrogram in Fig. 14 compares the samples of all clusters. After a comparison that was in line with the formal characteristics of the pottery, it was concluded that only a smaller group of samples stood out in relation to other pottery, and these were samples 352-45, 226-5, 414-64, 8-3, 398-20, 356-42, 428-9 and 7-18. This group is not dominated by samples from any cluster, but they are unique on account of their characteristics. On average, these samples are finer than the rest of the pottery, the same applies to their temper, and their walls are thinner. However, most of the samples do not show a tendency to group according to fabric.

ZAKLJUČAK

Istraživanje predstavljeno u ovom radu pokazalo je kako infracrvena spektroskopija može pomoći kod obrade keramičkog materijala iz starih iskopavanja, čija dokumentacija najčešće ne sadržava podatke koje danas smatramo osnovnima, kao što je dijeljenje materijala prema kulturnim slojevima ili označavanje točne pozicije svakog sloja i objekta. Upravo zbog takvih problema, kod dokumentiranja keramičkog materijala iz Osora pristupilo se metodi infracrvene spektroskopije prije nego što je klasičnim metodama obrađen cjelokupni materijal, ne bi li se ustanovilo je li interpretacija postojećih podataka o stratigrafiji vjerodostojna. Rezultati su ohrabrujući jer je utvrđena jasna razlika u sastavu keramike najdubljih i srednjih slojeva. Odnos među uzorcima iz pretpostavljenih površinskih slojeva i onih iz dubljih slojeva manje je jasan, što navodi na oprez: materijal iz tih slojeva je očito miješanog podrijetla, ali trenutno nije moguće odrediti razlog tomu. Moguća je pretpostavka da je stratigrafija u gornjem dijelu iskopavanja poremećena ili, kao druga mogućnost, da je prava pozicija tih slojeva iskopa ipak različita od one koju je bilo moguće samo pretpostaviti iz dostupnih informacija. Te će mogućnosti, zahvaljujući ovom istraživanju, biti uzete u obzir tijekom daljnje obrade materijala iz Osora.

Unatoč velikim razlikama u sastavu uzoraka unutar pojedinih skupina, nije utvrđeno postojanje skupine ili nekolicine uzoraka koji se bitno razlikuju od ostalih uzoraka i za koje se može pretpostaviti da predstavljaju uvoznu keramiku. Stoga je moguće potvrditi početnu tezu da se u cijelosti radi o domaćoj, lokalno izrađenoj keramici.

Na temelju podataka iznesenih u ovom radu moguće je zaključiti da je infracrvena spektroskopija veoma korisna metoda analize, ne samo za utvrđivanje podrijetla keramike, nego i za određivanje razlika u starosti, kada stratigrafija nije jasno dokumentirana.

CONCLUSION

The research presented in this paper has shown that infrared spectroscopy can assist in the processing of pottery materials from old excavations whose documentation in most cases does not contain data that are nowadays considered essential, such as the division of materials according to cultural layers, or, the marking of the exact position of each layer and object. Having these issues regarding the documentation of the pottery material from Osor in mind, we turned to the infrared spectroscopy method before we processed the entire material using conventional methods, in order to determine whether the interpretation of existing stratigraphic data is reliable. The results are encouraging because we established that there is a clear difference in the composition of pottery from the deepest layers, as compared with that from the middle ones. The relation between samples from presumed surface layers, and those from deeper layers, is not so clear, which demands caution: the material from these layers is obviously of mixed origin, but we are at the moment not able to determine the cause of this condition. It is possible to presume that the stratigraphy of the upper section of the excavation was disturbed, or, alternatively, that the true position of these excavation layers is nevertheless different from that which we were only able to assume from the available information. Thanks to this study, the aforementioned possibilities will be taken into account during the further processing of the materials from Osor.

Despite the great differences in the composition of samples within individual clusters, we were not able to establish the existence of a cluster, or even a few samples, which are significantly different from other samples, and for which it would be possible to assume that they represent imported pottery. We are hence in a position to confirm the initial hypothesis that we are dealing exclusively with locally produced pottery.

Based on data presented in this study we can conclude that infrared spectroscopy represents a very useful method of analysis, not only for identifying the origins of pottery, but also for determining differences in age when the stratigraphy is not clearly documented.

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