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Traditional building methods with lime mortar,
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Roman trowel from Viminacium, site of Više Grobalja
(photo documentation of the Institute of Archaeology
Belgrade, Viminacium project).
Fragment of mortar from the rampart of Viminacium fortress
(photo documentation of the MoDeCo2000 project).

SADRŽAJ / CONTENTS
Rasprave i članci
Treatises and Articles

Arheologija, istorija umetnosti i arhitekture
Archaeology, history of art and architecture

Manousos E. Kambouris, Spyros Bakas	A reappraisal of the ethnic Persian infantry in the Achaemenid armies	11
George Valentin Bounegru	A unique representation of Hercules discovered at Apulum	23
Marija Jović	Monetary circulation of late antique Naissus	29
Igor Bjelić	Use of building materials during the construction of Trajan's Bridge on the Danube	45
Bojan Popović	Glamija - Rtkovo, new considerations	59
Bojana Plemić, Ljubiša Vasiljević	A contribution to the knowledge of antique terracotta iconography in the province of Upper Moesia	73

Arheometrija, nauka o konzervaciji, restauracija kulturnog nasleđa
Archaeometry, conservation science, restoration of cultural heritage

Mihailo Radinović	Old collection and new insights: technological analysis of obsidian finds from the late Neolithic layers of Vinča-Belo Brdo	81
Aleksandar Bulatović, Maja Gajić-Kvaščev, Aleksandar Kapuran, Marija Ljuština, Vojislav Filipović, Ognjen Mladenović, Petar Milojević, Bogdana Milić	The FLOW project – a contribution to the study of the cultural transmission of the central Balkan communities and the neighboring regions in later prehistory	101
Simone Dilaria, Michele Secco	Mortar recipes through the ages. A brief review of data from prehistory to late antiquity	113
Roman Balvanović	Roman and late antique glass in the Mediterranean area and Serbia: its production, compositional types and provenance	127
Kristina Ponjavić, Maja Gajić-Kvaščev, Vojkan Milutinović, Dragana Gavrilović	Application of archeometric techniques in the study of wall paintings on the example of fragments of frescoe paintings from the Church of St. Nicholas (Crkva Svetog Nikole) in Baljevac, Serbia	145
Slobodan Bogojević, Kristina Šarić, Bojan Kostić, Suzana Erić	The efficiency of chemical cleaning of different metal artefacts from Felix Romuliana and Gradina archaeological sites (Serbia)	165
Maja Franković, Vesna Matović, Jelena Majstorović, Nevenka Novaković	Leitha limestones' properties and their degradation – case study Belgrade Fortress	183

Nigel Copsey The rudiments of traditional mortar preparation and use 199

Zaštita i interpretacija arheološkog nasleđa, arheološka dokumentacija, informacione tehnologije,
Pprotection and interpretation of archaeological heritage, archaeological documentation, information technologies

Silvana Blaževska, Angela Pencheva — Master conservation plan for the archaeological site of Stobi: goals and outcomes 223

Marko Nikolić, Ena Takač, Jelena Šćekić — Contemporary approaches to the revitalisation, presentation and promotion of the cultural and natural heritage of the part of the Roman Limes - case study of the late antique tomb in Brestovik 233

Milan Milovanović — Documentation office of the Institute of Archaeology in Belgrade as an organizational unit 253

Predrag Škundrić, Vanja Korać, Zoran Davidovac — EU cyber initiatives and international cybersecurity standards - an overview 269

Vanja Korać, Dragan Prlja, Gordana Gasmi — Influence of artificial intelligence on human rights 279

Prikazi
Reviews

Ljubiša Vasiljević — Anthony Harding, SALT White Gold in Early Europe, Cambridge University Press – The European Association of Archaeologists, serija Cambridge Elements – The Archaeology of Europe, Cambridge 2021 293

Ljubiša Vasiljević — Manjša rimska naselja na slovenskem prostoru / Minor Roman settlements in Slovenia, Jana Horvat, Irena Lazar, Andrej Gaspari (ur.), ZRC SAZU, Inštitut za arheologijo, Serija: Opera Instituti Archaeologici Sloveniae 40, Ljubljana 2020 295

Bojana Plemić — Izložba ''Božica i konjanici 1 – Kultni sinkretizam Donje Panonije", Galerija Arheološkog muzeja u Zagrebu, 5-30.VII 2022 299

Uređivačka politika časopisa Arheologija i prirodne nauke 301

Uputstvo autorima o načinu pripreme članaka za časopis Arheologija i prirodne nauke 306

Editorial Policy of the journal Arheologija i prirodne nauke (Archaeology and Science) 312

Submission instructions for the journal Arheologija i prirodne nauke (Archaeology and Science) 318

PREFACE

In the summer of 2022, the *1st International Conference with Workshop - Science for Conservation of the Danube Limes* was held in Viminacium, as the final event of the project *Mortar Design for Conservation - Danube Roman Frontier 2000 Years After (MoDeCo2000)*, financed by the Science Fund of the Republic of Serbia, with the aim of gathering participants connected by a common interest - research and protection of cultural heritage. The lectures covered topics from archaeology, history of architecture and construction, geology, conservation science, archaeometry, chemistry, materials science, physical chemistry, biology, physics, history of art, practical conservation and restoration, interpretation, documentation, and protection of heritage, as well as its management. Practical work, through the building of a wall with the use of materials present in Roman Viminacium, as a unique experience, brought together a large number of participants.

Although the topic of the project was related to historical mortars, the organisers wanted to bring together researchers and experts who deal with different materials used throughout history for the construction of buildings but also for the production of artifacts. The results of extremely complex multidisciplinary studies of historical materials are important not only for gaining knowledge about their composition and methods of production, the process of exploitation of raw materials, transport, and trade, but also for all kinds of connections between people. Their use ensures responsible conservation practices with the application of materials compatible with historical ones, but also the development of new products in the field of industry. One of the project aims is the promotion of the use of local raw materials and traditional techniques in the production of conservation mortars, but also their improvement in accordance with today's circumstances and the environment in which historical buildings are located. What all historical materials have in common is that they were mainly created using locally available raw materials, they were guided by the experience and practicality of people, and improved over generations.

Most of the papers in this volume of the scientific journal *Archaeology and Science* are dedicated to the topics of the Viminacium event, with their authors as participants. Given that the theme of the event connected an extremely large number of scientific fields, this volume includes other papers that relate to them, all contributing to the research, protection, and interpretation of cultural heritage.

Archaeology, as a humanistic science, in collaboration with natural sciences, provides solutions from the past employed by technical and technological sciences for the development of modern ones, invaluable to the contemporary world, especially regarding some of the most current topics, namely climate change and sustainable development. It is with this thought in mind that the content of this volume of the journal *Archaeology and Science* was conceived.

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A REAPPRAISAL OF THE ETHNIC PERSIAN INFANTRY IN THE ACHAEMENID ARMIES

ABSTRACT

The form and function of the ethnic Persian infantry of the Persian Wars is little explored, although there have been many issues correctly identified by a number of scholars. Such are stereotypes, an overeager use of Occam's Razor and a distinct refusal to merge data from sources of less than 100 years apart under the silent pretext of possible reforms and resets. The combination of the report of Xenophon with that of Herodotus, and then with Arrian and Strabo, identifies the Persian draftees of the home guard and of the establishments/colonies of Persians abroad. These troops may have been called Kardaka and initially trained as sparabara archers of the standing army for a 10-year period, and then, when admitted to the citizen class as reserves, they were redelegated as close-quarter battle troopers, bearing body armour. This report by Xenophon and Strabo identifies the elusive Persian cuirassiers serving with Mardonius in Herodotus as the mobilised reserve Persian infantry and elucidates Arrian's of Kardaka, suggesting a massive rearming effort by Darius III to hoplite standards.

KEYWORDS: ACHAEMENID PERSIANS, SPARABARA, TAKABARA, KARDAKA, CUIRASS, AKINAKA.

INTRODUCTION

The Persians recast the already ancient fighting duo of shield-bearer and archer, seen in Mesopotamian illustrations and occasionally mentioned in the Iliad (VIII.266-72), so as to maximize firepower. The Persian version included one shield-bearer (similar to the pavisarii of the Middle Ages) followed by nine archers, in a single file, which provided a deep landing zone for the arrows (Sekunda, 1989). This depth accommodated for errors in aiming and was also excellent for assaulting an enemy deployment in depth, destroying its cohesion. It also insinuates that archery duels were fought with arrows flying at relatively low angles, in direct shooting; else the spara shield would offer but little protection to the rear ranks. The high angle used by the English archers during the Hundred Years' War may not be an accurate paradigm. Xenophon, having fought both against and alongside the Persians, mentions high-angle shooting by Cretan archers as an oddity due to the lack of proper ammunition (Xen Anab III.4,17) and, while corroborating Herodotus on the large size of the Persian bows (Xen Anab III.4,17 and Her VII.61,1), he makes it clear that their range was less than the range of the Rhodian slingers (Xen Anab III.4,16), implying direct shooting.

Moreover, all archers were armed with a spear and sidearm (sabre, dirk, such as the "akinaka", or axe, such as the Scythian "sagaris") as were the shield-bearers; thus, they could all engage in hand-to-hand combat (Raaflaub, 2013); again, the reader of the Iliad can relate (Il XV.466-75). Once the arrows caused casualties and disruption, a violent charge was initiated to destroy the enemy, and this onslaught was performed by all the fielded troops, increasing both the power of the impact and the killing efficiency.

This was the Persian line infantry, called the Sparabara due to the Spara, the long, rectangular leather-and-wicker-made shield of the file leaders. It was very different and much lighter than the (mainly) plank-constructed pavises of the Middle Ages. Other nations of the area, like the Medes, used it or a version of it and, in any case, adopted it under the Persian sovereigns. It is possible that their use of such equipment predated that by the Persians, but this cannot be surmised. In his 7th book, Herodotus describes at least three more national contingents outfitted similarly to the Persians (Her VII.62).

The spara was rectangular and flat, thus providing coverage without any seams and openings, especially when in contact with the other spara of the rank. It was easy to set on the ground, to create a seamless barrier or rather a field fortification from where to shoot in relative safety, without burdening the wielders' hands and interrupting their firing sequence. It was very light, which allowed the wielder high mobility, such as during forced marches, violent charges, manoeuvring at a jog and fast pursuits in the heat of battle. Its beauty was, though, that it was not issued to all troops, but only to the file leaders.

It is unclear whether all troops of such a combined formation were called Sparabara; this issue relates, most probably, to the existence or not of shields for the nine archer-spearmen. Greek pottery shows Persian archers with sabres, with or without a cuirass, but never with a spear. The latter is obviously artistic license; the reliefs of Persepolis show Persian archers in ceremonial dress, with conventional quivers or combined "gorytos" quivers/bow cases, carrying spears and occasionally straight dirks (akinaka). What is a bit more confusing is that Greek pottery shows sabres, or rather cleavers, but the Persian reliefs and Herodotus refer to akinakes dirks (Her VII.61,1). The cuirass might have been issued selectively (Charles 2012). The obvious choice would have been to issue them to the dathapata file leaders of the sparabara who would bear the brunt of close-quarter combat and perhaps missile barrages. Such armour can be identified with the Egyptian style mentioned in Herodotus (Her I.135) and seen in Greek art. Additionally, the other type of cuirass, the iron-scale type (Her VII.61,1), was issued to or otherwise used by cavalry, at the very least by noble cavalrymen (Her IX.22,2), if not by the entire mounted host of Persian stock, and/or by the elusive cuirassiers (Her VIII.113,2), had they have been an infantry unit (Charles, 2012) as suggested in this work. Alternatively, they could be identified with one of the two 1,000-strong infantry royal guard units (Her VII.40-41), most probably the first one (numbered in order of appearance in the narrative of Herodotus), which was made up of commoners, with spear counterweights of a pomegranate shape (Her VII.40,2 & 41,3) and probably recruited on merit from the Immortals (Charles, 2012).

It is also unclear whether the spara-bearing file leader, portrayed with a cuirass or jerkin (obviously the Egyptian style mentioned in Her I.135 made from stuffed linen) on Greek pottery, was an archer as well. The Spara could be solidly planted on the ground, as seen in said pottery, so both hands were free, but only a portion of the abovementioned representations show a bow (but not a quiver) for spara-related troops (Miller, 2006/7). Herodotus (VII.61,1) confusingly endows all Persian national infantry with a full kit of wicker shield of unstated shape and size, a short spear, a long bow hanging from the shoulder (from where it could be brought to notch position with just one move within the left palm), one quiver on the back (for fast drawing of the reed arrows), iron-scale armour and a dirk hanging from the belt to their right side. Herein lies a problem: there is not one image of a Persian with such a full kit, making the description of Herodotus read like the full inventory of the infantry, rather than the standard-issue kit of an infantryman.

The spara was quite a feat of manufacturing, despite its mundane materials, and had a sizeable footprint. The size and form of the spara allowed the formation of a veritable shield wall, as mentioned above, with the file leaders planting their spara one next to the other to create a movable linear field fortification, from which they were entrusted to repulse by spear-thrusts any enemy resilient enough to cross the hail of arrows and assault their shield wall. It should be noted that, contrary to some views, there could be little possibility for more than one spara bearer per dathabam (10-man file). Even less so for an adjustable number of spear bearers according to the tactical situation (Ray 2009). The idea that an array of weapons was available to all soldiers and the selection was made before deployment is impractical for anything but pitched battle, as it denies the ability to deploy promptly after a forced march or in battles by encounter. It might be suggested that all sparabara, all ten warriors of the file, had a spara. This would corroborate with the abovementioned text of Herodotus (Her VII.61,1), and also with texts from Xenophon (Cyr I.2,9) and Strabo (Geog XV.3,19), although this would change the whole concept of the Sparabari as we understand it….

Thus, the Persian armies had multiplied their firepower, as almost all of the (first) line infantry shot bows and then doubled as shock troops (Raaflaub, 2013). The Persians had practically doubled the effective sizes of their armies, and by fielding quite large ones they were really able to cloud the sky with their arrows (Her VII.226). An ethnic Persian boy was taught from the age of 5 until 24 to ride, shoot a bow and speak the truth (Her I.136; Strabo XV.3,18), and then he was required to follow either a military career or be released to civilian life as a reservist, always prone to mobilisation (Xen Cyr I.2,13). There was a slight problem though: the infantry was by far the Persian decisive arm. Xenophon (Cyr I.2,15) estimates that the Persians were approximately 120,000 souls. This however, may mean the portion of the Persian nation that was eligible for conscription and fully enfranchised. The bondsmen/bandaka were the intermediate social stratum, between the slaves/mariaka and the aristocrats/azata (Sekunda, 1992) and accounted for the equivalent of the free citizenry, who were clearly the bulk of the manpower. These could not own a horse and had no military use for it. So how, and, most importantly, why would they need to "learn to ride since childhood"? Most probably, the renowned motto referred to the scions of the Persian nobility, similarly to the slightly more expansive and diversified syllabus of Homeric heroes and medieval knights. It is possible that this kind of training was provided to all enfranchised Persian youths who could afford the public training (i.e., azata and bandaka), possibly under the collective term of Kardaka (see below). The acquisition of a horse could occur during adulthood, due to legitimate gains from any conceivable resources or activities, including, but not limited to, plunder, the spoils of war, granting by the authorities for virtue or courage or nominal purchase or promotion. Thus, the training syllabus followed should have anticipated such possibilities and included basic horsemanship skills learning for all eligible conscripts to better exploit further developments in the career of any of them.

THE PERSIAN INFANTRY IN THE PERSIAN WARS

The long Persian bow, firing a long, hollow arrow shaft (Her VII.61,1) had a good range (Xen Anab III.3,15). The massive firepower practically reduced any need for defensive weaponry, which brought down the cost and increased the flexibility, speed and endurance of the troops. Although Persian troops are regularly mentioned as unarmoured (Her IX.62,3), Herodotus mentions iron-scale cuirasses for the Persian national infantry, possibly implying the first-rank Sparabara (Her VII.61,1) but this may be a mistaken supposition.

In any case, such armour was a quantum leap compared to the bronze-scale panoplies of centuries previous. Moreover, quilted jerkins and equivalents to Greek linothorax models are shown in pottery for imperial troops, the archers and/or sparabara. By any account, the protection afforded by the Persian shield and armour was optimised against arrows, as they were the only actual threat to the Persian war machine, and secondarily against a chance slashing blow in the melee. Still, this picture of both literary and representational evidence is very far from the picture of "naked", fully unarmoured troops explicitly referring to the Persian line infantry and considered a key reason for their defeat in Plataea (Her IX.62,3).

The short spear with the apple-like (or spherical, sensu lato) counterweight (Her VII.41) was more important than usually acknowledged. Short in length, it was useful in congested conditions, such as the melee after a storm of arrows. Its spherical counterweight and short length made its use safer for the rest of the ranks, contrary to the constant danger for the following ranks represented by the butt-spike of the Greek spear. This, usually disregarded, spherical counterweight allowed the user to hold the shaft far towards the back, which allowed the maximisation of the useful length and reach within a given total length, with minimal projection backwards. This feature further enhanced the collective safety and reduced the cumbersomeness of such a weapon. It must be noted that the Greeks had difficulty spearing in congested conditions and preferred spear fights at a distance in set-piece battles and/or on open ground. The Persian spearman, due to his nimbler weapon, could be more mobile in the open and more dexterous in congested conditions, although at the cost of a somewhat reduced reach. Some projections assigned a central grip in an overhead position as the sole technique of using the Persian infantry spear, resulting in limited reach, maybe only 1.4m. Both this conclusion and the notion of fragility due to its smaller shaft diameter (Matthew, 2013) might be due to a misunderstanding that confuses the dual-use palton of the cavalry with the counterweighted infantry spear attested by Herodotus (VII.41,3) and shown in various reliefs. The counterweight allowed, as mentioned before, a very asymmetrical hold, near the rear tip, and also both high and low positions, with the latter offering a longer reach and being reminiscent of the Iklwe of the Zulus under Shaka; the former was the only suitable grasp for use from behind a fully developed spara wall, where spearing over the upper edge of the spara was required.

Moreover, the counterweight allowed a policing function, as a less-than-lethal club for riot control, and an alternative military function: as a lethal club to strike at heads and to break inflexible shields and armour, thus giving the user a dual-use weapon: a battle club with substantial reach paired with the conventional spear. This is, by itself, a noteworthy innovation compared to the armament of the Assyrians in the Army of Xerxes, which included the lance, club and dagger (Her VII.63).

Furthermore, it is as yet unresolved what the Persian spearman-archer would do with his spear when shooting arrows: leaving it lying on the ground would make picking it up somewhat difficult, while the possibility that the sphere allowed it to balance upright should be taken into consideration and tested on different types of surface. Without the butt-spike of the Greek weapons it might have been planted on the ground head-on (Ray, 2009), which would expose its point to damage and rust; but also infest it with soil microbes, adding a septic dimension to any wound.

The sparabara may not have been intended for a defensive main function, meaning to pin down and bleed the enemy, as is commonly projected (Ray, 2009). Their purpose must have been the dispersal and stunning of the enemy. This would allow to tilt sideways or retract by any other means the few light spara, thus enabling a massive egress of the spearmen-archers. The latter would deliver a violent charge with close contact weapons to fragment the enemy by eroding his unity and dissolving his line, very much like the practice of the Roman legionaries some centuries later. Without this in mind, one cannot explain the use of spears barely able to reach a target positioned two ranks ahead by all 10 ranks. Practically, the fighting style of the Persian infantry was very Roman-like, perhaps lacking the same kind of body armour and using the bow instead of the javelin as a missile and the short spear instead of the gladius-type sword for close-quarter combat. (Xen Cyr I.2,9 & 13; Her VII.61,1; Strabo XV.3,19)

The file of ten men was both operational and administrative. It was the administrative unit, but also the standard file of one shield-bearer who led and commanded the file (Dathapatis) and nine, most probably, but not definitely, unshielded archers. All ten men were armed with a spear and sidearm. Thus, the standard file depth of a Persian unit was ten, and to increase the depth for a better defensive function or to adapt to a confined space, the successive deployment of units in consecutive lines was most probably the standard procedure. If a higher echelon was depleted or undermanned, personnel were reassigned and restructured to create full units. For example, a Persian century (Satabam) may be understrength, maybe because some dathaba had been dispatched to other guard/outpost duties and, thus, less than 10 dathaba were present. In mobilization, such dispatches would return from their remote deployment to the base of the unit/Satabam to bring the latter up to strength for expeditionary duty. Still, low manning and casualties could also be reasons for understrength dathaba. Consequently, a Satabam, originally of 100 men in ten Dathaba, if left with 70 men, would disband three of its Dathaba and use the residual manpower to fill the remaining seven Dathaba to full strength (Ray, 2009; Sekunda, 1992). The net result was that understrength units may cover smaller fronts but always had a steady, 10-man deep landing zone for their arrows, when assaulting the enemy.

The decimal organization does not exclude the possibility of a binary tactical division, where in each echelon one half would be under a vice-commander (Xen Cyr II.1,22-6). The 50-strong companies of the Kardaka trainees (Strabo XV.3,18) suggest such a scheme, perhaps from the dathabam (two half-files of 5) to the baivarabam (two commands of 5,000).

With Herodotus there is a tacit question: After the engagement at Plataea, the Imperial Army found refuge in their fortified camp, from where they repelled Spartan assaults. How exactly did they do that? The ready answer is "with their bows and javelins". However, they did not carry many javelins. The cavalry, if the later, 4th century BC practice is taken into consideration, would have been issued with the pair of palton double-purpose spears, one for hurling one for thrusting (see later), and in that day they had just shot all the available ones, and perhaps then some, after rearming at the rear. The infantry had their bows. They were shooting relentlessly and in some cases threw away their bows to revert to sidearms. Thus, many had no arrows, others no bows. If the case made below for the CQB (close-quarters battle) -oriented cuirassiers holds water, and some had no ranged weapons at all, what were they using?

The answer may be "their slings". Roman legionaries are supposed to have had training to this weapon as standard, and use it to repel attacks at their fortified camps. Perhaps due to this knowledge Strabo says that all Kardaka (meaning fully enfranchised draftees) had slings (Strabo XV.3,19). The sling takes no volume and has no weight, thus the vets may have carried it even when they deployed for CQB, with a sidearm and shield, and used it when and if needed, as in hunting. This suggestion is not accepted by Xenophon, who provides some useful details for the tactical use of the sling by the Persians (Xen Anab III.3,17 & 15 & 7) but explicitly mentions the slingers as a specialised branch of the Persian army, not the everyday rank and file (Xen Anab III.3,6 & 4,2). This, of course, may be due to the Greek practice, where nobody knew how to use a sling apart from some Rhodians, serving as Hoplites but having training, skill and knowledge in slinging as a national tradition, sport or customary weapon (Xen Anab III.3,16). Although Xenophon is highly unlikely to have been anything other than perfectly informed on all things Persian (he campaigned with Persians, side-by-side, for a year or so), it is the only plausible explanation, and not entirely unprecedented. It is still a mystery the way the Greek hoplites were expected to fight off their enemies on broken terrain. When in the defensive, how were they able to engage and repel the attackers. They were not trained slingers, and by casting stones and rocks they could not expect to stop hoplites, although it certainly helped. However, a most successful use of stones cast by hand is described (Thuc I.106.1-2) as a peculiarity, a phenomenon due to the very peculiar conditions of the terrain. What were they using in regular conditions, for example how were supposed to engage the attacking enemy the Athenian hoplites serving on and defending the Long Walls of Athens? The spear was useful at the last 2-3 meters. Not taking advantage of the exposed enemy for some tens if not a hundred metres was a waste, considering the investment in fortifications. Perhaps all these points might imply a tacit case for the javelin. All the troops were trained to use it, being the weapon of the hunter as the Greeks had no love for the bow. The insistence of Xenophon for the usefulness of the hunt as training for war (Xen Cyr I.2,10) cannot be explained if the casting of javelins is not considered a skill needed by everybody, hoplites included. The peltasts and other light infantry (and the cavalry from the early 4th century) kept using it even in field action and set-piece battles, where the hoplites would trust their spear. Whether the Persians would make a similar case (Xen Cyr I.2,8), instead of the abovementioned for the sling, remains plausible.

LATER SOURCES

The authority on the Persians is Xenophon, as he fought with and against them and saw and studied them from within. He is occasionally suspected of promoting his own ideas, some stemming from Spartan and others from Athenian practices, projecting them as Persian ones, especially in the semi-fictional Cyropedia. The point is, though, that most feudal/aristocratic societies had, throughout the ages, many things in common and, thus, similarities may be actual and not due to assumptions. For example, the fervently egalitarian Spartans, were equals amongst their peers; their society was strictly stratified and their kings commanded the utmost respect and were assigned divine lineage and honours, although not absolute power, except during wars (Her VI.56-8). This situation is not very different from the Persians': Xerxes did not wage war until after the, more or less biased, approval of the tribal council (Her VII.8). The proceedings of the Macedonian Kingdom were similar: Alexander had to persuade the army to undertake successive campaigns once a set objective was achieved (Arr Anab II.16-7).

Xenophon mentions that the Persian infantry was divided, by age criteria, into a standing and a reserve component (Xen Cyr I.2,13-14). Both components could be used for expeditionary service abroad, and they differed in both tactical employment and equipment. This differed from 5th century Greek practice but was similar to that of the Romans (Connolly 1981). The Greeks in the 4th century did differentiate, in terms of tactics, their infantry by age, but the basic equipment was that of the hoplite, minus the body armour. These lighter hoplites were the mobile Ekdromoi, the younger hoplites that assumed mobile tactics (Xen Hell IV.5,14-6). But in essence the Ekdromoi were able (and expected) to fight as the veterans did, in a phalanx. The non-phalanx infantry was not selected due to age, but to social status (Hanson, 1983).

Thus, Xenophon directly states that the Persian national infantry differentiated its armament according to its active or reserve status: the former were archers, the latter assault troops armed with hand-to-hand weaponry and issued with cuirasses (Xen Cyr I.2,13). Thus two major issues in Herodotus are resolved immediately: the first is the identity of the cuirassiers that Mardonius selected to remain with his host for the 479 BC campaign. They were the veteran Persians of the infantry, and not some cavalry regiment, as supposed based on the explicit mention of the cuirass of the cavalry commander Masistius in Plataea (Hdt IX.2), in the context of a 422 BC catalogue of cavalry equipment and on the explicit mention by Herodotus that the Persian infantry engaging the Spartans had no armour (Her IX.63,2). This common interpretation implies that there was Persian cavalry without body armor, something unsupported by evidence (including, but not restricted to, the abovementioned catalogue) and very unlikely due to their feudal status.

The second is the battle order of the Persians in successive lines, as realised by Mardonius (Her IX.31,2). It was simply two different lines of two different troop types. The younger troops, forming the standing army, were bow-armed sparabara (Sekunda, 1992). The veterans may well have been the takabara (ibid.), but this will be discussed later.

Another issue in Herodotus is the apparent incompatibility of his statement regarding the Persian infantry equipment in the invasion force (Her VII.61,1), where a bow, arrows, a spear, a sidearm, a shield and armour (cuirass) are mentioned, while the explicit description of said infantry in Plataea was unarmoured.

The first passage obviously refers not to the infantry equipment, but to the entire infantry arsenal in an aggregated manner. In this light, the latter passage refers to the mass of sparabara impacted by the Spartan phalanx once their arrow barrage had been defeated and their spara wall overcome. These troops, if caught before being exchanged with the posterior units, as was the legionary SOP, would have been slaughtered, given their disadvantage without protective armour.

There is an issue with the secondary equipment. The interpretation followed here accounts for the spara shields, carried by the commanders of the 10-man file, the dathabam. The spara protected the file from arrows and other missile exchanges. However, this leaves open the issue of individual shields for the rank and file for use in more contested conditions, as in the assault after the archers' barrage. Herodotus implies that the Persian archers were equipped with some sort of close-quarter weapons (Her IX.62,1) as secondary arms, but this is all. Shields are not mentioned. By the same token, the veterans are explicitly mentioned by Xenophon to bear armour and close-contact weapons (Xen Cyr I.2,13), but the examples he provides are limited to shields, axes, and sabres, plus a very clear but not helpful mention regarding equipment depicted in contemporary art. Whether spears were issued remains contentious. It is confusing that he insists, as does Strabo (Strabo XV.3,18-19), on the issue of a pair of dual-use spears (palta), while ceremonial and artistic depictions from Persia and Greece show counterweighted thrusting spears for somekind of-infantry, corroborating Herodotus (Her VII.41,3).

Greek art is mentioned by Xenophon and should, at this point, be brought into the discussion. Achaemenid troops are occasionally shown with cuirasses, axes, sabres, small scalloped shields or body shields. Initially, the Greek artists would have had witnessed live Persians themselves, or at least the equipment taken as booty, but eventually, pottery copies might have become a product of higher volume and lower fidelity. Patterns may have been created by different workshops and applied massively. Thus, some types of cuirasses could have been depicted whenever an armoured figure was needed, Greek, Persian, Amazon or whatever. This would explain the use of Greek type linen corselets, complete with Greek symbols, by Achaemenid troops, instead of the iron-scale type mentioned by Herodotus (Her VII.61,1) and Strabo (Strabo XV.3,19), although in later years the acquisition of weaponry, especially some specific items, did find their way across the borders, as in the case of the army of Cyrus the Younger (Xen Anab I.8,7). Whether Persian infantry with scalloped shields, and spears, obviously Takabara, may be identified with Xenophon's Persian veterans is a valid question, whenever cuirasses and sidearms are not shown. When they are shown, the identification may be considered secure. The file leaders of the sparabara could well have been issued with body armour as well, and there are such representations with a corselet being interpretable either as a scaled/lamellar version of a linothorax, or as a genuine linothorax, or as a padded jerkin made from some type of soft material. Oblong spara bearing troopers armed with bows, spears and sabres/ cleavers are often depicted in Greek art (Miller 2006/7)

Herodotus mentions nothing about javelins as a weapon of the Persian infantry, but seems to consider it having been issued to cavalry only, and as their main weapon at that (Her VII.61,1 & IX.17,3). Both imperial and Greek representations support this view, clearly showing spears, not javelins. The spherical, apple-like counterweights in imperial representations indeed imply spears, not javelins, for two reasons: the obvious one is that they would weigh down a missile, reducing its range and upsetting its balance. The less obvious reason is that they are immensely useful for spears as already mentioned. They allow a longer reach by balancing it when held near the back end, thus increasing the useful length of the shaft. The spherical counterweight also allows the weapon to be used as a crushing instrument, reversed as a mace, or held in two hands, like a fighting shaft in oriental martial arts. Even in Xenophon it is not clear whether the javelin was among the weapons of the standing army; it is clear that it was not used by the veterans.

Greek art shows Achaemenid troops with a spear or sidearm and a small shield. These are usually identified as takabara, and it has been suggested (Sekunda, 1992) that these were garrison troops rather than expeditionary troops. This might have been the case, but it is just as possible that these were the veterans mentioned by Xenophon and were encountered more often when the Greeks took the offensive, possibly deprived of the support of expeditionary elements if the aggressors launched surprise attacks. The cuirass may have been carried over or under the garment (Her IX.22,2). It is debatable whether double-scalloped shields in Achaemenid representations of spearmen suggests takabara and/or veterans (if the two are not the same). Another interpretation is that these are one of the two guard units (Her VII.40-1), with the other one being represented without shields, actually with spears only.

Successive baivaraba: a blunder or a tactical improvisation?

The area of impact of arrows shot by a baivaraba must have been roughly equal to its own depth, i.e., the depth of the dathabam, nearly 10-15 metres, which is double the depth of a standard hoplite phalanx. A hoplite phalanx running could cover that distance in 5-10 seconds, which means that it would be impacted by two arrows per archer before its motion makes necessary a correction of the aiming. A deployment based on successive baivaraba, if these were all made of sparabara, which is debatable as already mentioned, means that this zone would be made deeper, perhaps proportionately, which would also allow the target to remain for longer within the landing zone of the arrows without any aim correction being required. The preceding baivarabam, thus, would have time to correct its aim and adjust for distance while the target is pounded by the following baivarabam. In this way, the target, although running fast, would be kept under a continuous hail of arrows. Alternatively, when the quivers were empty, a baivarabam posted to the rear could slide through the ranks to the front (or a front one slide into the rear), to allow the rear one to emerge, so as to present the enemy with constant fire and a deep magazine, reducing any notion of vulnerability due to spending all the arrows of a quiver. Nonetheless, this is a hypothesis based on an all -sparabara contingent. If the second echelon were takabara, or the CQB-oriented Persian veterans, endowed with armour, they could well slide into position to take the brunt of the Greek onslaught with their better CQB-oriented equipment (Xen Cyr I.2,13).

KARDAKA: A REAPPRAISAL

The difference in equipment between the expeditionary and the reserve parts of the Persian national conscription (Xen Cyrop I.2,13-14) might be evident more than anywhere else during the reign of Darius III. In the battle of Gaugamela, there were no masses of sparabara, nor storms of arrows. A backward, pastoralist tribal unit of Persis, the Mardians (Her I.125,4), are explicitly stated to have beeen archers in the Acahaemenid deployment at Gaugamela (Arr Anab III.11,5), as if to underline that the other Persian infantry were not.

Actually, Arrian in Issus mentions two wings of 30,000 Kardaka each, describing them as hoplites and totalling 60,000 (Arr Anab II.8,6). The number is reminiscent of the extrapolated Achaemenid corps strength as described by Herodotus (Her IX.96,2 &VIII.126,1)and could well imply a common drafting area; Persis should be understood, due to their elite status, as being posted on the flanks of] the invaluable Greek mercenaries (Arr Anab II.8,6).

Thus, Arrian should be understood as mentioning Kardaka outfitted as hoplites, not Kardaka being (by definition) Barbarian hoplites. What the herodotean term was for such troops is elusive and would have shed light to their identity; the suffix –ka means man, generally a human subject (see amrtaka, bandaka, mariaka) but not trooper, which is –bara (artsibara, sparabara, takabara). With Strabo (XV.3,18) this is indeed the case and the meaning is looter, robber or manly one, possibly a wrong interpretation. Arrian might refer to some effort of the known military innovator Darius III, who issued enhanced offensive arms (Diod XVII.53,1) and fielded scythed chariots extensively (Arr Anab III.11,6-7; Diod XVII.53,1-2), along with elephants (Arr Anab III.11,6), to recast the Persian national infantry in a hoplite form (Charles 2012; Bosworth 1980), so as to follow the most successful paradigm of the day, that of his Greek mercenaries and "frenemies".

Whether the mercenary commander Charidemus of Athens was behind this rebooting is anyone's guess. His insistence to lead a campaign against Alexander with a specially raised army (Diod XVII.30,3), not a regularly drafted one, shows some anxiety over the selection, training and abilities of troops and perhaps a concern and pressing need to test his creation, which would have been heavily criticised, at the very least, by Persian aristocracy. His anxiety was so acute that it cost him his life, and the Persians their empire (Diod XVII.30,4-5). The Achaemenid deployment at Issus, with a first line of 90,000 heavy infantry, a third of which were Greek mercenaries (Arr Anab II.8,6) sounds suspiciously like the proposal of Charidemus (Diod XVII.30,3), with the 10,000 balance probably being cavalry in the Greek 1:10 cavalry to infantry ratio..

If indeed the Kardaka were the Persian troops mobilised for expeditions out of Persis (Xen I.2,9 & 13), the militia (Xen I.2,14) must have been left with the standard kit (Xen I.2,13). These were the 40,000 infantry troops mobilised by Ariobarzanes to defend the Persian Gates (Arr Anab III.18,2). The division of a national levy into two parts, with the younger part, the active army, being rebooted and outfitted with new gear while the rest, the veterans/reserves being left with the traditional outfit, has a historic parallel. It may be detected in the Antigonid creation of Romanised infantry out of their active army phalanx units (Sekunda, 1994, Polyb XXX.25,3). The whole idea of the Romanisation may have been a misunderstanding (Van Wees, 1997), with the objective not to introduce/produce a local version of the legionaries, but rather to develop a tactically flexible medium infantry type, the Thorakites troops of the era (Beston, 2002). The change, though, irrespective of its specifics, must have included only the active army component and not the reserves. Other cases of massive re-equipping, such as the Romans becoming hoplites and then manipularii (Diod. XXIII.2,1), include the Achaean confederates turning from hoplites (Paus IX.22,6) to thyreophoroi light infantry and then to fully armoured pikemen (Plut Phil 9,1-2) and the Lacedaimonians becoming pikemen (Plut Cleom 11,2) and are well attested, but whether the change referred to the whole levy or just to active units cannot be safely deduced; the whole levy is implied in all these cases, especially ex silencio.

If Xenophon's testimony and that of Strabo are combined, they produce a coherent picture: the

Persian males were divided by age into children from 5 or 7 to 16, youth to 25, grown men to 50, and elders over 50 (Xen Cyr I.2,4 & 8 & 13). The elders make up the militia and do not campaign abroad. When the Persian youths are mentioned they are only the enfranchised part of the male society, which graduated from the public education system (Xen Cyr I.2,15), and they qualified for leadership positions (Xen Cyr I.2,13). They served from 16 to 25 as the expeditionary, standing part of the Persian army (Xen Cyr I.2,12) - the Spartan counterparts served from 20 to 30. It is this part of the citizen body that must have been the Kardaka, as the translation by Strabo (XV.3.18) means anything from warriors to yeomen, while any association to the word Kara, the Persian conscript army (possibly its standing part but conceivably the full force), is for linguists to prove or reject. If the association exists then Kardaka (Strabo XV.3,18) were the members of the Kara, and this means soldiers. According to the meaning of the Kara, the standing or the full force, the Kardaka were the ones serving at any given time, (Strabo XV.3.18); originally outfitted as sparabara, at Issus as hoplites. If Kara implies the full force (Strabo XV.3.19), the Kardaka were outfitted with two different suites of weapons i.e. as Sparabara and as Takabara (Charles 2012), as described for youths and men by Xenophon (Xen Cyr I.2,9 & 13 respectively), rather than the obviously all-inclusive detailing of weaponry by Strabo (XV.3,19). The latter concept, based on the full force would fit their massive numbers in the works of Nepos (Datames 8.1, 100,000 Kardaka) and Arrian (Anab II.8,6 mentioning 60,000 Kardaka). The 60,000, as mentioned by Arrian, equals half the total number of the enfranchised Persians given by Xenophon (Xen Cyr I.2,15), that is 120,000. This relationship corroborates the practice of mobilizing only half the available force for a task (Xen Cyr I.2,9).

It is unclear what happened with the disenfranchised youths, who had no means of sustenance to graduate from public education (Xen Cyr I.2,15). One would expect that these would have been few in number as Persia became an empire, but in Sparta the Imperium drove more people to a disenfranchised status.

Given that Kardaka refers to both the cavalry and infantry draft (Strabo XV.3,19), it is not a troop type. It is a term for a socio-military classification, before and beyond any assignment of particular arms. Thus, when it is found in our sources it perhaps indicates a lacuna in the source's knowledge of the troop type, perhaps in a transient period or a period of experimentation. Whether the Kardaka of Datames were sparabara, takabara or Iphicrateans, archers, javelinists, lancers/pikemen/spearmen or any other troop type is impossible to conclude. What is very obvious, though, is that although Xenophon's account refers to the proceedings of a royal city (Xen Cyr I.2,9), this is not so; it applied in other parts of the realm, where the highest authority was not the king, at least not for the control of routine functions (Xen Cyr I.2,5). The same social mechanics applied in different cities both in Persia and in the Persian colonies located in different satrapies, where the layout of the Persian administration would have been established, as the highest authority was the king or the satrap (Strabo XV.3,18). In the latter case, land ownership for the Persians would have been at the expense of the defeated, (Her VI.20); for example, the Persians defending Sardis after the surprise of the insurgents' advance took them unawares (Her V.100-101), must have been of this category.

Last, but not least, Xenophon (Cyr I.2,8-9) and Strabo (XV.3,18) do not agree with Herodotus in one most important issue: the javelin, at least for the infantry. In Herodotus, javelins are the main (perhaps not the only) weapon of the Asabari cavalrymen. The infantry had short spears, and there is no mention of casting them. Xenophon and Strabo both agree that the equipment of the Kardaka (in the latter) and of the standing army/Kardaka (in the former) includes the javelin and that it was used regularly. Moreover, a pair of javelins were used as the cavalry palta, one for hurling, the other for thrusting. There is no mention of one spear, as is implied in Herodotus and seen in the representations. Either the infantry equipment had been changed, with the palton replacing the short spear, or the use of the palta was a part of the training applicable to cavalry service (Strabo XV.3,18) while being part of the syllabus of both arms. It must be noted that in Arrian and Xenophon the Persian cavalry does not use bows, they fight with palta and sidearms.

Similarly, the representations and Herodotus corroborate each other in the matter of counterweighted spears that could not be used as javelins. However, there is not one mention in Herodotus that suggests that regular infantry spears, like those of the Persian national contingent (her VII.61), were counterweighted. They were short, but the counterweight might have been a privilege of the elite units due to its peculiar tactical use, as already mentioned.

CONCLUSIONS

The ethnic Persians, in their homeland or when living in occupied territories, had a standardised public education system that produced fine soldiers and aristocrats, a landed warrior caste. Due to their conquests, few back home had want of means to undergo this formal training, similar to the Spartan agoge. The trainees and graduates were called Kardaka. They were sparabara during the Persian Wars and for their mandatory 10-year service as a standing army. Then they moved to the reserves and, when mobilised, they were deployed (as Takabara?) for close-quarter combat, with a shield, sidearm and body armour; this refers to the infantry. The cavalry, perhaps drawn from the aristocracy, underwent the same basic training, and riding was in the syllabus for everybody. An infantryman might get rich and be promoted to the cavalry in the course of war and conquest.

The expeditionary quotum of the standing army was 50%, contrary to the Spartan 2/3 of the total force. The veterans were liable for mobilisation for expeditions abroad, but the quotum is not mentioned. The reserves, not liable to be mobilised to campaign abroad ("abroad" being very relative in a vast empire) are not further discussed in our sources neither regarding their outfit nor in any other function.

The Kardaka were perhaps recast to hoplite standard by Darius III. The date is unknown, but they were deployed with hoplite equipment in 333 BC, at Issus, where their performance was substandard. Whether the veterans that valiantly defended the Persian Gates the following year, the last line of defence of Persis against Alexander, had been outfitted as hoplites as well is unknown; though they must have been the elders (militia) of the Persian system, trained during their tour of duty as Kardaka in the old ways and, thus, making hoplites of them would have been a bad idea and one that was most probably not pursued.

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REZIME

NOVI POGLED NA PERSIJSKU PEŠADIJU U VOJSCI AHEMENIDA

KLJUČNE REČI: AHEMENIDSKI PERSIJANCI, SPARABARA, TAKABARA, KARDAKA, OKLOP, AKINAKA

Forma i funkcija etničke persijske pešadije iz perioda Persijskih ratova slabo su istražene teme, iako postoje mnogi aspekti koje su brojni autori ispravno identifikovali. Stereotipi, preterana upotreba Okamove britve i izrazito odbijanje da se uklope podaci iz izvora koji su manje od stotinu godina udaljeni, posledica su prećutnog izgovora da bi to moglo izazvati promene i nova preslaganja. Kombinovanje Ksenofontovog izveštaja sa Herodotovim, a potom sa Arijanovim i Strabonovim, omogućava da se identifikuju persijski regruti iz redova rezervnih snaga dobrovoljaca iz naseobina/kolonija Persijanaca van matične zemlje; za ove trupe se možda koristio naziv kardaka i isprva su bili obučavani kao strelci sparabare za stajaću vojsku, za period od deset godina, da bi potom, nakon što su bili primljeni u redove građanske klase kao rezervisti, bili preusmereni na borbu prsa u prsa, noseći oklop. Ovi Ksenofontovi i Strabonovi izveštaji identifikuju neuhvatljive persijske kirasire koji su služili pod Mardonijem kod Herodota kao mobilisana rezerva persijske pešadije i razjašnjavaju Arijanovu napomenu koja sugeriše da je Darije III uložio ogroman napor da ponovo naoruža redove hoplita.

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A UNIQUE REPRESENTATION OF HERCULES DISCOVERED AT APULUM

ABSTRACT

The material presents a currently unique piece among finds from the former Roman province of Dacia. On the occasion of archaeological research for a real estate project, a clay lamp with the disc decorated in relief was discovered among other archaeological materials. The setting, preserved fragmentarily, renders the scene of one of the labours of Hercules, the third, the capture of the deer of the goddess Artemis. The artefact is manufactured from clay, modelled in a bivalve pattern and represents an import to Apulum. It was discovered in an early context, probably brought by the colonists who settled here after the establishment of the Roman province.

KEYWORDS: LAMP, APULUM, LABOURS OF HERCULES.

INTRODUCTION

The Roman site of Apulum, a veritable Roman conurbation in the province of Dacia, includes, besides the two urban centres at a distance of up to three km, the praetorium consularis and the camp of the XIII Gemina Legion, five distinct burial areas, arranged along the main communication pathways of the era. Preventive research occasioned by the development of the present city have revealed in recent years both archaeological structures that provide a coherent image of the ancient urban development, and heritage pieces with documentary value, some of them with a unique character.

The discovery to which we will refer below was made in the Partoș neighbourhood from Alba Iulia, Gemenilor Street, no number, during preventive archaeological research determined by the construction of an estate (Fig. 1). The research, still unpublished, led to the discovery of some traces from removed walls, corresponding to the urban phases of development, but also to an early level of a habitation with traces of wooden walls[1]. The archaeological material discovered was mainly ceramic, comprising the entire typological range of household dishes, but also fragments of luxury dishes - terra sigillata.

DISCUSSION

A lamp with the disc decorated in relief attracts attention from among the common usage pieces discovered. The piece was in a fragmentary condition, being glued and completed upon restoration. It comes from the early levels of habitation, from the same context from which a Cociș 19a1-type fibula (Bounegru *et alii* 2011, no cat. 229) also came.

The lamp belongs to the type with volutes and a rounded beak (Fig. 3). The border has a circularly arranged pearl ornament on the outside. The decor of the disc depicts a scene in which a bearded character holds a herbivore in his left hand by the muzzle while pulling its head back, while his right arm is raised. He is pressing the back of the animal with his left leg, which is bent at the knee. The animal, seen in profile, is a deer or roe deer, it is quite difficult to distinguish the forked ear and horn on the right side. Although fragmentary, the image retains a defining attribute for the interpretation of the character: under the right arm is depicted a club. The tank is hemispherical in profile,

1 Considering the topography of the first urban settlement at Apulum, our research concerns its eastern area.

Fig. 1 Map of Apulum with the location of the discovery marked.

Fig. 2 Oil lamp discovered at Carthage, apud Deneauve 1969.

supported on an annular base. Two small holes eccentrically located on the right side are preserved on the disk. An insertion orifice is also preserved on the beak. It has an overhanging, circular ear with a central groove.

Dimensions: length-15 cm, disc diameter – 10.4 cm, H. basin - 3.2 cm.

The tank is made of fine paste, and covered with a scarlet-coloured slipware. The beak and one of the sides show traces of functional wear. The artefact is a provincial import. The accuracy of detail indicates the use of a pattern copied from an original piece. The handle has two asymmetrical edges, and is crookedly glued to the tank.

The depicted scene represents the third labour of Hercules, the capture of the deer of Kerineya. Hercules seems to have on his head an *exuvia leonis*, while the club is positioned separately. According to mythology, the hero was required to catch the golden-horned deer of the goddess Artemis without hurting it, as this would upset her. After chasing it for a year he catches it on the plains of Arcadia without harming it. The labours of Hercules are a favourite theme in imperial art, with different forms of representation, especially on monuments,[2] but also on ceramics or on the discs of some Roman lamps.

In Vindonissa the discs of the published lamps illustrate a diverse iconography, several featuring the image of Hercules (Löeschcke 1919 cat. 49, 50, 71, 394). Several pieces decorated with the head of Hercules or Hercules' mask on an altar were discovered at Viminacium (Korać 2018, 613, 615).

In 1983 C. L. Băluță indexed all the oil lamps from intra-Carpathian Dacia. Studying the paper, preserved only as a manuscript, we noted that there are no pieces with iconographic representations related to Hercules or his labours. Later, in 1994, D. Alicu analysed typologically and stylistically the lamps originating in the research of Ulpia Traiana, the de jure capital the province. He mentions five representations of Hercules on the disc of some type I lamps (Alicu 1994, 42; cat 14-18). However, the iconographic composition is a simple, frequent one (Löeschcke 1919, pl. IV, 49;

2 For the representations on the monuments in Dacia, see Bărbulescu, Nemeş 1975, Bărbulescu 1977 and Bărbulescu 1978.

Fig. 3 Oil lamp discovered at Apulum.

Iványi 1935, pl. V, 10), Hercules sitting on a throne with a club in the front, without any reference to his labours. Representations of Hercules are also not usually found in the former province of Dacia Porolissensis,[3] which gives the piece from Apulum a special status.

Lamps decorated with scenes from the mythology of Hercules have been discovered in several provinces of the Empire. Several of the labours of Hercules have been found in Vindonissa since the beginning of the last century. The ninth labour, the battle with Hippolyte, queen of the Amazons, to obtain her belt, is illustrated on the disk of a Löeschcke IV-type lamp (Löeschcke 1919, 393, Abb. 29). The second labour, the killing of the Hydra of Lerna, is displayed on the disc of another lamp (Löeschcke 1919, 394). The same iconographic scene is found on a piece discovered in Cyprus (Oziol 1977, cat. 455, pl. 24). The hero fights Hydra dressed in a lion's fur, hitting her with the club he holds above his head in his right hand. In his left hand he has two arrows, and next to him is the bow with two additional arrows.

3 See: Roman 2006.

The disc of a lamp discovered in Germannia displays the sixth labour, the fight against the Stymphalian bird.[4] Hercules shoots a bow using arrows poisoned with Hydra's blood.

Several Italic lamps with a disk decorated with the image of Hercules are also present in the British Museum collection (Bailey 1980, 32-35). Of these, four present iconographic compositions representing the theft of apples from the garden of the Hesperides and the fight with the Stymphalian birds.

Another labour is presented in the collection of pieces from Carthage, in the necropolis of Bordj Djerdid, namely the struggle with the serpent in the garden of the Hesperides (Fig. 2). The only analogy with our artefact also comes from this site. On a Löeschcke VIII-type lamp from this site, with a border decorated with vegetal decor, we find an identical scene. Hercules grabs the deer by the horns with both arms, pulling its head back, while with his left knee he presses the animal to the ground (Deneauve 1969, 197, cat. 939, pl. LXXXV). Behind it, in the secondary plan, the club is depicted. The animal is better defined than on the Apulum artefact, having prominent horns and a well-defined mane.

CONCLUSIONS

Even though clay lamps are a frequent category in Roman-era finds, given the low purchase value they had and the large quantity in which they were produced, and the fact that most of them were locally manufactured. At Apulum there are many imported pieces, mostly Pannonian copies, which are distinguishable by the accuracy of the details or by the different quality of the paste or the applied slipware. They arrived as a result of commerce and were obviously a step-up, primarily in terms of quality, from the local production. Decorated lamps from Apulum are not numerous and mythological scenes are rare. The head of the Gorgon Medusa appears on two discs from lamps, one discovered in the area of the canabae (DAU 2008, 74) and the other east of the Municipium Aurelium. A third lamp shows a scene commonly found on these types of artefacts, that in which Zeus, transformed into a swan, seduces Leda (Ota 2009, 462).

The lamp presented by us is included in this set of decorated pieces that arrived in Apulum as imports, supplementing the local production. Its dating in an early context places it in the pre-municipal period of Apulum, being probably a piece brought directly by the population who settled here. In conclusion, we can state that our piece is, to date, the only lamp decorated with the works of Hercules known from the former Roman province of Dacia.

ACKNOWLEDGEMENTS

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REZIME

PREDSTAVA HERKULA IZ APULUMA

KLJUČNE REČI: LAMPA, APULUM, HERKULOVI ZADACI

Predstavljeni materijal jedinstven je među nalazima iz rimske provincije Dakije otkrivenim do sada. Tokom arheoloških istraživanja, pokrenutih zbog građevinskog projekta, glinena lampa sa diskom ukrašenim reljefom nađena je među ostalim arheološkim materijalom. Dekoracija, fragmentarno sačuvana, prikazuje scenu iz jednog od Herkulovih zadataka, konkretno, trećeg – hvatanje košute boginje Artemide. Artefakt je izrađen od gline, sa šarom u obliku školjke, i predstavlja uvoz u *Apulum*. Pronađen je u ranom kontekstu, verovatno su ga doneli kolonisti koji su se naselili ovde nakon zasnivanje ove rimske provincije.

* * *

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MONETARY CIRCULATION OF LATE ANTIQUE NAISSUS

ABSTRACT

The subject of the paper is the analysis of the monetary movements of late antique Naissus. The research is limited to the period from the end of the 3rd to the middle of the 5th century. The numismatic material comes from 13 locations, from the sites: Mediana, King Milan Square and Liberation Square, Niš fortress and Gradsko Polje, Jagodin Mala necropolis, Gorča, Ambasador, Obrenovićeva Street, and Vuk Karadžić elementary school. The mentioned localities are positioned both in the urban city centre and on its outskirts. Also, the context of the found coinage is different and diverse, coming from the city necropolis, hoards, the fortress, a residential villa, etc. Such a rich sample provides a detailed and comprehensive insight into the monetary movements of late antique Naissus and a good sample for comparison with sites in neighbouring provinces (Dacia Ripensis and Moesia Prima).

KEYWORDS: NUMISMATICS, NAISSUS, LATE ANTIQUITY, COINS, MONETARY CIRCULATION.

INTRODUCTION

Ancient *Naissus* was formed in the Nišava river valley and is known as the birthplace of the Roman emperor Constantine the Great. It represented an important crossroads of military and trade routes that led throughout the Roman Empire (Petrović 1979: 37; Vasić 2008: 9). The city experienced its economic and political prosperity at the end of the 3rd and the beginning of the 4th century. The most archaeologically researched parts of *Naissus* belong to this period, located within the city ramparts (the forum with the civil basilica, the main city street, and parts of the impressive villa with the octagon on Gradsko Polje). *Extra muros*, the researched sites included a residential villa on *Mediana*, public baths, smaller necropolises on the left bank of Nišava, as well as the main city necropolis on Jagodin Mala, which began to form and expand in Late Antiquity (Jeremić 2014: 8). It is particularly significant to discover the monetary flow in *Naissus* in the turbulent period of Late Antiquity, when the city reached its heyday during the reign of Constantine the Great and his successors and collapsed as a result of the Hunnic invasion.

In order to gain a complete picture of the monetary flow of late antique *Naissus*, the research included all processed coins from 13 locations, from the city centre and from the outskirts of the city. The chronological range is limited to the period from the end of the 3rd to the middle of the 5th century, i.e., the moment when the city was devastated by the Hun invasion. All coinage is divided into two categories based on the context in which it was found: group and individual finds (Map 1).

Group finds of coins include units such as hoards and safes in which coinage was successively collected. This type of find is significant because it gives us a picture of the monetary circulation over a certain period of time. The coins found on Liberation Square and Obrenovićeva Street, on Gradsko Polje, Vuk Karadžić elementary school, part of the "Maćedonci" hoard, and the hoard from *Mediana* fall under this category. (Table 1).

Square Oslobođenja			
Period	Pcs.	Mint	Pcs.
317-320	1	Aquileia	2
320-321	3	Alexandria	1
321	2	Antiochia	5
321-323	1	Arelate	2
323-324	1	Heraclea	36
324	3	Cyzicus	39
324-327	2	Constantinopolis	17
324-330	53	Nicomedia	14
326-330	1	Roma	2
330-335	129	Siscia	25
330-337	18	Thessalonica	66
334-335	1	Ticinum	2
		Treveri	1
Total:			215

Maćedonci (part of hoard)			
Period	Pcs.	Mint	Pcs.
341-346	3	Alexandria	7
351-354	5	Antiochia	1
355-361	34	Heraclea	1
364-365	4	Constantinopolis	3
364-367	304	Roma	19
364-375	9	Siscia	356
367-375	348	Thessalonica	341
367-378	7		
368-378	1		
375-378	9		
Total:			728

Obrenovićeva			
Period	Pcs.	Mint	Pcs.
294	2	Aquileia	8
295	4	Alexandria	20
295-296	5	Antiochia	4
296	1	Heraclea	49
296-297	8	Carthago	2
297-298	6	Nicomedia	10
297-299	7	Roma	3
298-299	3	Serdica	11
299	1	Siscia	9
299-300	1	Thessalonica	41
299-303	2	Ticinum	5
300	5		
300-301	4		
301	1		
302	3		
302-303	7		
303-305	2		
303/4-305	2		
304-305	13		
305-306	15		
305-307	1		
306-307	1		
307	1		
307-308	2		
308	1		
308-309	14		
308-310	39		
309-310	8		
310	16		
310-311	2		
311	1		
?	3		
Total:			181

Gradsko polje			
Period	Pcs.	Mint	Pcs.
312-313.	1	Cyzicus	1
312-320.	2	Siscia	11
318-319.	7	Thessalonica	18
319.	14		
321-324.	2		
325-326.	1		
326-327.	2		
328-329.	1		
Total:			30

Mediana			
Period	Pcs.	Mint	Pcs.
330-335.	2	Aquileia	5
335-341.	1	Alexandria	3
337-341.	2	Antiochia	1
341-346.	8	Arelate	2
351-361.	4	Heraclea	8
355-360.	1	Cyzicus	34
355-361.	9	Constantinopolis	17
364-365.	1	Nicomedia	9
364-367.	5	Roma	3
367-375.	25	Siscia	8
375-378.	1	Thessalonica	26
378-383.	3		
383.	18		
383-387.	1		
383-392.	57		
383-395.	14		
383-408.	9		
387-388.	2		
388-395.	1		
388-402.	4		
393-395.	7		
394-402.	1		
395-408.	2		
425-450.	1		
Total:			179

Primary school Vuk Karadžić			
Period	Pcs.	Mint	Pcs.
257-259.	1	Aquileia	1
295-299.	1	Antiochia	1
308-310.	1	Arelate	3
312.	5	Cyzicus	1
312-313.	4	Mediolanum	1
313.	32	Nicomedia	2
313-315.	3	Roma	10
314.	5	Siscia	38
314-315.	2	Thessalonica	6
315-316.	2	Ticinum	1
319.	3	Treveri	1
337-341.	1		
346-350.	2		
361-363.	2		
?	3		
Total:			67

Table 1 - Composition of group finds from the territory of Late antique Naissus

Map 1 - Mapped sites from the territory of Late antique Naissus (Tags: Marija Jović on @ GIS portal Gradske uprave Niš, https://gis.ni.rs/smartPortal/gunisPublic)

The hoard from Liberation Square was found during construction works in 1961, in the immediate vicinity of the ancient wall. It contains 215 coins dated from 317 to 334/5 (Janković Mihaldžić 2000: 37). The find from Obrenovićeva Street was discovered in 1936 and includes 181 folles from a short and homogeneous period from 294 to 311 AD (Janković Mihaldžić 1986: 25). The coins from Gradsko Polje were gifted to the National Museum in Niš in 1962, when 30 bronze coins, which are assumed to be from the city's necropolis, were handed over to the museum. Although there are few coins, the material composition is homogeneous and belongs to the short time span of 312/3 until 328/9 (Janković Mihaldžić 2002: 15, 17). At the end of 1959, during the foundation digging for the construction of the Vuk Karadžić elementary school in Niš, 67 pieces of Roman coins were found. Nominals can be classified chronologically from the sixth decade of the 3rd century to the seventh decade of the 4th century. Most of the specimens are bronze coins from the Tetrarchy period and one silver coin belonging to the Gallienus mint (257-259) (Janković Mihaldžić 2003: 23). The hoard from Mećedonac was discovered in 1944, at the "Strana" site. The hoard contains 3,971 well-preserved Roman bronze coins dating from Constantine I to Gratian (Janković Mihaldžić 2005: 54). This work covers the processed part of the hoard, which contains 728 coins[1]. During the archaeological research in *Mediana*, in 1961, a group find of coins was discovered in the horreum. It contained 227 specimens, of which 179 pieces were chronologically determined. The time distribution of minting spans the years 330/5 to 421/50 (Janković Mihaldžić 2008: 77; Јанковић Михалџић 2005: 54) (Table 1).

The category of individual finds includes coinage that was discovered during archaeological research, mostly stratified, as well as specimens that became part of museum collections through purchase. The analysis of individual finds of coins provides data on the volume of circulation over a long period of time. This category includes coins found during archaeological research in *Mediana*, King Milan Square, Jagodin Mala, in the premises of the "Ambasador" hotel, the "Gorča" business centre, and coinage from the numismatic collection of the National Museum in Niš (Table 2).

During previous archaeological research in *Mediana* from 1961 to 2011, 1,653 examples of Roman coins were discovered, of which 1,347 were precisely chronologically determined and date from 76 to 450 AD (Vasić 2021: 77; Janković Mihaldžić 2008: 34). The coins from the core of the late antique city of *Naissus* are also included, found during the research of the baths in the Niš fortress, comprising 399 specimens, dated to the period from 310 to 491 AD.[2] Part of the material consists of coins from the suburbs of late antique *Naissus*, obtained from the research of King Milan Square (19 pieces), carried out in 1990-1991 (Jović 2021: 104). Also, four coins discovered next to a brick built grave in the basement of the "Ambasador" hotel and two specimens found during the

1 On this occasion, I would like to thank Vesna Crnoglavac, the current director and advisor of the National Museum in Niš, for the provided data.

2 I owe a great deal of gratitude to Dr Miloje Vasić for providing the data on the numismatic material from the thermal baths in the Niš fortress and for his selfless help in the preparation of this paper.

Mediana

Period	Pcs.	Mint	Pcs.
1. vek	2	Aquileia	5
2. vek	1	Alexandria	4
2-3. vek	1	Antiochia	11
3. vek	6	Arelate	3
4. vek	235	Heraclea	38
4-5. vek	3	Carthago	1
5. vek	1	Cyzicus	39
76-292.	12	Constantinopolis	31
239-303.	20	Londinium	2
305-313.	40	Mediolanum	2
313-317.	26	Nicea	1
317-324.	83	Nicomedia	18
324-330.	50	Ostia	1
330-341.	236	Roma	21
335-361.	5	Serdica	4
351-366.	2	Sirmium	4
341-361.	389	Siscia	119
361-375.	187	Thessalonica	224
378-395.	32	Ticinum	8
404-406	1	Treveri	6
425-450.	2	Viminacium	9
?	14		
Total:		1347	

Square Kralj Milan

Period	Pcs.	Mint	Pcs.
1. vek	1	Edrine	1
3. vek	1	Cyzicus	1
134-138.	1	Constantinopolis	1
240-241.	1	Nicomedia	1
295-299.	1	Roma	2
311-313.	2	Thessalonica	4
336-340.	2	Viminacium	1
355-361.	2		
364-375.	1		
527-565.	1		
565-578.	1		
1444-1481.	1		
?	4		
Total:			19

Gorča

Period	Pcs.	Mint	Pcs.
302-303	1	Thessalonica	1
355-361	1		
Total:			2

Ambasador

Period	Pcs.	Mint	Pcs.
232-282	1		
270-275	1		
Total:			2

Tvrđava

Period	Pcs.	Mint	Pcs.
1. vek	1	Aquileia	7
2. vek	1	Heraclea	3
3. vek	3	Carthago	1
4. vek	95	Cyzicus	12
4-5. vek	14	Constantinopolis	10
5. vek	4	Nicomedia	3
vizantija	1	Roma	4
310-324.	3	Sirmium	3
324-337.	6	Siscia	15
337-341.	2	Thessalonica	32
341-354.	15		
355-361.	37		
363-375.	43		
378-383.	7		
383-393.	127		
393-395.	5		
395-408.	16		
408-425.	4		
425-455.	12		
476-491.	2		
?	2		
Total:			399

Jagodin Mala

Period	Pcs.	Mint	Pcs.
309-313.	2	Aquileia	2
317-318.	1	Cyzicus	2
321-330.	3	Constantinopolis	5
330-333.	1	Siscia	2
337-341.	3	Thessalonica	9
341-346.	2	Ticinum	1
351-361.	11		
364-367.	3		
367-378.	4		
378-383.	1		
383-395.	5		
394-408.	1		
532-537.	1		
570-571.	1		
583-584.	1		
595-596.	1		
Total:			41

National Museum of Niš

Period	Pcs.	Mint	Pcs.
324.	1	Constantinopolis	1
350-355.	1	Mediolanum	1
367-375.	1	Nicomedia	1
383-388.	2	Thessalonica	2
430-440.	1	Treveri	1
Total:			6

Table 2 - Composition of individual findings from the territory of Late antique Naissus

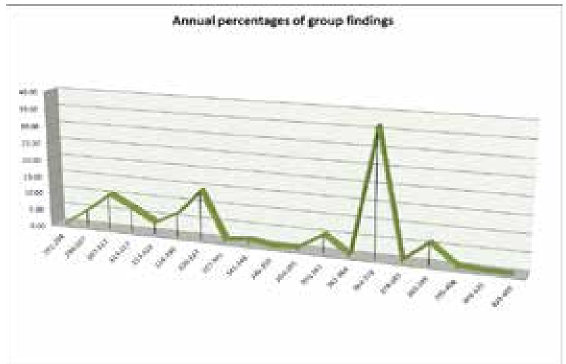
construction of the "Gorča" business centre belong to 3rd and 4th century coins and material from the suburbs of Naissus (Ajdić 1975: 38; Јовановић 1976: 76). The nominals found within the burial units originate from the late antique Jagodin Mala necropolis. Investigations of the necropolis began in 1932 and are still ongoing. The paper includes material up to that found during research on the premises of the "Benneton" factory, conducted in 2012 (Jeremić 2014: 15) (Table 2).

ANALYSIS OF MONETARY MOVEMENTS OF INDIVIDUAL AND GROUP FINDS OF LATE ANTIQUE *NAISSUS* FROM THE END OF THE 3RD TO THE MIDDLE OF THE 5TH CENTURY

An insight into the monetary flow of late antique *Naissus* will be made by analysing the annual percentages[3] of individual and group findings. The number of coins in circulation will be observed for shorter chronological sequences within the period from the end of the 3rd to the middle of the 5th century. Looking at each category of finds separately will give a more detailed insight into the difference in monetary flows of individual and group finds.

In the group finds category, 1,390 precisely dated specimens were subjected to analysis. Less than 1% of the samples were observed within the following chronological sequences: 292-294, 337-341, 341-346, 346-350, 350-355, 361-364, 378-383, 395-408, 408-425 and 425-455. The number of specimens of these sequences ranges from 0% to 6%. There is a slightly larger number of coins in the periods that belong to the ranges 294-330, 355-361, and 383-395, where percentages do not exceed 10%. The sequences 330-337 and 364-378 make up the highest percentage share (10.79% and 51.37%, respectively.) (Table 3).

If we take a look at the annual percentages of the group finds, a slight increase in coins in circulation between the sequences 292-294 and 307-313 is noticeable, when the first peak is observed. The circulation decreases from 313 to 324, only to peak again between 324 and 330 in the sequence 330-337. In the period from 337 to 364, the value of annual percentages is relatively low and uniform (0.37% - 1.41%) with a slight growth of 6.71% in the period 355-361. The highest number of coins in circulation can be observed from 364 to 378 (36.71%). Between 378 and 455, the circulation is very low (from 0% to 0.94%), with the exception of the period 383-395, when it is 6.14% (Graph 1).



Graph 1 - Presentation of coin flows of group finds from the territory of Late Antique Naissus

The number of precisely dated individual finds of coins is 1,387, where it can be seen that both categories of finds are almost equally represented in percentages (50.05% and 49.95%). The smallest percentage share of coins, in individual finds, which does not exceed 1%, is observed in the sequences: 292-294, 294-307, 350-355, 361-364, 378-383, and 408-425. The range from 1.08% to 6.63% of the coin prominence is in the periods from 307 to 330, 337-346, 395-408, and 425-455. A high percentage of coins is noted in the sequences 330-337 (11.39%), 383-395 (11.46%), 364-378 (16.37%) and in the period 355-361 (20.69%), when it is the highest (Table 4).

The analysis of annual percentages shows growth from 294 to 330-337, when the curve reaches its first peak. Between the years of 337 and 341, the number of coins is almost uniform from 10.24% to 11%. In the period from 341 to 361, sudden peaks and declines in the monetary flow are periodically observed. From 341-346, the annual percentage value is 2.6%, and in the next sequence (346-350) amounts to 15.03%, while an almost complete drop of 1.02% can already be seen in the next period 350-355. The maximum number of coins in circulation was recorded from 355 to 361 (22.83%). The value of the annual percentages between the years 361 and 455 almost

3 To obtain the annual percentages, it is necessary to first calculate the annual coefficients. The value of the annual coefficients represents the quotient of the number of samples within one period and the number of years that period includes: a=b/c. Adding all the annual coefficients (a, a1, a2, ...) gives the value (e). The value of annual percentages is obtained by the formula d= a x 100 / e (Vasić 2021: 95).

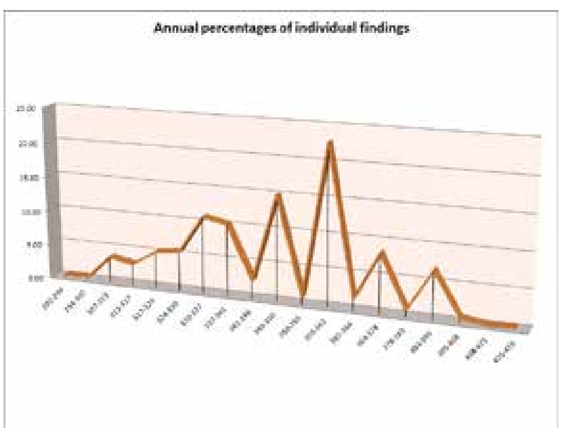
Period	Annual percentages
292-294	0.51
294-307	5.09
307-313	10.41
313-317	7.06
317-324	3.26
324-330	6.90
330-337	14.38
337-341	0.61
341-346	1.41
346-350	0.31
350-355	0.77
355-361	5.15
361-364	0.38
364-378	36.51
378-383	0.38
383-395	6.14
395-408	0.71
408-425	0.00
425-455	0.02

Table 3 - Annual percentages of group finds from the territory of Late Antique Naissus

Period	Annual percentages
292-294	0.37
294-307	0.36
307-313	3.74
313-317	3.01
317-324	5.22
324-330	5.65
330-337	11.00
337-341	10.24
341-346	2.60
346-350	15.03
350-355	1.02
355-361	22.83
361-364	1.67
364-378	8.43
378-383	0.93
383-395	6.81
395-408	0.72
408-425	0.12
425-455	0.27

Table no. 4 - Annual percentages of individual finds from the territory of late antique Naissus

never exceeds 2%, with the exception of sequences 364-378 (8.43%) and 383-395 (6.81%), when an increase is observed (Graph 2).



Graph 2 - Presentation of coin flows of individual finds from the territory of late antique Naissus

MONETARY CIRCULATION OF LATE ANTIQUE *NAISSUS* FROM THE END OF THE 3RD TO THE MIDDLE OF THE 5TH CENTURY

By comparing the monetary flows of the group and individual finds, a more complete picture of the coin circulation of late antique *Naissus* can be obtained. Also, by comparing monetary movements with the site of *Horreum Margi* in *Moesia Prima* and *Timacum Minus* in *Dacia Ripensis*, we will get an insight into the monetary circulation of the diocese of *Dacia* (Map 2).

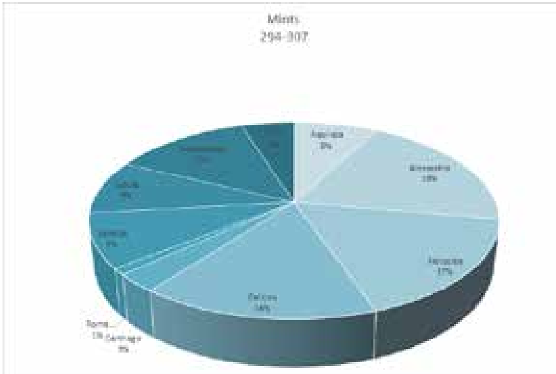
In the period from 292-294, the number of coins in circulation is relatively low in both categories of finds. In the next sequence, 294-307, in the case of individual finds, the situation remains unchanged, but in the case of the group finds, the circulation is increasing. It was recorded that the emperor Diocletian stayed in *Illyricum* during this period. During the year 293, Diocletian focused on the fortification of the Danube Limes, as well as visiting larger cities

Map 2 - The positions of the sites of Naissus, Timacum Minus and Horreum Margi in the diocese of Dacia, (Tags: Marija Jović on © Cplakidas / Wikimedia Commons / CC BY-SA 3.0, https://upload.wikimedia.org/wikipedia/commons/0/0e/Balkans_6th_century.svg)

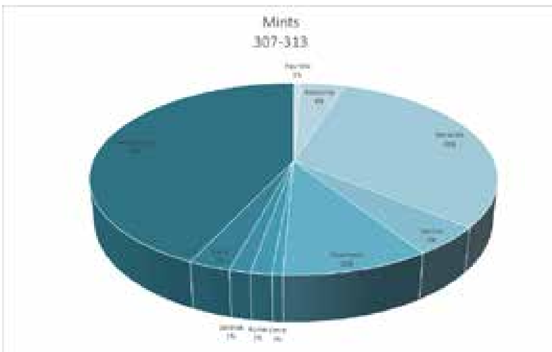
and mines. During the year 294, the emperor stayed in *Sirmium*, *Singidunum*, *Viminacium*, and *Cuppae* (Vasić 2008: 58). The increase in coin flow for group finds is possibly due to Diocletian's stay in this area. The supply of coins mainly originated from eastern mints (53%), but western (16%) and central mints (31%) are also present (Graph 3 and 4). In the 307-313 sequence, there is a noticeable increase in coin flows, even in the category of the group finds, where it reaches the first peak. Historically, this is a complicated period full of disagreements between pretenders to the throne. The Balkan provinces and Asia Minor were under the administration of Galerius until his death in 311, when Licinius took over the administration of the territory of the Balkans and established his residence in *Sirmium* (Vasić 2008: 63; Vasić 2008: 12) (Graph 3). The period from 308 to 310 was marked by Galerius' frequent trips, departing from *Serdica* or *Thessalonica*, and he

Graph 3 - Parallel display of coin flow of group and individual findings

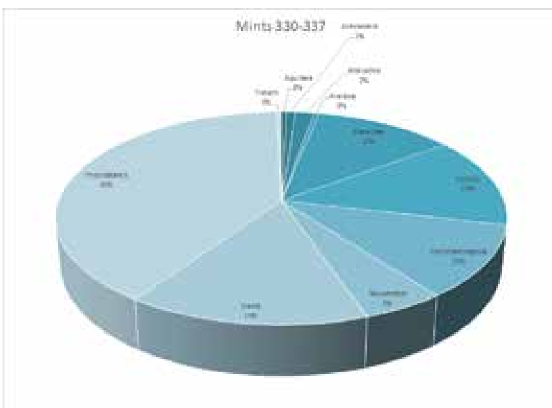
probably also passed through Niš (Vasić 2008: 12). The results of the mints percentage representation in the 307-313 sequence show a dominant share of Balkan and eastern mints (83%). Also, Thessalonica is by far the most represented with 43%, which can be explained by the closing of the Serdica mint in 308 and Thessalonica taking over (Božkova 1977: 7; Božkova 1994: 134) (Graph 3 and 4). The increase in circulation and the majority share of the Thessalonica mint can be explained by the desire of the rulers to expand their influence, as well as by the fact that Thessalonica became Galerius' main mint in 308, and at the same time the closest mint to the city of *Naissus*. From 313 to 330, a uniform and slightly increased circulation rate can be noticed. This period was marked by the diarchy of two rulers, Constantine I and Licinius, but also by frequent conflicts between the rivals. The first battle between the two rulers took place in 316 at *Cibalae*, after which Constantine spent most of his time in the Balkans and assumed power over this territory (Mirković 2012: 9). Constantine's final victory over Licinius in 324 enabled him to take over the entire Roman Empire (Lenski 2007: 78). During all the years of conflict between the two rulers, Constantine's frequent visits to the Balkans were recorded. His confirmed stays in *Naissus* took place during the years 319 and 321 and in the period from 316 to 324 he often passed through the city (Vasić 2008: 12). Although it would be expected that the increased deployment of military forces and the permanent stays of emperors in the Balkans would lead to a significant



Graph 4 - Percentage representation of mints in the sequence 294-307.

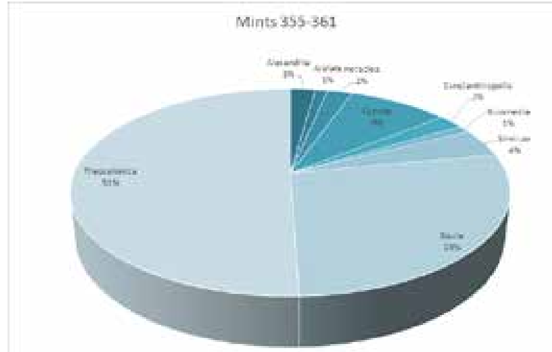


Graph 5 - Percentage representation of mints in the sequence 307-313.



Graph 6 - Percentage representation of mints in the sequence 330-337.

increase in the number of coins in circulation, the results indicate uniform and only slightly increased monetary movements. Also, a greater presence of western mints was noticed during this period, especially the Roma mints during the sequence 313-317, although the dominant share was still held by the Thessalonica and Siscia mints (Graph 3). The influence of the western mints, which were under Constantine's administration



Graph 7 - Percentage representation of mints in the sequence 355-361.

at the time, can be explained by the pretensions of the ruler to expand his influence and take over the territory of the Balkans. In the next sequence, 330-337, a significant increase in coins in circulation was observed in both categories of finds. Until the middle of 334, Constantine led battles against the Goths, Visigoths, and Sarmatian Argaragantes on the *Limes*, after which a long period of peace ensued in the Balkans. In the same year, Constantine passed through and stayed in *Naissus* (Vasić 2008: 14; Vasić 2008: 73). It is possible that the increased circulation was a consequence of the mentioned events. The almost exclusive presence of coins from eastern and central mints can be noticed, with the largest share of Thessaloniki at 42% (Graph 3 and 6). After the death of Constantine in 337, and until 341, the situation of individual finds remains unchanged in relation to the previous chronological sequence. Group finds show completely contradictory results, the number of coins in circulation drops drastically from 14.38% to 0.61%. Taking both categories of finds into account, during this period, there was still a significant number of coins in circulation. The territory of *Illyricum* was in the hands of Constans, who came to power at the age of 14 and was under the tutelage of his older brother Constantine II. His stay in *Naissus* between January 19 and February 2, 340 was recorded. Until the year 355, in group finds, the circulation is extremely low and does not exceed 1.5%. Individual finds present a slightly different picture, especially in the sequence 346-350, when the coin supply reached a new peak. In this sequence, significant reforms of Constans and Constantius II (348-354.) took place, but also the death of Constans in 350. (Vasić 1990: 25; Vasić

Period 330-337.			
Mints	Naissus	Horreum Margi	Timacum Minus
Alexandria	/	/	1.2%
Antiochia	3.28%	18.18%	1.2%
Arelate	6.56%	9.09%	/
Heraclea	14.75%	/	2.4%
Cyzicus	21.31%	9.09%	12.24%
Constantinopolis	2.46%	36.36%	14.29%
Nicomedia	8.20%	9.09%	5.10%
Roma	0.82%	9.09%	/
Siscia	9.84%	/	14.29%
Thessalonica	32.79%	9.09%	50%

Table 5 - Percentage representation of mints at the sites: Naissus, Timacum Minus and Horreum Margi, period 330-337.

Period 346-350.			
Mints	Naissus	Horreum Margi	Timacum Minus
Aquileia	3.70%	4.55%	/
Alexandria	1.85%	4.55%	/
Antiochia	1.85%	9.09%	/
Heraclea	5.56%	9.09%	/
Cyzicus	1.85%	/	4.17%
Constantinopolis	5.56%	4.55%	4.17%
Nicomedia	3.70%	13.64%	/
Roma	5.56%	18.18%	4.17%
Siscia	31.48%	/	33.33%
Thessalonica	38.89%	27.27%	54.17%
Treveri	/	9.09%	/

Table 6 - Percentage representation of mints at the sites: Naissus, Timacum Minus and Horreum Margi, period 346-350.

Period 350-355.			
Mints	Naissus	Horreum Margi	Timacum Minus
Aquileia	2.70%	20%	/
Alexandria	/	/	4.76%
Arelate	/	20%	/
Heraclea	10.18%	/	9.52%
Cyzicus	5.41%	/	/
Constantinopolis	13.51%	/	4.76%
Nicomedia	/	20%	4.76%
Roma	2.70%	40%	/
Sirmium	5.41%	/	33.33%
Siscia	13.51%	/	28.57%
Thessalonica	45.95%	/	14.29%

Table no. 7 - Percentage representation of mints at the sites of Naissus, Timacum Minus and Horreum Margi, period 350-355.

Period 355-361.			
Mints	Naissus	Horreum Margi	Timacum Minus
Aquileia	/	3.33%	3.57%
Alexandria	2.30%	/	/
Arelate	1.15%	/	/
Heraclea	2.30%	/	/
Cyzicus	9.20%	10%	7.14%
Constantinopolis	2.30%	20%	14.29%
Nicomedia	1.15%	/	7.14%
Sirmium	4.60%	13.33%	7.14%
Siscia	28.74%	6.67%	14.29%
Thessalonica	48.28%	46.67%	46.43%

Table no. 8 - Percentage representation of mints at the sites of Naissus, Timacum Minus and Horreum Margi, period 355-361.

Period 364-378.			
Mints	Naissus	Horreum Margi	Timacum Minus
Aquileia	0.26%	4.26%	2.74%
Alexandria	1.15%	25.53%	1.37%
Antiochia	0.26%	12.77%	/
Arelate	0.13%	/	/
Heraclea	0.26%	/	/
Cyzicus	0.26%	/	2.74%
Constantinopolis	1.28%	8.51%	2.74%
Nicomedia	0.26%	4.26%	4.11%
Roma	2.56%	14.89%	/
Sirmium	/	/	1.37%
Siscia	48.46%	23.40%	45.21%
Thessalonica	45%	6.38%	38.36%
Treveri	0.13%	/	1.37%

Table no. 9 - Percentage representation of mints at the sites of Naissus, Timacum Minus and Horreum Margi, period 364-378.

2021: 144). In addition to the mentioned historical events, which by their nature could not have had much influence on the increased coin flow in late antique *Naissus*, perhaps the cause can be sought elsewhere. Given that a significant part of the sample of individual finds is occupied by specimens found in *Mediana*, a site with increased construction activity in this period, which required a greater inflow of funds (Vasić 2021: 144), it is possible that all of the above affected the increased circulation. The distribution of coins was mainly carried out from central and eastern mints, among which Thessaloniki (43%) and Siscia (31%) dominate (Graph 3). Observing the monetary flow in the following chronological sequences, in both categories of finds, there are completely parallel, alternating rises and falls in circulation. Between 350 and 355, coin flows were almost at a minimum, only for the curve to reach a new peak in 355-361. The increased circulation was probably the result of Julian's stay in *Naissus* and *Mediana* for several months during the year 361 (Vasić 2008: 15). The supply of coinage remained unchanged, percentage-wise, Thessalonica and Siscia being more prominent (Graph 3 and 7). The next rise in circulation can be noted during the sequence 364-378, which may be related to the stay of Valentinian I and Valens in *Naissus* and *Mediana* in June 364 (Vasić 2008: 19). During the period from 378 to 383, coin circulation was extremely low, which was a logical consequence of the Battle of Hadrianopolis. The last increase in monetary move-

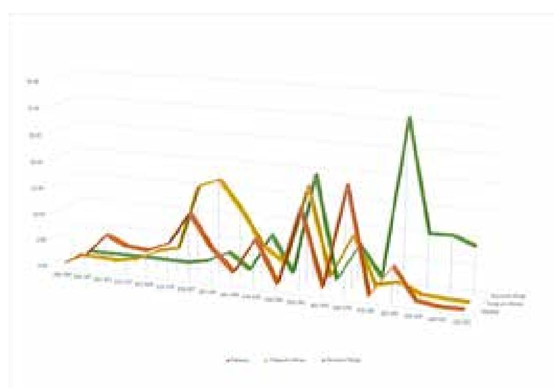
Mints	Naissus	Horreum Margi	Timacum Minus
Aquileia	8.16%	5.07%	/
Alexandria	/	8.70%	/
Antiochia	1.02%	7.73%	/
Arelate	2.04%	0.97%	/
Heraclea	6.12%	4.36%	/
Cyzicus	19.39%	22.95%	20%
Constantinopolis	12.24%	19.81%	30%
Mediolanum	1.02%	/	/
Nicomedia	11.22%	8.94%	20%
Roma	1.02%	10.87%	/
Siscia	5.10%	1.21%	30%
Thessalonica	31.63%	8.94%	/
Treveri	1.02%	/	/
Lugdunum	/	0.48%	/

Table no. 10 - Percentage representation of mints at the sites of Naissus, Timacum Minus and Horreum Margi, period 383-395.

ments, within the studied chronology, was recorded in the sequence 383-395. In this sequence, a period of stability prevailed on the territory of *Illyricum*, the distribution of coins was carried out predominantly from the eastern regions, but the presence of western regions is higher in percentage compared to previous periods.

Through a comparison of monetary movements from the sites of *Naissus* in *Dacia Mediterranea*, *Horreum Margi* 4 in *Moesia Prima*, and *Timacum Minus* 5 in *Dacia Ripensis*, we have tried to get a broader picture of coin flows of the prefecture of *Dacia* (Graph 8). The time span from 292 to 330 gives very similar results for all three sites. Throughout this period, the circulation was relatively uniform and low. *Naissus* and *Timacum Minus* have a closer annual percentage that does not exceed the value of 6.54%, while the values at the *Horreum Margi* site are somewhat lower, up to a maximum of 4%. A slight deviation is noticeable in the sequence 307-313 in the form of a slight rise (6.54%), in *Naissus*, while the values in the other two sites do not exceed 1%. *Timacum Minus* had significantly higher monetary circulation in the period of 337-346, and, although the annual percentages at *Horreum Margi* and *Timacum Minus* are lower, the growth and decline of circulation is almost parallel in all three sites. Almost identical coin flows can be observed in the chronological range from 346 to 455. At the site of *Horreum Margi*, from 395 to 455, the annual percentage values are higher compared to the other two sites, but the curve changes are identical.

The commentary on the analysis of the coin distribution is focused only on chronological sequences where material from all three sites is prominent. In the period from 330 to 337, Thessalonica is the most used mint by percentage, while Constantinopolis is the most prominent in the case of the *Horreum Margi* site. In *Naissus* and *Horreum Margi*, there is a minor influx of western mints (Roma and Arelate), however, the central and eastern mints dominate the supply (Table 5). The next section, 346-350, shows that in percentage terms the most prominent mint among all sites is Thessalonica. The distribution of coins in *Naissus* and *Timacum Minus* is mostly carried out from central mints, with only a small per-



Graph 8 - Parallel display of coin flow in the sites: Naissus, Timacum Minus and Horreum Margi

4 Numismatic data taken from - Vasić 1990: 101-121

5 Numismatic data as a result of the analysis presented at the INC 2022 - Warsaw - Jović 2022

centage of eastern mints. The percentage at *Horreum Margi* is a little different, because the share of the Roma mint is noticeable at 18.18%, which is negligible at the other two sites (Table 6). The next sequence, 350-355, provides completely different results in all three sites (Table 7). In *Naissus*, the supply was made primarily from the central and eastern mints. *Timacum Minus* shows similar results, although the Sirmium mint dominates, while the western mints are most represented at *Horreum Margi*. During the sequence 355-361, in all three cases, almost half of the coinage came from the Thessalonica mint (Table 8). Sequence 364-378 showed the same inflow of coins at *Naissus* and *Timacum Minus*, with the central mints of Thessalonica and Siscia being the most prominent. *Horreum Margi* had a slightly higher percentage share of eastern mints (Alexandria) compared to central ones (Table 9). The last observed period is 383-395. Here, the dominant distribution of coins was made from the eastern mints at all three sites, with a significant share of the Roma mint at *Horreum Margi* and the Siscia mint at *Timacum Minus* (Table 10).

CONCLUSIONS

The analysis of monetary circulation was performed on a sample of 2,777 precisely dated coins, which make up 86.35% of the total processed numismatic material from the area of late antique *Naissus*. Only one silver specimen was recorded, all other coins are bronze. Gold coins were not included in the analysis and only two examples are known that correspond chronologically to this research. Although Constantine the Great made the solidus the main unit of the monetary system, the circulation of the gold coin was limited. Solidi were used in the salaries of the army and administration, but were returned to the state coffers through tax collection (Depeyrot 2007: 238). A realistic picture of coin movements is obtained by analysing the bronze coins that the population used in everyday transactions. Bronze coinage entered circulation primarily through the army, and secondarily made its way to regular coin flows through trade transactions. By looking at the annual percentages, it can be concluded that at the very end of the 3rd century, the monetary circulation of late antique *Naissus* was very low. However, at the beginning of the 4th century and during the reign of Constantine the Great, it slowly grew and the circulation was almost uniform, until his death in 337. The following period, from 337 to 408, is characterised by alternating sudden rises and falls in circulation. The very end of the chronological sequence that is observed, 408-455, features minimal coin flow. Any significant increase in annual percentages can be mostly associated with the stays of emperors in the late antique *Naissus* area. Also, intensive construction activities, which required large amounts of coins, influenced the growth of monetary circulation. Since a significant part of the sample consists of coins from *Mediana*, the site that underwent extensive construction work, this probably contributed to the increased circulation. The inflow of coins was mainly from the central and eastern mints, among which Thessalonica and Siscia had a dominant share. In the period from 307-313, the presence of Roma mints increased noticeably, which is probably a consequence of Constantine's pretensions to expand his influence in the Balkans.

A parallel analysis of the monetary flow of the sites of *Naissus*, *Horreum Margi*, and *Timacum Minus*, which are almost identical, leads to the conclusion that the coin flow and further circulation were uniform in all the provinces of the diocese of *Dacia* and that the same laws, whether of a historical or economic nature, ruled these areas.[6]

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6 Dr Miloje Vasić first came to the same conclusion, which was later confirmed by analyses carried out in two independent studies of the monetary circulation of the Timacum Minus site, presented at the INC 2022 congress in Warsaw and the study of monetary movements of Naissus presented in this paper.

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REZIME

MONETARNA CIRKULACIJA U KASNOANTIČKOM *NAISSUS*-U

KLJUČNE REČI: NUMIZMATIKA, NAISSUS, KASNA ANTIKA, NOVAC, MONETARNA CIRKULACIJA.

Predmet rada predstavlja analiza novčanih kretanja kasnoantičkog Naisusa. Istraživanje je ograničeno na period od kraja 3. do sredine 5. veka. Numizmatički materijal je sa 13 lokacija, sa lokaliteta: Medijana, Trg Kralja Milana i Trg Oslobođenja, Niška tvrđava i Gradsko polje, nekropola Jagodin Mala, Gorča, Ambasador, ulica Obrenovićeva i OŠ Vuk Karadžić. Pomenuti lokaliteti pozicionirani su kako u urbanom jezgru grada tako i na njegovoj periferiji. Na osnovu konteksta u kome je pronađen novac je podeljen u dve kategorije: na grupne i pojedinačne nalaze. Grupni nalazi novca podrazumevaju celine poput ostava i kasa u okviru kojih je novac sukcesivno prikupljan, dok pojedinačni nalazi podrazumevju novac koji je otkriven tokom arheoloških istraživanja, uglavnom stratificiran, kao i primerke koji su otkupom postali deo muzejskih zbirki. Broj hronološki precizno određenih primeraka je kod obe kategorije gotovo jednak (grupni nalazi-1390; pojedinačni nalazi- 1387 primeraka). Komparacijom novčanih tokova grupnih i pojedinačnih nalaza dobija se kompletnija slika monetarne cirkulacije kasnoantičkog Naisusa. Takođe, poređenjem novčanih kretanja sa lokalitetom Horeum Margi (Horreum Margi) u Prvoj Meziji (Moesia Prima) i Timakum Minus (Timacum Minus) u Priobalnoj Dakiji (Dacia Ripensis) dobićemo u monetarnu cirkulaciju prefekture Dakije. Sagledavanjem godišnjih procenata može se zaključiti da je na samom kraju 3. veka opticaj novca kasnoantičkog Naisusa bio jako nizak. Ipak početkom 4. veka i za vreme vlade Konstantina Velikog opticaj polako raste i cirkulacija je gotovo ujednačena. Naredni

period od 337. do 408. odlikuju naizmenični nagli skokovi i padovi u opticaju. Sam kraj hronološke sekvence koja se posmatra 408-455. odlikuje minimalan novčani tok. Svaki značajan rast godišnjih procenata uglavnom se može povezati sa boravcima imperatora na prostoru kasnoantičkog Naisusa ili posledicom intenzivne graditeljske aktivnosti. Dotok novca uglavnom je bio iz centralnih i istočnih kovnica, među kojima su dominantan udeo imale Tesalonika i Siscija. Paralelnim sagledavanjem novčanih tokova lokaliteta su Naisus, Horeum Margi i Timakum Minus, koja su gotovo podudarna, nameće se zaključak da su dotok novca i njegova dalja cirkulacija bili ujednačeni u svim provincijama dijeceze Dakije i da su iste, zakonitosti, bilo istorijske ili ekonomske prirode vladale ovim prostorima.

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USE OF BUILDING MATERIALS DURING THE CONSTRUCTION OF TRAJAN'S BRIDGE ON THE DANUBE

ABSTRACT

Combining different building materials was not uncommon in Roman architecture. The use of various materials for the creation of the Trajan's Bridge on the former Danube Limes, that is wood, stone, brick and mortar, according to their characteristics, role in the construction, chosen construction methods, and pre-known behaviour of these materials over time, is one of the important features of the design of this building. The reasons for a deeper analysis of architect Apollodorus' solutions for the bridge regarding the achieved combinations of materials are the importance of the structure, the monumentality of its architecture, as well as the characteristics of the place where the bridge was built. The focus of this study will be on analyses of the bridge's masonry structures and, more precisely, the relationships between the building materials used for their construction. When studying the use of building materials, ancient writings were used, as well as analyses of the remains of the bridge in situ on the Danube banks of today's Serbia and Romania. The realised analyses point to new interpretations regarding the possible ways to span the spaces between the pillars on the riverbanks, and their connection to the choice of building materials.

KEYWORDS: BUILDING MATERIALS, CONSTRUCTION METHODS, MASONRY STRUCTURES, TRAJAN'S BRIDGE, ROMAN ARCHITECTURE, DANUBE LIMES.

INTRODUCTION

The remains of Trajan's Bridge are located in the riverbed and on the banks of the Danube river, where, on the left side of the river they are in the territory of today's Romania, and on the right side in the territory of the Republic of Serbia (Fig. 1). In Romania, they are today part of the urban fabric of the city of Drobeta – Turnu Severin, while on the Serbian side they are located 5 km from the small town of Kladovo, that is, 1.3 km east of the nearest settlement, Kostol.

On the initiative of Emperor Trajan, the bridge was designed by the architect Apollodorus, between 103 and 105, that is, between two Roman conquest campaigns in Dacia. On two occasions - in 1931 and in 1968, D. Tudor synthesised early knowledge about the remains on the Romanian side (starting with the 1858 research conducted by Deustler, Imbrišević and Popovici and the 1907 research conducted by Duppereux)(Tudor 1974: 47). At the same time, he presented his analysis and new views on the architecture of the bridge. The remains of the bridge were investigated on the Serbian side in 1979 and soon after they were published by its researchers Milutin Garašanin and Miloje Vasić on behalf of the Institute of Archaeology in Belgrade (Fig. 1) (Гарашанин и Васић 1980). More recently, C. Crăciun and A. Sion, and I. Bjelić have carried out further analyses based on all previous research (Crăciun and Sion 2006; Bjelić 2020).

Regarding the construction of the bridge, we can differentiate two parts: One part was on the shore and, according to the relief on Trajan's Col-

Fig. 1. The archaeological site of Pontes with the remnants of Trajan's Bridge (photo-documentation of the Institute of Archaeology, Belgrade)

umn in Rome, it was completely built as a masonry construction. The other part was settled in the river bed as a masonry construction, while above it was the wooden supporting structure of the road of the bridge.

One of the major characteristics of Trajan's Bridge is the combination of several types of wooden and masonry constructions in different parts of the bridge. Wood had specific functions when combined with masonry constructions on this structure. It served as formwork for the foundations of the bridge pillars on the shore, as an integral part of the caissons for building the foundations of the pillars in the riverbed, and as a wooden "reinforcement" in the form of horizontal beams and driven piles. The main function of the interior of the bridge pillars was to ensure the equal settlement of mortar and aggregate masses within the supports and to enable the stable support of the masonry pillars on the riverbed. The wood also served as the supporting structure of the wooden platform i.e., the road of the bridge that spanned between the individual pillars.

Ancient writings, visual representations, as well as analyses of the bridge's investigated parts by previous Romanian and Serbian researchers represent the basis for this research, aimed at analysing the combination of wooden and masonry constructions (for older historical sources see: Гарашанин и Васић 1980: 9). One of the most important writings about the construction of the bridge itself, that of Apollodorus himself, has not been preserved. Instead, its construction is witnessed by the texts of Dio Cassius, Procopius, and the poet Tsetses, some of which refer to the text of Apollodorus (On earlier literature and historical sources see: Гарашанин и Васић 1980: 8). In addition to written sources, there are also two important artistic sources: coins minted by the Roman Senate in 105 in honour of the construction of Trajan's Bridge and scenes on the metopes of Trajan's Column (scene XCVIII – XCIX and scene C – CI) (Vulpe 2002: 178 - 179). Previous researchers such as H. Dacoviciu, M. Garašanin and M. Vasić already indicated the justification of the reliability of the pictorial sources on Trajan's Column (Гарашанин и Васић 1980: 9). At the same time, they pointed out that the representations of the bridge on coins are very stylised and simplified. In their opinion, the sculptors of Trajan's Column had a solid idea of the appearance of the bridge based on Trajan's writings (the emperor's comments on the Dacian Wars). At this point, we would add a new opinion to this one. Namely, the sculptors of Trajan's Column could equally have consulted Apollodorus himself. Apart from the fact that Apollodorus was the creator of the concept of the execution of Trajan's Bridge and the Column in Rome, let us add that the sculptors could have had the writings of the mentioned architect in front of them in addition to the emperor's comments. In support of the reliability of the depictions of the bridge on Trajan's Column in Rome, we also point to the fact that the depiction on the Column in Rome is a rare detailed representation of a wooden bridge in the Roman Empire.

BRIDGE CONSTRUCTION ON THE COAST

The geographical similarity of the two banks of the river, i.e., the symmetrical topography, made it possible for the approaches to the bridge to be designed in an almost identical way. The preserved remains of the masonry structures of the bridge on the Romanian and Serbian banks indicate identical designs, applied materials, and types of constructions at the two approach endings of the bridge. Previous comparisons of masonry structures on the two banks by Romanian researchers also point to this finding (Crăciun and Sion 2006: 373). The dimensions of the most accessible and best-preserved parts of the bridge, i.e., those on the banks, indicate an exceptional similarity in design: the length of the supporting structures of the embankment pillars (including the platforms at the end pillars on the river's edge) is 39.90m on the left bank, while the length on the right bank is 39.29m (Crăciun and Sion 2006: 375).

The dimensions of the other elements of the pillars on the Serbian and Romanian banks also indicate the similarity of the structures on both sides of the approach to the bridge (Table 1). However, by looking at the values in the Table 1, it can be noticed that the lengths of the centre parts of all four supports are closer to each other than the values of the total lengths of the supports. Taking into account the measurements of the central part of the first pillar on the Serbian bank, Craciun and Sion calculated that the length of 9.76 m most probably corresponded to the length of 38 pedes, which should have been the length of the portal in its above-ground part (Crăciun and Sion 2006: 370).

The distances between the embankment pillars are different and range from 5.44 m between the first and second on the Serbian side to 6.52 m between the third and fourth pillar on the Romanian side (It is important to note here that the distance between the pillars, we primarily mean the distance between their central parts). The distances between the ends on the Romanian side are given according to the data of the Romanian authors (Crăciun and Sion 2006: 382). This information is important for considering the construction that bridged the space between the pillars on the bank, which we will see in the following text. All distances between individual pillars on one and the other side of the Danube are shown in Table 2.

Pillar foundations

Geotechnical tests of foundations carried out in 1983 by Romanian scientists indicated that the foundations lie on a bedrock made of clay and poorly cemented micaceous sands with marl intercalations. Blocks of crystalline schist and quartz were then placed over them, at a thickness of 30-50 cm, without bonding with mortar. Over these blocks, crystalline shale and quartz were used for masonry as well, bound with white mortar with the properties of modern hydraulic mortar (Crăciun and Sion 2006: 381).

Imprints of wooden planks for preparing the formwork of the foundations are most visible on the sides of the pillars (Fig. 2a). Since the remains

	Total length (m)	Total width (m)	The width of the central part (m)	The length of the central part of the pillar (m)	The length of the extension of the pillar (m)	The width of the extension of the pillar (m)
Pillar I – portal	16.66	6.36	4.76	9.76	3.60	5.50
Pillar II	14.12	4.75	2.36	9.40	2.38	4.13
Pillar III	13.95	4.15	2.38	9.40	2.30	4.15
Pillar IV (the platform part is not included)	13.42	4.95	2.95	10.10	2.85	4.95

Table 1. The values of the lengths of individual parts of Trajan's Bridge's masonry supports on the embankment (the attached values are based on the technical documentation of the Institute of Archaeology, Belgrade).

	I – II pillar	II – III pillar	III – IV pillar
Distance between middle parts of the pillars on the Serbian side (m)	5.44	6.23	6.52
Distance between middle parts of the pillars on the Romanian side (m)	5.50	5.75	6.60
Distance between ending parts of the pillars on the Serbian side (m)	4.31	4.71	4.31
Distance between ending parts of the pillars on the Romanian side (m)	4.40	4.00	4.13

Table 2. Distances between individual pillars on the Serbian and Romanian sides of the Danube river.

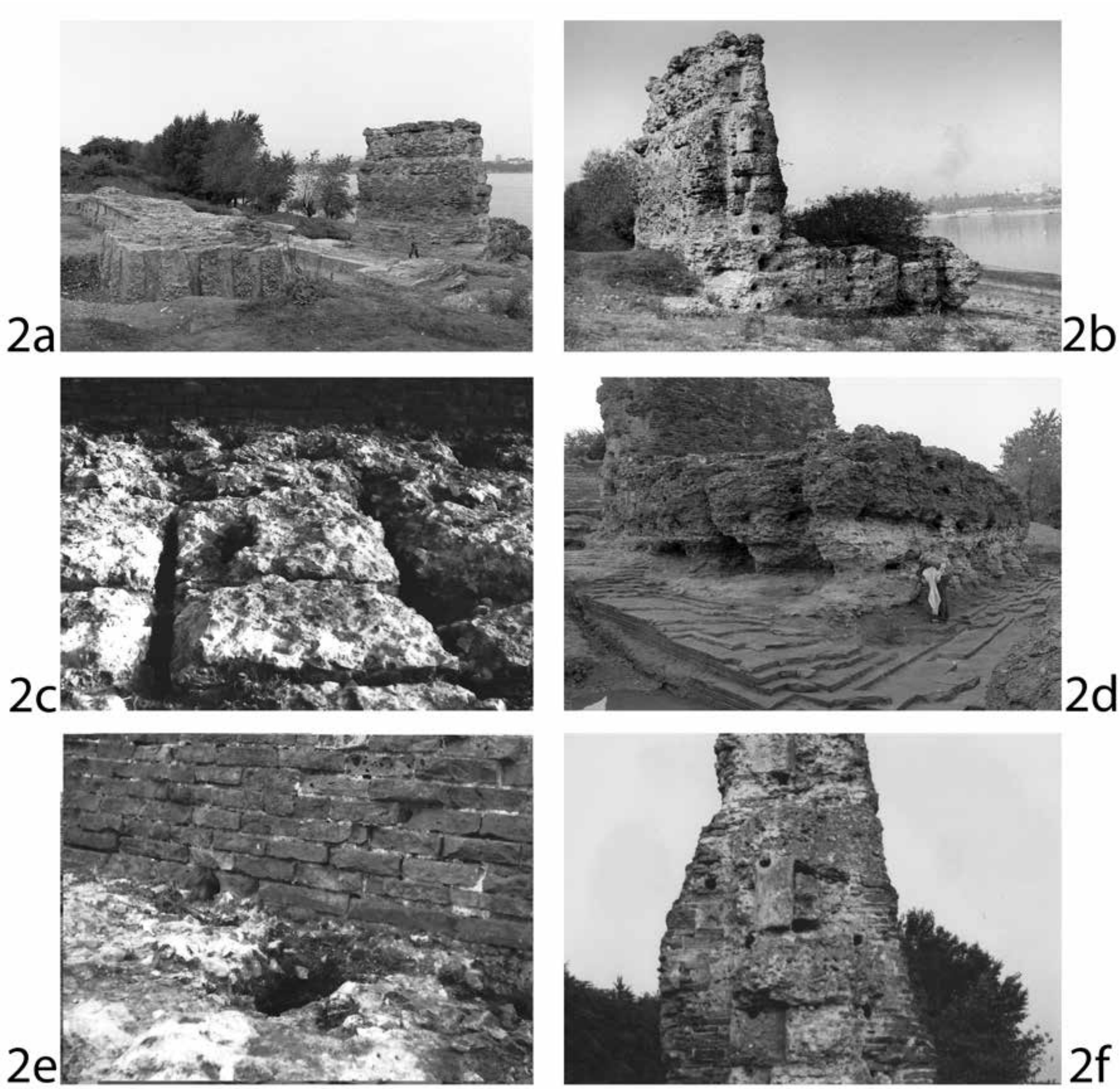

Fig. 2. a. Channels left as imprints from wooden planks of the formwork for the foundations of the first pillar in the foreground; b. The remnants of the fourth pillar of Trajan's Bridge; c. The imprints left from beams of the wooden grid system on the platform of the fourth pillar; d. Dense formation of stones and mortar tamped in the platform, with channels left from the horizontal wooden grid systems; e. a hollow left from a wooden post in the foreground of the platform and dense formation within the rows of bricks on the wall (opus testaceum); f. The only preserved ashlar and imprints from other missing ashlars on the side of fourth pillar; on their upper and bottom surfaces the channels left from wooden grids can be seen (photo-documentation of the Institute of Archaeology, Belgrade).

on the Romanian bank are very damaged pillars, no imprints of the formwork were registered. Therefore, on the Romanian side, there is no data on the size of the wooden formwork elements used for the foundations of the embankment pillars. On the Serbian side, there are clear prints of the vertical planks of the formwork on the faces of the foundations, which show the extent to which the *opus caementicium* was tamped and how the foundations were constructed. The fact that we can very clearly see these imprints from the planks shows that stones and lime mortar were tamped very strongly within the masses of the foundations. The method of execution of the formwork for the foundations of the bridge pillars was identical to that used for the foundations of the ramparts of the nearby Pontes castrum that protected the approach to the bridge. However, the main purpose of wooden boxes made up of planks and created for the execution of these foundations was in fact to prevent the collapse of the surrounding soil. Thanks to the clear imprints of the boards, the dimensions of their section, as well as other details, could be fully determined. The wood was cut into boards with a regular square section. The cross-section size of the wooden boards used in the foundation of the pillar with the portal (the first pillar) was 30 - 40 x 6 cm, for the second pillar it was 25 - 42 x 6 cm, and for the third pillar it was 45 x 6. We can also see the imprints in both directions: vertical and horizontal. The largest length of one horizontally placed board is 7.7m and it was registered on the southern face of the foundations of the third embankment pillar on the Serbian side. Lime mortar was poured inside the formwork formed in this way and larger stones (10-30cm) were hand-laid into it, and the whole mass was then tamped in order to achieve a compact foundation. During the tamping, the wooden formwork buckled and cracked, which was noted in several places on the foundations of the pillars on the bank (according to drawings and photos from the documentation of the Institute of Archaeology in Belgrade).

When it comes to the foundation of the platform along the fourth embankment pillar (Fig. 2b), within the space provided for the foundation, wooden posts were previously driven according to the modular system. With them, the future masonry construction of the foundation would be tied to the river bed. Getting stones hand-laid into the mass of lime mortar was carried out in several steps, which were coordinated with the successful laying of grids made of wooden beams. A closer look at the masonry remains in the foundation part of the fourth pillar shows us the density of stones and mortar around it (Fig. 2d). We can also recognise the rows of stones tamped in the mass of lime mortar, and that the dynamic of this process was aligned with the setting of a wooden grid system. The fact that there are no voids between stones shows us how firmly the rows of stones were tamped within the masses of the bridge foundation. Also, we can see the classic Roman *caementa*, made up of larger stones (10 – 30 cm), which is different from today's modern concrete aggregate, which consists of different sizes of small stones. This procedure made it possible to make a solid mass for the foundation of each pillar, which could carry the masses of the above-ground parts of the masonry structure in the embankment part. The same procedure was certainly used during the building of the foundations of the pillars in the river bed, as we will see below.

On the surface of a pillar platform are channels left from the rotten wooden grid system (Fig. 2c, Fig. 3), as well as holes from wooden posts by which the foundation was fixed to the riverbank soil. Wooden posts were very often used in Roman architecture in western Europe (Ulrich 2008: 80; Lancaster and Ulrich 2014: 174).

According to Crăciun and Sion, the wooden post imprints left on the platform of the fourth embankment pillar on the Romanian side had a cross-section of 0.32 (0.26) x 0.24 (0.15) m, while on the platform at Pontes, four different cross-sections of posts were recorded: 0.32 x 0.23, 0.25 x 0.18, 0.30 x 0.19, 0.30 x 0.30 m (for the Romanian data see: Crăciun and Sion 2006: 384). One of the oak beams preserved in the Museum of the Iron Gates most likely had the function of a post (Tudor 1931: 22; Crăciun and Sion 2006: 384). According to the documentation of the Archaeological Institute in Belgrade, the wooden posts were not directly connected to the horizontal wooden grids that were placed inside the core mass of the platform of the fourth embankment pillar at a certain vertical distance.

Embankment pillars above ground level

The first embankment pillar on the approach to the bridge (with the portal) was rectangular in plan and longer than other pillars, which can also be seen in Table 1. The next two pillars in the above-ground part had the shape of the Latin letter I, while the fourth embankment pillar had a more complex plan shape. The first part of that pillar was in the form of a platform, while the second one was in the form of a tall pillar (Fig. 2b, Fig. 3). Even the construction details within the first part resemble details from the foundation of the pillars in the river bed, along with the wooden grid system and the inner core of masonry made up of stones hand-laid in lime mortar. Above the foundation boundary of that part, made from bricks, wall faces were executed by using stone blocks. The other part of the pillar had blocks only at its protruding ends. The wall part between these ends had faces made of brick with an inner core of masonry made up of stones laid in lime mortar. Again, the remnants from a wooden grid system were registered.

The facades of the above-ground parts of the pillars, were built of bricks on the longitudinal sides (*opus testaceum*) (Fig 2e). However, the protruding endings of pillars on both sides (western and eastern) were built of stone blocks (*opus quadratum*) firmly connected to the rest of the pillars with a wooden grid. The stone blocks (or their impressions) that were found on the remains of the pillars on which the portal stood had a length of 1.45 m and a width of 0.79 m (Fig. 2f). One of the few preserved stone blocks used to connect the central part of the pillar with its ends on the fourth embankment pillar has a cross-section width of 0.43 m and a height of 0.65 m. However, the impressions of other blocks on the same pillar indicate that the width could have been up to 1.15 m, while the height of the blocks was registered in the range of values from 0.61 to 0.83 m (according

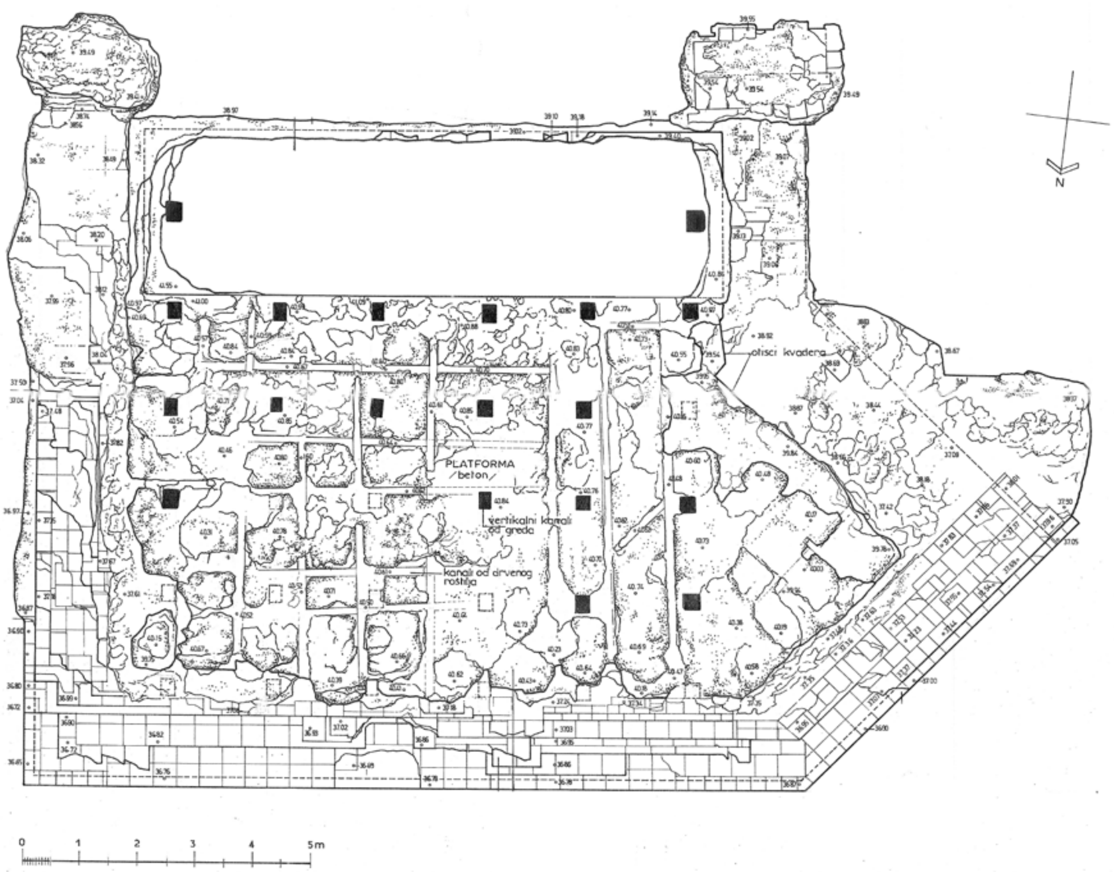

Fig. 3. Plan of the fourth pillar with its platform (technical documentation of the Institute of Archaeology, Belgrade and Petrović and Vasić 1980. Fig 5.)

to the technical documentation of the Institute of Archaeology in Belgrade). The imprints from the blocks were registered all along with the height of the pillar part of the pillar, as well as the voids and holes from the wooden grid system. Stone and bricks penetrate to different depths in the core filling mass of the masonry supports. The brickwork was done using large formats, especially in the area of the plinth. *Bipedales* and *sesquipedales* bricks were used, or bricks whose dimensions corresponded to the dimensions between the mentioned types, mostly 50 x 60 x 6 - 8 cm in size (Crăciun and Sion 2006: 383).

On the collapsed faces of the pillars, it is noticeable that the pouring and tamping of the *opus caementicium* were done in layers and were consistent with the installation of a wooden grid. The lower the compressive strength and uniformity of the mortar mixture, the greater would be the need for larger and more properly cut building units and vice versa (Vitti 2021: 3). For the ending parts of pillars on the bank, larger and accurately cut blocks were used, while the walls of the pillars between these ends were faced with layers of densely staggered bricks. In the cores of the pillars of Trajan's Bridge large pieces of irregularly shaped stone were used for the inside filling, firmly embedded in layers of lime mortar, and the combined settlement during the process of construction was controlled with a wooden grid.

At the western end of the platform, two important situations can be observed - there are no remains of wooden posts, and the network of wooden beams has a different orientation. This situation is present on both the Serbian and Romanian sides of the masonry structure1. According to Crăciun and Sion researchers, the absence of remains of wooden posts at the western end indicates two possibilities. Based on the first, they could have been embedded deeper in the river bed, so that their top did not reach the surface of the platform as those in the eastern part. Based on the second possibility, the use of wooden posts could have been replaced by another type of construction, by which the platforms at their western ends were fixed to the river bed (Crăciun and Sion 2006: 381). Concerning such possibilities, Crăciun and Sion assumed the existence of a modular system of 6 x 8 posts at the base of the platform (Crăciun and Sion 2006: 384). Additional rows of posts would be located, in that case, on the western and opposite eastern side of the platform. However, we cannot agree with this assumption since neither on the Serbian nor the Romanian side of the platform could we find material data that would confirm it. On the contrary, the state of preservation, or to be more precise, the damage of the platforms on both embankments of the Danube indicates the opposite - that there were as many piles as are visible on the surface of the platform near Pontes, that is, they were stacked in a modular system of 6 x 6 piles. This is primarily indicated by the better preservation of the remains on the Serbian side (Fig. 3).

The wooden grid system at the western projecting end of the fourth pillar platform has a different orientation than that of the rest of the platform surface (Fig. 3). The possibility that there are posts buried deeper in the river bed at the western end cannot, however, be ruled out, but at least one part of them would be visible on the damaged parts of the platform on the Serbian side. Even if such posts do exist, there was a particular reason for them not to appear in the western triangular projecting zone at the western end of the platform, nor 2 m west of the eastern edge of the platform.

There is another interesting detail in the depiction of Trajan's Bridge on the Column in Rome. Namely, if we adopt the thesis of the previous researchers about the reliability of that representation, we notice that the wooden platform with its longitudinal and transverse supporting beams crosses the level where the tops of the arches are located above the embankment structure of the bridge. In that case, the connection of the masonry arches with the wooden platform above the bridge can be viewed from a different perspective. Namely, taking into account that the average distance between the central parts of the embankment pillars was from 5.44 to 6.52 m, we notice that such a span was sufficient to be bridged with stronger wooden beams such as those used to form the supporting structure in the part above the riverbed. Using the representation of the bridge on Trajan's Column, two variants of the construction

1 For an insight into the preservation state of the remains on the Romanian side, see in: Crăciun and Sion 2006. 381. The state of preservation on the Serbian side is visible at the base of the platform depicted in the Fig.1 of this paper (photo documentation of the Institute of Archaeology Belgrade).

that bridged the spans between the pillars on the bank can be assumed. In either of those variants, it is indisputable that there were arches between the protruding endings of these pillars. According to the first variant, as assumed by earlier researchers such as Dupperex, Tudor, and S. Gušić, the spans between the middle parts of the embankment pillars would have been covered by barrel vaults (Fig. 4a) (Гушић 2015: 77, with older bibliography). According to another variant, between the pillars of the bridge on the banks, in the width between their arches, there was a wooden structure made of oak beams (Fig. 4b).

Apart from the depiction of Trajan's Bridge on the Column in Rome, the last conclusion is indicated by a few more details on the bridge construction itself (Fig. 4b). We have already indicated that the values of the length of the middle parts of the bridge's embankment pillars are closer to each other than the values of the total length of the masonry pillars. To be precise, this is the length of each middle part on the first three embankment pillars whose facades were built of bricks. In contrast, the total length of the pillar with the portal differs from the second and third pillars, while the length of the former also differs to some extent from the total length of the fourth embankment pillar (excluding the platform, of course). This would mean that the length of the aforementioned middle parts was more suitable for determining the equal width of the road on the bridge over all the embankment pillars. The same width is covered by the area of the grid system on the platform of the fourth embankment pillar, which is defined by longitudinal and transverse wooden beams, as well as vertically driven posts.

In this sense, the absence of wooden posts at the western end of the platform, which would have secured it to the river bed, can also be observed. Namely, at this point, we would assume that the wooden posts could also have had the function of additionally strengthening the connection of the wooden platforms for the arch supports with the structure of the masonry construction of the bridge. This is supported by the fact that all the imprints of the wooden posts were visible on the surface of the masonry platform of the fourth embankment pillar on the Serbian side, which indicates that they pierced its surface. Since *opus caementicium* did not pass over posts on the platform surface, this could only have been done for a special reason. According to the technical recordings and photographs at the Institute of Archaeology in Belgrade, they were not tied with a horizontal wooden grid system (Fig. 3), so the only other type of structure with which they would be tied is a wooden platform for carrying the wooden arch supports of the bridge. This view fits with the previous one regarding the possible width of the road on Trajan's Bridge (Fig. 4b).

PILLAR SUPPORTS IN THE RIVERBED

Studying Deuster's drawings from 1858, Dupperex reconstructed the shape of the masonry platforms in the river (Tudor 1931: 24). According to him, they were rounded rectangles with two equilateral triangles attached to the shorter sides. The tops of those triangles were directed upstream and downstream and had the function of facilitating the flow of the river so that during this process the creation of river sandbanks did not occur. It is interesting that on the platform next to the embankment pillar on the Romanian and Serbian banks, there are no triangular protruding endings on their eastern parts. However, Crăciun and Sion do not rule out the existence of such protruding parts to the east on pillars in the river bed (Crăciun and Sion 2006: 384).

Using Dio Cassius's statement, these pillars were reconstructed by Dupperex to be 18-19 m (60 ft) wide (Tudor 1931: 25). The method of the foundation of the bridge pillars in the riverbed is very similar to that indicated by Vitruvius in his comments on the method of the foundation of the perimeter walls near seaports a century before the building of Trajan's Bridge. Considering the similarity and importance of his descriptions concerning the construction of the foundations of Trajan's Bridge, they are reproduced here in full. (Crăciun and Sion 2006:381; Витрувије 2009: V, XII, 3 – 6.):

3. Then, in the place previously determined, a cofferdam, with its sides formed of oaken stakes with ties between them, is to be driven down into the water and firmly propped there; then, the lower surface inside, under the water, must be levelled off and dredged, working from beams laid across; and finally, concrete from the mortar trough—the stuff having been mixed as prescribed above—must be heaped up until the empty space which was within

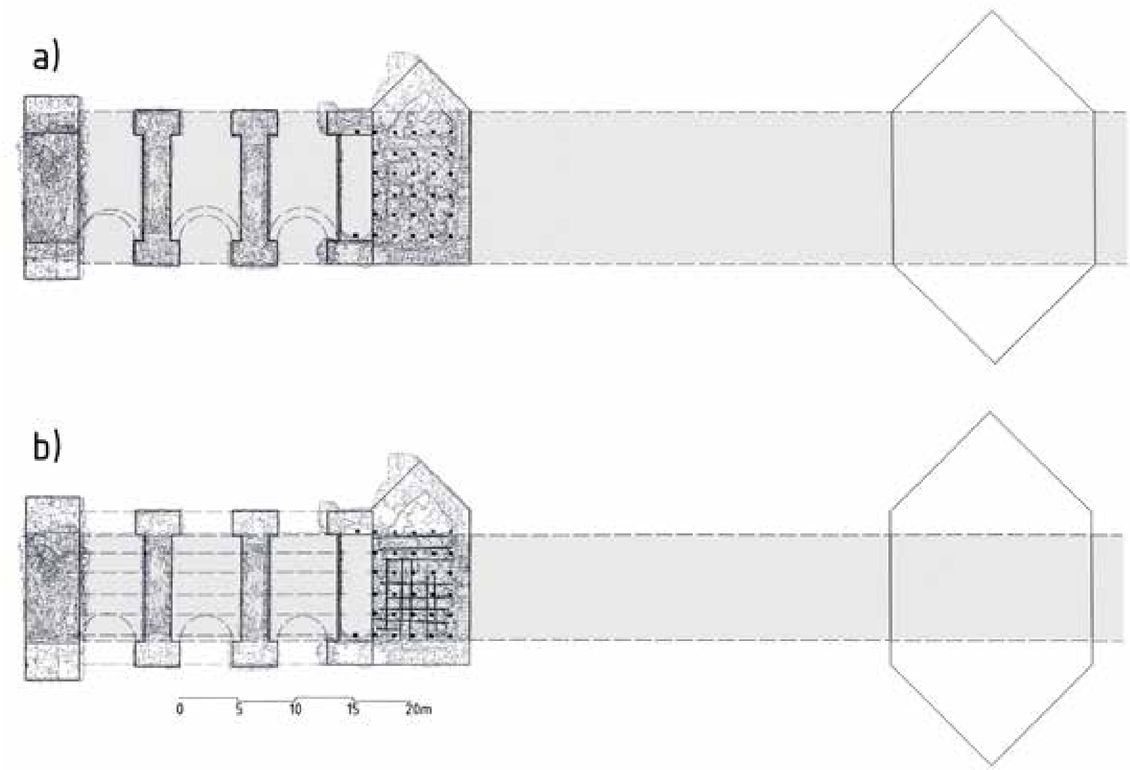

Fig. 4. Two solutions for spanning the spaces between pillars on the bank of the Danube: a. Variant with arches and vaults between middle parts – the width of the walking platform on the bridge is adjusted to the overall length of the second and third pillars; b. Variant with arches on the pillar ends and wooden beams between middle parts – the width of the walking platform on the bridge is adjusted to the length of middle parts of all pillars (technical documentation of the Institute of Archaeology, Belgrade, modified by I. Bjelić).

the cofferdam is filled up by the wall. This, however, is possessed as a gift of nature by such places as have been described above. […]

5. But in places where this powder (volcanic ash) is not found, the following method must be employed. A cofferdam with double sides, composed of charred stakes fastened together with ties, should be constructed in the appointed place, and clay in wicker baskets made of swamp rushes should be packed in among the props. After this has been well packed down and filled in as closely as possible, set up your water screws, wheels, and drums, and let the space now bounded by the enclosure be emptied and dried. Then, dig out the bottom within the enclosure. If it proves to be of earth, it must be cleared out and dried till you come to the solid bottom and for a space wider than the wall which is to be built upon it, and then filled in with masonry consisting of rubble, lime, and sand.

6. But if the place proves to be soft, the bottom must be staked with piles made of charred alder or olive wood, and then filled in with charcoal as has been prescribed in the case of the foundations of theatres and the city wall. Finally, build the wall of dimension stone, with the bond stones as long as possible, so that particularly the stones in the middle may be held together by the joints. Then, fill the inside of the wall with broken stone or masonry. It will thus be possible for even a tower to be built upon it.

Although the example of the construction of the foundation of the bridge in Mainz indicates the possibility of placing one row of planks that limit the volume of the foundation from the outside, the description of the destruction of the foundation on the Romanian side of the river speaks in favour of placing two concentric rows of planks for each pillar in the Danube riverbed (Tudor 1931: 22; Crăciun and Sion 2006: 380). At the same time, this description coincides with that mentioned by Vitruvius (*cofferdam with double sides*).

Based on the aforementioned Vitruvius' statements, as well as the recorded remains of caissons in the river, the statements of Dion Cassius and Tsetses about the use of caissons for the construction of pillars in the river bed can be confirmed (Каровић иЂорђевић 2004: 64-67; Karović, Mihailović and Vučković. 2008: 288, note 2; On earlier literature and historical sources see: Гарашанин и Васић1980: 8). According to the same source, the caissons were 120 feet (36 m) long and 80 feet (24 m) wide. Dupperex, however, warned that the height of the caissons in the deepest places of the Danube river bed, in that case, was significant (before the formation of the Đerdap II hydroelectric power station, the depth of the Danube at that location was about 7-8 m) (Tudor 1931: 33). If it is taken into account that each of the caissons for the pillars was 36 m wide and that, according to the aforementioned ancient writings, the distance between the pillars in the river bed was 56.70 m, then it follows that the width of the river bed at that location was narrowed by about 370 m by the construction of the bridge. This means that the width of the river bed was also reduced by about a third of its value, so the force of the river that flowed past the pillars had to be greater.

Based on Procopius' statements, it is also known that the course of the river was divided into two parts to lower the river level and build supports in the river bed (On earlier literature, historical sources, and Procopius's insight into Apollodor's writings see: Гарашанин и Васић 1980: 8). According to Tudor's interpretations, Apollodorus, therefore, had the opportunity to build at least 4 or 5 pillars on the dry part of the river bed (out of a total of 20 pillars that the bridge had in that part of the river bed) (Tudor 1931: 30 - 32). During the construction of the caissons of the other pillars towards the middle of the river bed, the depth of the river had to be lowered to at least 5-6 m, which is still high for the installation of the caissons recommended by Vitruvius. Even so, the pillar caissons that remained in the water had to be built on land. According to Tudor's hypothesis, which has survived until now as the only possible one, the caissons would then have been anchored at a certain distance and gradually filled with stone and wood to sink to the bottom. The caissons, according to Vitruvius' recommendations, would certainly have been laid so that their planks were facing each other, between which clay was then packed. Thus, a more suitable environment would be created in the interior of the caisson for the construction of the masonry structure of the bridge support. The rest of the water from the interior of the caissons was probably extracted by using an Archimedes' screw, which Vitruvius mentioned in this context above. After that, wooden posts were set in a grid system. A firm lime mortar was tamped within the empty interior of the caissons, so the wooden posts and beam grid system along with the boundary of caissons strengthened the foundations to the ground.

When it comes to the structure and appearance of the masonry pillars in the river, Tudor's reference to the testimonies of people who participated in the demolition of the pillars in the river bed on the Romanian side in 1909 is significant. According to them, at first, they encountered broken stone connected by "concrete" and horizontal layers of bricks. Next came horizontal rows of large hewn stone blocks connected with mortar. The blocks had different shaped blocks with channels on their upper surface. Inside the channel, wooden ties were found that connected two rows of blocks to each other (Tudor 1931: 27).

The placement of the wooden grid systems had to be coordinated with the placement of stone blocks along the edge of the masonry supports in the river bed. One of the best indicators of the method of combining blocks with wooden beams are the preserved blocks from the destroyed pillars on the Romanian side of the riverbed. After their destruction, the blocks were transferred to the yard of the river fleet command building in Drobeta - Turnu Severin. These blocks were technically recorded and published by Tudor, whose drawings we use here on this occasion (Fig. 5) (Tudor 1931: Fig. 8). The blocks were 110-140 cm long and 42 cm to 75 cm wide, depending on the position. Their height is between 56 and 60 cm (Tudor 1931: 27). On their top and bottom surfaces, carved channels, 7 - 8 cm wide and deep, are noticeable in different formations. According to their dimensions and the appearance of the channel, such hewn blocks correspond to those that can be seen on the fourth embankment pillar on the Serbian side of the river. The angles and position at which these channels are orientated and placed are adapted to the geometry of the blocks themselves and their place in the plan of the masonry river pillar. Some intersections of these channels were made at an angle of 90°, while others were at an angle of 135° (90° + 45°). In these channels, there were wooden beams that connected the core of one pillar with the blocks of its stone faces. Placing wooden grid systems in the interior of the masonry supports allowed the mass of stone and mortar to settle equally within the mass of the core. Finally, using a strongly tamped mass of mortar and stone, the compact core structure of these supports was formed, which is indicated by the fact that the remains of masonry supports in the riverbed have survived to this day.

The same method used for the wooden grid systems and posts in the masonry core of the platforms of the fourth embankment pillar was also used for the execution of the masonry supports of the bridge in the river bed. Major Imbrišević's report also points to the existence of pilots near the river pillars (Tudor 1971: 202; Crăciun and Sion 2006: 382). It is obvious that Apollodorus counted on several factors to ensure the stability of the masonry pillars of the bridge. The monumental masses of masonry supports were formed, strong enough to resist the force of the river, the humidity of the surrounding landscape, and temperature changes, and strong enough to carry the monumental wooden arches of the bridge's supporting structure.

Above that kind of prepared foundation, the wooden structure of the bridge was constructed. The kind of radial and concentric structure that we can see in the depiction of the bridge on Trajan's Column in Rome was probably most similar to the constructions of wooden scaffolding for the execution of the masonry arches on the aqueduct of Pont du Gard in France. Similar constructions were reinvented during the 18thcentury in France and Great Britain (for more information on these structures see: Bjelić 2020, with bibliography).

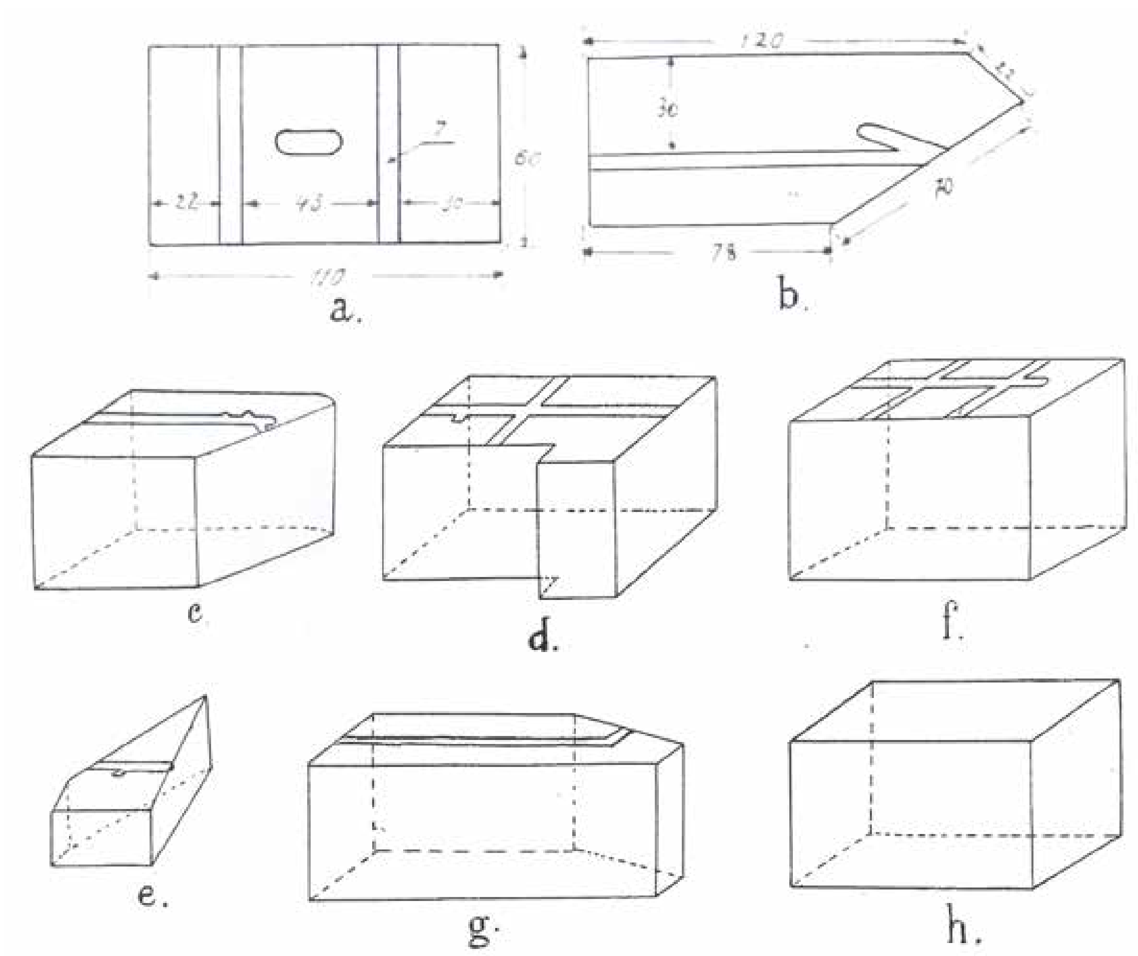

Fig. 5. Ashlars from the pillars of Trajan's Bridge in the Danube riverbed. On their surfaces, the carved channels for wooden beams can be seen (according to Tudor 1931, Fig. 8).

CONCLUSIONS

The study of the use of different materials in the construction of Trajan's Bridge indicates that without the analysis of ancient writings one cannot get a clearer picture of the former appearance of the bridge and ancient construction methods due to the pronounced damage of its remains. Writings such as Tsetses, Dio Cassius, Procopius, and Vitruvius enable us to get a clearer picture of the use of these materials during the construction of Trajan's Bridge.

Field data is certainly the most important in terms of specific methods of using different materials. In the case of Trajan's Bridge, it is particularly significant if elements of these materials are preserved in situ, but equally important are the imprints of specific elements in the *opus caementicium*. Imprints of wooden elements on part of the foundations indicate the way in which the foundation was formed and the degree to which mortar and stone were compacted, to achieve the best possible bond between these two materials. The analysis of the special positions of individual elements and materials on the embankment part of the bridge construction indicates the need to reconsider certain interpretations about the method of spanning the spaces between the pillars in this space. The method of spanning between the pillars in the river bed and the analysis of the dimensions of individual elements on the embankment parts of the structure indicates that the spaces between the embankment pillars did not have to be covered with barrel vaults, but with wooden beams. The aforementioned conclusion would also affect the speed of execution of the entire structure, which is characteristic of the entire structure of Trajan's Bridge.

In the example of Trajan's Bridge, we see a variety of construction methods. This is the result of the combination of different materials used during building in different environments (the parts of the construction exposed to water and those parts exposed to the air and soil). In the end, we can say that most of the processes undertaken during the construction of the bridge were devoted to the stability and durability of the structure. Bearing in mind that Romans did not know about static calculations and that their approach to the equilibrium of building structures was empirical, we can recognise that all the combinations of materials used during the construction of the masonry parts of Trajan's Bridge were devoted to most of the aspects of its security known to its builders. The wooden construction could not, of course, last long above the surface of the river, and there is a good probability that the Romans destroyed it themselves during the retreat from Dacia. However, the fact that masonry parts of the bridge remaining in the river bed and on the Danube banks of Romania and Serbia survived for such a long time speaks in favour of the idea that the supporting structure of the bridge must have been planned as thoroughly as Roman engineering could provide.

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REZIME

UPOTREBA GRAĐEVINSKIH MATERIJALA TOKOM IZGRADNJE TRAJANOVOG MOSTA NA DUNAVU

KLJUČNE REČI: GRAĐEVINSKI MATERIJALI, METODE KONSTRUKCIJA, ZIDANE STRUKTURE, TRAJANOV MOST, RIMSKA ARHITEKTURA, DUNAVSKI LIMES.

Posle prvog rimskog osvajanja Dakije, car Trajan je svom arhitekti Apolodoru dao izazovan zadatak da projektuje i izgradi najveći poznati most u antičkom svetu, dužine preko 1.000 metara, koji je premostio jednu od najvećih evropskih reka - Dunav. Brzina izgradnje mosta, koju je car morao zahtevati, nametnula je korišćenje više različitih metoda konstrukcija koje su se odnosile na konkretne elemente mosta.

Prateći umetničke i istorijske izvore, *in situ* ostatke i analogije u ostalim delovima Rimskog carstva, u ovom radu su izvršeni pokušaji definisanja izgleda konstrukcije mosta. Nju čine tri dela: deo mosta na obali reke, deo noseće konstrukcije u koritu reke i deo mosta preko površine Dunava. Dok je poslednji deo bio isključivo od drveta, a deo u vodi bio zidan, za izgled obalnog dela su moguće dve varijante, prema kojima je on mogao biti u celosti zidan ili izveden u kombinaciji zidane strukture i drvene kosntrukcije.

In situ ostaci na obalnim delovima mosta pokazuju specifične metode izgradnje ovog dela konstrukcije. Na delu stubaca u visini temelja reg-

istrovani su jasni otisci dasaka, koji pokazuju u kojoj meri je *opus caementicium* bio nabijen i kako su temelji građeni. Lica podužnih strana nadzemnih delova stubova, zidana su od opeke. Bočna lica nadzemnih delova stubaca zidana su kamenim blokovima čvrsto povezanim sa ostatkom stubova drvenim rešetkama.

Opravdanje upotrebe napred navedenih različitih građevinskih materijala možemo potražiti u ispitivanju Apolodorove potrebe za brzom izgradnjom mosta. Na danas sačuvanom stupcu kome pak nedostaje lice uočljivo je da je nalivanje i nabijanje *opus caementicium*-a vršeno slojevito i u skladu sa periodičnim postavljanjem drvenih rešetki u ulozi armature. Za unutrašnju ispunu stubaca mosta korišćeni su komadi kamena nepravilnog oblika dobro uronjeni u slojeve krečnog maltera, dok je ravnomerno sleganje u procesu izgradnje kontrolisano drvenom rešetkom.

Sve intervencije rimskih inženjera korišćene pri izgradnji zidanih stubaca Trajanovog mosta pokazuju da je njihov pristup bio empirijski, posvećen većini njima poznatih aspekata sigurnosti konstrukcija. Istovremeno, kombinovanje različitih građevinskih materijala za konstrukciju mosta bilo je verovatno uslovljeno potrebnom brzinom izgradnje, ali i okolnim prirodnim uslovima, odnosno dostupnošću i karakteristikama upotrebljenih materijala.

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GLAMIJA - RTKOVO, NEW CONSIDERATIONS

ABSTRACT

Glamija - Rtkovo is one of the important archaeological sites on the lower course of the Danube in Serbia. The discovered parts of architecture and movable finds offer the possibility for the analysis of architectural elements, used materials and mutual relationships of structures of older and younger fortifications, as well as their dating. Also, with more detailed analysis, it is possible to draw certain conclusions and principles on the basis of which a proposal for the ideal architectural reconstruction of the older fortification could be made, as well as a comparison with similar fortifications in the immediate vicinity.

KEYWORDS: LIMES, THE DANUBE, LATE ANTIQUE, ARCHITECTURE ANALYSIS, FORTS.

INTRODUCTION

The fortification at the site of Glamija, near the village of Rtkovo is located on the lower course of the Danube in Serbia. It is positioned 12 km downstream from the village of Kostol (ancient *Pontes*), opposite the Romanian village of Hinova (Fig. 1). The site is located on a small natural elevation along the steep bank of the Danube, due to which part of the fortification was irretrievably lost (Fig. 2). This is also the most prominent point opposite the Romanian bank, hence its strategic importance for the defence of the Danube Limes from enemy incursions. The existence of visible remains of the fortification was first recorded by Count L. F. Marsigli, and was then mentioned by other travel writers and explorers. In their reports, they mentioned a square fortification whose remains were visible even above the ground. (Marsigli 1726: 21; Kanitz 1892: 51) Today, the remains of the architecture are found only underground1, mainly due to decomposition and the extraction of its stone and other building materials by the resident population after the Second World War. It is probably for this reason that M. M. Vasić left this site out during the reconnaissance of this part of Limes (besides the fact that his focus was on prehistoric sites). (Васић 1910: 9-15)

In order to obtain the necessary elements for determining the shape and dimensions of the fortification, as well as the dating, archaeological research was undertaken in 1980-1982, and revision excavations in 2020. Then, the remains of two fortifications were discovered and confirmed, the smaller internal one that was extensively explored and the larger outer one that was partially explored2 (Gabričević 1986:71-91) (Fig. 3).

RESULTS OF ARCHAEOLOGICAL EXCAVATIONS

The smaller fortification, if we can call it that, has an irregular square base, irregularly placed in relation to the outer one, measuring 19.50 m x 19.50 m from the outside and 13.80 m x 13.80 m from the inside (Fig. 4). In some places, the huge rampart was preserved up to a height of 1.50 m,

1 Apart from the excavated parts of the site.

2 Documentation of the Museum of Krajina in Negotin from the excavation of the Glamija - Rtkovo site in 2020.

Fig. 1. Position of the site (drawing by B. Popović - on map in public use)

which was confirmed by the latest research, but in some places, it was devastated and broken down to the foundation level. The width of the foundation zone varies from 2.85 m to 3.05 m, while the width of the ramparts is reduced, on both sides, to 1.60 m via two symmetrical plinths. The foundations are solidly built with large pebbles and irregularly broken stones, bound with high-quality lime mortar (Fig. 5). The upper zone of the walls, above the level of the foundation, is built with half-hewn stone and in some places with brick fragments, while at a certain height there is a whole brick, measuring 35 cm x 30 cm x 6 cm, built in four rows as a levelling course. The levelling course was discovered in the zone of the north-western corner, and we can assume that such courses were also in the higher zones of the ramparts, which was a common case in the technique of building fortifications in the immediate vicinity, such as the Borđej and Mihajlovac sites. (Цермановић-Кузмановић и Станковић 1984: 219; Цермановић-Кузмановић 1979: 129) We

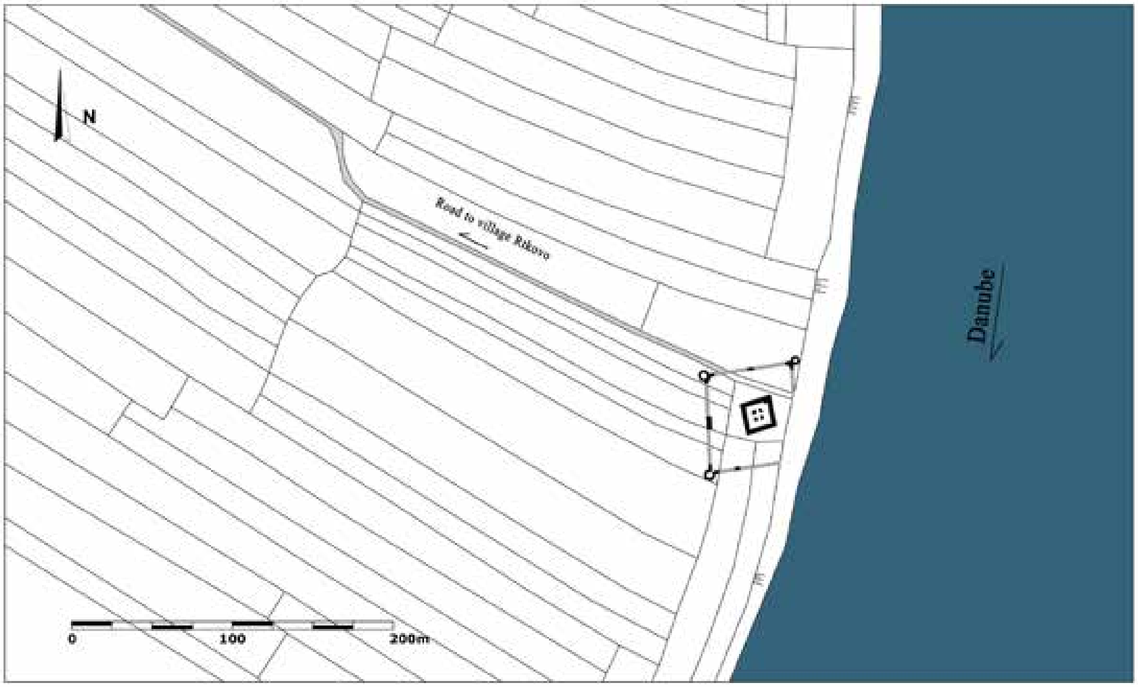

Fig. 2. The wider situation of the locality (drawing by B. Popović - based on technical documentation of the Museum of Krajina)

must emphasise that no bricks with seals have been found during the excavations so far, which makes it somewhat difficult to conclude which military unit was stationed here. The entrance to this fort was most likely located on the western side. Its position is not exactly determined, but it can be assumed based on the larger stone blocks in the zone of the walls' plinth. (Fig. 5)

In the central part of the internal fortification, four foundations were discovered, built of stone and, in some places, bricks bound with lime mortar (Fig. 6). They are arranged symmetrically, and they served as support for the masonry pillars of the upper structure. The pillars have irregular square bases with one rounded corner, measuring about 2.30 m x 2.30 m, and the bottom of the foundation was found at 2.20 m from the ground level, i.e., from the level of the preserved wall mass. The distance from the pillars to the rampart is about 3.50 m, while the distance between the pillars is about 1.50 m. In the inner part of the fortification, in the north-eastern corner, a masonry structure measuring 1.10 m x 1.90 m was discovered, emerging from the mass of the wall. There is a noticeable cascading level that can be connected to the stairs, while the larger levelled surface could be characterised as a landing from which one stepped on the second stair flight at a right angle (Fig. 7).

The same, uniform building material was used for the construction of the entire building, ramparts and pillars in the central part, which indicates that the building was built at the same time without any different construction phases, and with only later repairs. In places where it was possible, during the excavations in 1980-1982, the stratigraphy of the internal fortification was determined, which showed that the horizons were separated by layers of charred remains of wooden structures and rubble. (Gabričević 1986: 72) This was confirmed by excavations in 2020, to a greater extent, but there were no datable finds. Two horizons can be distinguished here, which are important for understanding the function of this fortification, the older of which is determined by the finds of coins of Valentinian I, Gratian, Theodosius, Honorius and Arcadius. The objects found in this layer, especially the fibulae and lamps, also belong to that period. The younger horizon, less rich in inventory, is defined by the coins of Anastasius and Justin I. (Gabričević 1986: 73) It is important to note that the presence of various finds, in addition to military ones, indicates considerable craft and agricultural activity of the residents of the fortification, as well as the importance of the Danube for their existence.

The outer fortification is positioned on a

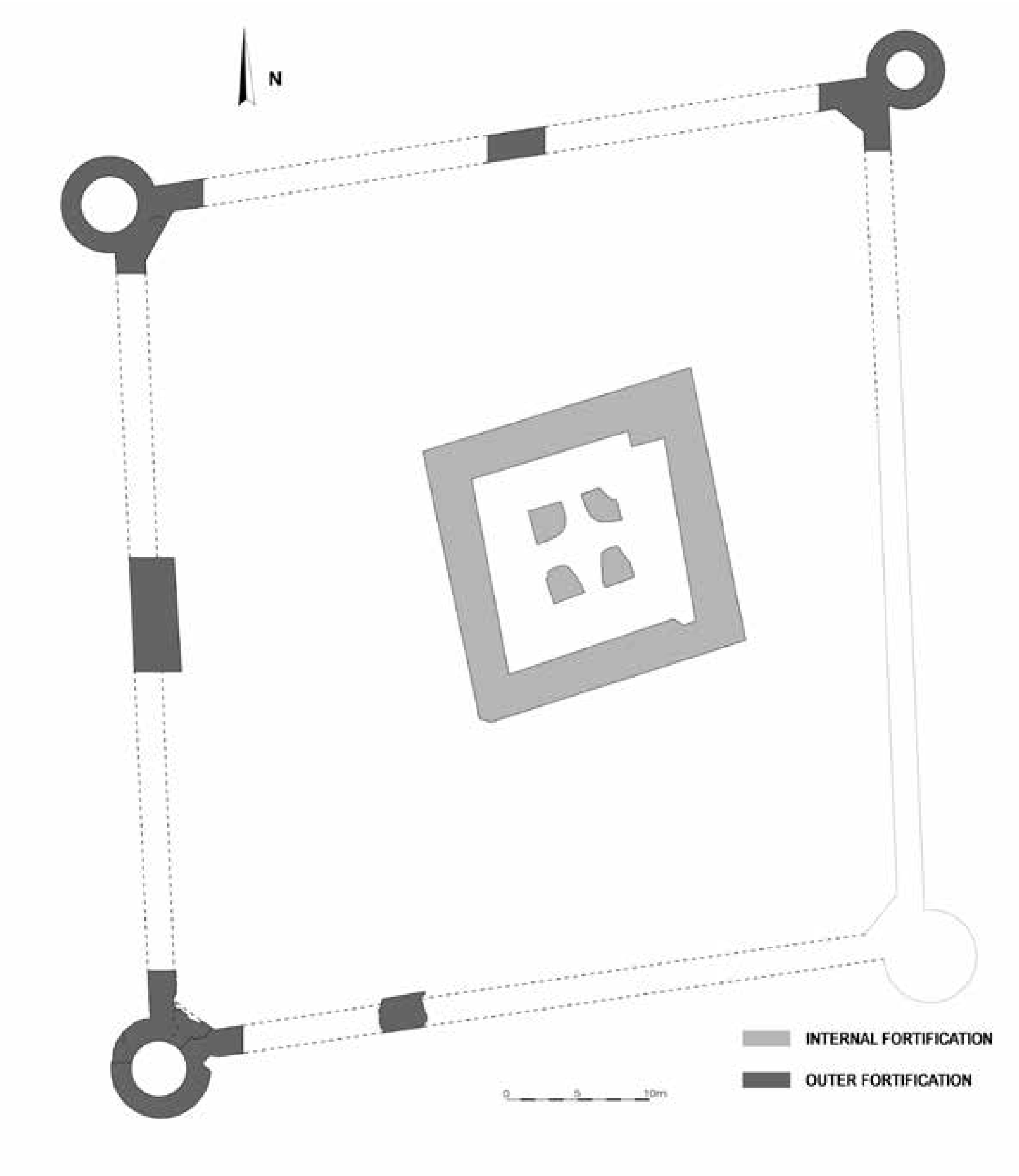

Fig. 3. Closer location of the site (drawing by B. Popović - based on technical documentation of the Museum of Krajina)

slightly sloping terrain that falls towards the river and follows an east-west orientation. Its base, which partially deviates from the regular square, consists of four angular circular towers and a rampart between them (Fig. 8). Excavations so far have confirmed the northern, southern and western ramparts, while the eastern one was probably destroyed by the flow of the Danube. The remains of the rampart are very poorly preserved, in some places only at the level of the foundation, and in others up to about 1 m high, while its width is extremely large, about 2.4 m (Gabričević 1986: 73). Based on the uncovered parts of the ramparts, it is possible to determine their direction and position. The length of the fortification in the east-west axis is 51 m, while the dimension in the north-south direction has been roughly determined to be about 50 m. The thickness of the ramparts in the foundation zone is about 3 m, while the upper zone is about 2.4 m wide. Three angular circular towers

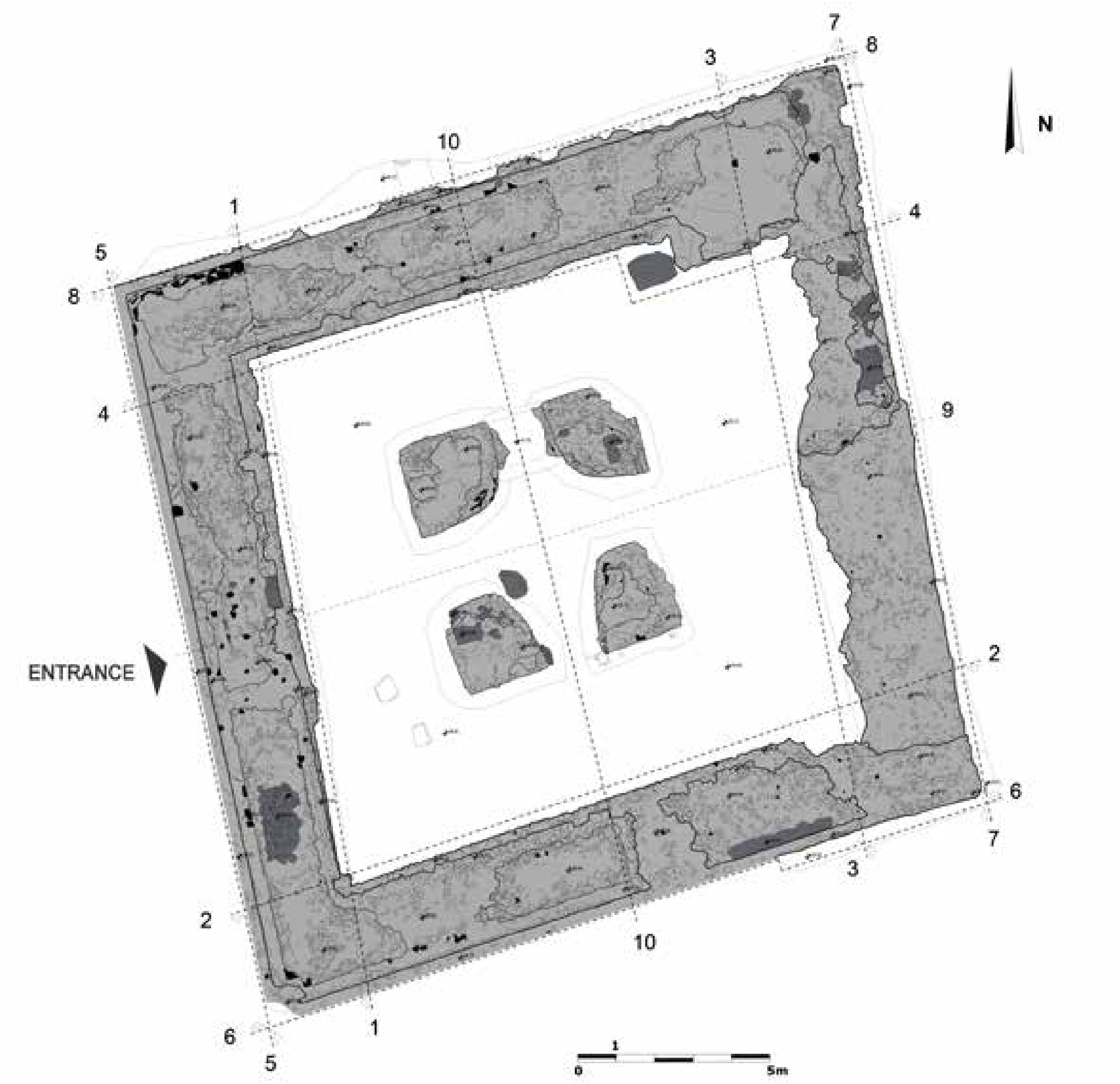

Fig. 4. Plan of internal fortification (drawing by B. Popović - based on technical documentation of the Museum of Krajina)

were also discovered, which intruded into the field in relation to the outer face of the rampart, with which they were connected by a heavily reinforced masonry segment that formed the bulk of the rampart. The towers were entered through this reinforcement, and the entrance was most likely formed into a barrel vault. The north-western and south-western towers have an external diameter of about 7.5 m, while the north-eastern one is slightly smaller at 5.3 m. They were built with half-hewn stone alternating with four rows of bricks, measuring 36 cm x 30 cm x 4.5 cm, which served as a levelling course, bound with high-quality lime mortar, creating huge joints 8 cm thick. During the excavation, it was found that the floor of the tower was paved with bricks. The walls of the towers have been preserved in some places up to 1.9 m high, which is very important for the later reconstruction during conservation. It is important to note that during the excavation, an expected layer of rubble along the ramparts was missing, whose existence would be expected in the case of a powerful structure, so the question arises whether the younger fortification was completed at all.

ANALYSIS OF FORT ARCHITECTURE

In order to clarify the connection between the outer and internal fortifications, excavations were undertaken in the intermediate space. No connection was found between these two structures either in their construction or in any other details.

Fig. 5. Construction and masonry techniques of the foundation and above-ground zone of the rampart (photo by B. Popović)

A significant height difference between the two fortifications was noted, which also contradicts any organic connection. In addition, the construction techniques used in both cases, as well as the asymmetric position of the internal and outer fortifications, support the hypothesis that these two structures were built at different times. Their construction was dictated by the strategic importance of this locality on the banks of the Danube. (Gabričević 1986: 74)

The investigation of the locality conditioned the level and scope of the analysis of the architecture, which would be significant for understanding the construction method and the constructive structure of this type of fortification, but also the basis for some future conservation solutions in order to present the site.

Older - Internal Fortification

A comprehensive analysis of the conditions on the ground and the documentation from the excavation concluded that the older fortification was compact and consisted of a huge masonry construction of a circumferential wall with four masonry pillar bases in the central part.

The perimeter wall was built on a huge foundation, about 3 m thick, which was reduced via two symmetrical plinths to a final width of 1.6 m. Based on the size of the foundation and the width of the rampart of 1.6 m, we can assume that the rampart had a considerable height. This assumption is also indicated by a large amount of rubble that occurs right next to the rampart, which represents the collapsed wall mass. The masonry pillars, which also have huge foundations, most likely supported the upper floor construction, as well as the roof structure. The distance between the perimeter wall and the pillars in the centre is about 3.80 m, which indicates that this could have been spanned with wooden beams, which would have carried the floor construction. In the highest zone, a hipped roof could easily have been formed over the entire space or only over the central part with pillars.

In support of the thesis with a wooden upper construction, there is also a large number of finds of metal wedges, nails and clamps that were most likely used to connect wooden structural elements, as well as a large number of roofing bricks found

Fig. 6. Construction and masonry techniques of the foundation zone of the pillars in the interior of the fort (photo by B. Popović)

in the rubble above the floor. (Gabričević 1986: 74) Also, in support of the storey construction, there is a rectangular mass of masonry in the northeast corner of the fortification, on which the remains of three steps and a landing, from which the second flight of the stairs was accessed at a right angle, can be identified. The second flight of stairs was most likely wooden because no masonry structure was found, so such a solution is the only possible one. The first flight of three steps is parallel to the north wall and approached from the eastern side, while the second flight was probably parallel to the east wall and was approached from a masonry landing. The position of the staircase next to the rampart determines the height at the exit part of the upper floor construction, as well as the organisation and structural assembly of the upper zone. If we were to assume, based on the free space where it is possible to form a wooden flight of a staircase, the number of treads and the height of each step, we get an approximate height of about 6 m from the floor level. This could be the elevation of the first-floor construction, but also the height of the walkway, if the rampart ends just above the level of the floor construction. The central part, which would be supported by the pillars in the centre, could then have a greater height with another floor that would have been accessed by stairs from the first floor. In that case, the assumed second floor could have served as an observation post and only the central part would have been covered. If the rampart had a full height, and the entire area was covered, the function of the fortification and the way it was used would be called into question (Fig. 9a and Fig. 9b). A similar masonry structure, positioned in the corner of the fortification, can be found at the sites of Donje Butorke and Mihajlovac (Цермановић-Кузмановић 1979; Цермановић-Кузмановић и Станковић 1986)

The entrance to the fortification, as we mentioned, was most likely from its western side, which is suggested by the stone blocks in the wall

Fig. 7. Masonry structure of stairs (photo and drawing by B. Popović)

mass at the level of the threshold. Such blocks are not found in other parts of the wall mass, so it is likely that they were part of the threshold or entrance zone. The area around the entrance is poorly preserved, but a regular unevenness of the wall mass is noticeable on that part of the western rampart. The level of the entrance and the level of the first step of the masonry part of the staircase, as well as their relationship with the second level of the plinth, lead to the conclusion that the floor rested precisely on the second level of the plinth, which indirectly indicates the level of the fortification's ground floor or the level of use, since the excavation reports do not mention a mortar floor. The position of the staircase also supports the assumption of the position of the entrance and the organisational scheme of the fortification in which only the western wall is suitable to contain the entrance opening. We find an almost identical structure at the sites of Mihajlovac-Mora Vagei, Donje Butorke and Borđej, which leads us to the conclusion that these were typical fortifications for this part of Limes.

Analysing the building materials used, it is noticeable that a uniform material was used for the construction of the internal fortification. The foundations were built with pebbles, sometimes with one row of bricks for levelling, while half-hewn stone was used for the upper zones of the face of the walls, for easier masonry work, and with a levelling course of four rows of bricks. The filling of the inner zone of the walls was usually rubble core - broken stone and pebbles with a lot of lime mortar (Fig. 5 and Fig. 6). This masonry work is characteristic of a fortification of the 4th century that is, of the period of Late Antiquity, and is found in many sites on the Limes built in that period. These facts support the assumption that the whole internal fortification was built at the same time and that the works on its construction were synchronised, and that they were carried out during the 4th century.

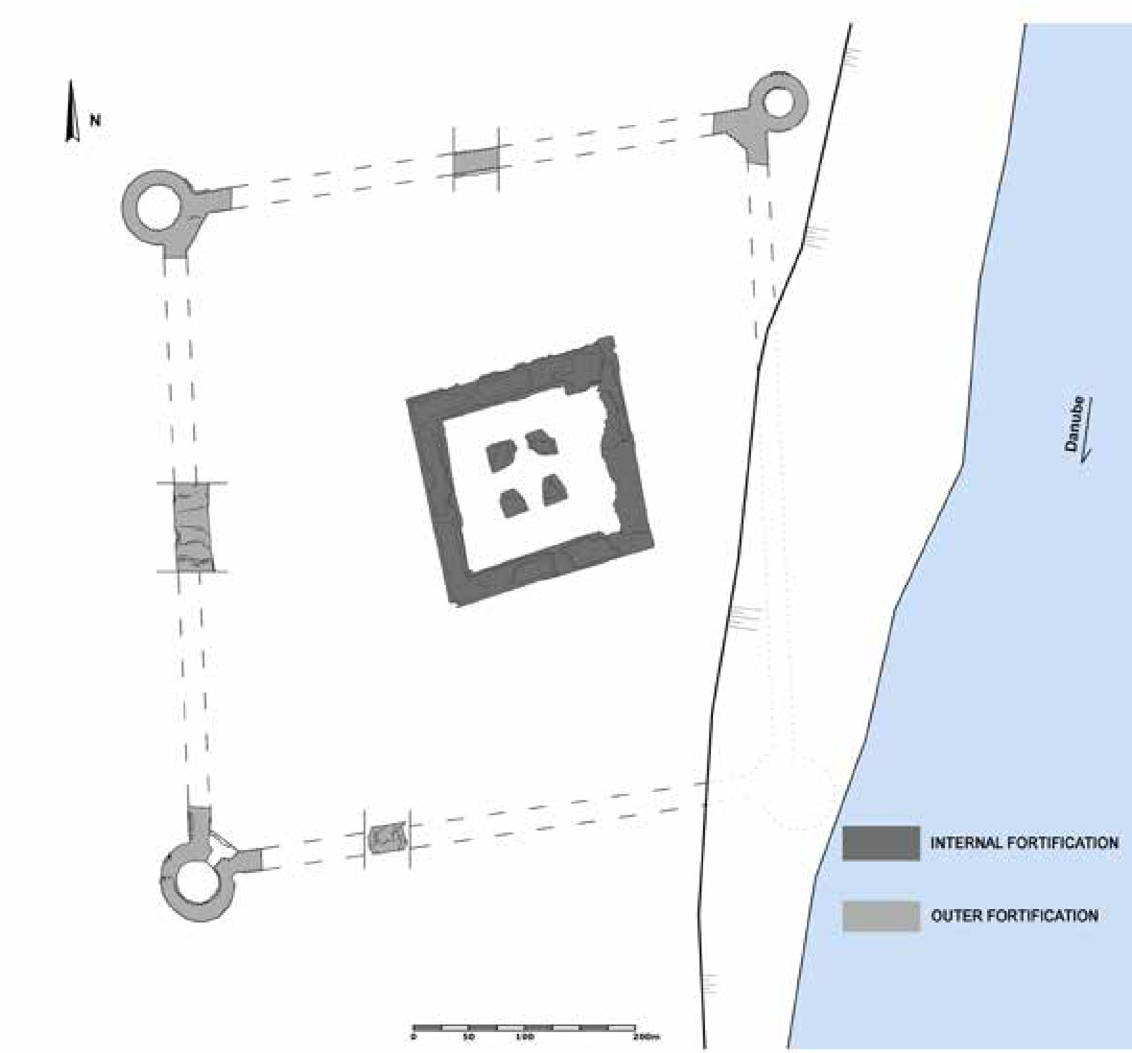

Fig. 8. Plan of external fortification (drawing by B. Popović)

Younger - Outer Fortification

The younger fortification, formed around the older one at a distance of about 20 m, has a completely different architectural structure and looks more like classic fortifications with towers and ramparts. The position of the towers on the corners is characteristic of the fortifications of Donje Butorke and Ljubičevac (Цермановић-Кузмановић и Станковић 1986; Паровић-Пешикан 1984), where the towers are placed on the corners, and their shape and dimensions almost match, with only minor deviations and differences. For example, in the Donje Butorke site, the towers have radially arranged buttresses on the outside, which had a constructive role to ensure stability due to the large slope of the terrain towards the Danube, while in other sites the situation was much more favourable and there was no need for this type of reinforcement. Also, the position of the towers, which extruded in relation to the rampart, is a characteristic of late antique fortifications and one of the most significant changes in the development of Roman fortifications. (Pop-Lazić, Rummel 2020: 231) Certain overlaps are also noticeable in the dimensions of the fortifications, so that the fortification in Donje Butorke has dimensions of 46 m x45 m, Ljubičevac about 52 m x 54 m, while the other fortifications are somewhat smaller.

The ensemble of the younger fortification - ramparts and towers, was built with larger stones and bricks in four rows, bound with lime mortar. The presence of larger broken stones with a lot of mortar that was used to fill the ramparts is also

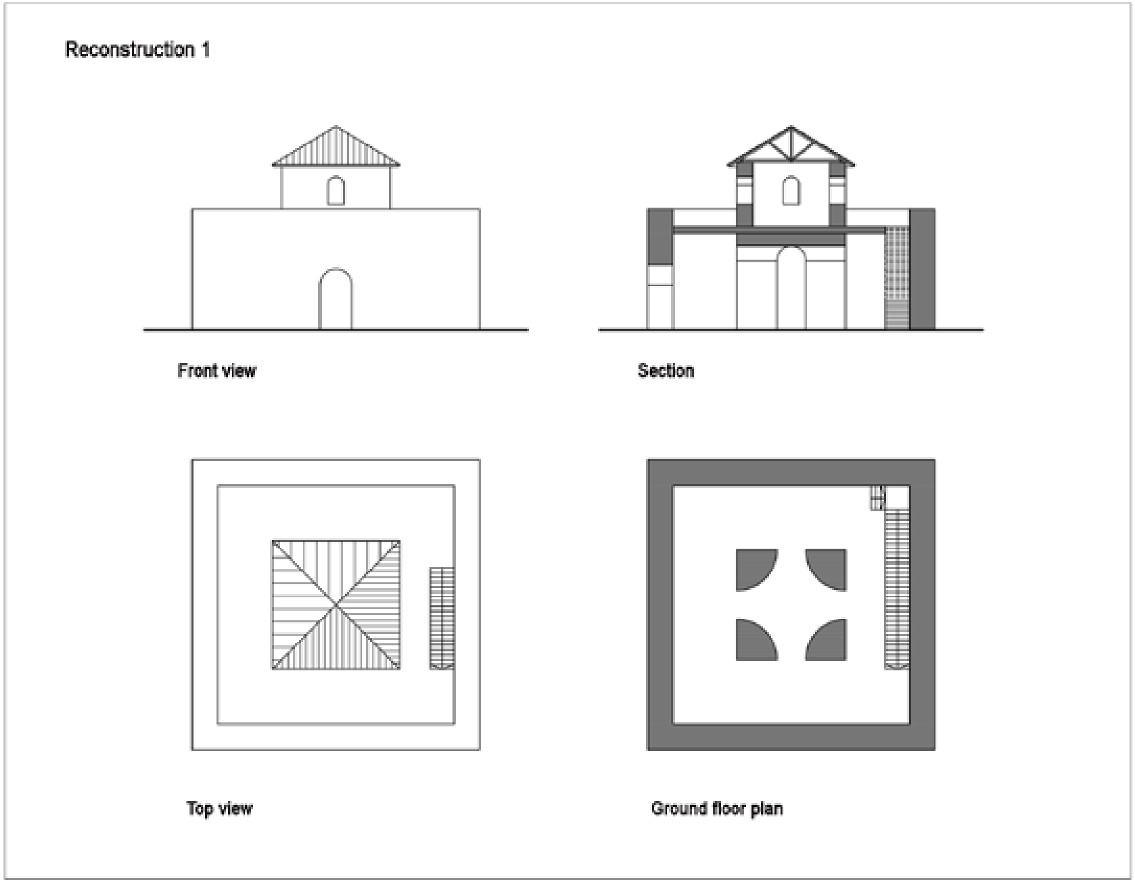

Fig. 9a. Schematic reconstructions of the watchtower (drawing by B. Popović)

noticeable. Here it is obvious that there are certain differences in the material used.

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Although it is assumed that the fortifications were built independently of each other, this can be said for the older fortification, while the construction of the younger one was influenced indirectly by its position, size and orientation. The choice of location was an important factor in the functioning of fortifications on the Limes. We can notice that it was influenced by many factors, but the most important is the relationship with the river, which was undoubtedly the main geographical feature that determined the border. One of the factors was the distance between the fortifications, as well as the relationship to the enemy territory. It is particularly interesting to note that from a micro-locational point of view, the positioning of the fortifications, in the part of the lower course of the Danube in Serbia, was followed by a lot of different parameters that defined the setting up of bases in Đerdap. The main characteristic of the fortifications from Čezava to Egeta is that they were placed directly along the Danube, or as close as possible to the river. Therefore, their direct topographical relationship to the river is fundamentally different from those observed in the upper course of the Danube in Serbia, where the fortifications were placed on the tops of the loess plains and terraces that formed next to the river, i.e., a few tens of meters above the Danube, as is the case, for example, in *Bononia, Cusum, Ad Herculem, Acumincum* and *Ritium*. (Pop-Lazić, Rummel, 2020: 227) This characteristic has led to the fact that in several cases, the Danube has washed away parts of fortifications that were often built on the unfavourable ground right next to the river, which is also the case with the younger fortification in Glamija.

As for the building materials used for the construction of the outer and internal fortifications, there are noticeable differences in their dimensions. The material used for the construction of the

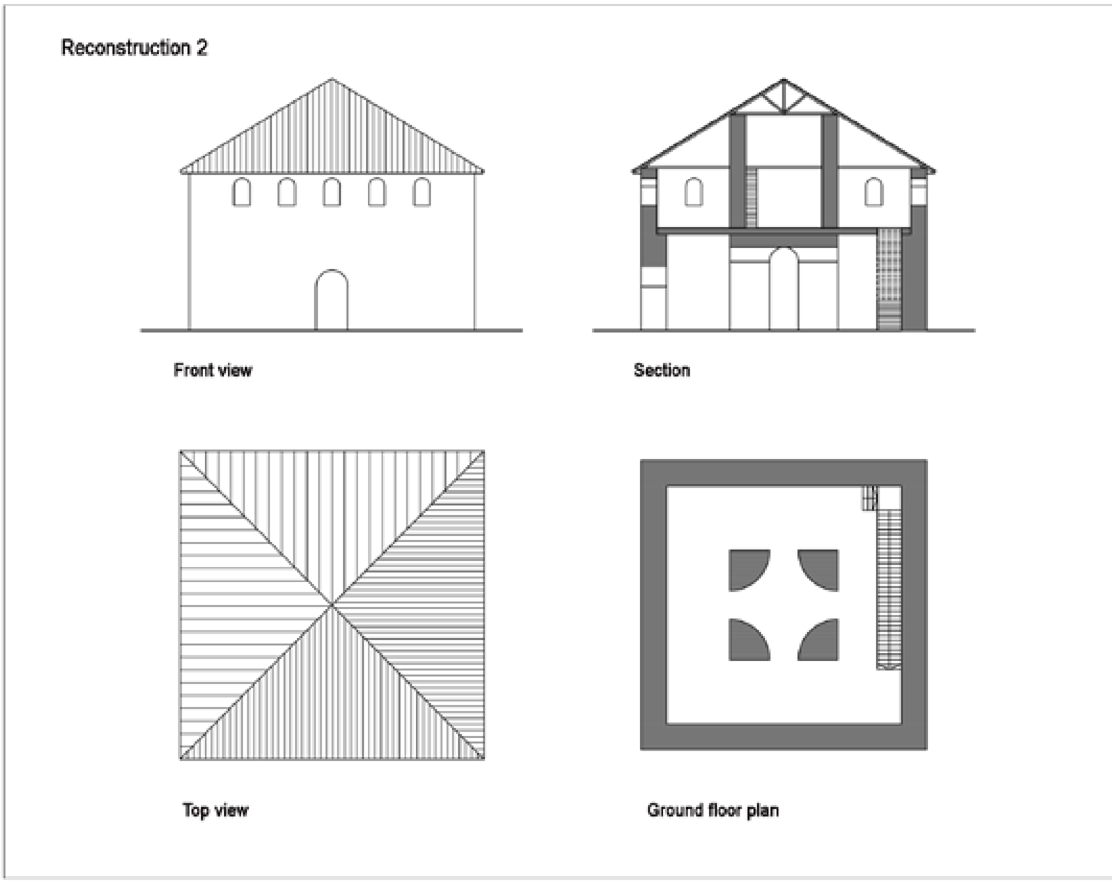

Fig. 9b. Schematic reconstructions of the watchtower (drawing by B. Popović)

outer fortification was larger than that used for the construction of the internal fortification, which is characteristic of a building of this size. The difference in the dimensions of the bricks and the mortar joints between them also stands out. For the internal fortification, the bricks measure 35 cm x 30 cm x 6 cm with 4 cm – 6 cm joints, while for the external fortification, the brick dimensions are 36 cm x 30 cm x 4.5 cm, and the joints are 8 cm. With the lime mortar, apart from the fine sand, the use of very coarse aggregate is noticeable in both fortifications, which is especially pronounced in the younger fortification.

CONCLUSIONS

The facts presented indicate that the two fortifications, the internal and the outer, were built in different time periods. The internal fortification, or watchtower, is dated in the literature to the second half of the 4th century, according to the coins found during the excavations (Gabričević 1986: 74), but it can also be dated thus based on the masonry technique and the materials used. It is assumed that the fortification suffered some damage at the beginning of the 5th century, when it was partially rebuilt (Gabričević 1986: 72). Also, (Fig. 10) analogies with similar fortifications in the immediate vicinity, Donje Butorke, Mihajlovac, Borđej and Ljubičevac, (Цермановић-Кузмановић 1979; Цермановић-Кузмановић и Станковић 1984; Цермановић-Кузмановић и Станковић 1986; Паровић-Пешикан 1984) indicate that this fort was built during the 4th century, i.e., that there was a series of fortifications built in the period of the first tetrarchy, at the time of Diocletian. The older fortification, which is a fortification in the true sense of the word, has not been clearly dated in the literature due to the complete absence of movable finds. (Gabričević 1986: 73) We assume, based on the dimensions, masonry techniques, as well as analogies with the already mentioned fortifications of Borđej (Цермановић-Кузмановић и Станковић 1984: 217) and Donje

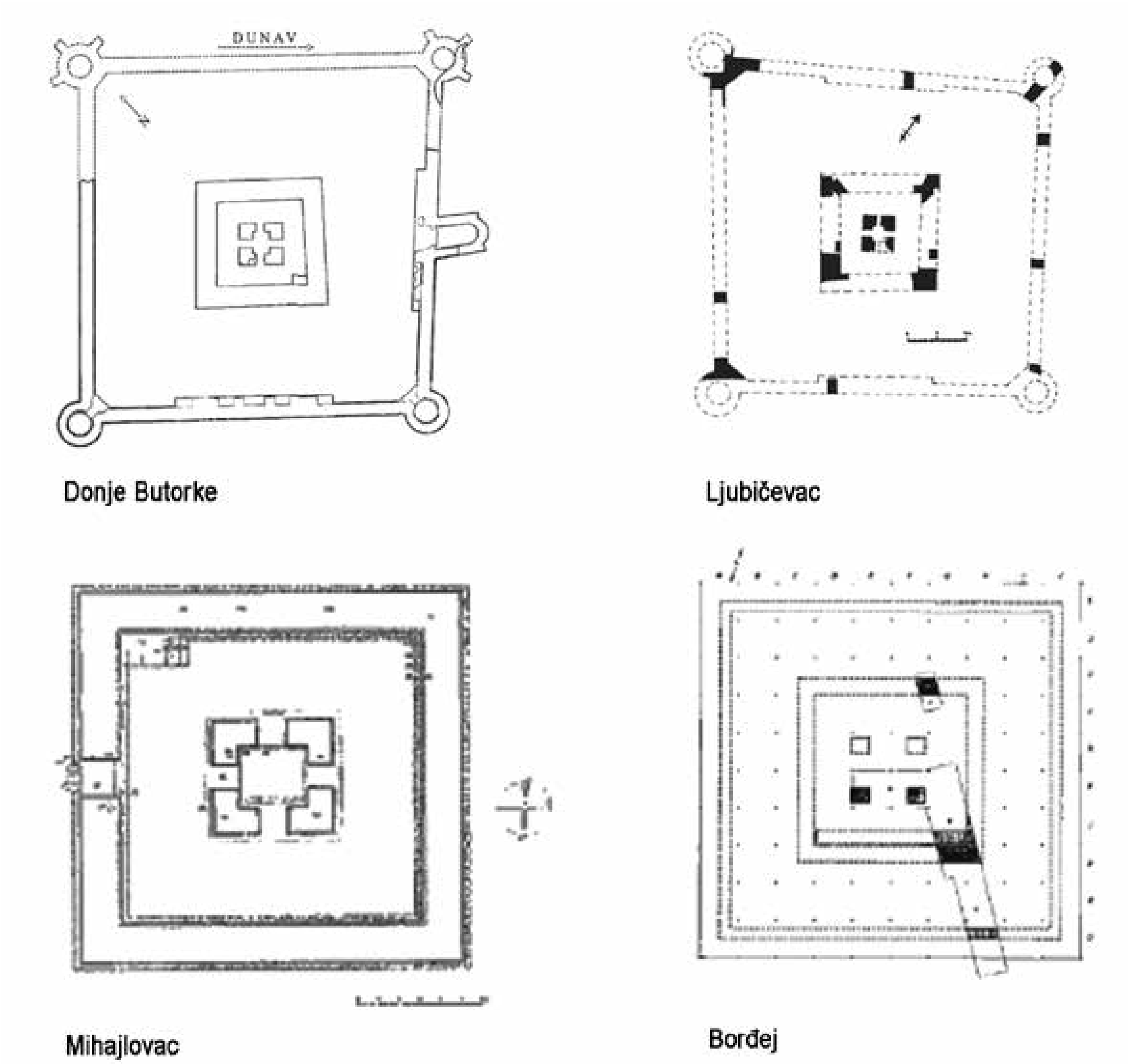

Fig. 10. Analogies - the fortifications that are most similar (according to Pop-Lazić, S. and Rumel, C., 2020)

Butorke (Цермановић-Кузмановић 1979: 127), that its construction was started in the 6th century, during Justinian's renovation of the Limes, and it is questionable whether it was completed. It is clear that it was built as an upgrade or modification of the existing structure in order to improve defence capabilities, that is, to fit in with the new trends of development in military architecture.

A number of questions also arise, to which we cannot now give an exact answer, one of them being how many soldiers were stationed in this fort in the first and later periods of its functioning, as well as the purpose of the building, which we assume was a watchtower. The question arises whether the soldiers were stationed in the watchtower or whether they came from a nearby fortification such as *Pontes*. Also, the question remains open as to what the watchtower looked like, how many floors it had and what its relationship was to the environment, from a military-tactical point of view. These and many other questions will hopefully be answered by new research.

The sites discovered so far, Glamija among them, provide us with a certain picture of the functioning of the Danube Limes over time, its formation, restoration and decay. The fortification on the site of Glamija is only one of the known mosaic fragments that shed light on the powerful phenomenon called the Limes.

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REZIME

GLAMIJA – RTKOVO, NOVA RAZMATRANJA

KLJUČNE REČI: LIMES, DUNAV, KASNA ANTIKA, ANALIZA ARHITEKTURE, UTVRĐENJA.

Utvrđenje na lokalitetu Glamija kod sela Rtkova nalazi se u donjem toku Dunava kroz Srbiju. Pozicionirano je 12 km nizvodno od Kostola (Pontes), a nasuprot rumunskog sela Hinova. Da bi se

dobili potrebni elementi za utvrđivanje oblika i dimenzija utvrđenja, kao i datovanja, preduzeta su arheološka istraživanja od 1980. do 1982. godine, kao i reviziona iskopavanja 2020. godine. Tada su otkriveni i potvrđeni, ostaci dva utvrđenja, manjeg unutrašnjeg, koje je istraženo u velikoj meri i većeg spoljašnjeg, koje je delimično istraženo.

Manje utvrđenje, ako ga tako možemo nazvati, je nepravilne kvadratne osnove, nepravilno postavljeno u odnosu na spoljašnje, dimenzija 19,50 m x 19,50 m. U središnjem delu unutrašnjeg utvrđenja otkrivene su četiri temeljne stope zidane kamenom i mestimično opekom, vezanim krečnim malterom. Spoljašnje utvrđenje pozicionirano je na blago nagnutom terenu koji pada prema reci i prati orijentaciju istok-zapad. U osnovi je oblika koji delimično odstupa od pravilnog kvadrata, dimenzija 50 m x 51 m, a čine ga četiri ugaone kružne kule i bedem između njih. Da bi se razjasnila povezanost između spoljašnjeg i unutrašnjeg utvrđenja, rađena su iskopavanja u međuprostoru, međutim nije pronađena veza između ove dve strukture, ni u njihovoj konstrukciji, ni u drugim detaljima.

Istraženost lokaliteta uslovila je nivo i obim analize arhitekture koja bi bila značajna za razumevanje načina gradnje i konstruktivnog sklopa ovakvog tipa utvrđenja, ali i osnova za buduća konzervatorska rešenja u cilju prezentacije lokaliteta. Na osnovu masivnosti temelja bedema i stubaca u središtu, kao i širine bedema od 1,6 m, možemo pretpostaviti da je bedem imao znatnu visinu, a da je karaula imala najmanje jednu etažu. Rastojanje između obimnog zida i stubaca u središtu je oko 3,80 m što ukazuje da je taj raspon mogao biti savladan drvenim gredama, koje bi nosile međuspratnu konstrukciju. U najvišoj zoni bi se lako mogao formirati četvorovodni krov iznad celog prostora ili samo iznad centralnog dela sa stupcima. Takođe, u prilog spratnoj konstrukciji ide i pravougaona zidana masa u severoistočnom uglu utvrđenja na kojoj se prepoznaju ostaci tri stepenika i podesta sa koga se pristupalo drugom kraku stepenica pod pravim uglom. Položaj stepeništa uz bedem uslovljava i visine na izlaznom delu međuspratne konstrukcije, pa tako i organizaciju i konstruktivni sklop osnove, ali i gornje etaže. U organizacionoj šemi osnove upitno je mesto ulaza u utvrđenje, koji je najverovatnije bio sa zapadne strane, na šta sugerišu kameni kvaderi u zidnoj masi na nivou praga. Ovakvi kvaderi se ne sreću u ostalim delovima zidne mase, pa je verovatno da su bili deo praga ili ulazne zone. Analizirajući upotrebljene materijale, dolazimo do istih zaključaka - da je starije utvrđenje, odnosno karaula, građeno nezavisno od mlađeg, čiji je položaj, orijentaciju i veličinu indirektno odredilo starije utvrđenje. Primetna je razlika u veličini građevinskog materijala, opekama i kamenu, kao i u granulaciji frakcija za spravljanje maltera.

Iznete činjenice ukazuju da su dva utvrđenja, unutrašnje i spoljašnje, građena u različitim vremenskim periodima. Unutrašnje utvrđenje, ili karaula-osmatračnica, je opredeljeno u drugu polovinu IV veka, prema nalazima novca, ali i prema tehnici zidanja i upotrebljenom materijalu. Takođe, analogije sa sličnim utvrđenjima u neposrednoj okolini, Donje Butorke, Mihajlovac, Borđej i Ljubičevac, ukazuju na to da je ovo utvrđenje građeno tokom IV veka, tj. da je to bio niz utvrđenja izgrađenih u periodu prve tetrarhije i vremenu Dioklecijana. Starije utvrđenje, koje je utvrđenje u pravom slislu te reči, možemo opredeliti u VI vek, na osnovu dimenzija, tehnika gradnje, kao i analogija sa već pomenutim utvrđenjima, odnosno u vreme Justinijanove obnove limesa, a upitno je da li je bilo završeno. Jasno je da je građeno kao nadogradnja ili modifikacija postojeće strukture u cilju poboljšanja odbrambenih sposobnosti, odnosno uklapanja sa novim tendencijama razvoja vojne arhitekture.

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A CONTRIBUTION TO THE KNOWLEDGE OF ANTIQUE TERRACOTTA ICONOGRAPHY IN THE PROVINCE OF UPPER MOESIA

ABSTRACT

This paper presents three accidental terracotta finds assumed to originate from the Kruševac surroundings. There is one plate with a relief depiction, known only from the National Museum in Kruševac documentation, and two finds from the antique archaeological collection from the National Museum in Kruševac – the bust of a figure in high relief and the head of a female figurine. According to the iconography characteristics of these smaller dimension objects, we see the possibility of their cult nature. Thus, the depiction on the plate with a nude male figure with the spear and shield is identified as an artistic presentation of the god Mars. Taking into account the shorter coiffure with signs of stylisation on the bust mentioned above, we assume that it presents a male figure, but due to the poor preservation, it is impossible to identify it. Finally, thanks to a typical melon (melonen) coiffure and accessory on the top of the head resembling a high raised diadem or krobylos, we have made a connection between the head of the figurine and female facial features of the iconography of the goddess Venus.

KEYWORDS: MARS, VENUS, TERRACOTTA, CULT, ICONOGRAPHY, KRUŠEVAC, UPPER MOESIA.

In the documentation of the National Museum in Kruševac, a small terracotta plate decorated with a relief presentation from an unknown site was recorded as a rare specimen in the Kruševac surrounding area, from where it is assumed it originates (Рашковић 2017: 337, TIII/6). In addition, this museum's archaeological collection also keeps two accidental pottery finds[1] with small dimensions. On this occasion, by analysing their artistic details, we tried to resolve to which deities they could possibly have belonged, that is, what could be their purpose. Namely, archaeological finds of Antiquity originating from the Kruševac surroundings most often represent objects of daily use,[2] while finds of a cult character are much rarer. However, in the somewhat broader surroundings, finds indicating worship of different cults have been recorded, among which Mithra's cult dominates, based on its frequency. That is how one marble relief dedicated to this deity was found during an excavation in the *Horreum Margi* fortification (Васић 1992: 379–385; Tapavički-Ilić i Petković 2017: 165-166, fig. 1), while Mithra's marble icons have also been recorded in the villages of Ražanj (Гавриловић-Витас 2017: 187-206, сл. 1-2), Nozrina (Plemić and Vasiljević 2021), Džigolj near Prokuplje (Цветковић-Кузмановић 1995: 165-169) and Dragovo near Rekovac (Зотовић 1973: 25). In addition, the collective find under the hill called Karađorđevo brdo, near Paraćin, has been also recorded in the literature, where, together

1 *Antique* archaeological *collection* of the National Museum in Kruševac, inventory number 6, 8.

2 A more luxurious find, rare in this area, is a bronze jug of the olpe type from the 1st century, ornated with silver, found in the village of Bošnjane on the left bank of the West *Morava river*, today in the National Museum, Belgrade, Поповић 1994: 276.

Fig. 1 Terracotta plaque with a relief decoration (documentation of the National Museum Kruševac).

with Mithra, there were other deities such as Apollo and the Thracian Horseman (Seure 1922; Cermanović-Kuzmanović 1963: 32–33; Срндаковић 2007). Furthermore, in the village of Nozrina, several votive reliefs dedicated to Sol-Apollo, the Thracian Horseman, Jupiter, and Juno were found (Рашковић 2013: 64, T. 4-5; Васиљевић 2017: 23-25), and on the *Praesidium Pompei* site, a Roman road station located in the village of Ćićina, a cult relief dedicated to Asclepius was found (Племић 2012, 291-298). However, these monuments, in terms of the manufacturing method, material and dimensions, are visibly different from the find presented in this paper, and whose stylistic characteristics and manufacturing quality indicate the possibility of belonging to lower social classes and potential creation in a local craft workshop.

First, we will present a terracotta plate decorated in relief, recorded in the documentation of the National Museum in Kruševac, although without the data regarding the site where it was found. This is an object of 8.2 cm in height and 6.3 in width from highly purified clay and with slightly lighter-colour baking. The standing figure of a young man with a cap on his head holding an elongated stick or spear-like object in his right hand while holding a round object in his left one is clearly identified (Fig. 1). The figure's left leg is slightly bent and seems raised onto a rock-like elevation. In front of the figure there is a shape resembling a pillar or profiled door-frame, while the scene is situated in the decorated frame whose ornaments in the form of a granulated border are observed only in the upper part, above the figure's head.

The fact that there were several finds in the wider surroundings of Kruševac connected with the cult of Mithra probably encouraged the previous opinion of the investigators that this deity could also be represented on the terracotta plate described above. So, the details like a cap on the head of the figure and an elongated object in the right hand are recognised as a *Phrygian* cap and a shepherd's crook (*pedum*), while Mithra, in his left hand, is offering food, as a part of the *Mithraic* Eucharistic, standing in front of a *Mithraeum* (Рашковић 2017: 337-338). However, it is known that the so-called *tauroctony*, a ritual scene in which the god Mithra kills a bull as the central presentation of *Mithraic* cosmogony, is actually the most commonly presented composition on objects of his cult (Cumont 1903; Hinnells 1975: 290-312; Merkelbach 1984: 153). The figure of the naked Mithra with a *pedum* is not a typical iconography even for the scenes of his cycle that appear around a central presentation on the complex icons of larger dimensions (Vermaseren 1956-1960: no. 1247, 1283, 1292-1293, 1301, 1400, 1472, 1920 and 1935). Additionally, a *pedum* occurs more often on Mithra's reliefs from Upper Moesia, but as an attribute of *dadophoroi, Cautes and Cautopates*, who usually surround the deity at the moment of tauroctony (Зотовић 1973: 130). Bearing in mind that all the mentioned Mithra reliefs from the area that is geographically close to Kruševac present typical depictions of the god Mithra in tauroctony, we believe that, based on the frequency of such an iconographic setting, it would be logical that the deity is also depicted in such a manner on the plate that we are discussing here.

Based on all the aforementioned, we would suggest a slightly different possibility for the identification of this relief presentation. Namely, the nude young man with a helmet, spear, and shield, is actually one of two typical art presentations of the god Mars, which originated most probably under the influence of Hellenistic art, i.e. the iconography of the Greek god Ares (Cermanović Kuzmanović i Srejović 1992: 333-334). In Roman mythology, this deity was primarily worshipped as the god of war (*Gradivus*), but also as a protector of agriculture and animal husbandry (*Pater*), which is why prayers were addressed to him to protect the land, both from enemies and natural disasters. Precisely because of the stated characteristics, his cult was widespread in Upper Moesia, which is confirmed by numerous finds, from epigraphic testimonies and small sculptures to jewellery and ceremonial objects (Васиљевић 2009). Moreover, it is known that most probably in the area of today's Kosmaj, a batch of coins was minted with the head of the god Mars on the obverse and armour on the reverse (Душанић 1971). Bearing all that in mind, we will presume that the long cap on the figure's head presented on the plate in question, like a Phrygian cap, is actually a stylised helmet with a tall crest, typical for the god Mars. Furthermore, we propose the identification of the attributes thus: in the right hand, the deity holds a spear (*hastae Martis*), and, in the left, a shield (*ancilla*), which is similar to the so-called Thracian shield, with a small round form, which was generally worn by members of the equestrian units, and Mars votive monuments on which he has epithet, *equitum,* are among the most numerous in the Upper Moesia (Mirković 1986: no. 299; Petrović 1995: no. 7-9; Јовановић 2007: 211). The parallels for such a depiction of Mars are found on the votive relief made of grey limestone dedicated to Jupiter, Mars, and Silvanus that is today built into the tower of the eastern rampart of the City of Smederevo (Цветковић 2009: 35-39; Васиљевић 2009: 200, сл. 1). Here, the nude Mars, with his weight on the right leg, is placed to the right of Jupiter. In the left hand, the deity holds a round shield, while the right one is next to the body, and maybe there was some attribute in it, such as a spear. In addition, a bronze figurine from Viminacium, today in the National Museum in Belgrade, with a height of 11.1 cm, has a similar iconography (Величковић 1972: 19, бр. 10; Јовановић 2007: 210-211; Васиљевић 2009: 201, сл. 2). Here, the nude young deity is presented in a standing position, of non-emphasised contrapposto, with the right leg slightly stretched *forward*. In his left hand he holds a small round shield in front of his thigh, while in his right hand, raised above his shoulder, the attribute is missing, but it is assumed that it might have been a spear or a trophy. A luxurious helmet with a tall crest is on the head, and Mars is covered with a short cloak, fastened at the left shoulder, partly covering the chest. Such iconography is probably based on the classical role of Ares *Borghese*,[3] attributed to the Greek artist Alcamenes, which was a prototype of numerous later Roman copies of this deity (Lawrence 1929: 221, pl. 69b). Unfortunately, the non-elaborated execution of the relief presentation on the plate from the Kruševac area makes impossible to perceive the additional details, so it cannot be stated with any certainty whether in this case the figure had a short cloak, like the figurine from Viminacium.

We will continue the overview of terracotta findings from the antique collection of the National Museum in Kruševac with a description of the small icon representing a bust, crafted in high relief (Васиљевић 2017: 24). It is an object with a width of 4.5 cm and height 4 cm, with a maximum relief height of 3.2 cm. It is a specimen of slightly less pure clay with a darker baking colour. On the obverse of this terracotta, there is a head with a part of the bust, slightly emphasised short coiffure with partially persevered traces of curled styling (Fig. 2). On the reverse of the find, there is an opening with a diameter of approximately 2 cm, which we assume might have served to hang the relief on a solid surface (Fig. 3). As the presentation is significantly damaged, here it is impossible to make a more accurate attribution, but the short hair leads us to the thought that it depicts a man. In addition, there is an open question as to whether this could be a deity, considering that this icon as a cult object could easily be transferred or be a part of a house altar.

Finally, we end this short overview with a description of a small pottery head made in high relief, with a width of 4.5 cm and height up to 5 cm, and with a maximum relief height of 2.5 cm (Fig. 4). It is a fragment made of well-purified clay and traces of fine-grained sand, and with a reddish

3 *Département des Antiquités grecques,* étrusques *et romaines*, Louvre (inv.no. Ma 866), https://collections.louvre.fr/en/ark:/53355/cl010279164 (accessed: 17/05/2022)

Fig. 2 Terracotta icon with a high-relief bust – obverse (documentation of the National Museum Kruševac).

Fig. 3. Terracotta icon with a high-relief bust – reverse (documentation of the National Museum Kruševac).

baking colour. Unlike the previous find, the features of a woman's face can be clearly recognised, with the axis slightly bent to the left, with a chipped nose and chin. Since only the coiffure of this head reveals more details, we will try, on that basis, to provide a proposal for the identification of this presentation. Namely, the hair parted in the middle and combed into strands towards the vertex, emphasising the sliced structure and usually collected in a low bun at the nape of the neck, belongs to the so-called melon (*melonen)* style. This is a fashion known from the Hellenistic representation of unmarried girls during the Roman period, popularised by Princess Plautilla from the Severan dynasty through her portraits (Cambi 2005: 124). Additionally, on the vertex, some kind of groove or ribbon that goes around the head is observed, above which there is a profiled accessory resembling the high-placed diadem that is characteristic of the *Venus Felix* iconography type, named after the statue from the second half of the 2nd century, today at the Pio-Clementino Museum in the Vatican (Delivorrias, Berger-Doer and Kossatz-Deissmann 1984: 79, no. 696, pl. 69; Hallett 2005, 199, 201, pl. 122, 219, 222, 238, n. 33, 332, 334), as well as the so-called Asia Minor type of Venus/Aphrodite (Битракова-Грозданова 1987: 138). Another possibility for interpreting the profiled accessory on the vertex is that here is a simply made top knot (*krobylos)* that represents a high bun similar to a bow-knot that often characterises the coiffures of the goddesses Venus and Diana. Such an iconography setting confirms numerous examples recorded across Roman provinces on the Central Balkans, as well as in Upper Moesia. These comprise various pieces of archaeological material, from monumental marble sculptures, preserved in fragments or completely, such as the head of Diana from Putinci near Ruma (Срејовић и Цермановић-Кузмановић 1987: 72–73; Племић 2017: кат. 11), then those from Sirmium (Venus or Diana?) (Popović 2006: 153–159; Племић 2017: кат. 12) and Mediana (Venus or Diana) (Vasić i Gavrilović-Vitas 2012: fig. 3–5; Племић 2017: кат. 13), as well as the statute of a head from Mediana (Venus or Diana) (Plemić 2013: 121-127; Племић 2017: кат. 19) to the sculpture of Diana Lucifera from Čitluk, or bronze figurines such as one from an unknown site in Upper Moesia, and votive reliefs (Племић 2017: кат. 15, 22, 74). Among the stated parallels, we would single out the marble head of the goddess from Mediana, today at the National Museum in Niš. Its coiffure style on the vertex, i.e., *krobylos*, has a flat, almost rectangular form that is not similar to a bow, and its shape resembles that from a terracotta in the National Museum in Kruševac, even though there is an entirely different stylisation of strands.

Considering the opinion that speaks in favour of the more probable possibility for the identification of the head from Mediana as the Venus of Capitoline type has been presented (Vasić i Gavrilović-Vitas 2012: 147), we would also point out that the find discussed here, can rather be classified in the iconography opus of Venus than Diana, which is evidenced by the previously mentioned possibility for interpreting her hairstyle. In terms of dating, based on the *melonen* coiffure, which

Fig. 4. Head of the terracotta figurine (documentation of the National Museum Kruševac).

was popular from the time of Princess Plautilla (202-205), the wife of Emperor Caracalla, we suggest the first half of the 3rd century as the earliest period of origin of this figurine.

At the end of this brief overview of the terracotta find from the National Museum in Kruševac documentation and the archaeological collection of the same, bearing in mind their possible cult nature, it is necessary to consider what their purpose could have been. Since these are finds of small dimensions that could be easily transported, they may have been an expression of an imported cult practice intended for house altars or some sacral facilities such as votive gifts. On the other hand, the technical and stylistic characteristics, showing a simple execution, indicate that they might also have originated in some provincial pottery workshops (Jeremić, Antonović and Vitezović 2018: 134-159). Additionally, the possibility that these are grave finds must not be ruled out, especially in the case of the female head, because the *Venus Funerariae* cult has been confirmed multiple times in the area of Upper Moesia (Јовановић 2000: 11-19; Глумац 2005: 369). However, without data on the context of the finds, it is impossible to discuss in more detail the places they were intended to be or their function. Therefore, we hope that this brief overview may serve as one of the guidelines for future research and that their results will enable a new, more complete knowledge about life in these areas during the period of Roman domination.

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REZIME

PRILOG POZNAVANJU IKONOGRAFIJE ANTIČKIH TERAKOTA NA TLU PROVINCIJE GORNJE MEZIJE

KLJUČNE REČI: MARS, VENERA, TERAKOTA, KULT, IKONOGRAFIJA, KRUŠEVAC, GORNJA MEZIJA.

U radu su predstavljena tri slučajna nalaza od terakote zabeležena u evidenciji Narodnog muzeja Kruševac: jedna pločica sa reljefnom predstavom, poprsje figure u visokom reljefu i glava ženske figurine. Shodno karakteristikama njihove ikonografije naslutili smo mogućnost da je ovde reč o kultnim predmetima. Tako je prikaz na pločici koji čini naga muška figura sa kopljem i štitom, identifikovan kao likovni obrazac boga Marsa. Imajući u vidu otvor za kačenje na reversu, uz vidljivo kraću frizuru sa naznakama stilizacije na poprsju, pretpostavili smo da ono prikazuje mušku figuru ali je usled loše očuvanosti nije moguće identifikovati. Konačno, glavu ženskih crta lica, zahvaljujući *melonen* frizuri i dodatku na temenu koji asocira na krobilos (*krobylos*) ili visoko podignutu dijademu, doveli smo u vezu sa ikonografijom boginje Venere.

S obzirom na to da su ovo nalazi manjih dimenzija koji su se mogli lako transportovati, moguće je da su predstavljali izraz importovane kultne prakse, namenjeni kućnim oltarima ili nekim sakralnim ambijentima kao votivni darovi. Sa druge strane, tehničke karakteristike i sumarnost izvođenja govore u prilog činjenici da su mogli nastati u nekoj provincijskoj radionici. Takođe, nije isključena mogućnost da se radi o grobnim nalazima, posebno u slučaju ženske glave jer je kult *Venus Funerariae* višestruko potvrđen na tlu Gornje Mezije. Pretpostavljajući da potiču iz okoline Kruševca, kao područja za koje nemamo dovoljno podataka dobijenih putem arheoloških istraživanja, dok se poznati materijal dobijen rekognosciranjem svodi na utilitarne predmete i novac, nadamo se da prikazani nalazi mogu poslužiti kao jedna od smernica nekim budućim istraživačima antičke prošlosti tog prostora.

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OLD COLLECTION AND NEW INSIGHTS: TECHNOLOGICAL ANALYSIS OF OBSIDIAN FINDS FROM THE LATE NEOLITHIC LAYERS OF VINČA-BELO BRDO

ABSTRACT

A large collection of obsidian finds from the Late Neolithic layers of the Vinča-Belo Brdo site, recovered during the excavations led by M. Vasić from 1929 to 1934, is curated in the Archaeological Collection of the University of Belgrade. Despite the long history of research of this collection, a detailed technological analysis of this material has not been conducted thus far. In this study, the results of technological analysis of 1,261 obsidian finds from the Late Neolithic levels of Belo Brdo are presented and discussed in the light of new data about the site. The results show that, although caution is needed when generating insights about the past based on this old collection, it can be a valuable source for making new inferences about the past.

KEYWORDS: OBSIDIAN, VINČA-BELO BRDO, LATE NEOLITHIC, TECHNOLOGY, BLADES, KNAPPING TECHNIQUE, SPECIALISATION.

INTRODUCTION

Numerous obsidian finds from the Late Neolithic layers site of Vinča-Belo Brdo (Serbia) have attracted the attention of researchers since the first excavations of M. Vasić (see reference 4 in Srejović, Jovanović 1957). Although Vasić generally considered the stone tools as anachronisms (Васић 1932: 52), due to his misinterpretation of the site chronology (see Borić 2016; Palavestra 2012; 2013; 2020; Palavestra, Babić 2016), he was quite interested in obsidian finds, rewarding laborers that found obsidian during the excavations (Garašanin, Garašanin 1953, 26, cited in Palavestra 2020: 79, footnote 70). Obsidian is mentioned in multiple parts of his monographs (Васић 1932; 1936a; 1936b; 1936c), as a raw material for knives and sidescrapers that were possibly used for shaving, tattooing, or as parts of tribulum (tool for threshing). Obsidian might have been particularly significant for Vasić as an indication of trade – he suggested that it possibly originates from the area of the Bükk Mountains (Васић 1932: 52; i.e., the area of Bükk culture, Carpathians, see Tripković 2004, footnote 17).

A large collection of obsidian finds that were collected during Vasić's excavations of Belo Brdo from 1929-1934 is curated in the Archaeological Collection of the University of Belgrade. In 1957, Srejović and Jovanović reported the results of the first systematic analysis of 1,398 obsidian finds from this collection (as well as flint finds, but they will not be discussed here). They noted that obsidian sporadically appears quite early in the sequence of the site (pit M, 10.13 – 9.35 m of relative depth[1]), while it disappears at 3.8 m of relative depth. Between the appearance and disappearance of obsidian on Belo Brdo, there are significant os-

1 Vasić excavated the site of Vinča-Belo Brdo in roughly 10 cm thick mechanical layers. For every find, the relative depth was recorded in relation to the "absolute zero" (Васић 1932; 1936a; 1936b; 1936c).

cillations in the frequency of finds from this raw material at different levels (see Figure 1 of their article). The *percentage of all obsidian finds* is 2.9% between 10.0 and 9.0 m, much higher between 8.6 and 8.0 m (54.6%), and then gradually decreases before its disappearance at 3.8 m. According to Srejović and Jovanović, the amount of obsidian indicated the intensity of connections between Belo Brdo and the neighbouring areas in the north (see also Kaczanowska, Kozlowski 1990).

Srejović and Jovanović (1957) have also conducted a typological analysis of obsidian finds. They indicated the presence of cores, knives (blades), fan-shaped and trapezoidal endscrapers, and pointed scrapers. Based on the presence of cores throughout the sequence, Srejović and Jovanović concluded that the knapping was done within the settlement. Two types of blades were distinguished: 1) straight with triangular or trapezoidal cross-section, from 0.7 to 5 cm long, with or without retouch, appearing in all levels from pits to 4 m; 2) curved blades with a triangular cross-section, without retouch, with a length between 3.5 and 6 cm, distributed between 9.0 to 5.0 m, but most frequently between 8.3 and 6.0 m. According to Srejović and Jovanović, the shape of obsidian blades is "determined by the very nature of the material ... thin blades, usually small in size with very sharp edges and without a large variety of shapes" (Srejović, Jovanović 1957: 258). They also noted two types of scrapers: 1) fan-shaped scrapers, in the "form of a circular segment or an irregular ellipse" (Srejović, Jovanović 1957), common in all levels; 2) trapezoidal scrapers that appear between 9.0 and 8.0 m and disappear around 4.5 m of relative depth.

Following the pioneer study of Srejović and Jovanović, many researchers were interested in the questions of the origin and distribution of obsidian from Vinča-Belo Brdo and other sites in the Central Balkans and Southern Pannonia (Chapman 1981: 80-81; Marić 2015; Milić 2014; 2016; 2021; Tripković 2004; Tripković, Milić 2008; William-Thorpe et al. 1984; Глишић 1968). The provenance of obsidian from Belo Brdo in the Carpathians (Slovakia, Carpathian 1 source) was confirmed by a chemical characterisation (Tripković, Milić 2008 and references therein), while the distribution of obsidian served for inferring possible cultural connections, trade and exchange models, site hierarchies, etc.

Despite this general interest in obsidian finds, the technological aspects of Belo Brdo obsidian were not extensively studied following the pioneer study by Srejović and Jovanović (1957). Srejović made only some sporadic insights about the obsidian, observing "fine, small blades" (Srejović 1981) from this material and suggesting obsidian was a "precious raw material for the production of sickles and precise tools" (Срејовић 2001). Although Radovanović et al. (1984) conducted a detailed, systematic analysis of different aspects of lithics from Belo Brdo, the obsidian collection was not thoroughly studied, as their focus was primarily on chert finds. These authors calculated the percentages of obsidian (in relation to chert) in different levels of the site, inferring that it was the highest between 9.0 and 7.0 m (10.0-9.1 – 20.3%; 9.0-7.0 – 69.5%; 8.0-7.1 – 69.9%; 7.0-6.6 – 5.8%; 6.0-5.0 – not calculated due to a small sample; 5.0-4.1 – 4.1%). Based on the predominance of blades (79.5%[2]) compared to flakes (19.8%) and cores (0.3%), they suggested that either the blades were produced outside the settlement and then brought to the site, or the obsidian was processed in other areas of the site from the ones that Vasić excavated. Radovanović et al. (1984) also noted that all 22 obsidian cores they analysed are microcores (10-20 mm in length) with pyramidal or chisel-edged morphology.

M. Milić (2016: 211) has also made certain insights based on the obsidian collection from Belo Brdo – the entire reduction sequence is present on Belo Brdo, indicating the on-site exploitation of obsidian cores, "although the cores were occasionally prepared before they were brought to the site" (pp. 211); obsidian cores have small dimensions (mean length is 1.7 cm) and a pyramidal shape; blades are predominant among the debitage types (80%); obsidian blades and bladelets were produced using pressure flaking (i.e. debitage), indicating a specialised production (Milić 2016: 223); blades rarely have use-traces and retouch. Milić also noted that there are "bullet cores and pressure-flaked blades" on Belo Brdo and other sites that she referred to as "important centres for obsidian distribution" (Milić 2016: 239).

Thus, despite a long history of research on the obsidian from Vinča-Belo Brdo, a detailed techno-

2 Percentages were calculated from the unnamed table in the upper part of page 19 of their work.

logical analysis has not been done on this collection. During the work on lithic finds from Vasić's excavations between 1929 and 1934, I analysed a total of 1,520 obsidian finds curated at the Archaeological Collection of the University of Belgrade. Based on the collected data, this study aims to explore the technological aspects of obsidian production on Belo Brdo during the Late Neolithic and contextualise these insights in light of new data about the site. A large number of finds in this collection provide a suitable sample for assessing the production technology and related questions, such as those regarding the changes in the applied knapping techniques (e.g., Bogosavljević Petrović 2015; 2018; Milić 2016; 2021), standardisation and specialisation (e.g., Bogosavljević Petrović 2015; 2018; Kaczanowska, Kozlowski 1990; Perlès 2001; Vuković 2011), certain aspects of trade (e.g., cores vs. nodules vs. blades; e.g., Milić 2016), etc. Another goal of this study is to determine the value of this collection, with all of its shortcomings (e.g., Palavestra 2020), for gaining knowledge about the past.

VINČA-BELO BRDO

The site is located on the right bank of the Danube river, approximately 14 km to the east of Belgrade (Serbia) and the confluence of the Danube and Sava rivers. Vinča-Belo Brdo was excavated in three large campaigns – from 1908 to 1934; between 1978 and 1986; 1998-ongoing (see Tasić 2005; 2011b). The rich stratigraphy of the site contains archaeological remains from the Neolithic to medieval period, but the majority of deposits are from the Late Neolithic, and they had a huge impact on the study of this period at both a local and regional scale. The site was continuously inhabited during the whole Late Neolithic of the Central Balkans, for around 800 years (~5300~4500 BC) (Tasić et al. 2015a; 2015b; 2016). For more information about the site, the reader is referred to other sources (e.g., Tasić 2005; 2011).

1929-1934 excavations (M. Vasić)

As previously mentioned, the obsidian collection in the Archaeological Collection of the University of Belgrade consists of finds collected during the excavations conducted between 1929 and 1934. In these campaigns, Vasić excavated new trenches P and G (Palavestra 2020). Despite the existence of the "main axis" during the 1929-1934 excavations, i.e., a linear reference point in relation to which Vasić (occasionally) positioned the excavated material, he did not take many notes about the spatial (horizontal) distribution of objects and artifacts (Palavestra 2020), and some very general and selective information can be drawn from his journals, publications, and excavation plans (see Palavestra 2020 for an overview). Thus, the context of finds is largely missing for the obsidian collection from these excavations. However, the most recent excavations (1998-ongoing) have shown that the (small sample of) 14 obsidian finds were found in different areas of the site (mainly the cultural layer), and there are no indications of obsidian workshops and other specific contexts for obsidian finds on Belo Brdo and other Late Neolithic sites in the region, as on some other Late Neolithic sites (e.g., Robb 2007: 202-203).

Vasić excavated the site in 10 cm mechanical levels (strip digging, Palavestra 2020: 98) and meticulously noted the vertical distribution of finds. The relative depth of objects and features was noted in journals, excavation plans, and on the artifacts themselves (see Palavestra 2020). A relative depth was measured as a vertical distance from the "zero", "an absolute reference point" (an elm on the top of the hill, Palavestra 2020). Although this arbitrary reference point was a basis for all measurements of relative depth, it was possibly excavated and removed in later campaigns (Марић 2011). Another issue is that Vasić's "10 cm" mechanical levels were sometimes larger, reaching up to 30 cm (Palavestra 2020). Finally, in attempting to relate the relative depths of 1929-1934 material with those from previous campaigns, Vasić added certain values to the relative depths of the finds excavated from the P and G trenches (0.5 m, 1.8 m) (Palavestra 2020).

Based on the evidence provided by Palavestra (2020), the validity of Vasić's system of measuring vertical disposition seems questionable. However, two strands of evidence show that the relative depths of Vasić are fairly robust and give a valid chronological sequence:

1) W. Schier (1996; 2020) was able to reconstruct the correct chronological ordering of Vasić's (1929-1934) 10 cm units (levels), by conducting a frequency seriation (a method of relative dating)

based on the frequency of ceramic types in different levels of the site. The correct chronological ordering is expected if the layers are not mixed, disturbed, or inappropriately excavated. As Schier (1996: 144) concluded: "the chronological resolution of Vasić's 10 cm levels is far better than generally assumed".

2) In 2015, Tasić and colleagues published the results of a comprehensive analysis of the absolute chronology of Vinča-Belo Brdo, based on the radiocarbon dating of samples from Vasić's excavations (Tasić et al. 2015b). In total, 85 radiocarbon determinations were made on 82 samples, while a Bayesian framework was applied to establish a formal chronological model of the site, where prior knowledge about the stratigraphic position of samples (age-depth model) and possible reservoir effect were incorporated. Despite noting the presence of a certain number of outliers, Tasić et al. (2015b: 38) concluded that the "chronological resolution of Vasic's 10-cm spits is far clearer than previously thought".

Thus, although Vasić's evidence should be critically re-evaluated when possible, it seems the relative depths of the material from the Archaeological Collection are robust indicators of the chronological ordering of artifacts. Nevertheless, "it should be pointed out that the mentioned demarcations by meters must not be taken too sharply" (Garašanin 1979: 152).

SAMPLE

A total of 1,520[3] obsidian finds from the Archaeological Collection of the University of Belgrade were analysed. After excluding 16 finds from the Early/Middle Neolithic (Starčevo culture) and 243 finds without a relative depth, 1,261 obsidian finds from the Late Neolithic levels of Belo Brdo are discussed here. Interestingly, the number of finds reported here differs from the numbers reported in other publications: Srejović, Jovanović 1957 – 1398 with relative depth; Radovanović et al. 1984 – 1488 in total; Tripković 2004 – 1488 in total. The reason for these differences in the number of finds in the collection is unknown to the author of this work. Concerning the number of finds with an identifiable relative depth, some relative depths possibly became unreadable several decades after the analysis of Srejović and Jovanović or Radovanović and colleagues.

To explore the temporal variability in obsidian production, the material was classified according to the commonly used Milojčić's periodisation: Vinča A (9.3 – 8.0 m), Vinča B (8.0 – 6.0 m), Vinča C (6.0 – 4.0 m), Vinča D (4.0 – 1.3 m). Although Milojčić's Vinča D phase ends at 2.5 m (Tasić et al. 2015b, Table 8), the material from the younger Late Neolithic levels (up to 1.3 m) is also included here for chert/obsidian comparisons (see below) to assess the entire sample of Late Neolithic finds (see Tasić et al. 2015b).

METHODS

For reconstructing different aspects of production technology, a technological analysis (e.g., Andrefsky 2005; Inizian et al. 1999; Kooyman 2000; Pelegrin 2006; 2012; Shea 2013; Tostevin 2012) was applied to obsidian finds. To better illustrate certain aspects of obsidian production, a comparison was made with chert production on Belo Brdo, which will be published elsewhere (Radinović, in preparation). General information was collected about all obsidian finds – ID, box number, bag/case number, relative depth, raw material properties (colour and texture), type of product, (blank type or flake type), and presence/absence of fragmentation. A more detailed attribute analysis was conducted on obsidian cores and prismatic blades, as the laminar technology was the main goal of the knapping process (Bogosavljević Petrović 2015; 2018; Milić 2016; Radovanović et al. 1984; see below). In the case of cores, the following attributes were recorded – core type (flake/blade core), pattern of removals, core morphology, dimensions (length of the debitage surface, length and width of the striking surface) and mass, while for the blade cores the shape of the debitage surface and the regularity of removals were also noted.

The assessment of diachronic changes in technological aspects of obsidian production was mainly based on the variability of blades, as they provided sufficient samples for statistical analyses. For blades, data was collected about taphonomy (fragmentation, presence of post-depositional sur-

3 It should be noted that the number of 1,520 obsidian finds discussed here is slightly higher than the number of obsidian finds that will be published in my doctoral thesis (1465; https://doi.org/10.17605/OSF.IO/JRC9D), as I subsequently analysed an additional 55 obsidian finds from this collection that were absent during my work on the thesis.

face modifications and pseudo-retouch), metrics (mass, maximal length, width, and thickness in the different parts of blades), morphology (presence of cortex and back, directionality of removals, number of dorsal negatives, debitage profile and distal end type, blade regularity), detachment features (properties of the striking platform, presence/absence of lip, bulb, bulbar scar, ripples, and mesial belly), and the characteristics of retouch (retouch distribution, Clarkson's index of invasiveness; Clarkson 2002). Based on the collected data, different aspects of production, such as the knapping method and technique (e.g. Damlien 2015; Inizian et al. 1999; Pelegrin 1990; Sollberger, Patterson 1976), and maintenance of blades were assessed.

Additionally, a geometric morphometrics (GMM) analysis in the form of Elliptic Fourier analysis (EFA) was utilised on whole unretouched blades for assessing certain aspects of obsidian production that are related to the choice of knapping technique (Radinović, Kajtez 2021). Geometric morphometrics is a set of tools for quantitatively analysing the shape of objects (e.g., Slice 2007), while the EFA is the most commonly used GMM approach for analysing closed contours of objects that vary primarily in two dimensions (e.g., Caple et al. 2017; Kuhl, Giardina 1982). For gaining insights into the possibly utilised knapping techniques, the outlines of obsidian blades from Belo Brdo were compared with outlines of experimentally produced chert blades (Lengyel, Chu 2016; Muller et al. 2017; Pelegrin 2006; 2012; Sørensen 2006; see Radinović, Kajtez 2021), as there is still no reference collection of obsidian blades produced by different knapping techniques.

A detailed description of the EFA and the analytical protocol for the analysis of blade outlines are published elsewhere (Caple et al. 2017; Hoggard et al. 2019; Kuhl, Giardina 1982; Radinović, Kajtez 2021) and will be only briefly summarised here. Images of the dorsal sides of blades were edited and used for digitising the blade outlines. A .tps file for storing the outline coordinates was created using the tpsUtil 1.78 software (Rohlf, 2019), while the tpsDig 2.31 software (Rohlf 2017) was used for digitising blade outlines with 200 equidistant points. Before proceeding with visualisations and statistical analyses, the outlines were normalised using the R programming software (R Core Team 2020) and the *Momocs* v. 1.3.2. package (Bonhomme et al. 2014), to remove the effect of size, rotation, and location. The first 20 harmonics, which describe 99.9% of blade outlines, were retained for assessing and comparing the variability of blade outlines. Principal Component Analysis (PCA; e.g., Shennan 1997: 265-303) was used for exploring the variability of blade outlines.

All visualisations and statistical analyses presented in this paper were performed in the R programming language (R Core Team 2020), using the following packages: *dplyr* v. 1.0.3 (Wickham et al., 2021), *ggplot2* v. 3.3.3, (Wickham 2016), *ggpubr* v. 0.4.0 (Kassambara 2020), and *lsr* v. 0.5.2 (Navarro 2015). Following the principles of open science (e.g., Marwick 2017), the analytical protocol for data collection, data, and code for reproducing the majority of statistical analyses and visualisations (except chert-obsidian comparisons) are available at the Open Science Framework (OSF) platform (https://doi.org/10.17605/OSF.IO/FNVPK).

RESULTS AND DISCUSSION

The distribution of obsidian finds according to relative depths and Milojčić's phases is shown in Fig. 1. The number of obsidian finds is low in the earliest Late Neolithic levels, notably increases at around 9.0 m of relative depth, then sharply decreases after 7.7 m and remains low before the disappearance of obsidian at 3.8 m (although there is one find with a relative depth between 3.9 and 3.0 m). The percentage of obsidian in relation to chert decreases from 47% in Vinča A to 1.6% in Vinča D (Fig. 2). The percentages of obsidian are smaller than those reported by Radovanović et al. (1984), most probably because these authors did not analyse the entire chert assemblage from the Archaeological Collection (Radinović, in preparation). However, data from the "third glance" of Belo Brdo (Tasić 2011; Tasić 2015a) is notably different regarding the counts and percentages of obsidian: 1) the percentage of obsidian in relation to chert is much smaller than 69.9% (Radovanović et al. 1984: 14) or 47% (Fig. 2) in any of the phases – it is between 1 and 5% (personal insight into the collection from deep sounding, Tasić et al. 2016), as on most of the other sites from the period (see Milić 2016; Tripković 2004 for an overview); 2) the obsidian does not disappear from Belo Brdo in the

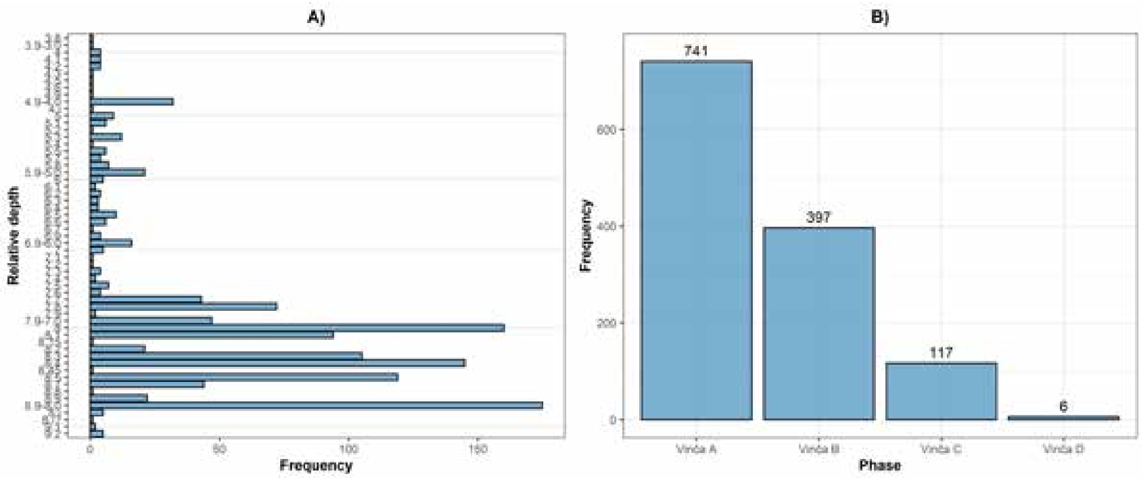

Fig. 1. The distribution of obsidian finds from Belo brdo according to a) relative depths and b) Milojčić's phases.

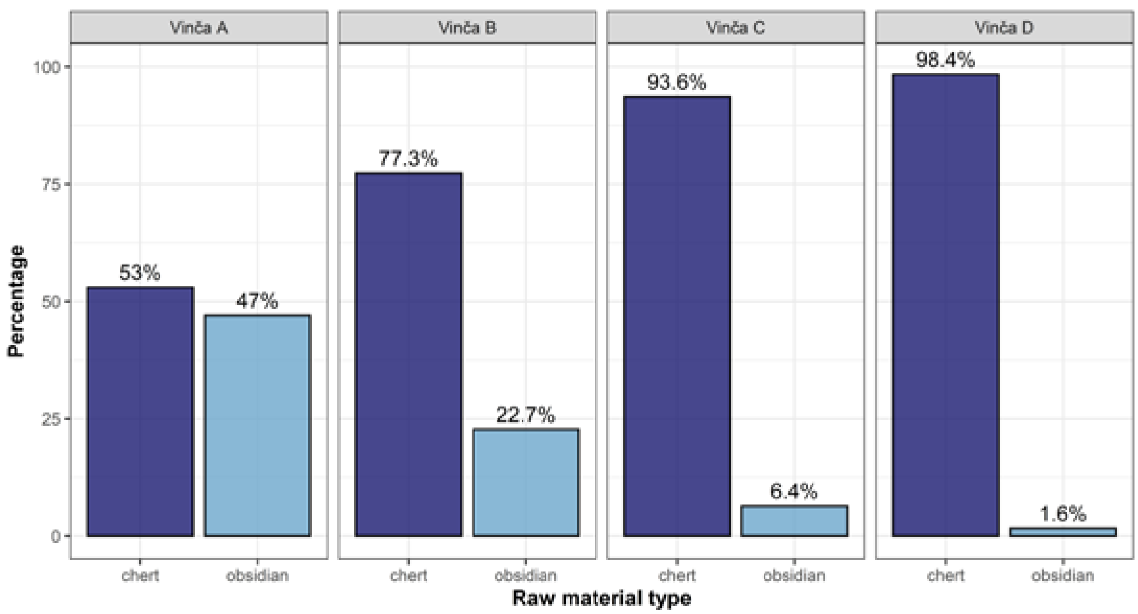

Fig. 2. The percentages of chert and obsidian in Milojčić's phases.

latest Late Neolithic phase (i.e. after 3.8 m) (Milić 2016: 208-209; Tripković, Milić 2008). These discrepancies are possibly caused by a recovery or storage bias in the case of Vasić's collection, and they might have important implications:

1) Lower percentages of obsidian possibly question the role of Belo Brdo as a trading (Bogosavljevic Petrovic 2015; Chapman 1981: 83) or redistribution centre (Milić 2016: 66; see also Milić 2021), "social core" (Milić 2016: 208), suggested settlement hierarchies (e.g., Chapman 1981: 137), and the models of trade and exchange (e.g., Chapman 1981: 80-81; William Thorpe et al. 1984). Very high percentages of obsidian on Belo Brdo (and possibly other sites that were excavated by early researchers; e.g., Mileker 1938, cited in Tripković 2004) are possibly a consequence of some kind of bias (e.g., storage) – lower percentages make more sense given the fact that the obsidian trade was generally a small-scale endeavour (Milić 2016).

2) Based on the presence of obsidian in Vinča D, it can be concluded that the cultural connections with the northern neighbours did not cease during this period, which is in line with other research on the distribution of obsidian in the region – for instance, Selevac (Voytek 1990: 441-442) and the sites in the Vršac area (e.g., Chapman 1981: 80-81) have obsidian in the final Late Neolithic phase.

From a total of 1,261 finds with a relative depth, there are 14 cores (1.1%), 1,231 flakes (97.6%), and 16 pieces (1.3%) characterised as waste/undeterminable. The percentage of flakes decreases in later phases, while the percentage of cores increases through time (Fig. 3). These temporal differences in the structure of collections are statistically significant, as indicated by the Fisher's exact test (n = 1261, X-squared = 48.922, df = 6, $p < 0.01$), but slight as indicated by a small effect size (Cramer's V = 0.14). Based on the high number of flakes sensu lato (flakes and blades), it has been suggested that the obsidian blades were not produced on the site (Radovanović et al. 1984). However, a high degree of core exploitation (e.g., Sullivan, Rozen 1985) – for example, Sheets and Muto (1972), produced 83 blades from a single core – and a high fragmentation rate might also explain this pattern. A low percentage of waste/undeterminable pieces possibly requires an explanation – for instance, it could be a consequence of collection/preservation bias (Radovanović et al. 1984: 55) or very skilful production.

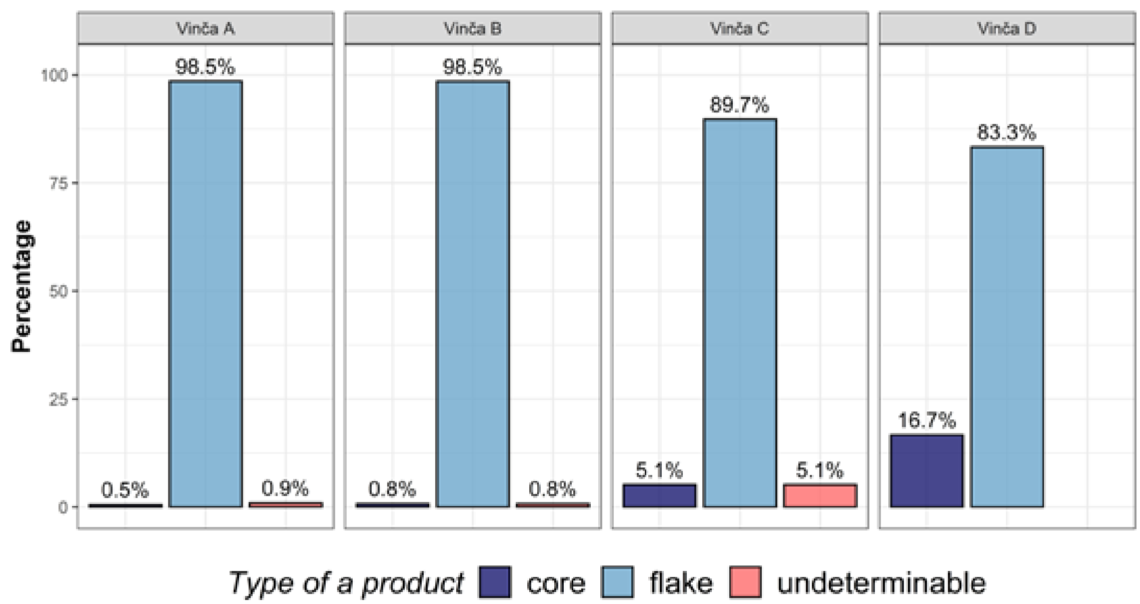

Fig. 3. Percentages of different types of knapping products in Milojčić's phases.

Cores

From a total of 13 obsidian cores, there are 10 blade cores and 3 flake cores. However, two out of the three flake cores have blade-like negatives – recurrent removal of flakes with parallel edges – but these negatives do not have sufficient elongation (length / width > 2) to be considered blades in the strict sense. As these two cores have very small dimensions (~10 mm) and mass (< 1 g), they might represent blade cores in the final phase of exploitation. All three flake cores have a different pattern of removals (unidirectional, bidirectional, and multidirectional), while their shape is conical/pyramidal in two cases and irregular in one case.

One blade core is fragmented, so it was not possible to observe all features on this core. Two blade cores were made on flakes, while for the remaining 7 cores it was not possible to determine their initial properties. The majority of blade cores are single-platform (unidirectional; n = 7), apart from one opposed-platform core and one core with multiple (more than two) platforms. The shape of blade cores is predominantly conical/pyramidal (n = 4), but there are single occurrences of other core shapes (tabular, bullet-shaped, polyhedral, plano-convex, and irregular). Debitage surfaces of blade cores are triangular (n = 3), rectangular (n = 4), semi-oval (n = 1), or irregular (n = 1). Blade negatives are moderately regular on 8 cores and very regular on only one core.

Obsidian cores have small dimensions (their dimensions are generally around 1 to 2 cm; see also Milić 2016: 211) and are much lighter than chert cores (Fig. 4), weighing from 0.2 to 4.5 g.

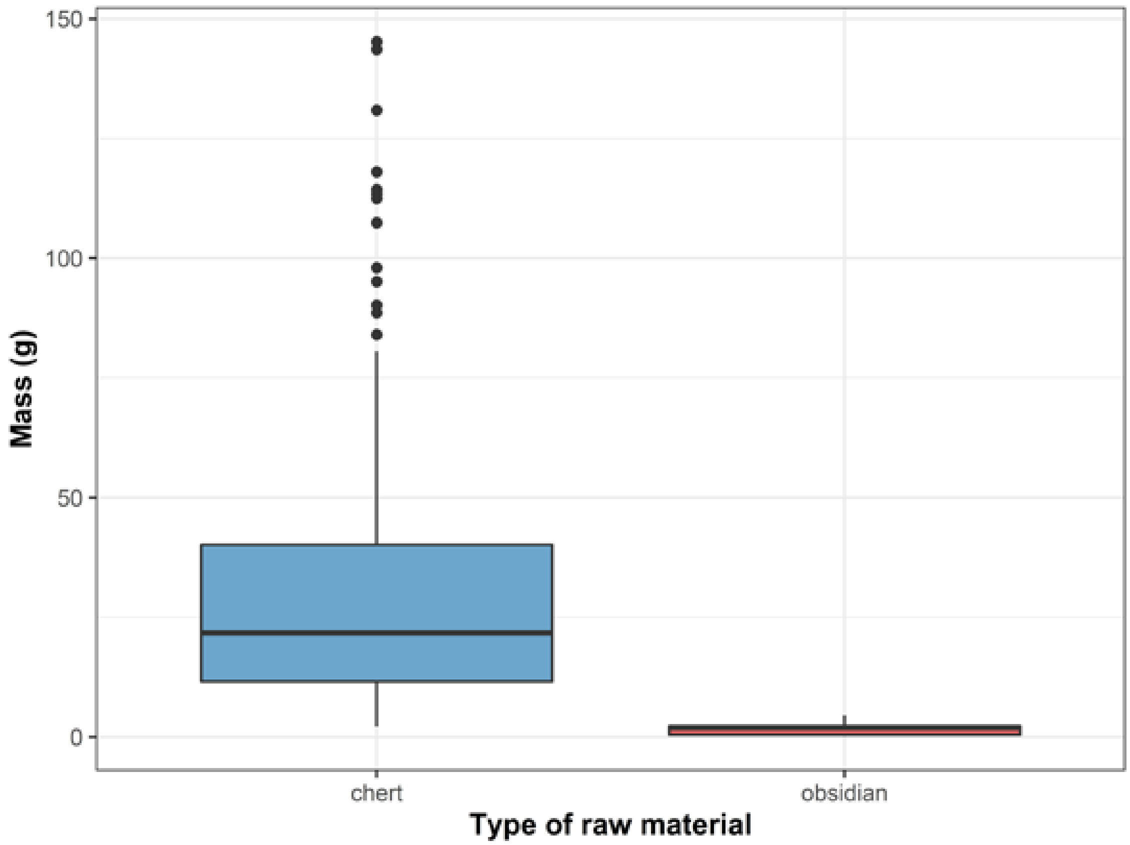

Fig. 4. Box-plot diagram comparing the mass of chert and obsidian cores (Radinović 2022, 50).

The differences in the mass of chert and obsidian cores are statistically significant as indicated by the Mann-Whitney U test ($n = 271$, $U = 3334.5$, $p < 0.01$), with a moderate effect size ($r = 0.36$). Such a high degree of exploitation of obsidian is not surprising given the fact that this exotic raw material probably had some symbolic value for the Neolithic communities in the area (Tripković 2003; Трипковић 2001).

Blank production

Of 1,231 flakes sensu lato, 961 (78.1%) are blades and the remaining 270 (21.9%) are flakes. The percentage of blades is probably even higher, as 57 flakes have blade-like features but cannot be classified as blades with certainty due to fragmentation. Moreover, there are 12 core rejuvenation flakes that are related to blade production, removed in order to renew the striking or the debitage surface of blade cores. Overall, it is clear that blade production was the main goal of the knapping process.

There is only one cortical flake, possibly indicating that the decortification process was not done within the settlement, while the presence of only two blades with a cortex suggests a similar conclusion. However, the presence of two crested blades and 12 rejuvenation flakes indicates on-site blade production, so prepared or semi-prepared laminar cores may have been brought to the settlement where the blade production took place (Bogosavljević Petrović 2015; Milić 2016).

A large percentage (87.6%) of flakes and blades are either intentionally or unintentionally fragmented. Apart from the intentional fragmentation of the prehistoric knappers (e.g., Anderson-Whymark 2015; Slavinsky et al. 2019), some blades were probably fragmented by the excavators of the site – Vasić was rewarding laborers that found obsidian during excavations, so they were intentionally fragmenting obsidian pieces to get higher wages (Garašanin, Garašanin 1953, 26, cited in Palavestra 2020: 79, footnote 70). Moreover, obsidian is a highly brittle material and obsidian pieces are often very thin, so many obsidian flakes might have been fragmented by different post-depositional factors (e.g., Burroni 2002).

Blades

There are 41 whole or almost whole blades in the studied collection, while the remaining blades represent proximal, medial, and distal fragments of blades or, rarely, longitudinally fragmented pieces (Siret fracture) and whole blades with pronounced edge damage. Some blades have breakages that are perpendicular to the flaking axis, which might indicate intentionality in producing regular pieces (Fig. 5). Pseudo-retouch is the most common taphonomic damage, but there are also other post-depositional traces in the form of edge damage, striations, concussions, etc.

The whole obsidian blades are shorter, narrower, thinner, and more standardised than chert blades (Fig. 6). The length of whole unretouched obsidian blades ranges from 12.3 to 61 mm, with a mean of 25.8 mm. The distribution of length of whole blades is not completely continuous and shows the existence of a certain number of outliers (Fig. 7), but there is no clear distinction between blades and bladelets/microblades (Tixier 1963, cited in Inizian et al. 1999, 73). The empirical observation made by Tixier is often uncritically paralleled to other collections (Inizian et al. 1999, 73), even though he suggested that the distinction between blades and bladelets should be established empirically on a case-by-case basis. There is a general trend of decrease in length of whole unretouched blades in younger phases (Table 1), but the Kruskal-Wallis H test shows no statistically significant differences between the groups (n =

Fig. 5. A selection of obsidian blades with regular breakages that are often perpendicular to the flaking axis, possibly indicating intentional fragmentation.

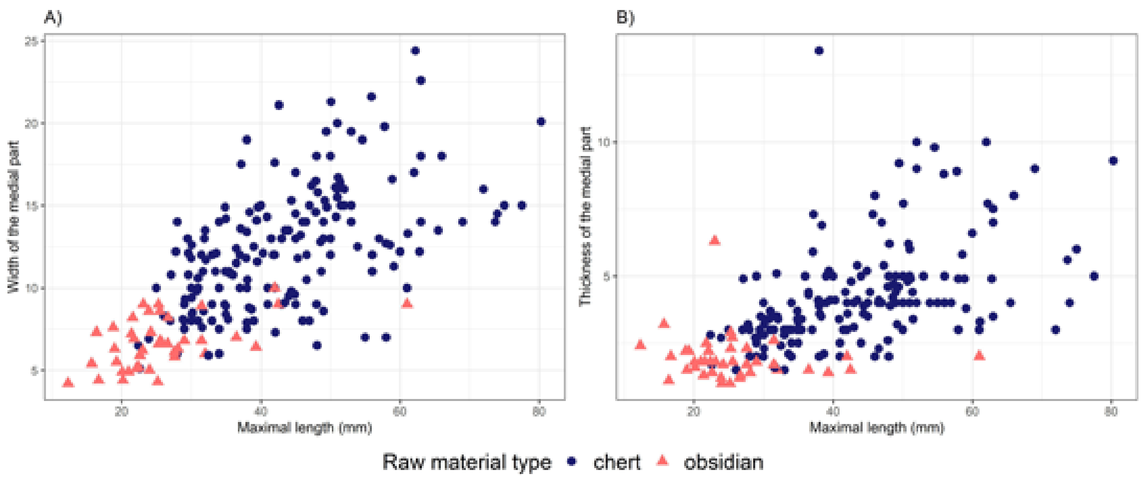

Fig. 6. Scatter-plots comparing the a) maximal length and width of the medial part and b) maximal length and thickness of the medial part of whole unretouched chert and obsidian blades.

40, H = 2.62, df = 2, p = 0.27), so sampling effects cannot be excluded. The length of whole blades becomes more standardised through time, as indicated by the values of coefficient of variation (Table 1), but the low sample sizes are not sufficient for making reliable conclusions.

The maximal length of many entirely preserved obsidian blades (Fig. 5) is generally larger than the maximal dimensions of cores (1 to 2 cm), supporting the conclusion that the obsidian cores are in the later stages of exploitation (see also Radovanović et al. 1984: 20). However, there is a possibility that the whole unretouched blades are not a representative sample of originally produced blades – e.g., Belo Brdo inhabitants might have intentionally fragmented only the larger blades, or thinner blades were more prone to breaking. Although there is a complex relationship between the dimensions of the striking platform and the size of blade blanks, and linear measurements are not suitable for precisely predicting blade size, larger striking platforms are generally expected for larger blades, especially when the punctiform platforms are excluded (see Muller, Clarkson 2014). This knowledge was used for roughly estimating the relative size of broken blades in comparison to entirely preserved blades. Based on the platform dimensions (Fig. 8), it seems that fragmented blades were generally as large as the entirely preserved blades or larger.

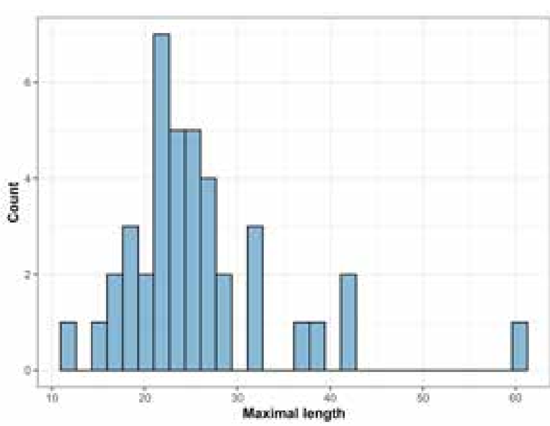

Fig. 7. Histogram showing the distribution of maximal length of whole unretouched obsidian blades.

As already mentioned when discussing obsidian cores, blades were mainly produced from unipolar cores. A similar conclusion is reached by observing blade negatives – they are predominantly parallel (n = 894), less commonly converging (n = 52), and very rarely diverging (n = 1) or multidirectional (n = 3). The Fisher's exact test shows no statistically significant differences in the directionality of removals for blades from different phases (n = 950, p = 0.23, Cramer's V = 0.08), indicating no changes in the knapping method. Concerning the platform preparation, predominantly triangular and trapezoidal striking platforms are most commonly (~1/2) smooth (plain) in all phases, followed by dihedral and damaged (~1/4), facetted and scarred platforms (~1/20), while punctiform and intentionally removed platforms are very rare.

One of the most important aspects of blade production is the choice of a knapping technique (e.g., (Inizian et al. 1999, p. 30; Pelegrin 1990). It is commonly acknowledged that there is an over-

Phase	Count	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	CV
Vinča A	24	27.3	9.9	12.3	61	36.4
Vinča B	12	25.0	6.8	16.7	42.5	27.3
Vinča C	4	20.7	4.2	15.7	25.5	20.3

Table 1. Descriptive statistics for the length of whole unretouched blades by Milojčić's phases.

lap in the features of blades produced by different knapping techniques, so the determination is generally done at the assemblage level rather than inferring the technique for every individual blade (e.g., Damlien 2015; Kooyman 2000: 78). Similarly to Pelegrin and Inizian (2013), based on the presence of different technological stigmata in the sample, I excluded the knapping techniques that were unlikely to have been used for producing the majority of blades. However, as the research on the question of the knapping techniques was discussed mainly for chert (but see Pelegrin 2012), the results should be taken with some caution as there are probably some differences in the fracture mechanics of different raw materials (e.g., Damlien 2015). Moreover, multiple factors influence the observed technological stigmata, such as the properties of the percussor (e.g., Driscoll, Garcia-Rojas 2014; Lengyel, Chu 2014; Pelcin 1997; Pelegrin 2006: 45) or skill level (e.g., Herzlinger et al. 2017), further complicating the recognition of the knapping techniques.

Many features of obsidian blades from Belo Brdo – such as the thinness of blade profiles (mean thickness of the medial part ~ 2 mm) and striking platforms (mean thickness is 1.9 mm), the presence of a lip on 25% of blades with a preserved striking platform, the predominance of diffuse bulbs – are inconsistent with the application of direct percussion with a hard hammer (sensu Inizian et al. 1999: 74; Kooyman 2001, 79, Figure 43; Pelegrin, Inizian 2013). As the striking platforms are not concentrated, but rather spread/wide (Fig. 8), soft stone direct percussion might also be excluded (sensu Pelegrin, Inizian 2013). Punctiform and thin oval butts that are characteristic of pressure debitage (see Damlien 2015: 127) are rare (0.8%). The bulb of percussion is diffuse on 60% of blades, indicating the possible usage of soft hammer (rather than hard hammer) percussion, while there is no consensus on the bulb properties for indirect percussion and pressure blades (see Kooyman 2000: Figure 43; Pelegrin 2006). The percentage of blades with a bulbar scar is 53.6%,

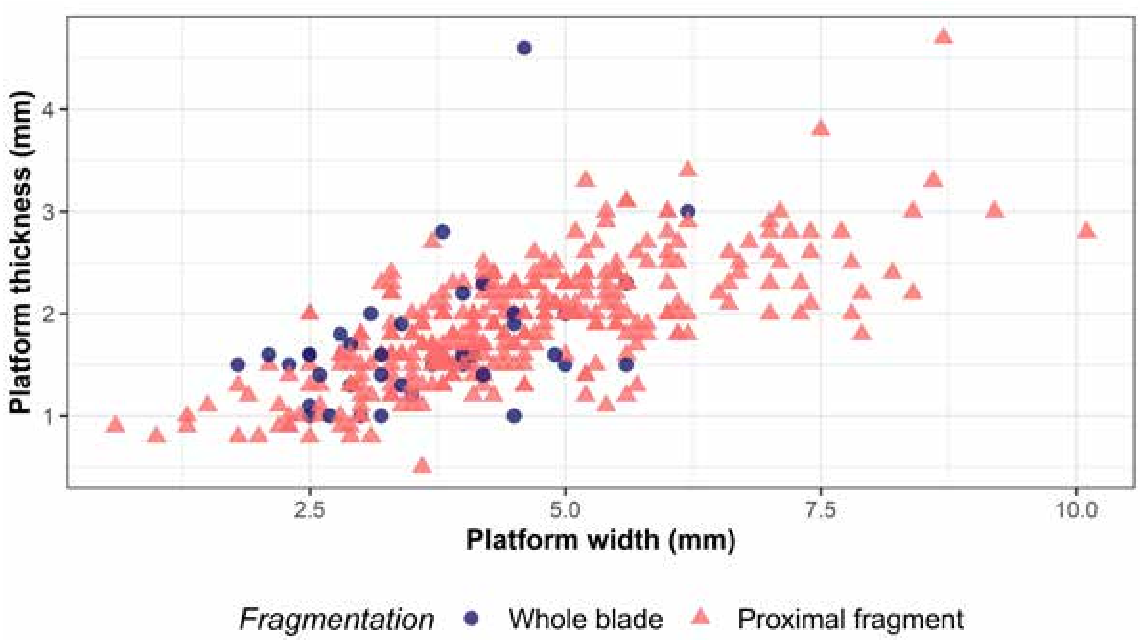

Fig. 8. Scatter plot showing striking platform dimensions for whole and fragmented blades (proximal fragments).

which is, according to Kooyman (2000: Figure 43), consistent with direct percussion using a soft hammer – in the case of the indirect or pressure technique the bulbar scar is rare. However, Table 3 in Damlien (2015; see also Pelegrin 2006: 47) shows that indirect percussion and pressure debitage can also produce moderately high percentages of blades with a bulbar scar (indirect – 45.6%; pressure – 58.1%), so these two knapping techniques cannot be excluded based on the frequency of bulbar scars. A mesial belly, typical of indirect percussion (e.g., Pelegrin 2006), appears only on one out of 41 whole blades from Belo Brdo.

Another important aspect for differentiating between various knapping techniques is regularity – blades produced by indirect percussion and especially pressure debitage are more regular than direct percussion blades (e.g., Buchanan et al. 2016; Inizian et al. 1999; Pelegrin 2006). Milić (2016) has suggested that obsidian blades in this collection are very regular and were possibly produced by pressure debitage. According to a subjective measure of blade regularity that was based on a visual assessment (e.g., Damlien 2015), 5 blades (0.5%) are irregular, 810 blades (85.1%) are moderately regular, and 137 blades (13.3%) are very regular. Percentages of irregular, moderately regular, and very regular blades somewhat differ among the phases (**Table 2**), but Fisher's exact test has shown that these differences are not statistically significant (n = 953, p = 0.22, Cramer's V = 0.05). The percentage of very regular blades is higher than expected for direct percussion techniques but lower than for indirect and pressure techniques (Damlien 2015, Table 3).

To assess the issue of blade regularity more formally and explore other aspects of blade shape that are related to the knapping technique (Radinović, Kajtez 2021), the Elliptic Fourier Analysis was applied to the outlines of whole obsidian blades. The first three principal components, which explain a total of 94.3% of blade outline variability, are elongation, side-to-side symmetry, and tip-base width ratio (Fig. 9). Based on the PCA plots (Fig. 9), it can be concluded that the obsidian blades from Belo Brdo are most similar to blades produced using direct percussion. However, certain blades have features that are not typical for direct percussion – they are somewhat more elongated than the majority of other obsidian blades from Belo Brdo; the maximal width of certain blades is located in the proximal part, which might be indicative of a pressure debitage (Fig. 9); e.g., Inizian et al. 1999; Pelegrin 2006; Radinović, Kajtez 2021). Another indication for the possible use of pressure debitage for blade production is the presence of a regular bullet-shaped core (Fig. 10), typical for this knapping technique (e.g., Inizian et al. 1999).

To summarise the insights based on different morphological and technical stigmata –direct percussion using a hard hammer and probably a soft stone hammer can be excluded as unlikely; the features that are typical for blades produced by indirect percussion and pressure debitage are not common in the studied sample; thus, direction percussion using a soft organic hammer seems to be a predominant knapping technique for producing the obsidian blades from the Late Neolithic levels of Vinča-Belo Brdo. However, there are some features of blades (bullet-shaped core, location of maximal width in the proximal part, somewhat higher percentage of very regular blades) that are consistent with the use of pressure debitage. Thus, this knapping technique might have been sporadically used for producing obsidian blades. Pelegrin (2012) defined five modes of pressure debitage – from the use of a hand-held pressure tool to the use of a lever – and suggested that the maximal width of blades is suitable for distinguishing between them. By comparing the distribution of the maximal width of very regular obsidian blades (0.5 to 0.7 mm) from Belo Brdo with the maximal width of experimentally produced blades in Figure 18.12 of his article, it can be concluded that modes 1, 2, 3, and 4 were possibly utilised by Belo Brdo inhabitants. However, these blades from Belo

Phase	Irregular (%)	Moderately regular (%)	Very regular (%)
Vinča A	0.5	85.2	14.2
Vinča B	0.3	82.9	16.8
Vinča C	1.3	92.4	6.3
Vinča D	0.0	100.0	0.0

Table 2. Percentages of irregular, moderately regular, and regular blades in Milojčić's phases.

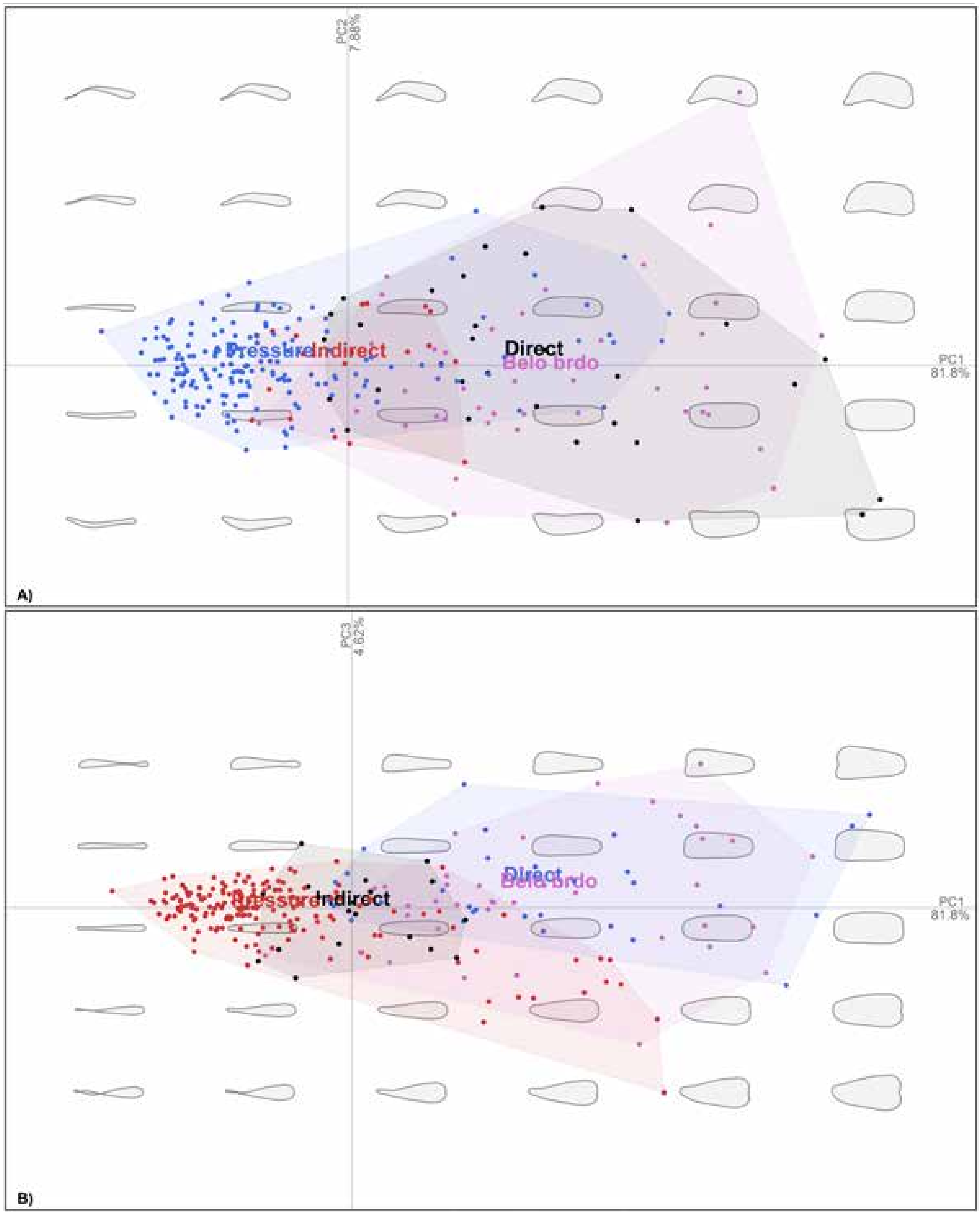

Fig. 9. Scatter plots of a) PC1 and PC2 and b) PC1 and PC3 showing the main shape differences between the whole unretouched obsidian blades from Vinča-Belo brdo and blades that were experimentally produced using different knapping techniques (see Radinović, Kajtez 2021): direct percussion (black), indirect percussion (red), pressure debitage (blue), Vinča-Belo brdo (purple).

Brdo are not as elongated and regular (symmetrical and standardised) as the blades produced by modes 3 and 4 (Radinović, Kajtez 2021, Fig. 7), so modes 1 and 2 seem most likely. Although mode 1 and 2 of pressure debitage require a high skill level, they can be fairly easily transmitted by observation and imitation, unlike more complex modes of pressure debitage (Pelegrin 2012). Thus, it is questionable if the presence of these modes of pressure debitage is indicative of craft specialisation (cf. Milić 2016: 223).

Fig. 10. Bullet-shaped core from Belo brdo site.

Retouch

Only 8 out of 270 (3.0%) of flakes are retouched on a lateral side (sidescrapers), a distal end (endscrapers), or an undeterminable side (scrapers) in the case of fragmented pieces. The percentage of retouched obsidian blades is also low, as only 70 out of 961 blades (7.3%) are retouched. Clarkson's index of invasiveness ranges from 0.03 to 0.41, with a mean of 0.11, indicating that the blades were usually only lightly retouched. A small number of retouched pieces and Clarkson's index of invasiveness show an opposing image to that of cores, where an effort was made to exploit the raw material as much as possible, which is an intriguing insight.

CONCLUSIONS

A large collection of obsidian finds from Belo Brdo, curated at the Archaeological Collection of the University of Belgrade, has had an important place in providing knowledge about the Late Neolithic on both a local and regional scale. In this study, it was shown how the preliminary data from new excavations of Belo Brdo questions some long-established facts that were based on this obsidian collection, such as the disappearance of obsidian during the Vinča D phase and large percentages of obsidian in relation to chert,[4] as well as the corresponding narratives. Thus, caution is needed when interpreting the material from this (and other) old collection(s), and the narratives that were based on it should be re-evaluated when possible.

On the other hand, this collection offers a rare opportunity to explore lithic technology and other aspects of Late Neolithic societies based on such a large quantity of finds. The amount of obsidian that was brought to the site was probably small in comparison to chert (see footnote 4), but it was used for producing a large number of small (short, narrow, and thin) blades. As there are almost no cortical pieces, while there are pieces from subsequent stages of core reduction (crested blades, core rejuvenation flakes, flakes, cores and waste), it seems that the obsidian was imported in the form of partially prepared cores or decorticated nodules to Belo Brdo, where the blade production occurred (see also Bogosavljević Petrović 2015: 84, 410; Milić 2021: 570). The very small dimensions of cores indicate that obsidian was fully exploited by Belo Brdo inhabitants, probably as they valued this raw material that originated from a distant source, although retouch was rarely applied to prolong the use of flakes and blades or (re)shape them. The predominant knapping technique for producing blades seems to be direct percussion using a soft organic hammer (*cf.* Milić 2016; Milić 2021: 573), while the pressure technique might also have been utilised sporadically. There seem to be no notable diachronic changes in the choices of the utilised knapping techniques, as suggested for the production of chert blades (Bogosavljević-Petrović 2015; 2018). However, the identification of knapping techniques in the archaeological record "remains as much a delicate matter as an interesting one" (Pelegrin 2006: 66).

Based on the very high degree of core exploitation, the production of fairly regular and standardised blades, and the low incidence of knapping errors (e.g., crushed platforms, overshot blades), it can be concluded that the knap-

4 It should be noted that the obsidian pieces are very light – the mass of all 916 obsidian blades and cores is between 338 and 436 g (taking into account the precision of the scales), so all the obsidian pieces could have been produced from a relatively small amount of raw material. In contrast, some chert cores from Belo Brdo weigh more than 100 g (Radinović, in preparation). Thus, it is questionable if the commonly used percentages of obsidian/chert pieces are good indicators of the amount of obsidian that was brought to the site.

pers at Belo Brdo were skilled at producing fine blades from obsidian cores. The blade production technology shows no notable diachronic changes over the course of some six centuries (from 9.3 to 3.8 m, see Tasić et al. 2015b), indicating that the technological knowledge was faithfully transmitted down the generations. Therefore, the obsidian production at Belo Brdo might best be explained by the concept of "skilled production and social reproduction" (Apel, Knuttson 2006). However, despite the possible presence of pressure debitage and the inference about the skilled production at Belo Brdo, craft specialisation should not be easily assumed – there are no indications of more complex modes of pressure debitage (modes 3 and higher; Pelegrin 2012), which require a very high skill level and a more intimate process of transmission of knowledge (Pelegrin 2012), nor does the current contextual data point to the existence of specialised workshops. Thus, there are no reasons to suggest that there was a (full-time) specialised production of obsidian tools, which is in line with most other evidence regarding artifact production in the Late Neolithic of the Central Balkans (see Amicone et al. 2020; Chapman 1981; 2020; Greenfield 1991; Kaiser and Voytek 1983; Porčić 2019; Radivojević, Rehren 2016; Spataro 2018; Vitezović, Antonović 2020; Vuković 2011).

Collections of artifacts from old excavations represent an important part of our cultural heritage, and care should be taken to preserve, document, explore, and present these collections. The results of this study show that, although caution is needed in generating insights into the past based on this old collection due to the shortcomings of Vasić's evidence (see above; Palavestra 2020), it can be a valuable source for making new inferences about the past.

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REZIME

STARA KOLEKCIJA I NOVI UVIDI: TEHNOLOŠKA ANALIZA OPSIDIJANSKIH NALAZA IZ KASNONEOLITSKIH SLOJEVA LOKALITETA VINČA-BELO BRDO

KLJUČNE REČI: OPSIDIJAN, VINČA-BELO BRDO, KASNI NEOLIT, TEHNOLOGIJA, SEČIVA, TEHNIKA OKRESIVANJA, SPECIJALIZACIJA.

U Arheološkoj zbirci Filozofskog fakulteta u Beogradu deponovan je veliki broj nalaza od opsidijana, prikupljenih tokom iskopavanja Miloja Vasića između 1929. i 1934. godine. I pored duge istorije istraživanja Belog brda i alatki od okresanog kamena sa ovog lokaliteta, detaljna tehnološka analiza ovog materijala do sada nije sprovedena, već se uglavnom radilo o veoma opštim uvidima u ovu kolekciju. U ovoj studiji analizirano je 1261 nalaza od opsidijana iz slojeva kasnog neolita, sa ciljem da se sintezom rezultata tehnološke analize sa novim saznanjima o lokalitetu pruže novi uvidi o životu kasnoneolitskih zajednica na ovim prostorima. Podaci sa novih iskopavanja Belog brda (od 1998. godine) pokazali su da je validnost određenih aspekata Vasićeve kolekcije opsidijana upitna, verovatno usled određenih pristrasnosti u prikupljanju ili skladištenju nalaza – veoma visoki procenti opsidijana u određenim fazama dovedeni su u pitanje, s obzirom da je procenat opsidijana u odnosu na rožnac daleko manji kada se posmatra materijal sa novih iskopavanja; opsidijan ne nestaje sa Belo brda tokom finalne faze kasnog neolita (tj. nakon 3.8 m) kao što je zaključeno na osnovu Vasićeve kolekcije, već je prisutan i nakon toga. Sa druge strane, veliki broj nalaza u ovoj kolekciji svakako je omogućio da se steknu određeni uvidi u različite aspekte tehnologije izrade opsidijanskih alatki. Rezultati su pokazali veoma visok nivo iskorišćenosti jezgara, koja su mahom korišćena za proizvodnju „finih“ (kratkih, tankih i uskih) sečiva. Tehnološka analiza ukazala je da je za proizvodnju najvećeg broja sečiva verovatno korišćena tehnika direktnog okresivanja upotrebom mekog organskog čekića, dok je tehnika pritiska (modovi 1 i 2) mogla biti korišćena za dobijanje manjeg broja sečiva. Na osnovu različitih tehnoloških aspekata zaključeno je da su se obradom opsidijana bavile vešte zanatlije, koje su reprodukovale svoje znanje, s obzirom da nisu uočene dijahrone promene u obrascima okresivanja, ali nema naznaka da se radilo o specijalizovanoj proizvodnji opsidijanskih sečiva. Može se zaključiti da, iako je potreban oprez pri intepretaciji ove kolekcije opsidijanskih nalaza, ona može poslužiti za sticanje novih uvida o prošlosti.

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THE FLOW PROJECT – A CONTRIBUTION TO THE STUDY OF THE CULTURAL TRANSMISSION OF THE CENTRAL BALKAN COMMUNITIES AND THE NEIGHBORING REGIONS IN LATER PREHISTORY[1]

ABSTRACT

The paper presents the basic research principles of the project THE FLOW (Interactions-Transmission-Transformation: Long-distance connections in the Copper and Bronze Age of the Central Balkans), which is carried by the Institute of Archaeology in Belgrade, the Institute of Nuclear Sciences "Vinča, and the Faculty of Philosophy, University of Belgrade. The theoretical and methodological perspectives of the project research engage an interdisciplinary approach based on analytical techniques incorporated within archaeology and natural sciences, such as physics and chemistry. The project's goal is to apply an exact method to the problems of the origin of raw materials for the production of four specific groups of objects made of obsidian, pottery, copper, and bronze. Each of those materials represents a unique problem and requires a specific treatment, presented within this paper, together with the existing practice, analytic techniques, and methodological procedures for the collected samples. Further, the project incorporates the collection of absolute dates through AMS and OSL dating, with the application of the latest OxCal 4.4. calibration. The acquired dates, combined with the disposition of samples and raw materials will serve as the backbone for the creation of spatio-temporal models and the formation of an SQL database, all with the goal of creating the interpretative basis for the study of local paleo-economies, long-distance connections, and social networks in the Central Balkans during the Copper and Bronze Age.

KEYWORDS: CASE STUDY, PROVENANCE STUDIES, OBSIDIAN, POTTERY, COPPER, BRONZE, ABSOLUTE DATING, SPATIO-TEMPORAL MODEL, SQL DATABASE.

1 This paper is the result of the project THE FLOW - Interactions-Transmission-Transformation: Long-distance connections in Copper and Bronze Age of the Central Balkans, funded by the Science Fund of the Republic of Serbia (Programme IDEAS, Grant no. 7750074).

The phenomena of the so-called imported objects – artifacts whose characteristics do not match the geographic region in which they are found, but rather a neighbouring one, or even a more distant region, has been recorded on archaeological sites from various periods and across the globe. This phenomenon has intrigued several archaeologists, anthropologists, and other scholars, who have, with more or less success, attempted and continue to attempt to explain and interpret it.

Likewise, the aforementioned phenomena have been observed in the Central Balkans, at archaeological sites from various periods, although its most notable manifestation is connected with those sites correlated with the later phases of the Early Iron Age (6th-3rd century BC). On those sites, especially in the territories of the South Morava and Vardar basins, the phenomena can often be observed through the appearance of the so-called Hellenized pottery, identical to examples from concurrent sites in Greece.[2] Those examples are represented by vessels typical of the classical and Hellenistic style in Greece (skyphoi, amphorae, oinochoai, etc.), decorated in black-figure painting, the so-called Saint Valentin vases,[3] and other objects characteristic of the ancient Greek culture. Interestingly, a similar setting can be observed in the far southwest of present-day Serbia, on barely excavated settlements in the vicinity of Novi Pazar, Sjenica, and Tutin.[4] Such an example firmly highlights the tight connections and contacts between the ancient communities of the Central Balkans and their southern neighbours. However, the question arises whether such pottery in the Central Balkans represents an "import" from the south, or rather a transfer of knowledge in pottery production and decoration between the local communities and their neighbours, which enabled them to produce pottery identical to the examples in Greece. Recent multidisciplinary research and analyses, which are being increasingly utilised in archaeology, have indicated that the presumed "Greek" pottery was made of local clay and most likely in local workshops.[5]

The successful collaboration of two disciplines, archaeology and materials science, resulted in the idea that such research could be "pushed" further to the past, to the Copper and Bronze Age (5th-2nd millennium BC), a time much less known to archaeology, especially regarding the questions of social contacts and interactions between populations that inhabited the Balkan Peninsula.

The ideal archaeological site for the analyses of pottery composition (provenance study) was the recently excavated Early Bronze Age necropolis in the village of Ranutovac near present-day Vranje (22nd-19th century calBC).[6] Interestingly, the stylistic and typological characteristics of the ceramic inventory from the necropolis resembled the pottery production of northern Greece and Pelagonia (the so-called Armenochori or Pelagonian cultural group),[7] rather than that from the Central Balkans. In order to determine the origin of such pottery, several different analytical methods were applied and the provenance study was conducted in line with the state-of-the-art archaeometry methodology.[8] A short overview of archaeometry methods in provenance studies that led to the results of the aforementioned study is to be highlighted. The determination of the origin of archaeological pottery represents an extremely complex procedure that includes the research into different levels of similarities between sherds within an archaeological context, comparison of the material composition of a selected group of ceramic sherds, comparisons with the potential source/sources of raw material (clay pit) in the vicinity of the site, and an examination into the production technology and other materials that were utilised during that process (pigments for decoration, tempers, etc.). The process of determining the origin of ceramic artifacts that includes all of the aforementioned aspects is called the provenance study. Besides the archaeological techniques, such as typological analyses, modern provenance studies universally include the examination of material using various instrumental tech-

2 Микулчић и Јовановић 1968; Alexandrescu 1978; Паровић-Пешикан 1992; Popović 2003;Крстић 2005; Булатовић, Филиповић и Капуран 2016; Вранић, 2022.

3 Соколовска 1986; Tonkova 1997.

4 Паровић-Пешикан 1992; Премовић-Алексић 1984; Премовић-Алексић 2014; Ljuština 2021.

5 Gajić-Kvaščev et al. 2014; Gajić-Kvaščev et al. 2015; Mirković et al. 2015.

6 Bulatović 2020.

7 Garašanin 1983.

8 Gajić-Kvaščev, Andrić, Vuksanović 2020.

niques. Modern archaeometry successfully applies both destructive and non-destructive analytical techniques, sometimes separately and sometimes complementary, in order to provide the answer to questions related to the origin of raw materials and/or the production technology.[9] Regardless of the analytical approach, modern archaeometry studies include the application of advanced mathematical techniques for processing the results of the analyses, including the state-of-the-art principles of machine learning and artificial intelligence.[10]

The aforementioned research concluded that all of the sampled ceramic vessels from the necropolis were made of clay from the local clay pit in Suvi Dol, which is being used by potters even today.[11]

Worthy of mention are petrographic examinations of ceramic inventory from the site of Zlatica in Omoljica and Najeva Ciglana in Pančevo, both attributed to the Vatin culture of the Middle Bronze Age. The results of the petrographic analyses have indicated that the pottery workshops from both of the researched sites prepared local clay in a similar, although specific, manner.[12] The valuable results of those pieces of research opened new insights and gave birth to new ideas, which were soon, with a good deal of joint work and constant "multidisciplinary" consultations, transformed into a project: THE FLOW - *Interactions-Transmission-Transformation: Long-distance connections in Copper and Bronze Age of the Central Balkans,* which is financed by the Science Fund of the Republic of Serbia (from 2022 to 2025, IDEAS Grant no.7750074), and which incorporates the joint work of archaeologists, physicists, and chemists.

The problem of the origin of raw materials within THE FLOW project will be examined through four case studies: pottery, copper artifacts, bronze artifacts, and obsidian artifacts.

The pottery will be analysed using several different analytical techniques (pEDXRFS-*Portable Energy Dispersive X-Ray Fluorescence Spectrometry,* rFTIR- *Fourier Transform InfraRed Spectrometry in reflection mode,* and XRD-*X-ray diffraction*), and the analyses will be focused on vessels and fragments of vessels, clay pits in the vicinity of origin sites, and the soil from the archaeological features in which the vessels were recorded. For the first time, THE FLOW project will apply the elemental analyses of soil to determine the potential discordances in the stratigraphy of the sites. The archaeological sites that will provide the pottery for the analyses have been carefully selected and represent well-researched sites with a finely determined stratigraphy and absolute chronology, such as Bubanj and Velika Humska Čuka near Niš, Ranutovac near Vranje, Hisar in Leskovac, Svinjarička Čuka near Lebane etc.[13] Following the collection of ceramic samples, they will be documented (photographed and marked). The pottery samples for this case study will be prepared according to current practice.[14] Suitable surfaces of samples will be mechanically scratched, washed, finely polished, rinsed, and dried. Samples prepared in such a manner are suitable for non-destructive examination of elemental composition using EDXRF spectrometry, and the analyses of the presence of chemical bonds using FTIR spectrometry. Following the non-destructive examination of samples, they will be examined using the diffractometry technique (XRD). This technique will require a small sample (approximately 1g) from suitable parts of sherds, which will serve for the examination of crystalline structure and the identification of crystalline phases in pottery, which should, besides the chemical composition, indicate the production technology. All of the instrumental techniques will be conducted within well-established and attested analytical procedures.[15] This will allow further mutual comparisons of the results, which will be treated in several different ways and processed in a manner that enables their application within the provenance algorithms. The algorithms to be applied are unique and have been developed from the long-term research by the team from the Vinča Institute of Nuclear Sciences.[16] The interpretation of the acquired results will represent the result of

9 Gajić-Kvaščev 2013; AndrićiGajić-Kvaščev 2017.

10 Kvaščev, Gajić-Kvaščev, Đurović 2012.

11 Gajić-Kvaščev, Andrić,Vuksanović 2020; Gajić, Kvaščev, Andrić i Bulatović 2022.

12 Gómez-Gras et al. 2021.

13 Bulatović and Milanović 2020; Bulatović and Milanović 2021; Bulatović 2020; Stojić 2001.

14 Gajić-Kvaščev et al. 2018.

15 Gajić-Kvaščev and Andrić 2013; Jančić-Heinemann at el. 2013.

16 Gajić-Kvaščev et al. 2012.

the multidisciplinary work of natural sciences researchers and archaeologists.

The second case study is focused on copper objects, the analyses of lead isotopes and other impurities within the copper, as well as the analyses of copper ores from mines or surface copper deposits located in those regions that display a higher concentration of copper artifacts. Such analyses have so far been conducted on copper finds from archaeological sites in eastern Serbia, attributed to the beginning of the Middle Bronze Age.[17] This case study is primarily focused on the Copper Age (Eneolithic), meaning the period between 4500 and 2500 calBC. However, isotopic analyses of lead will be conducted on copper from bronze artifacts as well, as it will be particularly interesting to compare the origin of copper and tin from bronze artifacts, for which the origin was sought beyond the Central Balkans.

The territory of north-eastern Serbia, one of the largest copper deposits in south-eastern Europe, bears exact evidence for the earliest copper extraction in Europe (c. 5000 BC) (Borić 2009, 204)[18] and, therefore, represents a logical starting point for research into the origin of copper during the Copper and Early Bronze Age. From an archaeological aspect, the territory of north-eastern Serbia represents a well-documented region, especially following the rescue archaeological excavations within the Iron Gates region during the second half of the 20th century. Unfortunately, locations in which mining and metallurgical activities were most likely conducted have been almost completely destroyed or at least largely devastated due to the flow of time and industrialisation. Such a scenario is understandable since the “hunger” for metals has always driven metallurgy based populations to increase production in search of profit, without preserving the technological traditions or cultural heritage.

One of the best pieces of evidence for the production of metal artifacts, both in the past and today, are casting moulds, which were based on examples from the Bulgarian Eneolithic, made primarily of stone (Tylecot 1992:13) and later of clay or sand. Within the territory of north-eastern Serbia, the only moulds originate from the Late Bronze Age and the Early Iron Age.[19] Several excavation campaigns on the metallurgical sites of Trnjane, Ružana, and Čoka Njica in the vicinity of present-day Bor, which bear evidence of copper metallurgy from the beginning of the Middle Bronze Age, yielded no finds of casting moulds. This indicates that the prehistoric communities that exploited the copper deposits of Tilva Roš in the vicinity of present-day Bor during the 2nd millennium BC engaged solely in the production of copper ingots, which were subsequently distributed to other centres, mixed with tin, and further transformed into bronze. However, the territory of Timok Valley in north-eastern Serbia yielded numerous finds of Copper Age shaft-hole axes, of which some were extremely large.[20] Also, the latest excavations of Kozija pećina (Goat Cave) near Rudna Glava, yielded a pit with pottery attributed to the Sălcuţa culture, traces of burning, and fragments of metallic slags and copper particles, which represent the first solid evidence of copper metallurgy from the end of the 5th and the beginning of the 4th millennium BC (All of the relevant information and insight into finds were provided by courtesy of our colleague Prof. Dr D. Mihailović, the director of the aforementioned archaeological excavations).

Hence, the isotopic analyses of lead from copper axes in the territory of Timok Valley could provide us with exact evidence on the origin of such artifacts, and determine whether those were imported or locally produced during the 4th millennium BC.

The objects planned for those analyses are mostly Early Eneolithic shaft-hole axes of the *Jasladany* type, and chronologically younger axes of *Kozarac*, *Pădureni*, and *Pătulele* types (For questions of function, distribution, and chronology of such axes refer to Antonović 2014). Similar analyses have been previously conducted in the territory of Central Europe, therefore providing a significant database for the comparison of our results.

The third case study is focused on the isotopic analyses of tin (Sn^{124}) within bronze (Bronze is an alloy of copper and tin) objects from the Middle and Late Bronze Age (1900/1800-

17 Kapuran, Živković and Štrbac 2016; Mehofer et al. 2021.

18 Jovanović 1982.

19 Јевтић 1982; Лаловић 1976.

20 Гарашанин 1954: 51; Јовановић, Николић и Јовчић 2018.

1100/1000 calBC). This case study is based on the fact that copper deposits are known throughout the Central Balkans, while tin deposits, with their most common ore – cassiterite, are extremely rare. A decade ago, a higher concentration of bronze objects was highlighted on necropolises within western Serbia, in the immediate vicinity of Cer Mountain - a known source of tin ore cassiterite.[21] Such disposition and high concentration of bronze objects served as a basis for the formation of the international and multidisciplinary *Jadar* project, which has been ongoing for more than a decade. The project employs archaeologists, physicists, geologists, and other related researchers from the Institute of Archaeology in Belgrade and Brooklyn College in New York. The collaboration has yielded a significant number of scientific results, based on both the scientific and experimental methods.[22] The project has determined that the Milina River, which runs from biotite and biotite-amphibole granodiorites of the Cer Mountain, bears enough tin (Approximately 80% of tin in cassiterite from Cer Mountan) for the production of one bronze pin within several hours of panning.[23] Further, the isotopic analyses of tin have determined the existence of several unique "fingerprints" that separate bronze objects from the Balkans into several groups according to the origin of the tin.[24] These remarkable results, published in renowned scientific journals, have inspired us to further explore it as one of the case studies within THE FLOW project.

The isotopic analyses of tin will serve for the comparison of finds that belong to certain and/or several chronological, regional, or cultural-historical groups. This portion of the project will not be addressed solely through one problem, but rather several smaller case studies, of which some will combine the questions of the origin of both tin and copper within the same object, such as axes of the *Pătulele* type, which are certainly attributed to the Late Bronze Age, or Central European types of swords with a tang that occur in the Central Balkans at the end of the Bronze Age and the beginning of the so-called Transitional Period (12th-11th century BC).[25] Some of the Central European types, such as *Stätzling*, *Moškjanci*, *Novigrad*, and *Marina*, occur solely within the confluence zone of the Great Morava,[26] while their origin varies from northern Italy to the upper course of the Tisa river. The reason for such an occurrence of uncommon types of weapons far from the source territories has not been determined so far, especially considering that there is no "visible pattern" in their distribution, which is the case with swords of the *Reutlingen* type and flame-shaped spears. Another interesting question arises regarding the origin of slightly earlier Mycenaean types of swords, arrows, daggers, etc. Namely, it remains unknown whether such objects represent Aegean imports from the second half of the 2nd millennium BC or products/imitations from workshops within the hinterland of the Balkans.[27] Specific, and uncommon types for the Balkan Danube region are also two bronze cauldrons with double cross-shaped staples, which are connected with Central Europe and the Upper Danube region.[28]

In addition to the aforementioned, a particular focus will be placed on the origin of metals in several horizons of hoards in the Central Balkans, since those represent a Late Bronze Age phenomenon of the Central Balkans that originates from Central Europe. Hence, it is important to provenance copper and tin from hoards, and partially resolve the century-old question of their origin. Finally, one of the studies will be focused on bronze jewellery, since certain forms represent local tradition, while other forms suddenly occur without previous utilisation within local populations. The isotopic determination of the metal source could provide a peculiar relationship with a long-lasting utilisation of certain types of jewellery, and vice versa.

The final case study will be focused on the origin of obsidian artifacts from Copper and Bronze Age sites in the Central Balkans. In contrast to studies conducted for the obsidian finds from the Late Neolithic in the Central Balkans, primarily linked to the evidence from the Vinča site of

21 Muhly 1985; Durman 1997.

22 Bankoff et al. 2013; Huska et al. 2014; Mason et al. 2016; Булатовић et al. 2017; Powell et al. 2017; Powell et al. 2019.

23 Huska et al. 2014.

24 Powell et al 2018; Mason et al. 2016; Mason et al. 2020.

25 Филиповић 2015; Bulatović and Filipović 2017.

26 Filipović and Mladenović 2019.

27 Паровић-Пешикан 1995.

28 Jacanović 1995.

Belo Brdo, which were analysed in the scope of techno-typological and geochemical attribution,[29] chipped stones made of this raw material are not only rare in the later contexts but are still greatly lacking detailed analyses and contextualization. **THE FLOW** project, therefore, aims to address obsidian artifacts from the Copper and Bronze Age in its area of focus, bearing in mind their exotic origin (with the closest outcrops of obsidian being situated in the Carpathians, to the north, and in the Aegean islands in the south of the study area) and their distribution at a time when metals took the central role for the production of tools in prehistoric communities. Small collections deriving from the latest fieldwork or already partially recorded by colleagues (e.g., J. Šarić) studying the procurement, manufacture, and consumption strategies of lithics at major sites will be expanded with a new programme looking at the provenance, production, and function. Newly excavated or dated strata from Velika Humska Čuka, Bubanj, and Kalenić Livade will be used together with distinct museum collections in order to examine the role of imported objects in a range of domestic activities and their relationship in the production of local versus exotic raw materials, as well as to look at the reasons behind importing such objects into the local communities. Finally, the attempts of the long-distance exchange network reconstruction will benefit from the collaboration with the project partner M. Milić and the employment of pXRF analyses, to directly investigate obsidian provenance based on the study of trace elements like in previous studies.[30]

Results of all of the analyses from the presented case studies will be minutely analysed and mutually compared, both within these case studies and with the existing case studies. This step of the project will employ the *spatiotemporal* models, which serve to model absolute dates of sampled objects and the disposition of raw materials acquired through conducted analyses. This step requires the dating of all of the samples and/or archaeological features from which the samples originate. Therefore, **THE FLOW** project will acquire 30 AMS absolute dates (*Accelerator Mass Spectrometry*), and 14 OSL absolute dates (*Optically Stimulated Luminescence*) for pottery samples that do not originate from reliable archaeological features. Following the latest OxCal 4.4. calibration, the dates will undergo Bayesian modelling, and the locations of sampled objects will be georeferenced in GIS.[31]

The existing narratives and interpretations, and the fresh data acquired from **THE FLOW** project, including absolute dates, various analyses, georeferencing, etc., will allow the formation of an SQL (*Structured Query Language*) database, which enables operations between various relationships of the input data.

Such a research method will enable certain theoretical frameworks, as well as archaeological/anthropological concepts/models regarding the long-distance connections and social networks of the Central Balkans during the Copper and Bronze Ages.

During the entire course of the project, results will be presented on different scopes, from local educational workshops and scientific institutions to renowned international journals, which is, in fact, one of the main goals of the project.

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REZIME

THE FLOW PROJEKAT – PRILOG STUDIJI KULTURNIH KONTAKATA POPULACIJA CENTRALNOG BALKANA I SUSEDNIH OBLASTI U POZNIJOJ PRAISTORIJI

KLJUČNE REČI: STUDIJA SLUČAJA, POREKLO SIROVINA, OPSIDIJAN, KERAMIKA, BAKAR, BRONZA, APSOLUTNO DATOVANJE, SPATIAL-TEMPORAL MODEL, SQL BAZA PODATAKA.

Rad prezentuje osnovne istraživačke smernice projekta THE FLOW (Interactions-Transmission-Transformation: Long-distance connections in Copper and Bronze Age of the Central Balkans), koji sprovode Arheološki institut, Beograd, Institut za nuklearne nauke “Vinča” i Filozofski fakultet, Univerziteta u Beogradu. Teorijske i metodološke perspektive istraživanja podrazumevaju multidisciplinarni pristup zasnovan na analitičkim tehnikama koje nude arheologiji prirodne nauke poput fizike i hemije. Cilj projekta je da se egzaktno pristupi problematici porekla sirovina za izradu predmeta korišćenih u praistoriji, koji će se odvijati kroz studije slučaja usmerene na nalaze izrađene od četiri vrste materijala: keramike, bakra, bronze i opsidijana. Svaki od navedenih materijala zahteva posebno tretiranje pa je u radu izložena osnovna istraživačka problematika, dosadašnje prakse, analitičke tehnike i metodološke procedure u ispitivanju prikupljenih uzoraka.

Analize vezane za poreklo sirovina u proizvodnji keramičkih predmeta podrazumevaju nedestruktivna ispitivanja elementnog sastava EDXRF spektrometrijskom tehnikom, kao i analizu prisutnih hemijskih veza korišćenjem rFTIR spektrometrije, nakon čega će uzorci biti tretirani difraktometrijskom tehnikom (XRD), kako bi se ispitale kristalne strukture i faze u keramici, što pored hemijskog sastava treba da ukaže i na tehnologiju izrade. Sledeća studija slučaja podrazumeva analizu predmeta od bakra, tačnije analizu izotopa olova i drugih nečistoća u bakru, što uključuje i komparativnu analizu sa rudom bakra iz rudnika ili površinskih kopova koji se nalaze u blizini regiona sa konstatovanom koncentracijom bakarnih predmeta, među kojima se u prvom redu izdvajaju sekire tipa Jasladany, Kozarac, Padureni i dr. Treća studija slučaja odnosi se na analizu izotopa kalaja (Sn^{124}) u predmetima od bronze na osnovu koje će biti izvršeno upoređivanje nalaza iz dobro definisanih hronoloških, regionalnih ili kulturno-istorijskih celina, što se posebno odnosi na Rojtlingen, Štacling, Moškjanci, Novigrad, Marina i Mikenske tipove mačeva, kao i sekire tipa Patulele i bronzana koplja plamenastog lista. Prisustvo predmeta od opsidijana retko je analizirano u kulturama bakarnog i bronzanog doba, iako je iz ranijih studija poznato da oni uvek predstavljaju import, s obzirom da se njihova najbliža ležišta nalaze na Karpatima i egejskim ostrvima, tako da će akcenat biti stavljen na rekonstrukciju mreža razmene putem pXRF analiza na predmetima iz muzejskih zbirki i novotkrivenih nalaza iz pouzdano datovanih celina.

Pored ovih analiza projektom je predviđeno dobijanje apsolutnih datuma za celine iz kojih potiču uzorci, putem AMS i OSL tehnike datovanja uz korišćenje najnovije OxCal 4.4. kalibracije datuma. Dobijeni datumi uz precizno određenu dispoziciju uzorka i sirovina biće upotrebljeni za stvaranje spatial-temporal modela i formiranje SQL baze podataka koje će rezultirati stvaranjem interpretativnih osnova u proučavanju lokalnih paleoekonomija, long-distance veza i socijalnih mreža kod populacija na centralnom Balkanu tokom bakarnog i bronzanog doba.

* * *

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MORTAR RECIPES THROUGH THE AGES. A BRIEF REVIEW OF DATA FROM PREHISTORY TO LATE ANTIQUITY

ABSTRACT

Mortars, composite materials used to bind together masonry elements and to seal and waterproof architectural surfaces, have been employed by human populations for sheltering purposes since the beginning of technological evolution of mankind, constituting the first attested products of pyrotechnology since the Neolithic period. Over times, selection of raw materials and optimization of recipes and mixing procedures allowed to diversify and optimize their properties, in order to meet the most sophisticated demands of human cultures. In this contribution, a brief excursus of the evolution of mortar technology from the Palaeolithic to the late Roman times is reported, with a particular focus on the selection of functional compounds to push some specific properties of these binding composites within differentiated human societies.

KEYWORDS: ANCIENT MORTARS, LIME, CLAY, GYPSUM, POZZOLANIC AGGREGATES, OPUS CAEMENTICIUM, COCCIOPESTO, NATURAL HYDRAULIC LIME

INTRODUCTION

Mortars are man-made lithoid building materials composed of a combination of inorganic and sometimes organic elements. Two components are necessary for the production of a mortar, namely the binder and the aggregates.

Binders are materials that, when mixed with water, form plastic blends that harden to a solid compound after a certain timeframe. The main binders employed in antiquity are clay, gypsum and, in particular, lime.

Aggregates are all those natural or artificial materials constituting the volumetrically dominant skeleton of the mortars, bound together by binder reaction, and preventing the formation of fractures in the compound after the complete evaporation of water.

Mortars produced in antiquity were not standardised. The physical (porosity, permeability, hydraulicity, etc.) and mechanical (tensile strength, toughness) properties of ancient mortars can vary on the basis of the selection and mixing of the components. Different compositions are influenced by the local availability of raw materials, mixing techniques and the different context of use (i.e. wall joints, foundations, flooring). In this paper, a brief review of the evolution of mortars' making techniques and selection of raw materials from the Palaeolithic to the late Roman times will be presented.

Fig. 1. Palatial Knossos (Crete), wall-paintings (partially restored) (Dilaria in press).

PRE AND PROTOHISTORY

The oldest binder used in antiquity is clay. The earliest cases date back to the Palaeolithic period, with several evidence from African sites. During the Neolithic period, in Mesopotamia, Persia and Anatolia, clay-based mortars developed and were intensively applied for the lining of walls and floors. This kind of mortar was also used as a mild waterproofing agent for wooden roofs and sometimes as a binder for wall joints (Artioli, Secco, Addis 2019; Hobbs, Siddall 2011). Several examples come from the site of Çatal Höyük in Anatolia (Hodder 2006).

The earliest evidence of production of lime-based mortars come from the site of Hayonim in Israel, dated to the 11th millennium BC (Kingery, Vandiver, Prickett 1988). Later evidence are attested in other sites in the Near and Middle East dated to the 8th to 7th millennium BC. In these contexts, mortars were primarily used as revetments of floors and walls (Kingery, Vandiver, Prickett 1988).

In a period chronologically akin to the Near-Middle Eastern cases, lime-making technology developed in the Danubian area, as demonstrated by the findings at the Neolithic (or perhaps even Mesolithic) site of Lepenski Vir in Serbia (Srejović 1972). It is unclear, however, whether this evidence should be regarded as a fortuitous and isolated experience, completely unrelated to eastern examples. However, simple lime-based mortars identified in some Neolithic sites in Thrace and in the Greek's Ionian islands (Kefalonia) (Wright 2005) suggest some type of transmission of the technology from the Levantine area to the Danubian-Balkan territories.

It has also been observed that as early as the Aceramic Neolithic period, the production of hydraulic mortars may have been experimented for the first time. At Aşikli Höyük in Anatolia (Hauptmann, Yalcin 2001), some rudimentary hydraulic mortars were obtained by mixing aerial lime with reactive volcanic tuffs and vegetable ash. However, the case appears isolated so far and probably accidental, as the first mixtures displaying the same properties spread in the Mediterranean several millennia later.

Fig. 2. Plastered water-tank from ancient Paleros, Acarnania, Greece (5th century BC) (Dilaria in press).

Regarding Egypt, it is generally believed that the use of lime binders was unknown, or extremely limited. A prototype of limestone-based concrete has been found in the pyramids at Giza (Barsoum, Ganguly, Hug 2006). In this territory, until the Ptolemaic period, the production of gypsum-based mortars primarily developed (i.e. Hemeda, Sonbol 2020). Thanks to the local availability and ease of firing of evaporitic stones (~200 °C), gypsum binders got a wide utilization in this territory, mainly as renders, at least since the Predynastic period (c. 5000-3150 BC), or even earlier. Other protohistoric evidence of the production of gypsum-based mortars come from the island of Cyprus (Philokyprou 2019).

During the Bronze Age, lime-based binders started being ordinarily employed by the Aegean societies. Several evidence come from all the major palatial sites in Crete, where these mortars were primarily used for the revetment of floors or walls. Wall plasters were then often painted in wall-paintings (Fig. 1) (Jones 2005). On the other hand, the use of mortars as structural elements is lacking.

From these periods the first "pozzolanic" mortars, started being systematically produced. The pozzolanic reactivity in a mortar-based material occurs when some aggregates chemically interact with the calcium hydroxide $Ca(OH)^2$, namely the "slaked lime" (portlandite) in a liquid solution. The chemical nature and mineralogical structure of the reaction products depend primarily on the content of free silica and aluminum from the aggregate that entered into reaction with the lime (Dilaria et al. 2022a). Some pozzolanic mortars, obtained by mixing aerial lime with *terracotta* fragments, are attested in some sites from Cyprus dated to the Late Bronze Age (late 2nd millennium BC) (Theodoridou, Ioannou, Philokyprou 2013).

CLASSICAL AND HELLENISTIC AGE

From the Minoans, the pyrotechnology for the production of lime binders was transferred to the Mycenaean culture and, in historical times, endorsed by the Greek societies. In these periods, mortars continued being primarily used for the revetment of hydraulic infrastructures (Fig. 2) or

Fig. 3. Mortar bedding of a Hellenistic mosaic in Pella (4th century BC) (photo by Simone Dilaria).

for the production of floor surfaces and floor beddings (Fig. 3). The first waterproofing pozzolanic mortars produced by adding pyroclastic rocks to lime-based mortars are dated to the Late Classic and Hellenistic Age and were primarily used for the revetment of hydraulic infrastructures. Among the earliest cases, dating to the 4th-3rd c. BC, there are the (revetment?) concretes of the cisterns at Kamiros in Rhodes, analysed in the late 1890s (Koui, Ftikos 1998). However, this case needs further analytical in-depth study in light of the advancement in this field of research. Other analyses have detected reactive tuff fragments in the mortar renders of a cistern in Pergamum (Brinker, Garbrecht 2007, 100), while fractured and possibly fired pumices and reactive flints were recently documented in the revetments of some hydraulic infrastructures and floor beddings in Corinth, dated between the Classical and the Hellenistic Ages (Siddall 2019) as well as in many Hellenistic sites in ancient Macedonia (Pachta *et al.* 2014, 847; Stefanidou, Pachta 2015). In certain occasions, volcanic pozzolans were documented also in floor bedding mortars. For example, they were detected in the preparation layers of some pebble mosaics in the Palace of Aigai and in the houses of Pella too (Papayianni, Patcha 2008; Pachta, Stefanidou 2018).

It is not clear if the Greeks were actually the first to use purposely volcanic pozzolans in mortars. By the analysis of some water tanks' revetments in the Punic Pantelleria and Carthage, dated to the 4th and 3rd centuries BC, volcanic pozzolans were observed. According to the hypotheses formulated by the scholars (Schön et al. 2012; Schön 2014, 203-212), volcanic pozzolans in the mortars of Carthage were not locally sourced but were probably imported from Pantelleria. This outcome might testimony one amongst the first trans-regional trades of volcanic pozzolans before the Roman Era (Secco *et al.* 2020, 78-79; Bonetto, Dilaria 2021).

Moreover, in the Phoenician and Punic cultures, from the Levantine area to the territories of North Africa, including Sardinia, Southern Spain and Sicily, hydraulic mortars for cisterns' waterproofing were produced by adding plant and animal ashes to lime-based binders (Lancaster 2015, 201; 2019, 35-38). In these regions, this constructive tradition was maintained also during the Roman period, as attested in Nora in Sardinia (Fig. 4) (Secco et al. 2020, Bonetto, Dilaria 2021).

Concluding with the pre-Roman evidence of pozzolanic aggregates, the unusual employ of reactive slags (litharge, iron/manganese) in lime-based mortars was documented in the cisterns' renders of the Laurion in Attica, chronologically framed to the 4th century BC (Papadimitriou, Kordatos 1995).

THE ROMAN ERA AND LATE ANTIQUITY

The spread of the Latin culture in the Mediterranean led to a broader use of mortar-based materials that, differently from the previous times, were not uniquely employed as renders. From the 3rd century BC or, more likely, during the 2nd century BC, lime-based mortars began to be used by Roman builders as a structural material for the creation of thick wall cores and foundational casts of monumental buildings. The rapid expansion of Rome in the Mediterranean, along with the deduction of new colonies, greatly influenced this change. In

Fig. 4. (left) Ash and charcoal enriched mortar in a Roman cistern from Nora (Sardinia); (right) Cross-section of a sample of an organic ash-rich sample from a cistern render of Nora (photos by Simone Dilaria).

fact, the need for realizing rapidly new cost-efficient buildings that emulate the magnificence of the full-body Greek monumental architecture represented the essential ground for the spread, from the Middle Republican Age onwards, of the *opus caementicium* (mortar-based structure), a solid, versatile, easy-to-produce and low-cost building material (Fig. 5) (Mogetta 2015; 2021).

The development of the *opus caementicium* was complemented by an extensive use of volcanic pozzolans in the mortars. Vitruvius celebrated the properties of the *pulvis puteolana*, a particular volcanic dust, quarried in the localities between Baia and Pozzuoli in Phlegraean Fields and the Vesuvius, that was recommended for the making of hydraulic concretes of maritime piers (Fig. 6) (Vitr. 2.6.1-2; 5.12.2; Plin. nat. 35.166). This material obtained a broad commercialization in the Empire from the Imperial Age onwards, being extensively used in the making of the *opus caementicium* piers of the main Roman harbours in the Mediterranean (Brandon et al. 2014; Marra et al. 2016a; Sec-

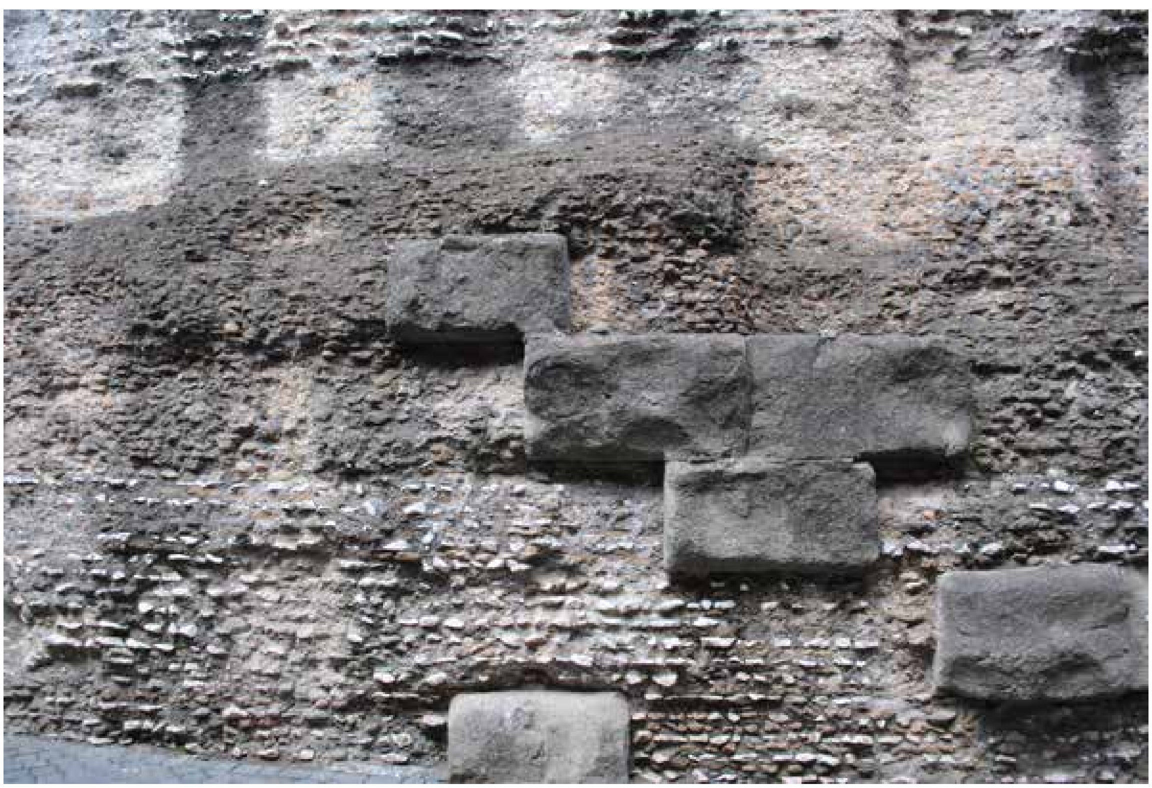

Fig. 5. *Opus caementicium* foundation of the Hadrian Mausoleum in Rome (today's Castel Sant'Angelo) in Rome (mid 2nd century AD) (Dilaria in press).

Fig. 6. Volcanic tuffaceous outcrop in Baia (Phlegraean Fields) (Dilaria in press)

co et al. 2022). The *pulvis puteolana* was also used for the construction of overground buildings, not only in the territory around the gulf of Naples (Miriello et al. 2010; De Luca et al. 2015; Paternoster et al. 2007; Sossio Fabio et al. 2018; Rispoli et al. 2019a; 2019b), but also in far regions, as recent researches are indicating for Sardinia (Nora) (Fig. 7) and Northern Italy (Aquileia) (Fig. 8). In Nora, in fact, the pyroclastic aggregates, probably imported from the gulf of Naples, were extensively used in the 2nd and 3rd c. AD in masonry construction (Ongoing research by S. Dilaria, J. Bonetto, C. Previato and M. Secco) and revetments (Dilaria, Marinello, Zara 2022; Bonetto Dilaria 2021). In Aquileia, this aggregate was detected in the *opus caementicium* vaults of the Late Antique Baths (Dilaria et al. 2022b; Dilaria in press) and in the bedding layers of the *orchestra* of the theatre (ongoing research by S. Dilaria, A.R.Ghiotto, J.Bonetto, M. Secco).

Fig. 7 - Volcanic pozzolans (mainly pumices and fragmented tuffs), probably from the Gulf of Naples, in the bedding of the parietal opus sectile of the Temple of Aesculapius in Nora (3rd century AD) (Dilaria in press).

In their treaties, Latin authors mentioned also other volcanic pozzolans having properties similar to the *pulvis puteolana*. Vitruvius described the *harenae fossiciae* as red (*rubra*), black (*nigra*) and light brown (*cana*) quarry sands (Vitr. 2.4.1; cited by Plin. nat. 36.175; Fav. 8.1; Pall. 1.10.1) to be used to obtain particularly tough and durable mortars (Lancaster 2021). The *harenae fossiciae* were identified by the scholars in the cinerites of the Middle Pleistocene eruptions of the Colli Albani, in the *facies* of the so-called Pozzolane Rosse, Pozzolane Nere and Pozzolanelle (Jackson *et al*. 2007; 2010; Lancaster 2019), although some scholars do not completely agree on this point (D'Ambrosio *et al*. 2015).

Vitruvius finally mentions the *carbunculus*, probably corresponding to the blackish scoria-

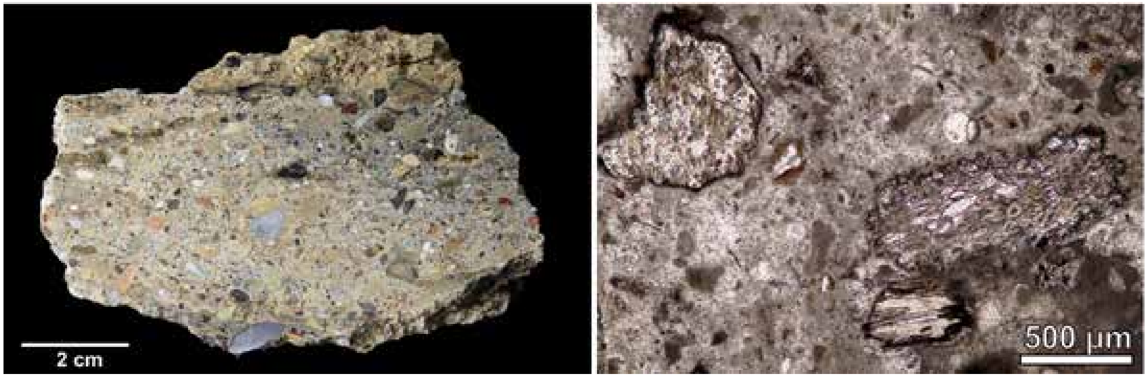

Fig. 8. (left) Cross-section of a sample of volcanic pozzolan enriched mortar from the bedding of the orchestra of the Roman theatre of Aquileia (beginning of 1st century AD); (right) micrograph of transmitted light of pumice aggregates in the mortars of the floor bedding of the orchestra of the Roman theatre of Aquileia (parallel nicols) (Dilaria in press).

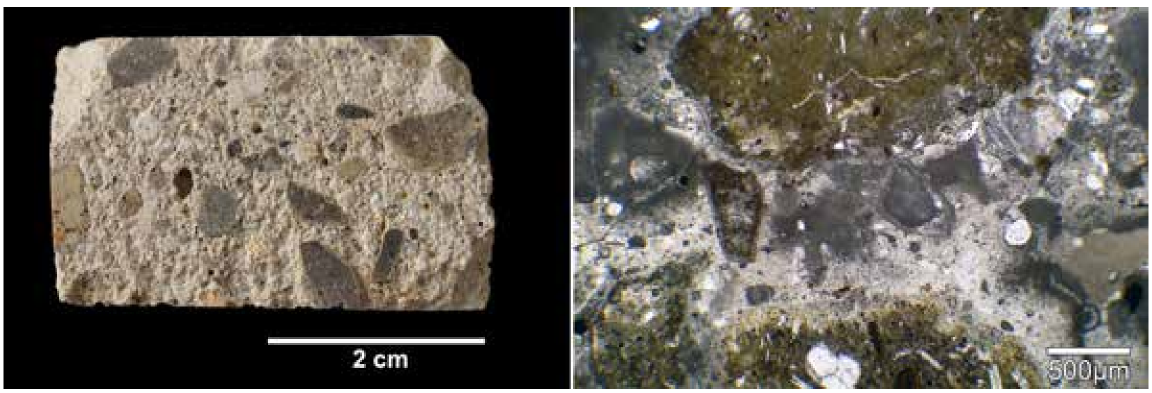

Fig. 9. (left) Cross-section of a mortar sample enriched with volcanic pozzolan from the Euganean hills from the masonry structures of the theatre of Montegrotto; (right) micrograph of transmitted light (parallel nicols) of reacted volcanic aggregates (breccias) (photos by Simone Dilaria).

ceous deposits of the Sabatini Mountains in ancient Etruria (nowadays corresponding to the Northern Latium). The *harenae fossiciae* were extensively exploited since the Middle-Late Republican age to produce mortar-based materials in Rome (Jackson et al. 2011; Marra et al. 2016b; Seymour et al 2021; Schmölder-Veit et al. 2016; Boccalon et al. 2019) and in the sites around the city (Murgatroyd 2016; Botticelli et al. 2021; Boularand, Turci, Bromblet 2022), but, unlike the *pulvis puteolana*, apparently did not obtained a broad distribution out of the territories where they were locally available.

However, the trading of volcanic pozzolans did not involve only the Campanian ones. Recent analyses of sand ballasts from the Wreck B of Pisa (1st century CE) have detected pyroclastic pozzolans whose geochemical fingerprint is compatible with the products of *Vulsinii* volcanic outcrop (northern Latium) (Marra, D'Ambrosio 2013). Pozzolans from these outcrops were detected in the mortars of Vulci and *Vulsinii* in Etruria (D'Ambrosio et al. 2015).

In the provinces of the Empire, in certain occasions, local builders and engineers experimented volcanic materials in mortars having properties resembling the traditional central-Italian pozzolans. These "alternative" pozzolans were locally sourced and their distribution probably remained mainly intra-regional. These include the so-called Rhineland Trass, a particular tuff attested in the mortars of some Roman buildings in Cologne (ancient *Colonia Ulpia Traiana*) (Lamprecht 1984, 46-49; Wang, Althaus 1994); tuffs from Turkish volcanic outcrops were exploited for the production of mortars employed in some centres of Asia Minor, such as Sagalassos (Callebaut et al. 2000; Degryse, Elsen, Waelkens 2002), Nysa and

Fig. 10. (right) Cocciopesto wall joints (foundation) from the Palace of Galerius (left) in Thessaloniki (late 3rd century-early 4th century AD) (Dilaria in press).

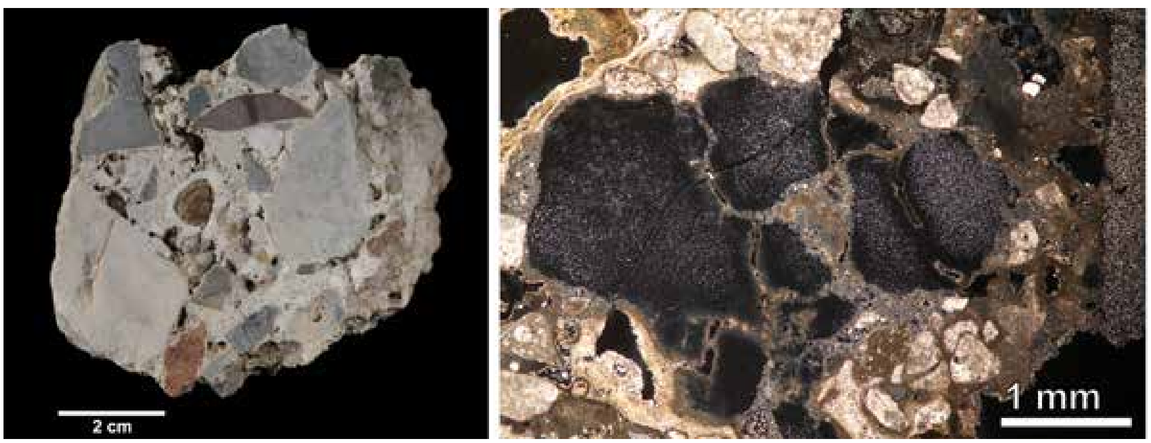

Fig. 11. (left) Cross-section of a sample from the concrete foundation of the Republican Walls of Aquileia (beginning of 2nd century BC); (right) micrograph of transmitted light optical microscopy (crossed nicol) of a lump of the natural hydraulic lime from the concrete sample (Dilaria in press).

Aigai (Uğurlu Sağın, Engin Duran, Böke 2021) and Pergamum (Özkaya, Böke 2009); the use of obsidian and perlites in the structural mortars of the Roman theatre of Nora in Sardinia (Columbu, Garau, Lugliè 2019), with a geochemical characteristics compatible with Monte Arci (southwestern Sardinia), represents another isolated case of exploitation of local alternative pozzolans. Similarly, some latitic and rhyolitic breccias from the Euganean Hills (northeastern Italy), on which the research is still in progress under the coordination of Michele Secco, were used in the *opus caementicium* foundations of the theater and amphitheater of the Roman Patavium as well as in several sites in the hinterland (preliminary report in Bonetto *et al*. 2021, 54-59). For example, the presence of Euganean breccias was recently found in the mortars of some Roman public buildings of Montegrotto (PD), the ancient *Fons Aponi* (Fig. 9). Ongoing research are targeted to the compositional characterization and definition of the exact provenance of these local volcanic pozzolans. Other evidence of "alterative" volcanic pozzolans are unfortunately based only on archaeological observations (Bonetto *et al*. 2019, 464-465; Lancaster 2015, 26-27 with additional data reported in WebCat. 2-C contained online at www.cambridge.org/vaulting).

In Roman times the manufacturing of hydraulic and water-resistant mortars did not involve volcanic pozzolans only. In this period, the use of *cocciopesto* mortars, produced by mixing finely ground *terracotta* fragments with lime, continued and massified. These mortars were used not only as hydraulic revetments but also for wall joints, in particular from Late antiquity onwards (Fig. 10). Reactive diatoms as pozzolanic material were also mentioned by some scholars (Pecchioni, Fratini, Cantisani 2014, 36). In Magdalengsberg (ancient Noricum), reacted iron slags were documented in lime-based Celtic-Roman (Böttger, Thiedig, Knöfel 2002).

Finally, prototypes of "natural hydraulic lime" in Roman times obtained by the calcination of impure limestones, i.e. marls, (Bonazza *et al.* 2013 ; Lezzerini *et al.* 2017; La Russa *et al.* 2015; Izzo *et al.* 2018; Nikolić, Rogić 2018;) or cherty limestones and breccias, containing microcrystalline silica (Cantisani *et al.* 2002; Drdácký *et al.* 2013), were documented in several circumstances, as recently observed in the concrete foundations of the Republican Walls of Aquileia (Fig. 11) (Dilaria et al. 2019; Dilaria in press; Bonetto in press). Besides the traditional pozzolanic mortars (i.e. cocciopesto, volcanic ash and organic ash rich mortars), it is unclear whether the production of natural hydraulic limes was pursued by ancient crafts or rather depended on the type of limestone suitable for calcination available in the proximity of the site of employment. In fact, the cases of natural hydraulic lime in ancient times always come from sites where impure limestones outcrops were present nearby, thus making the hypothesis of some unawareness about the properties of the final product rather likely.

CONCLUSIONS

This contribution clearly demonstrates the pervasiveness of the application of different types of binding mixtures in diversified human cultures since the beginning of the technological development of mankind. Such a class of functional materials represents a key for the interpretation and parametrization of social advancement within societies, in relation to the optimization of sheltering techniques in primitive human groups, and to complex architectural development in more advanced cultures. The study of mortar recipes over times and in different geographical contexts, often reciprocally disconnected, indicates a thorough knowledge of local resources and a significant awareness of material properties and mutual interaction among them, even though they were simple empirical technological processes. In this perspective, the scientific study of such anthropogenic materials constitutes a promising research field, not only for the archaeometric characterisation of archaeological and historical tangible and intangible contexts, but also for the development of novel building materials, less environmentally impacting and more respectful of the anthroposphere.

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REZIME

RECEPTURE MALTERA KROZ VEKOVE. KRATAK PREGLED PODATAKA OD PRAISTORIJE DO KASNE ANTIKE

KLJUČNE REČI: ANTIČKI MALTERI, KREČ, GLINA, GIPS, PUCOLANSKI AGREGATI, OPUS CAEMENTICIUM, COCCIOPESTO, PRIRODNI HIDRAULIČNI KREČ.

Maltere, kompozitne materijale koji se upotrebljavaju za spajanje zidnih elemenata, za zaptivanje i davanje vodootpornosti arhitektonskim površinama, ljudska populacija je koristila u svrhu izrade skloništa od početka tehnološke evolucije čovečanstva, stvarajući prve posvedočene proizvode pirotehnologije od neolita. Vremenom su izbor sirovina i optimizacija receptura i postupaka mešanja omogućili da se diverzifikuju i optimizuju njihova svojstva, kako bi se odgovorilo na najsofisticiranije zahteve ljudskih kultura. U ovom prilogu je dat kratak pregled evolucije tehnologije maltera od paleolita do kasnog rimskog doba, sa posebnim fokusom na odabiru funkcionalnih jedinjenja kako bi se neke specifične osobine ovih vezivnih kompozita podstakle u različitim ljudskim društvima. Detaljnije će se baviti prvim primenama jednostavnih veziva na bazi gline u praistorijskim i protoistorijskim društvima, uz rane eksperimente sa pirotehnologijom maltera na bazi kreča. Zatim će biti opisana evolucija tehnologija veziva u grčkom i helenističkom dobu, sa posebnim osvrtom na razvoj prvih pucolanskih smeša, nakon čega će uslediti detaljan opis izuzetnog tehnološkog razvoja hidrauličnih i pucolanskih strukturalnih kompozita u rimskom društvu.

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ROMAN AND LATE ANTIQUE GLASS IN THE MEDITERRANEAN AREA AND SERBIA: ITS PRODUCTION, COMPOSITIONAL TYPES AND PROVENANCE

ABSTRACT

The paper gives a synthesis of Roman glass production, compositional types and provenance of Roman soda-lime-silica glass (natron glass) during the Roman and Late Antiquity epochs. It briefly discusses a small production of plant-ash glass, which appears among the Serbian glass finds. The paper describes the production process and components used in glass production and the two-phase production model of Roman glass. It presents the main compositional features of the most typical Roman glasses during the first three centuries CE: Roman blue-green glass, naturally colourless glass, and antimony-decolourised glass. It also describes new glass types that appeared during the 4th century: Roman manganese-decolourised glass, HIMT, Foy série 3.2, Jalame, and Roman Sb+Mn. It then gives characteristics of the most-represented glass-type of the 6th century, the Foy série 2.1 and its subtypes with elevated concentrations of iron.

The paper discusses the provenances of the mentioned types and the methods used for their determination: circumstantial evidence, major and minor element concentrations, and isotopic ratios and rare earth patterns. There is also a discussion on the types of glass from Serbia, giving a brief sketch of its evolution in time and contextualising it within finds reported from the wider Mediterranean area. It shows that the distribution of particular glass types in Serbia generally reflects the distribution in the wider area. The important exception to this is Foy 3.2, which seems to be more present in Serbian assemblages, started to appear earlier (3rd century) and lasted longer (6th century) than in the Western Mediterranean.

KEYWORDS: GLASS, COMPOSITIONAL TYPE, PROVENANCE, ROMAN PERIOD, NATRON, PLANT ASH.

INTRODUCTION

Glass in the Roman Empire was not just a material, it was a highly valued product and prestigious commodity whose manufacture needed significant technological knowledge and skill. Glass production during Roman times followed the manufacturing practice used in several other ancient technologies, namely a two-phased production. This means that the product was first partially manufactured in a convenient place (usually close to the resources and energy sources), and then transported to the place of consumption, where it would be completed to a finished product (Foy and Nenna 2001; Foyet Nenna 2003). Roman glass was also produced in a two-stage process: first, raw glass was produced in furnaces close to the natural sources of good-quality sand and natron flux. After cooling, the glass slab was broken into small pieces of raw glass and transported by ships across the Roman Empire. In the furnaces close to the consumption sites, the glass was remelted and blown or cast into glass objects for everyday use (Freestone et al. 2000; Freestone (2003; 2004); Gorin-Rosen 2000; Foy et al. 2003; Nenna et al. 2000). To differentiate between the two phases of glass production, it is customary to label the sites primary production sites (glass making) and secondary production sites (glass working).

Archaeological studies have established that raw glass was produced in relatively few places in the Eastern Mediterranean and transported across the vast space of the Roman Empire for local glass production (Freestone et al. 2000, Nenna et al. 2000; 2003). To discover the provenance of primary glass, to establish the main compositional types and to map their spread across the Empire through time, means to cast light on the vast Roman commercial routes and trading patterns and, thus, to gain an insight into the important part of the Roman society, its economy and commerce.

The most typical Roman glasses during the first three centuries CE were: Roman blue-green glass, naturally colourless glass, and antimony-decolourised glass. New glass types appeared during the 4th century: Roman manganese-decolourised glass, HIMT, Foy série 3.2, Jalame, and Roman Sb+Mn. The most-represented glass-type of the 6th century was the Foy série 2.1 and its subtypes with elevated concentrations of iron.

We will give a general picture of what is known about the Roman glass production, glass types and glass commercialisation during the Roman and Late Antiquity epoch, and briefly discuss how data from Serbian contemporary sites fits into the broader picture.

ROMAN GLASS PRODUCTION

Glass is an amorphous solid produced from silica and lime, with various additives used for glass modification, like colouring, decolouring, and opacifying. Glass in the Roman Empire was mostly natron glass (or soda-lime-silica glass, according to its main constituents) (Nenna et al. 1997; Foy et al. 2003). It was produced by adding natron (mineral soda low in potash) to batches to serve as a metallurgical flux to lower the silica melting temperature. The main source of sodium for Roman natron glass was the mineral trona, found in high quantities in the Wadi El Natrun evaporitic lakes in Egypt, close to Cairo (Freestone et al. 2000). The Wadi El Natrun region is well documented with primary glass production sites (Nenna et al. 1997).

Lime was added to the glass as a stabiliser. Its role can be seen in the case of the glass from ancient Egypt, produced without lime, that was unstable and dissolved with time. The most common source of CaO in natron glass were sea-shells, washed ashore, ground by waves and mixed naturally with beach sands. On more rare occasions, when silica sand was used, shells might have been deliberately added to batches of natron glass to increase the lime content (Freestone et al. 2000). The best sand used in Roman glass making, which was also mentioned by Pliny the Elder (Gaius Plinius Secundus, Naturalis Historia, ed. Karl Friedrich Theodor Mayhoff, Teubner, 1897), was the beach sand around the mouth of ancient River Belus, close to Haifa in what is today Israel. Brill (1988) has demonstrated that Roman glass could have been produced using Belus-type sand and natron from Wadi El Natrun. Natron glass was by far the most represented type of glass during the first seven or eight centuries CE.

Another type of flux used was ash, produced by burning halophytic plants, which grow on saline soils rich in potassium. The main source of CaO in this type of glass is plant-ash flux, so a sand low in lime or crushed quartz could have been utilised in the glass production (Freestone et al. 2000). In the Mediterranean basin, this technology was employed during the Old Era, and from the Late Byzantine/Early Islamic glass making transition that occurred during the late 7th to 8th century CE (Phelps et al. 2016). The reason for replacing natron with plant-ash as flux is assumed to have been the exhaustion of trona reserves in Wadi El Natrun. However, evidence of a small, perhaps specialised production of plant-ash glass in Egypt during this era of natron has been discovered (Rosenow and Rehren 2014, 2018). Several glasses of this type are reported from two sites outside Egypt, in Crete (Oikonomou et al. 2021) and Serbia (Balvanović et al. 2022).

Roman glass technology

The two-phase model of Roman glass production is based on the scarce evidence of primary glass furnaces, and on the fact that they are all located near the shores of the Eastern Mediterranean. The only Roman primary glass production sites were discovered in Egypt (Nenna et al. 2000; 2003) and Levant (Freestone et al. 2000). Furnaces from Bet Shearim, Israel, show that each firing might have produced several tons of raw glass. Upon cooling, primary glass blocks were crushed to small chunks and exported throughout the Empire, as shown by several ship-wrecks carrying large amounts of raw glass or crushed glass (cullet) (Freestone et al. 2000). Ship-wreckages such as the 2nd century CE Iulia Felix (Silvestri et al. 2008), 3rd century Ouest-Embiez (Mardikian and Girard 2010), and 11th century Serçe Limanı (Bass 1979), contained raw glass, cullet and glassware. This evidence strengthens the two-phase model assumption and indicates that glass was widely traded over the Roman maritime trading network across the Mediterranean Sea.

The two-phase model of glass production facilitates pinpointing the origins of primary glass production, since the composition of a finished glass object depends on the composition of primary glass used for its production and, thus, on the composition of sand from which it was made. Since the raw glass, being an imported product, was not always available at a local glass-working workshop, and to lower costs of raw materials, broken old glass, cullet, was often added to the batches in the secondary workshops. Iulia Felix had glass cullet sorted according to its colour, indicating that glass-makers and glass-workers were in good control of the glass-manufacturing process (Silvestri et al. 2008). The practice of recycling varied both in time and with compositional types of the glass. Some glass types were not recycled much (Foy 3.2) while some were recycled very much (Foy 2.1). Roman Sb+Mn glass was produced using antimony-decolourised and manganese-decolourised cullets. Recycled glass leaves, as a chemical signature, elevated concentrations of trace elements like copper, antimony, tin, nickel and zinc, well above normal concentration in sands (Foy et al. 2003). The cut-off values for these elements need to be established for every compositional type of glass, starting from its primary glass concentrations.

In order to market glass objects, the glass was fashioned to the contemporary market demands. The glass could be initially produced colourless (by using very clean sand) or decolourised (using antimony or manganese). It could be of more bluish or greenish colour, depending on the furnace redox conditions (reducing conditions producing a bluish colour, oxidising conditions producing a greenish tinge).

It could be naturally coloured, like green HIMT or Foy 2.1 glass types. It could deliberately coloured, often light blue (with copper) or dark blue (with cobalt), or black (with iron). The colouring was mostly done in the secondary workshops, and is confirmed by elevated trace elements concentrations, like copper, cobalt, or iron (Balvanović and Šmit 2022).

Glass trading patterns

The small number of primary production sites (situated mostly in the Eastern Mediterranean) and large number of local workshops across the Empire used for glass working, were interconnected over a vast glass trading network. The geographical distribution of various glass types, as demonstrated by many works, are not equal for particular types. Some types are found more in the entire Mediterranean (Foy groups 1-3, Foy et al. 2003), others only in the East (Foy groups 4-10). They are not equally distributed even within smaller regions, as shown by the high presence of Foy 3.2 in the Balkans, compared to Italy and other regions in the Western Mediterranean. This shows that trading patterns for the glass were quite complex and changed over time. The glass might have travelled over direct links, or by coastal routes, hopping from port to port. It might have been imported to inner regions by land, or by river routes, like the Danube waterway. It is an open question whether it usually travelled with some other commodities, and with which ones, or on ships dedicated to glass transport, or if it was just an add-on commodity. Reconstructing these routes by mapping the entire Mediterranean region, with compositions and provenance analysis of raw glass, is a major effort.

COMPOSITIONAL TYPES OF ROMAN GLASS

Two most represented types of glass during the 1st – 3rd century CE in the Roman Mediterranean are common Roman blue-green glass and colourless glass. Both are transparent and are either very lightly coloured or colourless.

Roman blue-green glass

Roman glass, common glass with bluish or greenish hues, was the most common glass in the 1st to 3rd centuries CE. It also had a remarkably stable elemental composition, making it a suitable reference glass with which to compare other glass types. Average compositions, calculated for 227 glasses of this type, are around 16.6% of Na_2O, 2.6% of Al_2O_3, 7.5% of CaO, 0.6% of Fe_2O_3, 0.13% of TiO_2 and 0.6% of MgO (Table 1, Nenna et al. 1997). Roman glass was produced using clean sands, with low heavy mineral concentrations in sand, Fe_2O_3 + MgO + TiO_2 = 1.9% on average (Table 2). Its colour, bluish or greenish, depends on the redox conditions in the furnace, resulting in different amounts of ferrous and ferric ions. Brill has shown that this glass might have been produced using Belus-type sand and natron from Wadi El Natrun.(Brill 1988; Freestone et al. 2000)

Roman colourless glass

Roman naturally colourless glass was produced using very clean sands, with the least amount of the sand impurities, like heavy minerals, that give colour to glass (Table 2). Thus, Group 1b (a single glass, Jackson 2005), contains 0.29% of iron, 0.45% of magnesium, 0.07% of titanium oxides and virtually no manganese oxide. Naturally colourless glass from Kosmaj, group K3, had similar concentrations, on average 0.32% of iron, 0.48% of magnesium, 0.05% of titanium and 0.2% of manganese oxides (Stojanović et al. 2015). Heavy mineral concentrations in sands from which the Kosmaj naturally colourless glass is produced is 1.2%. Objects manufactured from this type of glass were likely considered luxury products.

During the 1st to 3rd centuries CE, Roman glass was decolourised using antimony. Antimony, the principal decolouriser of this period, is a strong decolouriser. The amount of antimony used to decolourise the colouring effect of iron is roughly 1:1. The ratio of antimony to iron oxides in antimony-decolourised glasses in Mala Kopašnica (Stamenković et al. 2017), is 1.01±0.37, and in Egeta 0.83±0.28 (Balvanović et al. 2022).

Fourth century change in glass compositions

During the 4th century, manganese started to replace antimony as the main decolouriser. The reason is hypothesised to have been the exhaustion of antimony bearing ores. Manganese is a less efficient decolouriser than antimony, requiring around double that of antimony to produce the same result. The ratio of manganese to iron oxides in the manganese-decolourised glass of Mala Kopašnica is 2.67±1.13 and in Egeta is 1.72±0.43. Since, in this period, the amount of colourless glass cullet available from earlier times, decolourised with antimony, was sufficient, is was widely used for recycling with new, manganese-decolourised raw glass and cullet. In this period, Roman Sb+Mn decolourised glass was quite represented in the archaeological record. In Kosmaj, the group K2 was decolourised using 0.21±0.05 of antimony and 0.29±0.017 of manganese oxides, while iron was 0.42±0.07. The average ratio of the sum of the two decolourising agents to iron is 1.2:1 As the antimony glass became less and less available, the amount of antimony in recycled glass decreased, but it was still found in smaller quantities. The amount of antimony in 6th century window glass of type Foy 2.1 in Jelica is 125 ppm (Balvanović et al. 2018, Balvanović and Šmit 2020).

While during the first three centuries CE, the Roman glass was mostly lightly-coloured blue-green glass or colourless glass, in the 4th century it was often darker colours, such as green, olive-green or amber. It is not clear what brought this change; possibly a change of fashion or the exhaustion of supplies of very clean sands. The darker glass began to show in significant percentages in archaeological records of the 4th century.

Several naturally coloured glass types were reported from this period. They obtained their darker colour from higher concentrations of heavy minerals, derived from sand impurities (4.3% for Foy série 2.1, 7.5% for Foy group 1, Foy et al. 2003). Authors reporting these glass types gave names that best described their respective chemical compositions, like HIMT (High Iron, Manganese, Titanium, Mirti et al. 1993), HIMT 1 and HIMT 2 (Foster and Jackson 2009), strong HIMT and weak HIMT (Foster and Jackson 2009), HIT (High Irona, Titanium, Freestone 1994), HLIMT (High Iron, Lime, Magnesium, Titanium, Glioz-

			wt%										*ppm*		
glass group/No	location/c. AD		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Sr	Zr	Sb
Roman glass	Roman Empire	mean	16.63	0.59	2.59	69.54	0.12	0.75	7.48	0.13	0.73	0.62			
n=227	*1st-4th*	*std*	*1.50*	*0.29*	*0.38*	*2.53*	*0.05*	*0.24*	*1.18*	*0.14*	*0.74*	*0.48*			
group E	Aosta	mean	17.44	1.02	2.55	67.06		0.94	5.67	0.56	2.09	1.51	550		
n=9	*3rd -5th*	*std*	*1.25*	*0.16*	*0.34*	*3.66*		*0.38*	*0.4*	*0.15*	*0.22*	*0.55*	*40*		
HIMT 1	Romano-British	mean	19.11	1.00	2.49		0.05	0.50	6.08	0.33	1.72	1.36	501	117	400
n=123	*4th-5th*	*std*	*1.12*	*0.16*	*0.29*		*0.02*	*0.12*	*0.66*	*0.11*	*0.33*	*0.26*	*55*	*61*	*300*
HIMT 2	Romano-British	mean	19.65	0.78	2.17		0.05	0.58	6.02	0.12	1.00	0.72	446	31	900
n=220	*4th-5th*	*std*	*0.97*	*0.10*	*0.18*		*0.01*	*0.12*	*0.67*	*0.02*	*0.17*	*0.10*	*52*	*19*	*500*
HIMTa	Cyprus	mean	18.2	1.07	2.98	66.3	0.06	0.44	5.9	0.48	2.10	1.76	400	219	7700
n=9	5th-7th	*std*	*1.0*	*0.17*	*0.28*	*1.5*	*0.02*	*0.10*	*0.9*	*0.15*	*0.44*	*0.33*	38	55	7700
HIMTb	Cyprus	mean	17.7	*1.15*	*3.28*	*65.1*	*0.14*	*0.41*	*5.5*	*0.58*	*1.68*	*3.55*	410	250	4900
n=5	*5th-7th*	*std*	*0.1*	*0.12*	*0.22*	*0.5*	*0.03*	*0.03*	*0.2*	*0.08*	*0.16*	*0.14*	12	33	3100
group 1	France, Tunisia, Egypt	mean	19.12	1.23	2.88	64.49	0.11	0.41	6.22	0.49	2.02	2.28	498	216	7
n=43	*5th*	*std*	1.34	0.24	0.26	1.36	0.04	0.08	0.85	0.12	0.4	0.86	87	61	15
série 2.1	France, Tunisia, Egypt	mean	18.49	1.23	2.54	64.43	0.18	0.79	7.80	0.16	1.60	1.35	669	85	132
n=51	*6th -7th*	*std*	*1.24*	*0.15*	*0.15*	*1.06*	*0.04*	*0.14*	*0.69*	*0.02*	*0.37*	*0.66*	*86*	*10*	*202*
série 3.2	France	mean	18.79	0.65	1.92	68.07	0.08	0.44	6.99	0.09	0.95	0.70	536	57	18
n=17	*turn 5th/6th*	*std*	*0.85*	*0.16*	*0.15*	*1.49*	*0.03*	*0.08*	*0.74*	*0.02*	*0.34*	*0.15*	*106*	*11*	*34*
Levantine I	Apollonia, Israel	aver	15.17	0.63	3.05	70.64	0.15	0.63	8.07	0.12	<0.10	0.48	391	52	
n=9	6th-7th c.	*std*	*0.91*	*0.09*	*0.17*	*1.98*	*0.05*	*0.20*	*1.48*	*0.00*		*0.13*	*80*	*9*	
Levantine II	Bet Eli'ezer, Israel	mean	12.20	0.63	3.32	74.89	0.12	0.46	7.16	0.13	0.10	0.58	369*	71*	
n=27	7th – 8th c.	std	1.32	0.09	0.28	1.48	0.03	0.08	0.59	0.03	0.00	0.22	50*	11*	
Egypt I		mean	17.07	0.84	4.46	70.94	0.08	0.43	2.72	0.55	0.04	1.79	185	189	1
n=2	Ahihus, Tiberias, Israel, 7th -8th century	Std	1.41	0.04	0.11	1.68	0.04	0.01	0.06	0.01	0.00	0.04	6	10	1
Egypt II	several sites, Israel	mean	14.17	0.58	2.53	70.32	0.10	0.30	9.53	0.26	0.09	0.95	185	175	4
n=55	8th -9th century	Std	1.11	0.19	0.24	1.09	0.03	0.13	0.82	0.04	0.23	0.15	41	33	12

*n=5.

Table 1. Mean values and standard deviations of glass groups mentioned in the text. (Sources: Roman glass - Nena et al. 1997; Group E - Mirti et al. 1993; HIMT 1, HIMT 2 - Foster and Jackson 2009; HIMTa, HIMTb - Ceglia et al. 2015; Ceglia et al. 2017; group 1, série 2.1 and série 3.2 - Foy et al. 2003; Apollonia and Beťeliezer – Freestone et al. 2000. Egypt I, II – Phelps et al. 2016; Blank entries – data not published).

group	cent. AD	$(Fe_2O_3+TiO_2+MgO)/SiO_2$	$(Al_2O_3+K_2O+CaO)/SiO2$	sum	TiO_2/Al_2O_3
Roman glass *n=227*	1st – 4th	0.019	0.156	0.175	0.05
naturally colourless 1b *n=1*	Late 2nd – 4th	0.012	0.147	0.159	0.02
naturally colourless Kosmaj K3 *n=4*	1st – 3rd	0.012±0.003	0.147±0.009	0.159±0.01	0.02±0.001
AD/N1 (Mn) *n=45*	1st – 4th	0.017±0.004	0.158±0.014	0.174±0.016	0.024±0.009
AD/N2 (Sb) *n=4*	2nd – 3rd	0.014±0.003	0.112±0.007	0.127±0.010	0.047±0.015
série 3.2 (non t.) *n=2*	1st - 2nd	0.023±0.003	0.124±0.007	0.147±0.009	0.045±0.011
groupe 1 (HIMT) *n=43*	5th	0.075±0.017	0.148±0.014	0.222±0.024	0.169±0.032
série 3.2 *n=17*	5th / 6th	0.021±0.004	0.138±0.016	0.159±0.020	0.049±0.009
série 2.1 *n=51*	6th – 7th	0.043±0.011	0.173±0.012	0.216±0.016	0.062±0.007
Levantine I (Apollonia)	6th – 7th	0.017±0.003	0.168±0.028	0.185±0.030	0.021±0.010
Levantine II (Bet'Eliezer)	7th – 8th	0.018±0.003	0.147±0.008	0.164±0.010	0.029±0.013
Egypt I	7th – 8th	0.045±0.001	0.107±0.005	0.152±0.006	0.122±0.005
Egypt II	8th - 9th	0.026±0.004	0.176±0.015	0.201±0.016	0.103±0.015

Table 2. Amounts of heavy and light minerals in the glass making sands for several Roman glass types, and TiO_2/Al_2O_3 ratio differentiation between Levantine and Egyptian sands. Note that the naturally colourless glass from such distant places as England (1b) and Serbia (K3 from Kosmaj) have the same concentrations of sand impurities. This hints at the use of the same sand. Note also that Levantine types have a lower TiO_2/Al_2O_3 (< 0.25) ratio than Egyptian groups (> 0.45). (Sources: Foy et al. 2003; Gallo et al. 2013; Nenna et al. 1997; Foster and Jackson 2010; Foster and Jackson 2009; Phelps et al. 2016; Freestone et al. 2000).

zo et al. 2016a), Ca-rich HIMT, Gliozzo et al. 2016b). However, new data demonstrated that some of these names cover very similar compositions. HIMT 1, strong HIMT and Foy group 1 are now considered HIMT. HIMT is now divided into HIMTa and HIMTb, according to the iron content (Ceglia et al. 2015). HIMT 2 is now considered to be very similar to Foy 3.2, while Weak HIMT, HLIMT and Ca-rich HIMT are considered akin to Foy 2.1 (Freestone et al. 2018).

Egypt, perhaps Sinai, is considered to be the source of sand used to produce HIMT glass. Sand from Egyptian beaches has high concentrations of heavy minerals, derived from the Nile and washed ashore by sea currents and winds (Nenna 2000, 2003; Freestone et al. 2005; Gliozzo et al. 2015). Roman antimony-decolourised glass and série 3.2 are also considered to be of Egyptian provenance (Schibille et al. 2016), but different to that of HIMT, since the sand used in its production is much cleaner.

However, not all the glass of the 4th century had darker colours. Roman manganese-added glass was colourless. Its supposed provenance is the Levantine coast (Brill 1988). The Jalame-type glass, with or without added manganese, shows a wide colour pallet (colourless, aqua, green or olive), and appeared in the mid-4th century in PalestineThe type with no added manganese has higher alumina (2.7%) and lime (8.77%) and lower sodium (15.74%) than the Roman glass. Higher alumina and lime are explained by feldspar-rich sand, while lower sodium by the geographical distance from the Wadi El Natrun natron deposits.

Série 3.2 was almost colourless or slightly coloured (Foy et al. 2003), and had a manganese-decolourised composition, manufactured with more pure sands. Its composition is broadly similar to that of antimony-decolourised Roman glass and is considered of Egyptian provenance.

Sixth and seventh century glass types

The 6th – 7th century glass from Apollonia in Israel, termed Levantine I (Freestone et al. 2000), is high in feldspar derived alumina (3.05%) and lime (8.07%), and low in heavy mineral derived iron (0.47%) and titanium (0.07%), and low sodium (15.17%), very similar to Jalame glass (also classified as Levantine I).

Glass from the 7th – 8th century furnaces in Bet Eliezer is termed Levantine II (ibid.). It has even lower sodium (12.3%) and lime (7.36%) and higher alumina (3.26%) than Levantine I. Even lower sodium in later Levantine II is interpreted as the exhaustion of the trona deposits of Wadi El Natrun over time.

Late Antique natron glass from Egypt is termed Egypt I (Gratuze and Barrandon, 1990). It is richer in alumina (4.46%) and iron (1.79%) compared to Levantine glass. It was produced from the late 7th/ early 8th to the late 8th century CE. Around 780 CE, this type was replaced by the type Egypt II, the last natron glass produced in Egypt (Schibille et al. 2019). Egypt II is lower in alumina (2.53%) and higher in lime (9.53%) then Levantine glass (Foy et al. 2003, Phelps et al. 2016).

Independently, Foy et al. (2000, 2003) describe ten glass groups from the Mediterranean, dated to Late Antiquity. Four of these also appear in the Western Mediterranean (groups 1-4). Compositionally, Foy group 1 is similar to HIMT 1, and group 2 is similar to HIMT 2. Foy group 3.1 corresponds to Levantine I, while group 4 is similar to the Roman antimony decolourised glass. Regarding Eastern Mediterranean types, Foy group 7 is akin to Egypt II, and groups 8 and 9 to Egypt I. The compositional differences between these groups are depicted in the Primary Component Analysis diagram (Fig. 1).

Plant ash glass

During the period between from the 1st to the 7th century CE, the flux used in the production of glass in the Mediterranean and continental Europe was the mineral natron. During the same period, the Mesopotamian region, east of the Euphrates river, continued its centuries-old tradition of halophytic plant-ash glass production. Plant-ash glass would not make its comeback to the Mediterranean before the Islamic transition during the 8th – 9th centuries CE (Phelps et al. 2016). No plant-ash glass production is recorded in the Mediterranean and Western Europe during this epoch, with the exception of a very limited, presumably specialised, production of halophytic plant-ash glass, evidenced first in Egypt (Rosenow and Rehren 2014, 2018) and most recently reported from Crete (Oikonomou et al. 2021) and Serbia (Balvanović et al. 2022).

PROVENANCE

"In Syria there is a region known as Phoenicia… In this region is the source of the river called Belus that, after five miles, disembogues into the sea close to the Ptolemy colony… The sand from the river Belus is ground and purified by the power of sea waves and it becomes very clean… The coast upon which this sand is deposited is no more than five miles long, but nevertheless this was for many centuries the only place which provided materials for glassmaking" (Gaius Plinius Secundus, Naturalis Historia, ed. Karl Friedrich Theodor Mayhoff, Teubner, 1897). This testimony of Pliny the Elder was the map for early archaeological efforts to find primary glass production sites.

Primary production sites and supposed provenances

As already mentioned, there are relatively few reported Roman primary glass production sites, and all are located in the coastal areas of the Eastern Mediterranean, like Apollonia, Jalame, Bet Eli'ezer (Hadera), today Israel, and in Wadi El Natrun in Egypt, near the Nile delta. Seventeen furnaces were discovered in Bet Eli'ezer, each capable of producing several tons of raw glass in a single firing, as evidenced by the nine ton glass

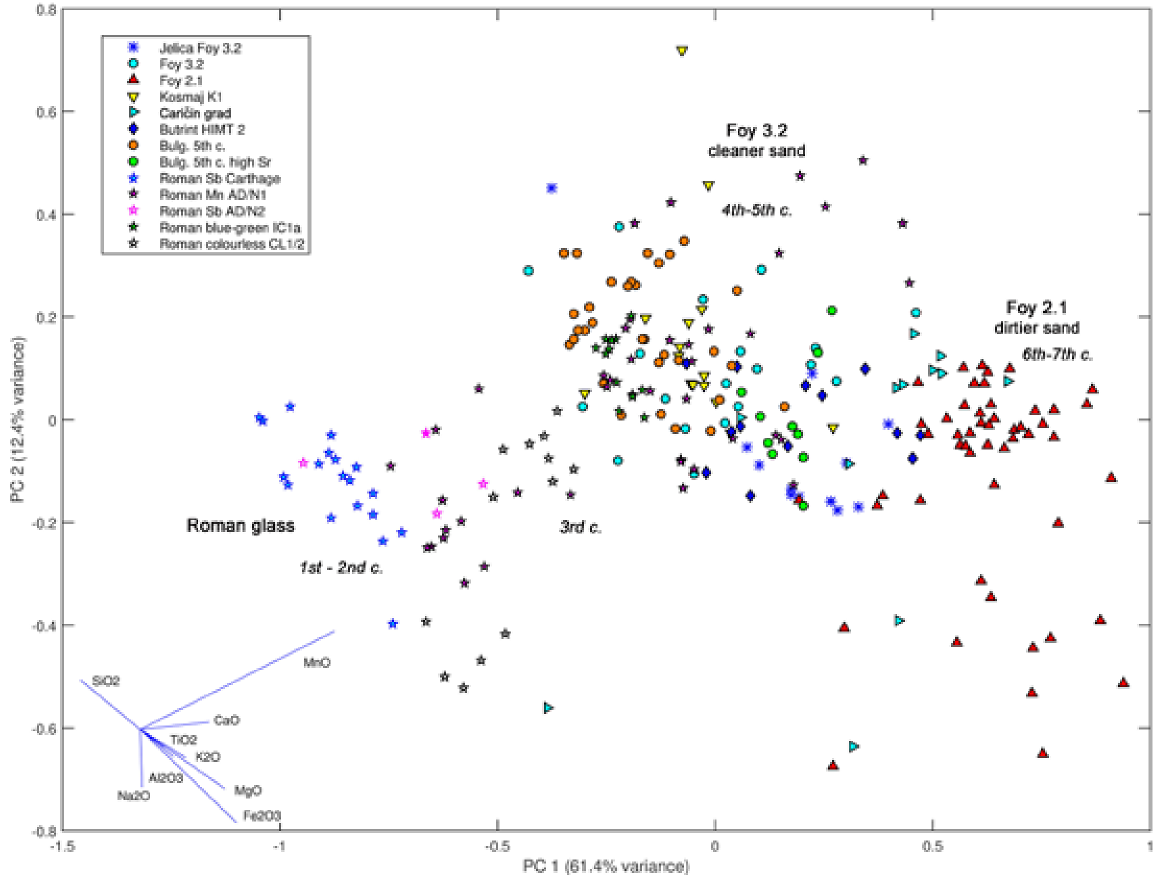

Fig 1. Principal component analysis of 256 glasses from 14 Roman and Late Antiquity natron glass groups. The diagram compares compositions of six glass groups from the Balkans, five Roman glass groups (with added manganese and with no added manganese, naturally coloured and decolourised) and Foy série 3.2 and 2.1. Vectors of oxides: Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, MnO, Fe_2O_3 lower left (Source: Balvanović and Šmit, 2022).

slab discovered in nearby Bet She'arim (Freestone et al. 2000). Such a topography of primary glass production sites, together with circumstantial evidence of glass finds in the region, and the writings of Pliny the Elder, formed the basis for the two-phase production model of the Roman glass.

The two-phased glass production model, in general, facilitates the possibility of the determination of the primary production sites. The elemental composition of a glass object reflects the composition of the primary glass used in its production and this, in turn, reflects the composition of the sand used in the primary furnace. Several relationships between concentrations of particular elements in glass were used as indicators of the compositional characteristics of particular sands and, thus, their possible origins. TiO_2/Al_2O_3 and Al_2O_3/SiO_2 ratios differentiate high-titanium-low-alumina Egyptian sands from high-alumina-low-titanium Levantine sands (Schibille et al. 2016). A SrO/CaO versus MnO biplot is used to evaluate the amount of strontium that derives from lime (because manganese ore can contain some strontium), which can be useful in provenance determination in some cases. A value of SrO/CaO around 60 is characteristic of Eastern Mediterranean coastal sands (Freestone et al. 2018). Higher values of Na_2O to SiO_2 possibly indicate an Egyptian primary glass manufacture, implying the abundance and availability of the mineral trona in Egypt (Freestone et al. 2000). How these minor elements ratios can differentiate between the types of sands used for glass production, is depicted in Fig. 2.

Taking such relationships and the circumstantial evidence into account, several hypotheses for the provenance of particular glass groups were suggested. It is considered that Levantine glass was manufactured with sands from around the mouth of the ancient Belus river in today's Israel (Brill 1988). This sand has high concentrations of feldspars and lime

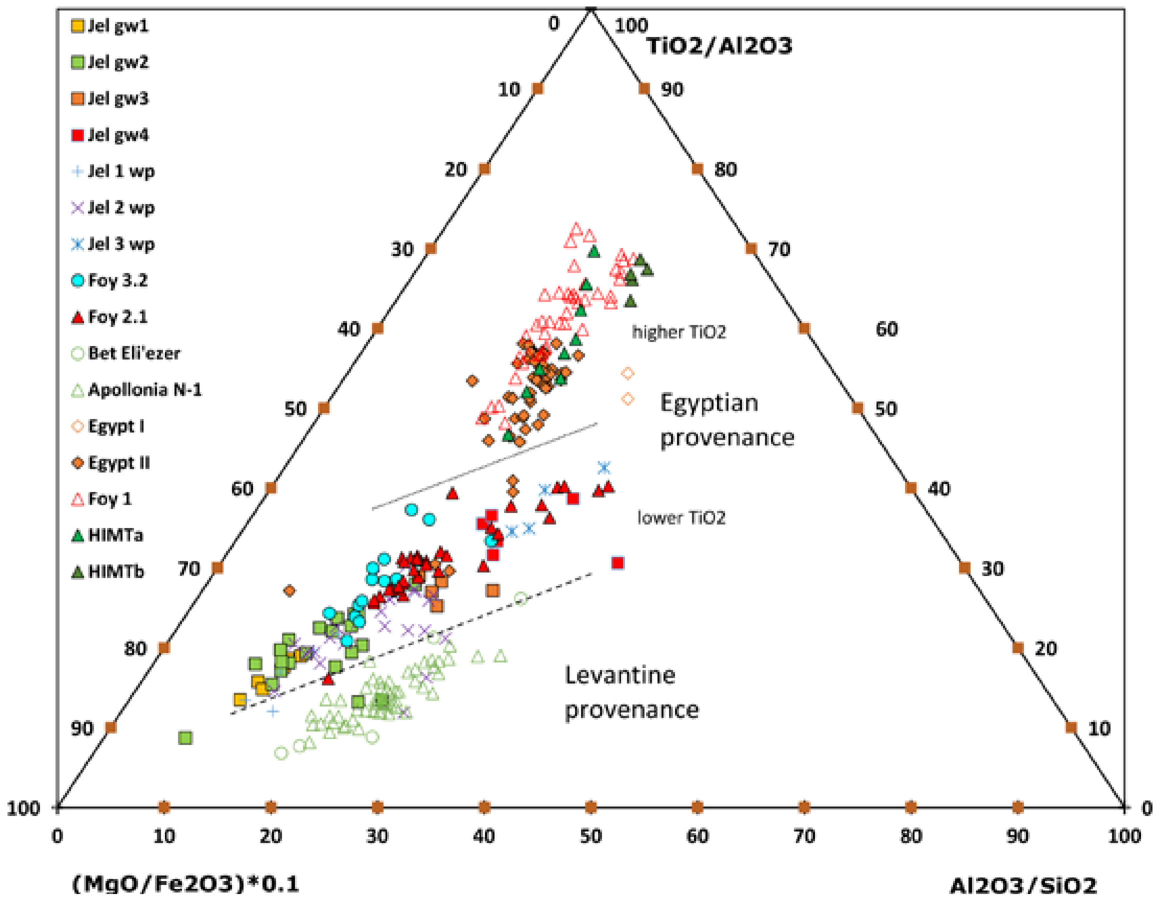

Fig. 2 Triangular diagram of TiO_2/Al_2O_3, Al_2O_3/SiO_2 and MgO/Fe_2O_3 for Jelica glassware (gw1-gw3) and Jelica windowpane glasses (Jel wp 1-3), plotted against selected Late Antiquity glass groups. The diagram is indicative of mineralogical composition of glass-making sands, thus of sand provenance. Ratio MgO/Fe2O 3 is scaled for easier differentiation of groups. Note that there are two groups of glasses of Egyptian provenance, differentiated mostly by the TiO_2/Al_2O_3 ratio.

and low concentrations of heavy minerals. Roman manganese-decolourised glass is also thought to be of Levantine origin (Brill 1988, Schibille et al. 2016).

It is considered that HIMT glass, very rich in heavy minerals, was manufactured using sands from Egypt, possibly Sinai. This is supported by isotopic analyses (Nenna 2000, 2003; Freestone et al. 2005; Gliozzo et al. 2015). Roman antimony-decolourised glass and Foy 3.2, are thought to be of Egyptian provenance (Schibille et al. 2016, Maltoni et al. 2016, Paynter and Jackson 2018). A very different type, Foy 2.1, with high concentrations of impurities, is also considered to be of Egyptian provenance (Foy et al. 2003). A unique Late Antiquity glass with exceptionally high alumina has been discovered in Turkey (Rehren et al. 2015).

Other provenances of glass-producing sands were also suggested. These include Western Mediterranean (Brems et al. 2012; 2013) and Greece (Silvestri et al. 2017). Wadi El Natrun in Egypt is considered the main source of mineral soda used for fluxing. Other possible locations, like the lakes al-Barnuj in Egypt (Shortland et al. 2006), and Pikrolimni in Greece (Dotsika et al. 2009), are also suggested.

Determination of provenance by isotopes and rare earths

Some other tracers are indicative of geochemical processes underlying the sand formation and can serve as “fingerprints” of particular sands. The most common ones used in provenance determination of Roman natron glass are isotopic ratios of strontium, neodymium and hafnium, and rare earth patterns.

Isotopic Ratios. The ratio of strontium isotopes $^{87}Sr/^{86}Sr$ can differentiate between beach sands and inland sands. This stems from the fact that beach sands derive most of their CaO from seashells, while inland sands derive it mostly from lime. Seashells have a $^{87}Sr/^{86}Sr$ ratio close to contemporary seawater (0.7092), while these ratios in lime reflect the ratios at the time of its geologic formation. Thus, the $^{87}Sr/^{86}Sr$ ratio can provide a differentiation between coastal and inland glass-making sand. However, this ratio does not differentiate between Levantine and Egyptian sands (Barfod et al. 2020), suggesting the use of beach sands in both cases.

Barfod et al. (2020) showed that hafnium isotope composition is very good discriminator between Egyptian and Levantine sands and, by implication, glasses. This stems from the fact that hafnium on Egyptian and Levantine beaches derives from the mineral zircon, brought in by the Nile and longshore sand transport by sea currents and winds. It is known that zircon drops out from the transport along the route, yielding lower concentrations of hafnium and, significantly, changing its isotopic composition along the way. This difference in Hafnium isotopic ratios indicates that Roman Sb glass, Foy 2.1 and Egypt I were produced in Egypt, while Roman Mn, Levantine I glass from Apollonia and Jalame glass have a Levantine provenance.

REE Patterns. Another set of provenance indicators are rare earths patterns. The geochemistry of rocks participating in sand formation is reflected in rare earth patterns. REE patterns are concentrations of rare earths normalised to the upper continental crust (Kamber al. 2005). REE patterns of glass assemblages of Foy 2.1 type of glass from Visigothic Spain (Balvanović and Šmit 2020) are shown in Fig. 3. The Foy 2.1 type has a variant with higher concentrations of iron oxide, called Fe-rich Foy 2.1. The assemblage is divided into three groups according to the iron oxide concentrations, with low iron (average of 0.94%), high iron (1.77%) and very high iron (2.66%). Their respective REE patterns are depicted.

With the increase of iron from the low iron to high iron group, concentrations of REEs also increase, while the shapes of the REE pattern remain the same, i.e., the differences in their respective heights are due to iron concentrations (0.94% versus 1.77%). This indicates the same origin of iron in both groups. The same is true for the patterns of high iron and very high iron, but with the exception of cerium and hafnium, which decrease with increases of iron concentrations. This might indicate different type of mineral iron and, thus, likely point to a different provenance of the sand.

GLASS IN SERBIA DURING THE ROMAN EMPIRE AND LATE ANTIQUITY

How do Roman and Late Antiquity glass finds from Serbia fit into the wider picture of glass type distribution over the entire Mediterranean, and through time? The changes in glass compositions that occurred during the 4th century and again during the 6th century CE, are also reported from Serbia (Table 3, Fig. 4). After the domination of Roman glass (mostly naturally colourless and decolourised with antimony), manganese became the main decolourant in the 4th century, just as in the other areas of the Mediterranean. The newer, manganese-decoloured glass, was recycled with older, antimony-decolourised glass, yielding Roman Sb+Mn glass. New types of glass appeared, like Foy 3.2 and HIMT. The specificity of Serbian Foy 3.2 glass is that it seems to be among the oldest yet reported in the literature. The Kosmaj K1 group (Foy 3.2 type of glass) is dated to the 3rd to 4th century and some glasses to the 2nd to 3rd century. The lightly coloured Foy 3.2 type, with small concentrations of sand impurities, was also sometimes recycled with antimony - decolourised glass, although not often. During the period between the 2nd and 4th century, glass was imported to Serbia from two sources of primary glass production: Egypt (around three quarters of analysed glasses) and the Levantine coast (around one quarter, Fig. 4, Tab. 3).

From the 6th century, earlier compositional types vanish from the archaeological record, and a new type, Foy 2.1, with a darker colour, reflecting high concentrations of impurities in the sand, and heavily recycled, dominate the Serbian landscape. The exception to the disappearance of earlier types is Foy 3.2, which continued well into the 6th century. Foy 3.2 type among Serbian finds spans the period from the late 2nd to early 3rd century (Kosmaj K1) to the late 6th century (Jelica). It is noteworthy that Foy 3.2 appears among the 6th/early 7th century Serbian assemblages of windowpanes and glassware from Jelica and among raw glass from Caričin Grad (Iustiniana Prima) (Drauschke and Greiff, 2010) with not insignificant percentages (on average 12%). Thus, Foy 3.2 glass from Kosmaj and Caričin Grad significantly widen the 4th to 5th century timespan of Foy 3.2 glass, as earlier considered. A comparison with the published data shows that this type of glass was much more common in the Balkans then in contemporary Italy. In addition, the percentages of Foy 3.2 type

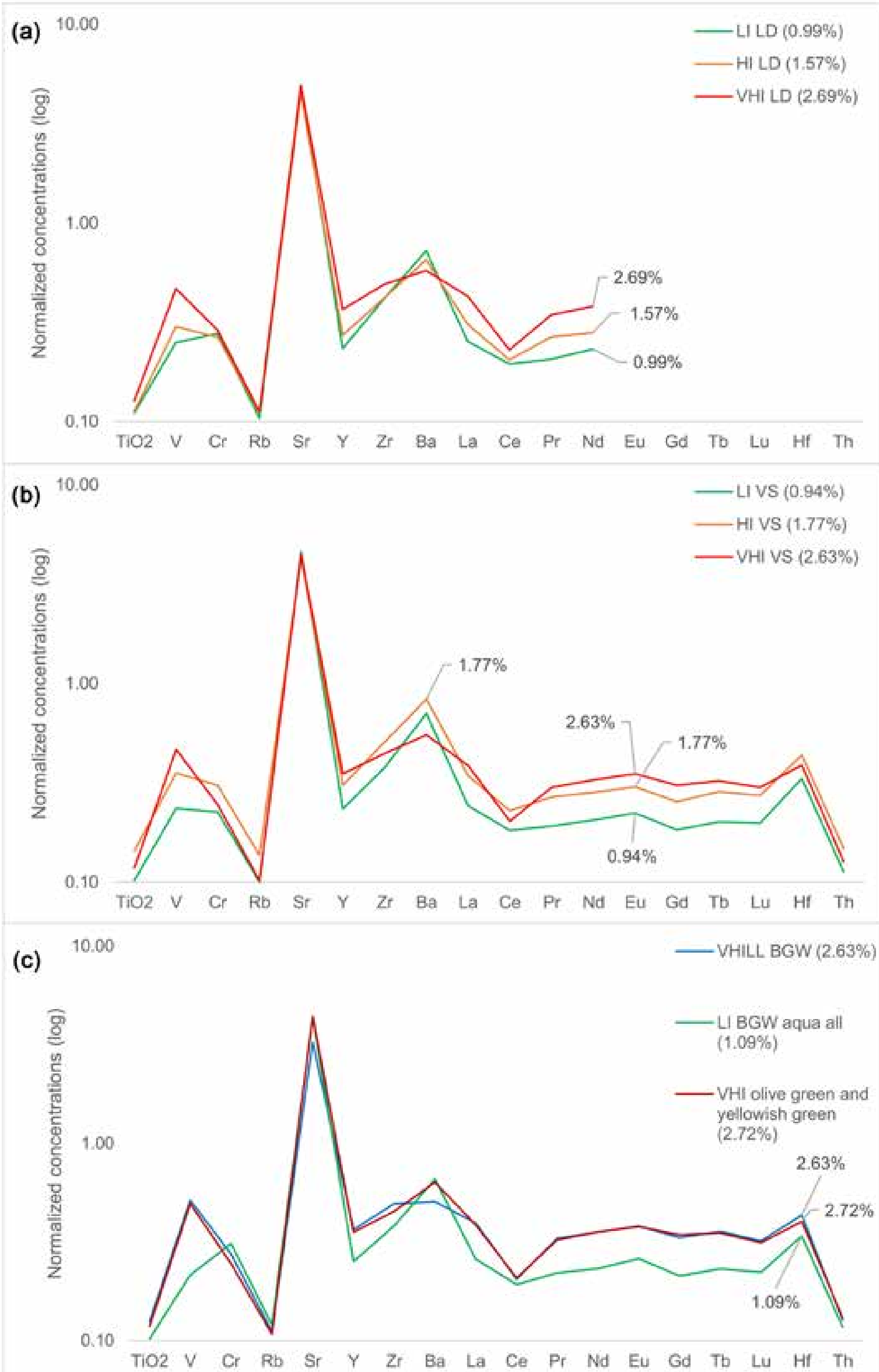

Fig 3. Trace element patterns of Fe-rich Foy 2.1 glasses, grouped by iron concentrations. Values normalised to the upper continental crust [38]. Groups from the Lower Danube (a), Visighotic Spain (b) and Byzantine glass weights (c). Note that for the Lower Danube REE dataset only La-Nd measurements are reported (Source: Balvanović and Šmit, 2022).

Table 3.

compositional type	Mala Kopašnica	Kosmaj	Viminacium	Mediana	Egeta	Jelica	Caričin grad	Sum
century	2nd – 4th	late 2nd/early 3rd – 4th	3rd – 4th	late 3rd – 5th	4th	6th/early 7th	6th/early 7th	
Roman blue-green								0
Roman naturally colourless		4						4
Roman Sb decolourized	7		9		7			23
Roman Mn decolourized	8		6	11	3			28
Roman Sb+Mn decolourized		14			1	1		16
Foy série 3.2		15	5	19		12	2	53
HIMTa			1	8				9
HIMTb			1					1
Jalame Mn			1					1
plant-ash			1				2	3
coloured	2		2			5	4	13
Foy série 2.1 LI						48	14	62
Foy série 2.1 HI						5	2	7
Foy série 2.1 VHI						11	1	12
outlier			1			1	1	3
TOTAL	17	33	27	38	11	83	26	235

Table 3. Glass from 2nd – 6th/early 7th century sites in Serbia, divided into compositional groups (Sources: Stamenković et al. 2015; Stojanović et al. 2015; Balvanović et al. 2022; Drauschke and Greiff 2010).

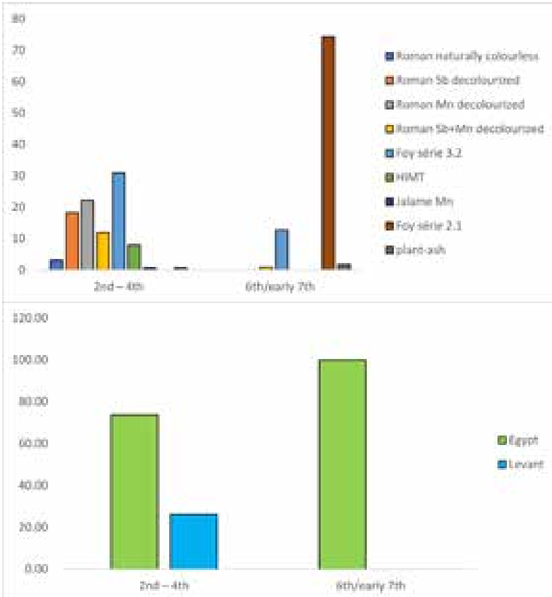

Fig 4. Up: Percentages of compositional types among 126 glasses from 2nd – 4th century and 109 glasses from 6th century, that are reported from Serbia. Down: supposed provenance of these glasses (Sources: Stamenković et al. 2015; Stojanović et al. 2015; Balvanović et al. 2022; Drauschke and Greiff 2010).

among the glass assemblages published from the Balkans seem to increase eastwards, possibly indicating that the import of Foy 3.2 raw glass came from the East rather than from the West. The possible candidate is the Danube waterway (Fig. 5). However, this hypothesis will have to be re-examined when more data on Balkan glass finds becomes available.

Another important change in the Balkans, regarding raw glass trading routes, seems to have happened during the 6th century. Data shows that raw glass in this period was imported exclusively from Egypt. This is also in accordance with the wider picture of the Mediterranean region, notably Italy.

CONCLUSIONS

The Roman soda-lime-silica (natron) glass evolved, both compositionally and in its distribution, with time. The compositional change reflected the changing compositions of sands used in the production of primary (raw) glass. This was the consequence of a change of sand mines, a routine that had to be practiced whenever good quality sand was exhaust-

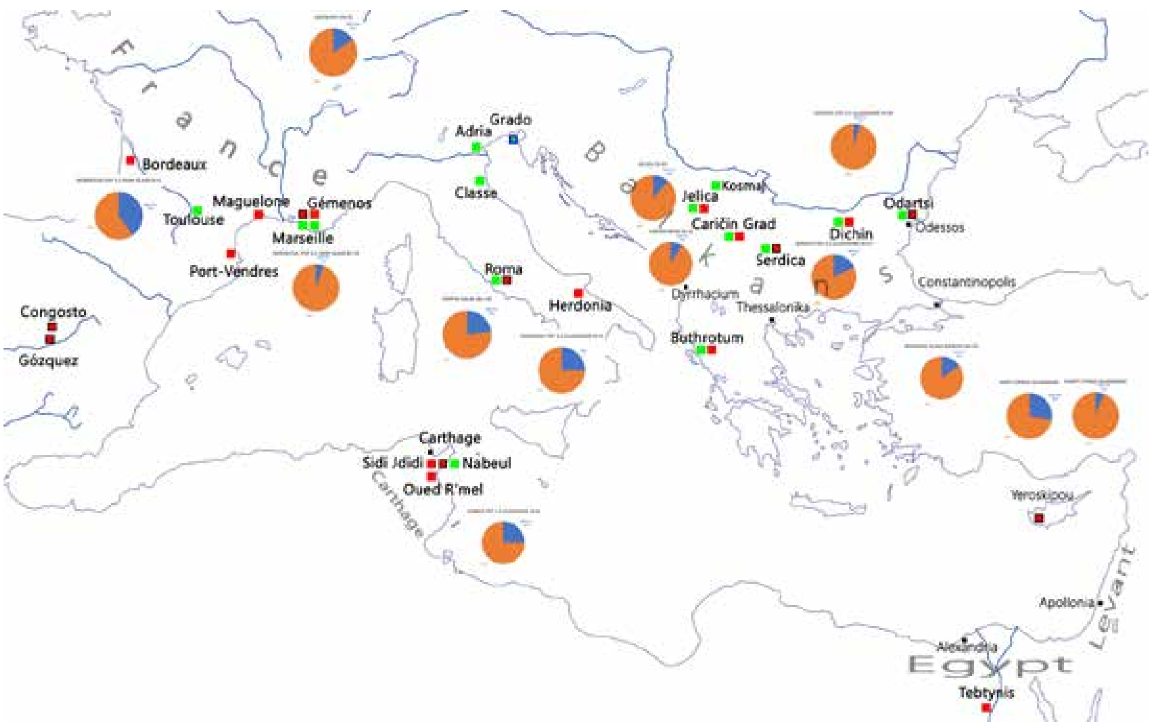

Fig. 5. Distribution of Late Antique glass types in the Mediterranean. Pie charts show percentages of glass types within reported assemblages. Yellow and blue pie charts show percentages of high iron glasses among Foy 2.1 types in particular regions. Note that distributions are different in different regions. In the Balkans, Foy 3.2 is more represented than in Italy (Sources: Foy et al. 2003; Schibille et al. 2016; Stamenković et al. 2015; Stojanović et al. 2015; Balvanović et al. 2022; Drauschke and Greiff 2010; Cholakova et al. 2016; Conte et al. 2016; Schibille 2011; Ceglia et al. 2015; Mirti et al. 1993; Gliozzo et al. 2015a).

ed at a particular quarry. Despite this, the "classical" Roman blue-green glass was of remarkable compositional stability, and it lasted for several centuries. Considerable change stared during the 4th century, when manganese started to replace antimony as a decolouriser, and when several new types of glass, often with darker colours, appeared, such as the HIMT class of glasses. Besides this darker glass, a variety of other colours also appeared, like Jalame glass, with or without added manganese, and very lightly coloured Foy série 3.2. Later, yet newer glass compositions appeared, in the 6th century Foy série 2.1, in the 7th century Levantine II and Egypt I, and in the 8th century Egypt II. The era of natron glass ended with the replacement of natron with plant-ash flux, a change that happened with the Islamic transition, during the 8th and 9th centuries. However, a small, possibly specialised, production of plant ash glass production has been reported from Egypt, and glass of this types has also been reported from Crete and Serbia.

The glass compositions and period of their distribution followed this general picture of the Mediterranean, with an important exception. It seems that glass of the type série 3.2 appeared in the archaeological record earlier and lasted longer than in other parts of the Mediterranean, notably Italy. It also seems that the ratios of this type of glass in the reported assemblages in Serbia (and the eastern and Central Balkans as a matter of fact) are higher compared to other parts of the Roman Empire. This suggests that the commercial routes importing the raw glass of this type were different. The data suggests that série 3.2 was imported to the eastern and Central Balkans via the Danube.

APPENDIX – GLASS COLOURS

Natural colours of the Roman glass range from colourless and nearly colourless to coloured, depending mostly on the amount of iron in glass-making sand and redox conditions in furnace. Roman glass could also be intentionally coloured (with iron, cobalt, copper, manganese) or decolourised (with antimony and manganese). Bellow are the photographs of glasses from several sites in Serbia, showing various types of glasses and their typical colours (Figs. A-C).

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Fig. A. Left: colourless glass C-123e from Egeta (4th century). Middle: naturally coloured glass, sample 17b (Gradina on Jelica, 6th c. AD), of type Foy 2.1, with Fe_2O_3 = 0.91%. Right: naturally coloured glass, sample 28 from Jelica, of type Foy 2.1 high-iron, with Fe_2O_3 = 1.96% (Sources: Balvanović and Šmit 2020, C-123e is not published).

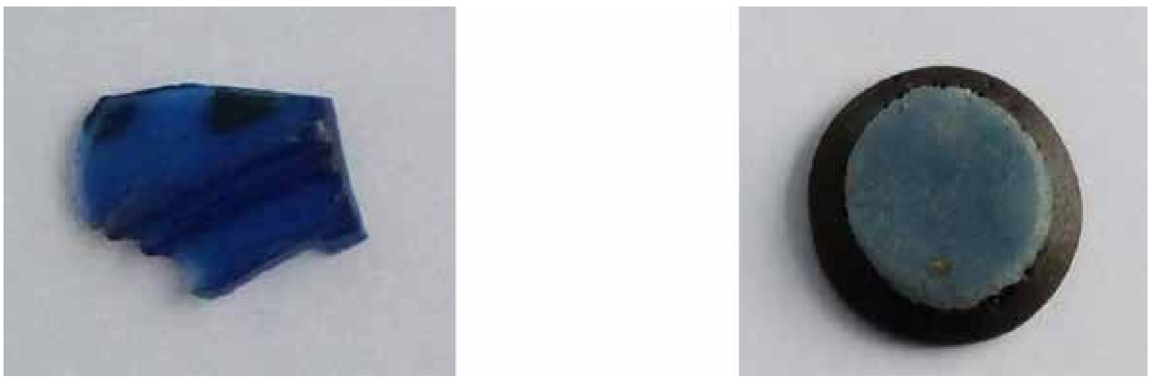

Fig. B. Left: glass 16 from Gradina on Jelica (6th century) coloured with 580 ppm of cobalt; right: glass 24 from Jelica (6th century) coloured with 1830 ppm of copper (Source: Balvanović and Šmit 2020).

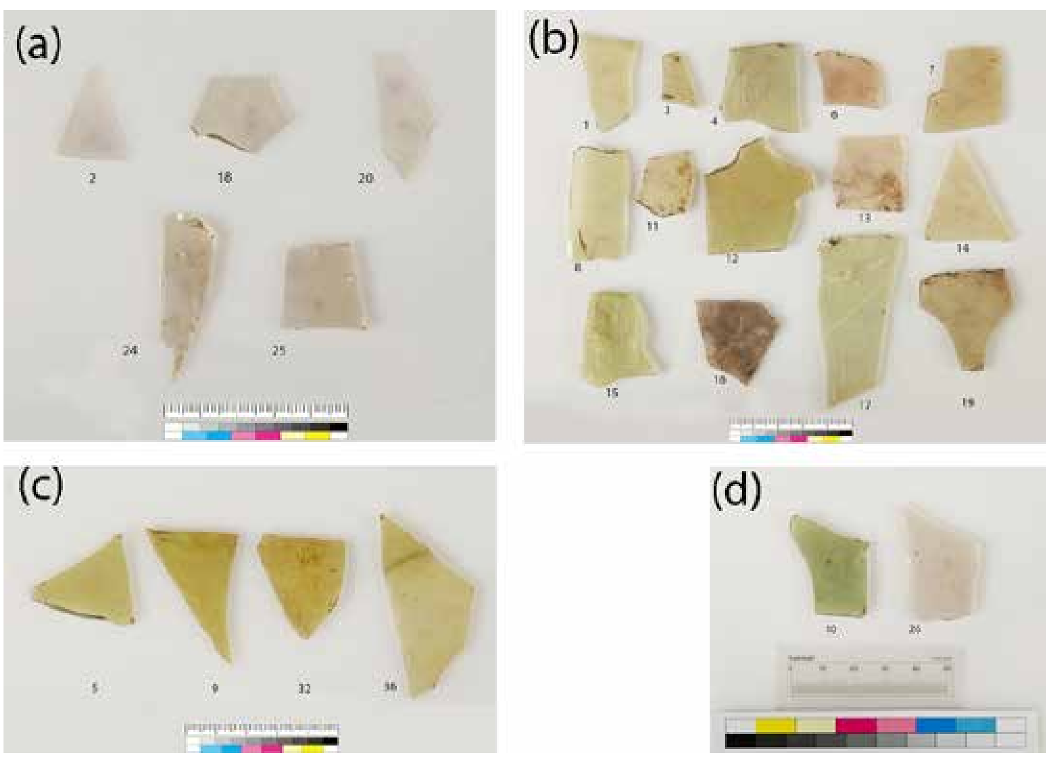

Fig. C. Photographs of windowpane glasses from Jelica: a. Jelica 1 - almost colourless glass of type Foy série 3.2 (average Fe_2O_3 = 0.70 %); b. Jelica 2 - light olive-green and amber glass of type Foy série 2.1 (average Fe_2O_3 = 1.00 %); c. Jelica 3 - deeper olive-green glass of type Foy série 2.1 high-iron (average Fe_2O_3 = 2.71%); d. Jelica 4 - glass of type Foy 2.1 with 2.26 % of iron oxide (left) and glass of type Foy 3.2 with 0.46% of iron oxide (right) (Source: Balvanović et al. 2018).

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REZIME

RIMSKO I KASNOANTIČKO STAKLO U OBLASTI MEDITERANA I SRBIJI: PROIZVODNJA, KOMPOZICIONI TIPOVI I POREKLO

KLJUČNE REČI: STAKLO, KOMPOZICIONI TIPOVI, POREKLO, RIMSKI PERIOD, NATRON, BILJNI PEPEO.

Rad daje sintezu proizvodnje rimskog stakla, kompozicionih tipova i porekla primarnog stakla tipa soda-kreč-kvarcni pesak (natronsko staklo) za vreme rimske epohe i epohe kasne antike. Takođe, kratko opisuje malu proizvodnju stakla od biljnog pepela, koje se pojavljuje i među staklima nađenim u Srbiji. Rad opisuje proizvodnju primarnog stakla i komponente koje se u proizvodnji koriste, i dvofazni model proizvodnje rimskog stakla. Rad daje karakteristike sastava tipičnih tipova rimskog stakla: plavo-zeleno rimsko staklo, prirodno bezbojno staklo, bezbojno staklo obezbojeno antimonom; potom tipove stakla koji se pojavljuju tokom IV veka: rimsko staklo obezbojeno manganom, HIMT, Foj 3.2, Džalame i bezbojno staklo obezbojeno antimonom i manganom. Rad opisuje karakteristike najčešćeg tipa tokom VI veka, odnosno Foj 2.1, i njegove podtipove sa povišenom koncentracijom gvožđa.

Daje se prikaz porekla navedenih tipova i opis metoda upotrebljenih za određivanje porekla: nalazi stakla sa okolnostima nalaza, koncentracije glavnih i sporednih elemenata, izotopski odnosi stroncijuma i hafnijuma, obrasci retkih zemalja. Rad opisuje rasprostranjenost kompozicionih tipova stakla pronađenih u Srbiji, daje kratak prikaz promene rasprostiranja tipova sa protokom vremena, i stavlja ove nalaze u širi mediteranski kontekst.

Rad pokazuje da rasprostiranje pojedinih tipova u Srbiji uopšteno prati njihovo rasprostiranje u širem okruženju. Važan izuzetak od ovoga predstavlja tip Foj 3.2, koji je, kako se čini, češće zastupljen među analizovanim srpskim kolekcijama stakla, a koji se pojavio ranije (III vek) i trajao duže (VI vek) nego u širem prostoru Mediterana.

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APPLICATION OF ARCHEOMETRIC TECHNIQUES IN THE STUDY OF WALL PAINTINGS ON THE EXAMPLE OF FRAGMENTS OF FRESCOE PAINTINGS FROM THE CHURCH OF ST. NICHOLAS (CRKVA SVETOG NIKOLE) IN BALJEVAC, SERBIA

ABSTRACT

During the archaeological research of the Church of St. Nicholas, in Baljevac, Serbia, fragments of wall paintings were found in Pit no. 1, located in the nave area. The fragments were determined to be from the second phase of the construction of the church (13th century). Several fragments of different and pure tones were selected to examine the composition of the mortar and pigments, as well as the painting technique. Analytical techniques and the results obtained by their use during the examination of the selected fragments are presented in this paper. With a suitable selection of analytical techniques, all the pigments that had been used were identified, the chemical composition of the mortar determined and a parallel made with the materials analysed so far from wall paintings from similar periods. The importance of modern archaeometric tests in modern conservation-restoration practice is highlighted and guidelines for continuing research are presented.

KEYWORDS: EDXRF, FTIR, RAMAN SPECTROSCOPY, WALL PAINTINGS, ARCHAEOMETRY, CULTURAL HERITAGE, FRAGMENTS, PIGMENTS, CHURCH OF ST. NICHOLAS IN BALJEVAC

INTRODUCTION

Laboratory and/or *in-situ* examinations, destructive or non-destructive, on samples or whole objects, provide data on the composition of materials, technology and manufacturing techniques, causes of damage and degree of degradation of a given cultural property. The data obtained by analytical methods serves primarily to identify the materials used, which is why they can also help in the selection of a suitable conservation procedure. Additionally, generated analytical data can reveal the authenticity of the materials used and everything that a given item has undergone over the course of time.

When it comes to wall paintings, the analytical techniques applied can be non-destructive, micro-destructive or destructive. Non-destructive and micro-destructive analytical techniques are preferable when working with archaeological and museum material, which is why special attention is paid to the selection of the appropriate instrumental technique that can provide answers to the questions asked. It is very important to know the possibilities and limitations of analytical techniques, in order to reach the most accurate results and high-quality interpretation.

The ruins of the medieval Church of St. Nicholas, in Baljevac near Raška, a single-nave basilica with façades, and an apse divided by blind arcades, has Romanesque properties, hence, it was included among the churches of the so-called coastal type very early on (Fig. 1). At first, it was believed that it was built at the end of the 12th century (Дероко 1932: 36–39), however, based on a detailed analysis of its secondary parts, primarily the windows, the dating was revised in more recent scientific literature to the middle of the 13th century (Чанак - Медић, Кандић 1995: 207–203). The fresco paintings in the interior of the church are only partially preserved, mostly in the lower zones, and they were dated into the 14th century on the basis of their style (Станић 1973: 64–67; Станић 1974: 53–74). From the 18th century, the church was in ruins, without a roof and exposed to atmospheric influences, which led to a lot of damage on the painted layer. The existing protective roof structure was built in 1935/36 and is one of the early examples of conservation practices in Serbia.

In 2016, Institute for the Protection of Cultural Heritage, Kraljevo, began archaeological research with the goal of gathering data for the formulation of a reconstruction project (Грујовић Брковић, Алексић Чеврљаковић 2016: 75). The research has shown that the building from the 13th century represents a restored older church with the same plan. During the archaeological campaign in 2017, under the level of the original floor in Pit no. 1 (Fig. 2) in the area under the dome, a fresco painting was discovered, corresponding to the second phase of the building of the church. This closed unit was created in the 14th century, after a

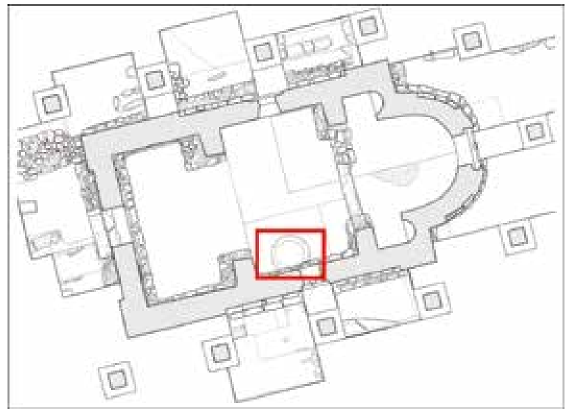

Fig. 1. Position of Pit no. 1 in the nave of the Church of St. Nicholas, in Baljevac (Drawing by A. Matović; documentation of the Institute for the Protection of Cultural Heritage, Kraljevo).

new painting of the walls (Berke 2009, 16; Turinski 1990: 5, 6), when the remains of older frescoes were set aside along with the Romanesque stone decorations, kitchen and table pottery,[1] stonemasons' tools and other movable finds, which clearly indicate a restoration context.[2]

In this paper, the importance of the previously mentioned archaeometric techniques in the study of the composition of the mortar and pigments of wall painting is shown precisely on the example of fragments found in the nave area of the Church of St. Nicholas, in Baljevac, which are kept at the Institute for Cultural Heritage Preservation, Kraljevo, today. The knowledge on the use of pigments in painting throughout history was very important for the drawing of relevant conclusions within this research, showing the necessity of a multidisciplinary approach to cultural heritage research.

PIGMENTS USED IN THE MIDDLE AGES

Information on paints from the Greek and the Roman period can be found in manuscripts by Theophrastus, Vitruvius and Pliny. Theophrastus (4th century BC) wrote the oldest treaty, *De lapidibus*, on rocks. Vitruvius (*Marcus Vitruvius Pollio*, 1st century BC), in his work *De architectura libri*

1 Certain bowl and pot fragments contain traces of pigments and were most probably used as paint palettes.

2 Unpublished archaeological research of V. Milutinović,

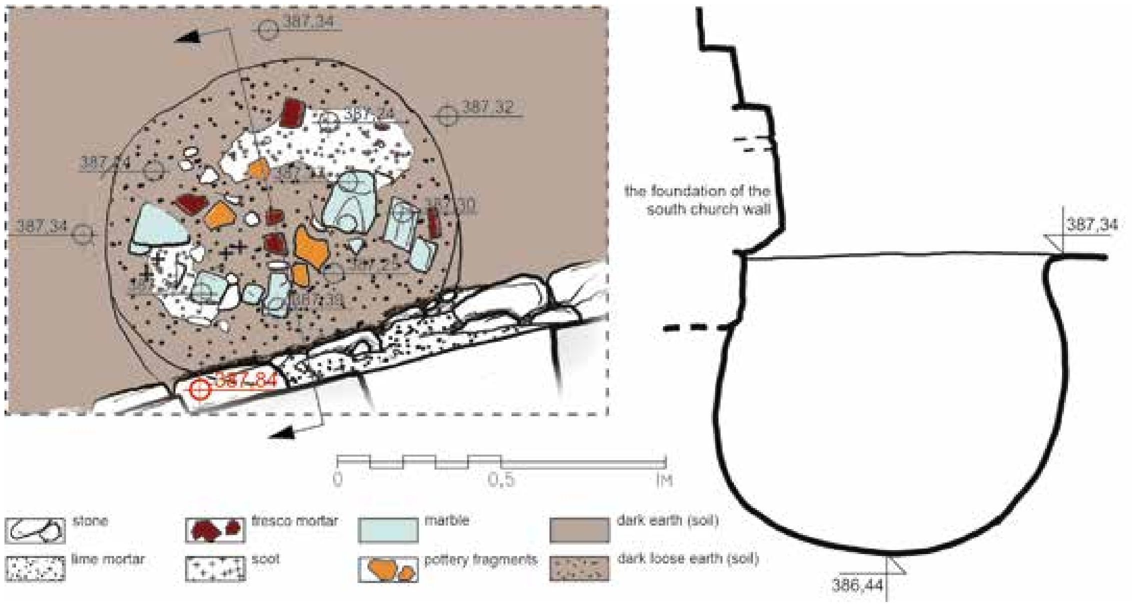

Fig. 2 Base of Pit no. 1 at the infill level, with a cross-section after it was emptied (Drawing by A. Matović; documentation of the Institute for the Protection of Cultural Heritage, Kraljevo).

decem, dealt with painting technologies and types and groups of paints, aside from architecture. Pliny the Elder (*Gaius Plinius Secundus Maior*, 1st century BC), in his book *Naturalis Historiae*, wrote about painting and colours, among other things. Those same colours continued to be used by painters from the medieval period as well, with the difference that Egyptian blue, one of the oldest synthetic pigments, ceased to be in use after the Roman period (Turinski 1990: 34; Mazzocchin at al. 2003: 129; Riederer 1997: 23–45; Rogić et al. 2012: 285–287). When it comes to blue, lapis lazuli was the shade that was used the most in the Middle Ages.

Data on pigments used in the Middle Ages come from a manuscript on painting and painting techniques, described by Heraclius in his three books *De Coloribus et Artibus Romanorum*. There, he described how different colours are obtained from plants and minerals. In this paper, the focus will be on the inorganic pigments that were used most often in medieval wall paintings. In his third book, Heraclius describes the preparation of the white tempera *Alumen*, which should be mixed with water and resin on marble, then dried and reduced to powder, and then mixed with egg whites. He also writes about the preparation of lead white *Cerus* and red lead *rubeum minium*. The lead white paint was prepared by placing lead plates in a vessel, pouring very strong vinegar into it, then closing the vessel and putting it in a warm place for a month. Once the vessel was opened, everything would be scraped off the lead plates and placed in a new vessel, which was to be heated over a fire, and the contents would be stirred until they became as white as snow. If the paint was kept over the fire for a longer time and stirred, it would become red *minium*. If the *minium* was left on the fire for a longer time, without stirring, it would revert to lead white again. For the preparation of tempera from green earth, *Malvam* would be mixed with vinegar or "good wine", green earth added to that mix, which would result in tempera, which would be used for wall paintings. To make green paint from copper or brass: copper plates were placed in a vessel with white wine vinegar and left there for 1–3 months, and after this period the pigment would be obtained (M. Medić 1999: 162, 197–201).[3]

The *List of various arts* by the German monk Theophilius Presbyter (*Schedula diversarum artium*) is an extensive manual on painting techniques from the early 12th century. He wrote about the use of lead white, red lead, cinnabar, ochre, arsenic, green earth, azurite, lampblack, vine black, etc. He described the process of making cinnabar

3 There is no data on Heraclius' origins, but it is believed that he could have been Greek, or perhaps Italian from Lombardy, and that his books were written before the manuscript of Theophilius Presbyter, Heraclius XXXIX.

with sulphur and mercury over fire. He also gave a recipe for the preparation of "green salt" from copper plates, salt, oil, honey, and vinegar (hot urine was also used instead of vinegar). To obtain Spanish green, he used small copper plates and vinegar, and noted that scales should be used to measure the ingredients (M. Medić 1999, 247–295).

Some of the most commonly used pigments in the 12th century, which we assume could also have been used on fragments and samples of wall paintings from the Church of St. Nicholas near Baljevac, are calcium carbonate (chalk), ochres, red iron oxides – red earth, cinnabar, red lead, green earth – *Terre Verte* and black pigments:

Calcium carbonate (chalk). White pigments can be different forms of calcium carbonate, they can come from limestone, chalk, marble, mollusc shells or bird eggs (Siddall 2006: 28). The three natural types of calcium carbonate are: aragonite, calcite and vaterite. Natural chalk, calcium carbonate, is a natural inorganic pigment, used from prehistoric times to the present day. Chalk is the name of calcium carbonate from Crete, which has become the common term (Ling 1991: 209).

Ochres. Yellow ochre is a natural mineral consisting of silicon and clay, coloured by the iron mineral goethite, and may contain traces of gypsum or manganese. It is found all over the world. Tones range from cream and yellow to brown and greenish. A higher amount of iron and manganese gives ochre a dull tone. It gains a reddish hue from heating (Turinski 1990: 22). Ochres have been identified in cave paintings (Altamira, Lascaux), as well as in paintings from Egypt, Greece and Rome. Ancient ochre was first used by Polygnotus and Mykon (Плиније старији XXXIII, IVI. 158, translation taken from: Медић 1999: 143).

Red iron oxides – red earths. Red earth is a natural inorganic pigment. Red earths have been used in all parts of the world from prehistoric times to the present day. These pigments contain a large amount of iron oxide. They are most often light red (hematite, rust), but they can range from orange to yellow (lepidocrocite, also known as esmeraldite or hydrohematite) and from dark brown to black (maghemite). They appear under the names: English red, Pompeiian red, *terra di pozzuoli*, *caput mortuum*, Spanish red, Neapolitan red, Persian red, Indian red, Venetian red and others (Кајтез 2011, 57). Red earths are extremely lightfast and stable in all techniques (Andrejević 1983, 63).

Cinnabar. Cinnabar is a natural inorganic pigment, obtained from the mineral cinnabarite (mercury sulphide). This ore is dried, ground, washed and heated, and used as a pigment after being dried again. It is orange-red, with excellent covering power and good performance. The oldest example of a wall painting on which cinnabar was used comes from the Neolithic village of Çatalhöyük (7000–8000 BC). There is no data on cinnabar being used in Egyptian or Mesopotamian painting. It was mostly used in ancient Greece and Rome (Turinski 1990: 25). Cinnabar deposits can be found throughout Europe, Asia, Persia, the Balkans, Italy, and in Serbia, in the vicinity of Avala and Prijepolje (Бабич 2003, 221–222). Artificial cinnabar was created in the 8th century (vermilion). There is no chemical difference between natural and artificial cinnabar. The only visual difference is that the natural pigment has coarser grains and a cooler tone than the artificial one. Two names are used: vermilion and cinnabar. Vermilion is the standard name in England and America, referring to the mercury sulphide pigment. Cinnabarite is a name derived from mineralogists and crystallographers and refers to the crystalline form of mercury sulphide (Gettens, Feller, Chase 1972: 45).

Red lead. Red lead, or *minium,* is a red synthetic pigment with a fine texture and good coverage. It was found in silver mines, and was highly valued. According to Theophrastus, *minium* was discovered by the Athenian Callias, who was heating red earth from silver mines, trying to obtain gold (unsuccessfully), and *minium* was, thus, created. It was imported from Spain, raw. In Rome, the ore was prepared, and the state would determine the selling price (Ling 1991: 209–209; Плиније старији 2011, XXXIII, chapter 11, 121). A red pigment called *Usta* was obtained by accident during a fire in Piraeus, after a cerusite vessel was burnt (Плиније старији 2011: XXXV, chapter 6, 114; Плиније старији 2011, XXXV, xx. 38; translation taken from: Медић 1999: 147). Another type of *minium* used to be obtained from a lead-coloured stone that was found near certain metal veins in silver and lead mines. This stone would turn red after being calcified, and it was also used as an imitation of *minium*. Surfaces painted with *min-*

ium, as with those painted with cinnabar, had to be protected with Punic wax (Плиније старији 2011, XXXIII, chapter 8, 120–122).

Green earth – Terre Verte. It belongs to pigments of natural inorganic origin. These are clays with a large amount of silicates and the minerals glauconite and celadonite, hydrosilicate of potash, aluminium, iron and magnesium. The colour varies from cool bluish-green to warm yellow and olive hues. Green earth was used for painting in Egypt, Greece and Rome, and also in later periods. Deposits of green earth have been found in today's Czech Republic, Italy, France, Baltic countries, Cyprus, Poland, Hungary, England, Germany, etc (Aliatis et al. 2009: 532).

Black pigments. Black from grapevines – vine black, has a composition of almost pure carbon with admixtures of impurities. It is obtained by charring cane stalks and other plant residues (dehydrated stalks, fruit stones, pomace, etc.). Polygnotus and Mykon made black ink from grape skins in Athens and called it grape pomace ink (Плиније старији XXXV, xxv. 41, translation taken from: Медић 1999, 147). This kind of black is lightfast, compatible with all binders and has a good covering power (Andrejević 1983, 82; Turinski 1990, 38). Charcoal, soot black, has been used as a pigment from the earliest times to the present day. It is obtained by heating wood with limited air contact. Charcoal is a common name for all black pigments, which are traditionally produced by charring organic matter, such as wood. Charcoal can also include lampblack, obtained by collecting soot from oil lamps, being a product of burning oil, candles or resin. The composition of it is pure carbon, with minimal oil admixtures. Such blacks are obtained by burning natural gas, resin or resinous wood, oil, fat, stone and brown coal (Andrejević 1983, 82). Vitruvius wrote about the black colour obtained from wine lees, prepared by drying wine lees, boiling them and mixing with glue. In this manner, an excellent colour for painting walls was obtained, as well as Indian ink (Vitruvius, book VII, X, translated by M. Lopac 1951, 161). Painters came to Serbia from abroad by invitation, but there were also painting workshops of local masters throughout the Middle Ages. Foreigners had a decisive role in the turning points in Serbia, when they brought the latest artistic concepts and high standards from developed milieux. Mostly, major painters from Constantinople or Thessaloniki worked in Serbia.

INSTRUMENTAL ANALYTICAL TECHNIQUES APPLIED DURING RESEARCH

Optical microscopy (observation of the wall paintings with a USB microscope). With the use of a USB microscope (Fig. 3), we can examine and document various pieces of the surface and save information regarding the properties of the surface of a wall painting. It is a very simple and practical observation method.

Fig. 3. Examination of the surface of the painted layers of fragments with a USB microscope (Photo by K. Ponjavić).

A digital USB microscope provides additional information that cannot be detected visually. With the option of manual focus adjustment, it records data at a magnification of between 50 and 500 times (Fig. 4). When connected to a computer, it is possible to take photos or make video recordings. Optical microscopy is very useful for studying the condition and physical structure, texture, various damage, interventions that occurred at a later point, granulation of pigments or aggregates, deposits and the presence of craquelures. Optical microscopy is also used on samples prepared by a special procedure that allows for an analysis of the stratigraphy of the layers on a cross-section. The stratigraphy or cross-section of a sample can yield very interesting results in the form of underpainting and overpainting, as well as the thickness of colour layers. Additionally, mortar layers and their difference in thickness, as well as aggregate grain size can be clearly observed, which can be especially enhanced by polishing the sample. There are several types of microscopes used for such examinations that are owned by laboratories throughout Serbia. The choice of microscope depends primarily on the type of information one wishes to obtain from the examination, as well as the ability to sample and prepare the material in a suitable manner for the examination of cross-sections (either by microscopy at lower magnifications or even by using scanning electron microscopy with energy-dispersive spectroscopy SEM-EDS, which provides information on the elemental chemical composition, and is suitable for the analysis of both mortar and pigments) (Rogić 2017: 71–79).

Fig. 4. Appearance of the painted layers of fragments with a magnification of ca 50x (Photo by K. Ponjavić).

Energy-dispersive X-ray spectroscopy (EDXRF spectroscopy). One of the most commonly used instrumental techniques for the analysis of materials from which works of art were made is energy-dispersive X-ray spectrometry. The many advantages of this instrumental technique have enabled its development over the years, making it an indispensable step in any modern archeometric study (Gajić-Kvaščevet al. 2012, 1025–1033; Rogić et al. 2012: 268–290; Rogić 2014; Rogić 2017: 71–79). Some of the advantages that should be highlighted are: it is non-destructive, non-invasive, multi-elemental (information is obtained on almost the entire elemental composition of the examined material with just one analysis), there are devices with which the analysis can be performed *in situ*, handling of the equipment is simple, results of the analysis are obtained in a very short time and in the same place where the test was performed (no additional processing of the results is required, nor the use of databases of comparative spectra to establish the elemental composition, which is extremely important if it is necessary to repeat the measurement or choose a different measuring place, since that decision can be made very quickly), and it is extremely available and reasonably priced. The disadvantages of this instrumental technique are not easy to overcome, but they are not too great a hindrance for its widespread use in the examination of almost all inorganic materials from which cultural heritage objects are made. The main disadvantage of this method is the impossibility of detecting organic materials (since the detection range is usually from energies corresponding to the detection of silicon – Si), as well as chemical compounds in which the detected chemical element is included (because chemical bonds between molecules cannot be detected with this method). The method is sensitive to the sample matrix, which significantly complicates the quantitative analysis.

EDXRF spectrometry for a non-destructive characterisation of pigments on fragments of wall paintings was performed with the use of

XRF spectrometers with a millimetre-sized beam, which was developed in the Department of Chemical Dynamics at the Vinča Institute in Belgrade and is specifically intended for the analysis of cultural heritage objects. The EDXRF spectrometer consists of an air-cooled X-ray tube (Oxford Instruments, Rh-anode, max 50 kV, 1 mA) with a pinhole collimator and a Si-PIN characteristic X-ray detector (6 mm^2/500 mm, Be window, 12.5 mm thick), connected to a DSP (X123, Amptek Inc.) for spectrum acquisition. Two laser pointers were used for the correct positioning of the analysed sample at the point of intersection of the incident beam and the axis of the detector (Fig. 5). The experimental conditions were as follows: 40 kV – no filter, 800 μA and measurement time 100 s. These parameters were kept constant during all measurements.

Fig. 5. Detail of an EDXRF spectrometric examination of the dark red pigment on a fragment of a wall painting (Photo by M. Gajić Kvaščev).

Fourier transform infrared spectroscopy (FTIR). Infrared (IR) spectroscopy is a frequently used instrumental technique with a developed methodology for examining materials of cultural heritage objects. In a similar way to XRF spectrometry, an initial excitation induces a physical effect in the examined material and the consequences of such an event are monitored. Fourier transform infrared spectroscopy, FTIR, is most commonly used for a qualitative analysis of a wide range of organic and inorganic samples, and is also suitable for archaeological and museum objects because it requires a very small amount of the sample, and there are also instrumental solutions that make this analysis completely non-destructive for the tested material. Three areas of electromagnetic radiation can be used for material excitation:near infrared, 13000–4000 cm^{-1}, mid infrared, 4000–200 cm^{-1}, which is most often used for testing materials of cultural heritage objects, and far infrared, 20^0–10 cm^{-1}. By detecting the vibrational changes of the atoms around the balanced position in the molecule, one can talk about the crystalline or non-crystalline mineral properties of the examined material. This technique is multi-informative, and can also be used in the field for *in situ* analyses. The result of such an analysis is an extremely complex spectrum that requires multiple levels of processing and comparison with a spectrum database in order to determine the composition and characteristics of the material, based on the position and shape of certain spectral areas.

Raman spectroscopy. Raman spectroscopy is another instrumental technique that can be implemented in non-destructive modes of operation. As with FTIR analysis, Raman spectroscopy enables analyses of both inorganic and organic materials (identification of pigments, bearers and binders, precious stones, etc.) (Grujić-Brojčin et al. 2013, 111–117; Paternoster et al. 2005, 21–28). The basic principle of Raman spectroscopy is very similar to infrared and these two techniques are considered complementary in terms of the result obtained by these analyses. In Raman spectroscopy, the excitation is achieved by a laser beam, with the inelastic scattering on molecules of the examined material allowing a determination of their structure. Some of the advantages of Raman spectrometry are the fact that it is non-destructive, non-contact, it can be performed in air and without sample preparation, although there are versions of instruments for which analyses are performed in a non-invasive way and *in situ*. A simple analytical procedure, short analysis time, very small areas that can be analysed (e.g., the size of a pigment grain) are some of the characteristics of this method. The resulting spectrum is analysed though comparison with reference spectra from spectrum databases. A special database of reference spectra has been developed for the application of Raman spectroscopy for analyses of cultural heritage objects. The application of this technique has yielded significant results in the characterisation and identification of pigments, results that have led to a better understanding of the nature of colour degradation, also in the study of material stratigraphy, the study of the state of conservation of the substrate or, for example, the characterisation of new restoration products.

RESULTS OF THE EXAMINATIONS OF FRAGMENTS

Seven fragments of wall paintings were selected for the examination using the EDXRF spectrometric non-destructive technique for pigment analysis (Fig. 6). Figure 7 shows that iron and calcium were detected in the sample as main elements and potassium, titanium and manganese as trace elements. This EDXRF spectrum is characteristic of earth pigments, which suggests, in this case, that red earth was used as a painting pigment. It can be seen in Figure 8 that the same composition of chemical elements is present in the point recorded on the ochre colour (iron and calcium in addition to potassium, titanium and manganese, which are present in traces). This elemental composition suggests the use of yellow ochre, another pigment from the range of earth pigments. By comparing these two spectra (Fig. 9), we see that the calcium intensity is slightly higher in the EDXRF spectrum recorded on ochre, while the height of the iron peak remains constant. This result suggests that there may be a difference in the thickness of the ochre layers and the dark red painted layer. A spectrum was recorded on sample B (Fig. 10), in which chemical elements were identified, indicating that an earth pigment, green earth, was used (Fe, Ca as main elements, and K, Sr, Ti and Mn as trace elements). Similar to fragment B, the elemental composition of the pigments analysed on fragments C and G indicates the use of an earth pigment, green earth (Fig. 11). The difference in the height of peaks of the main chemical elements, iron and calcium, and the visual evaluation of the

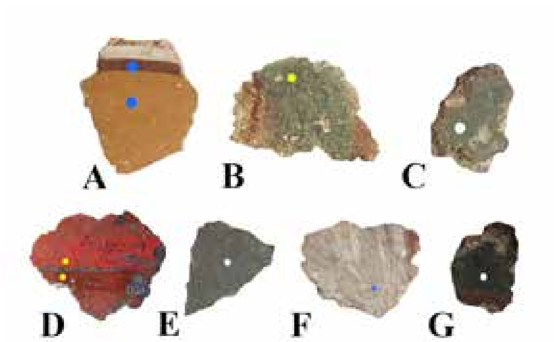

Fig. 6. Non-destructive examinations of pigments on fragments were performed in places marked by dots on the picture (Photo by K. Ponjavić).

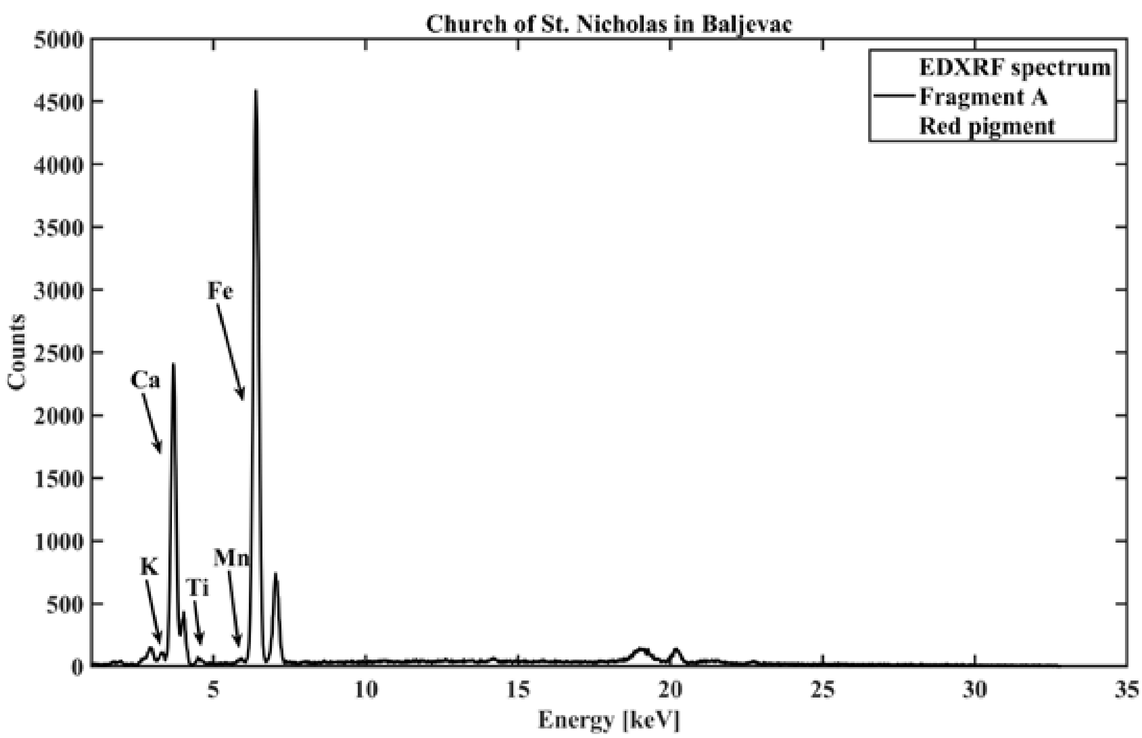

Fig. 7. EDXRF spectre of fragment A, red pigment.

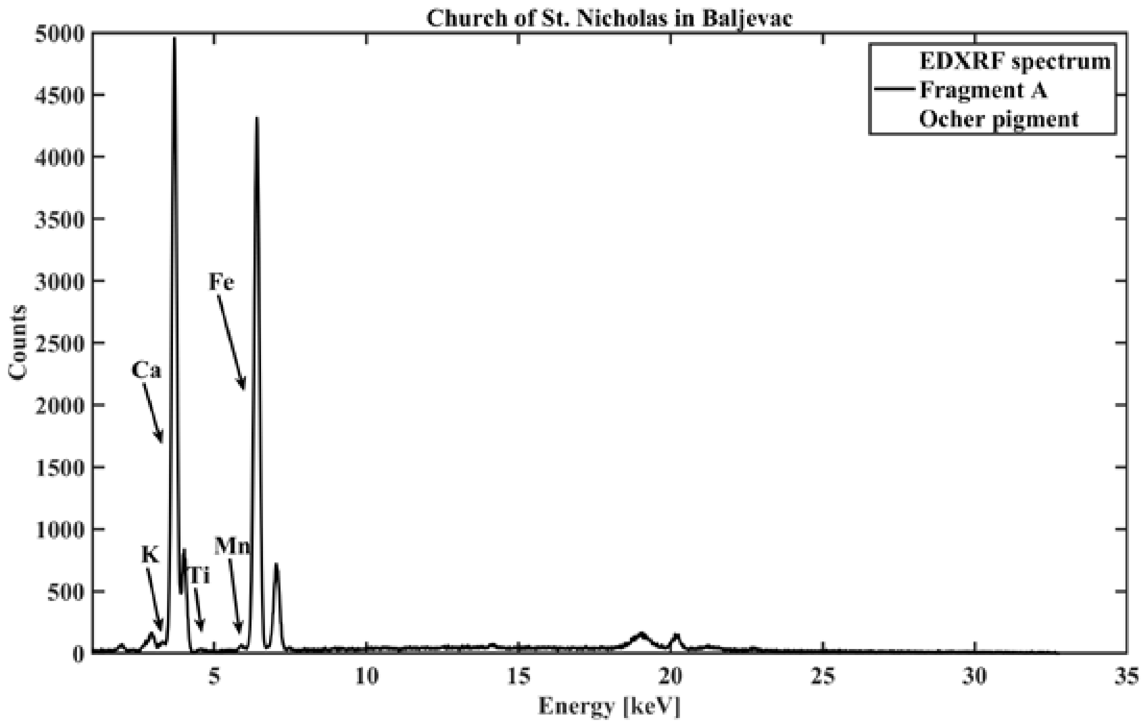

Fig. 8. EDXRF spectre of fragment A, ochre pigment.

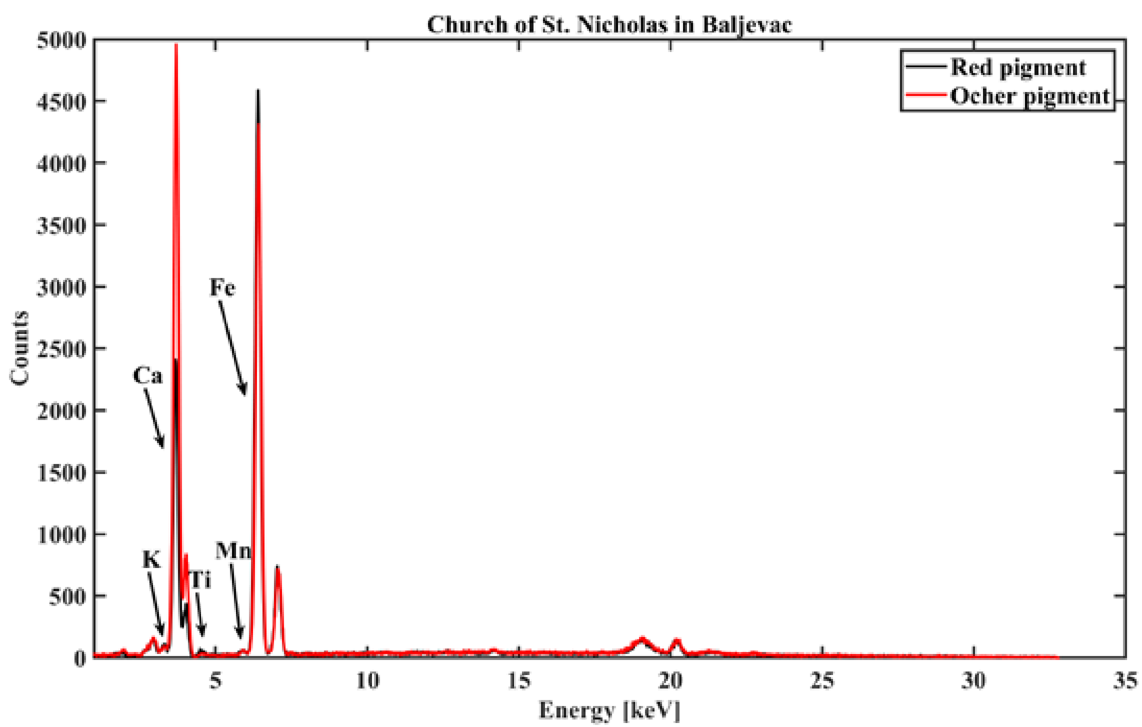

Fig. 9. Comparative EDXRF spectres of fragment A, dark red and ochre pigment.

shade of the analysed spot indicate a mixing of the green pigment with, most likely, a darker pigment that does not change the EDXRF spectrum (black pigment). The heights of calcium peaks indicate different thicknesses of painted layers on these fragments. The EDXRF spectrum recorded on fragment F can serve as a reference spectrum for mortar (Fig. 12). Considering the height of the

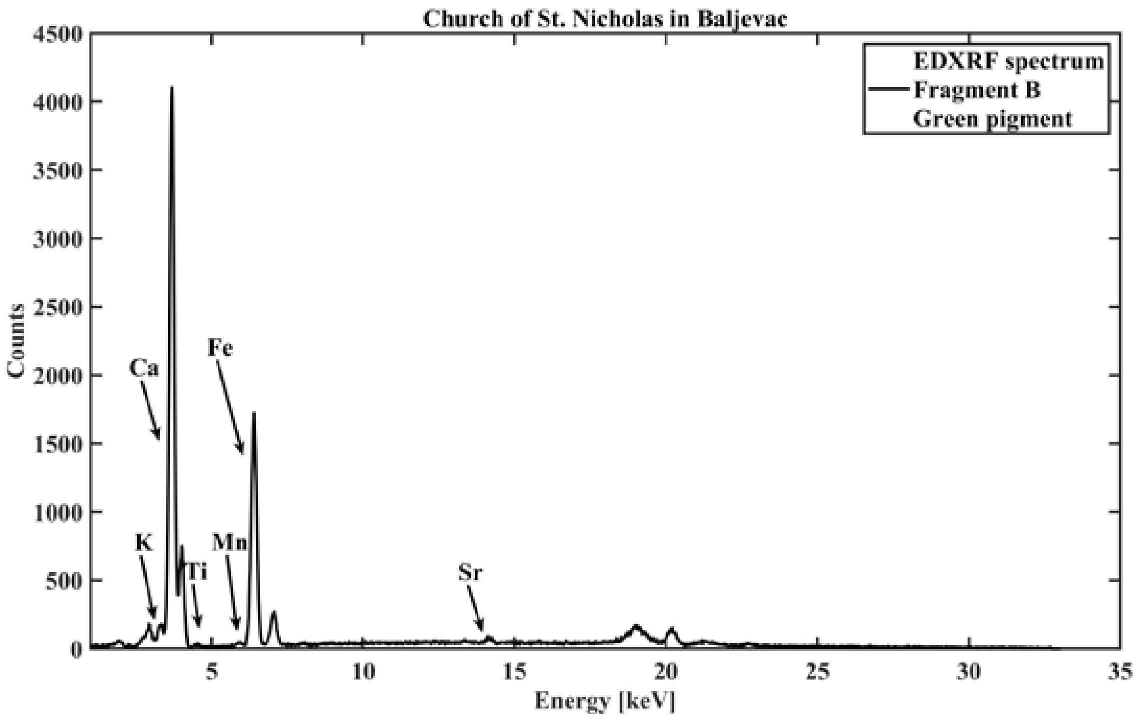

Fig. 10. EDXRF spectre of fragment B, green pigment.

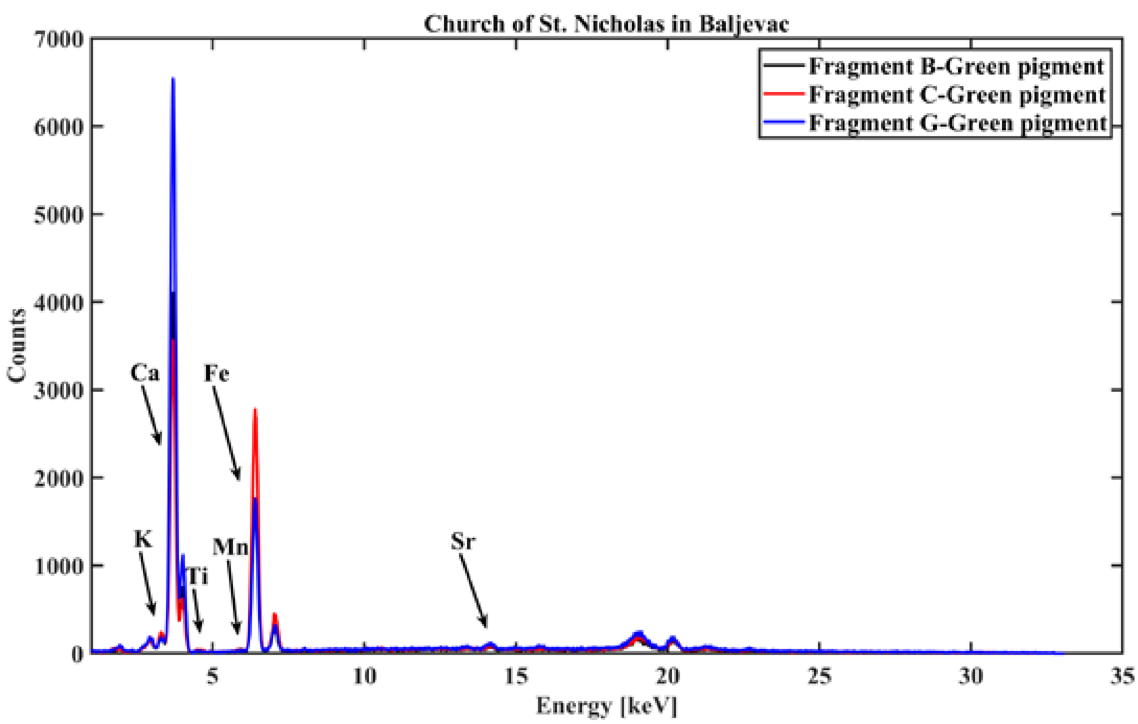

Fig. 11. Comparative EDXRF spectres of fragments B, C and G, green pigment.

iron peak, this chemical element can be considered a "companion" of the materials that make up the mortar. The height of the peak at an energy level of 2.3 keV indicates the use of calcium carbonate, chalk. The EDXRF spectrum recorded on the red part of fragment D, which is lighter in tone, indicates that cinnabar was used. Aside from the characteristic elements of mercury and sulphur, of

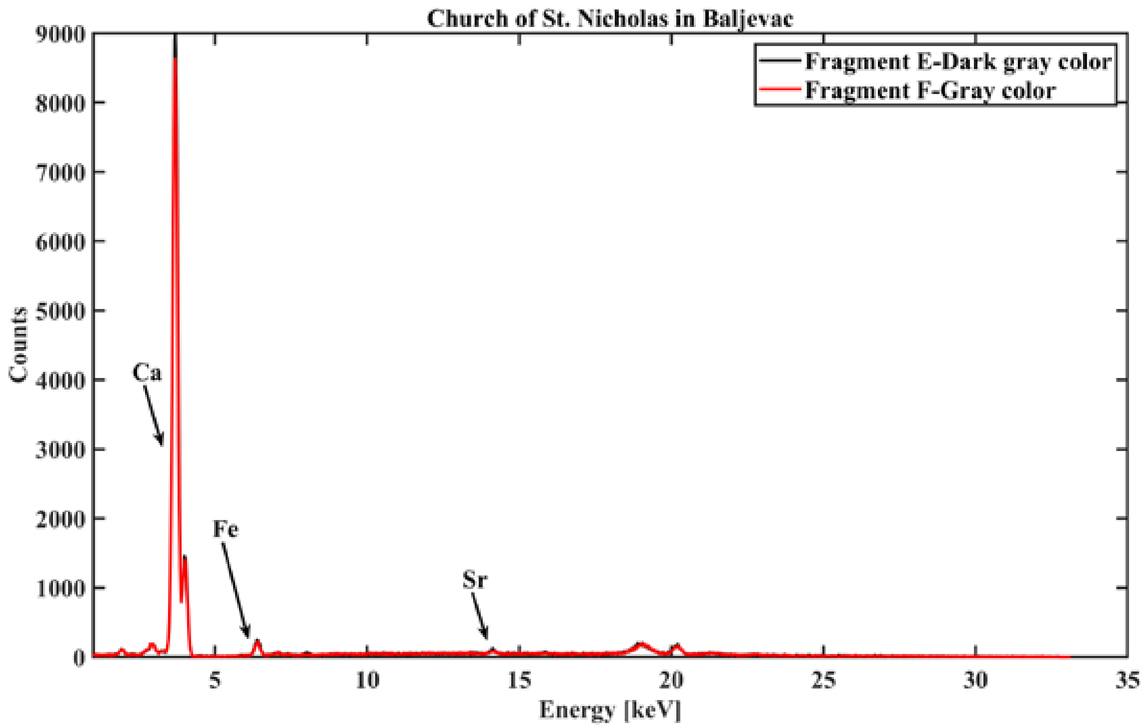

Fig. 12. Comparative EDXRF spectres of fragments E and F, grey.

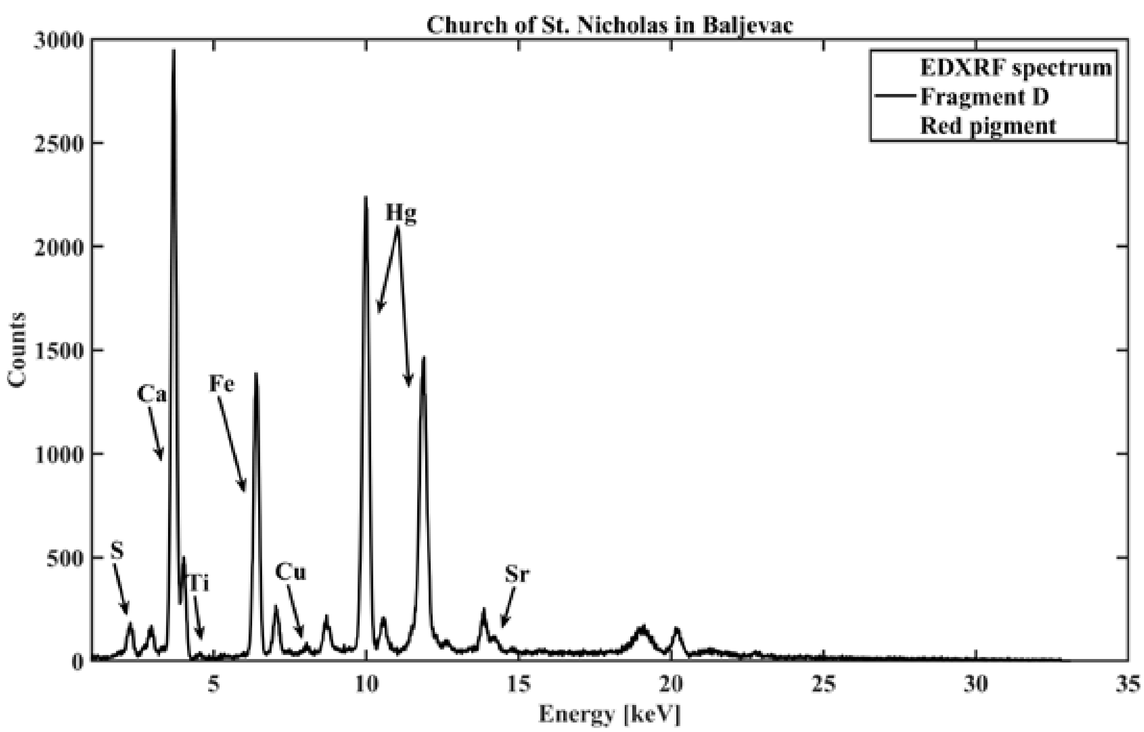

Fig. 13. EDXRF spectre of fragment D, red pigment.

which the cinnabar pigment consists, calcium was also detected as a main element, as well as titanium, copper (which can be a companion of cinnabar from cinnabarite ore) and strontium (Fig. 13). The darker red tone on fragment D consists of iron and lead as the main elements, which can help determine which red pigment was used (Fig. 14). It can be deduced that two pigments were used,

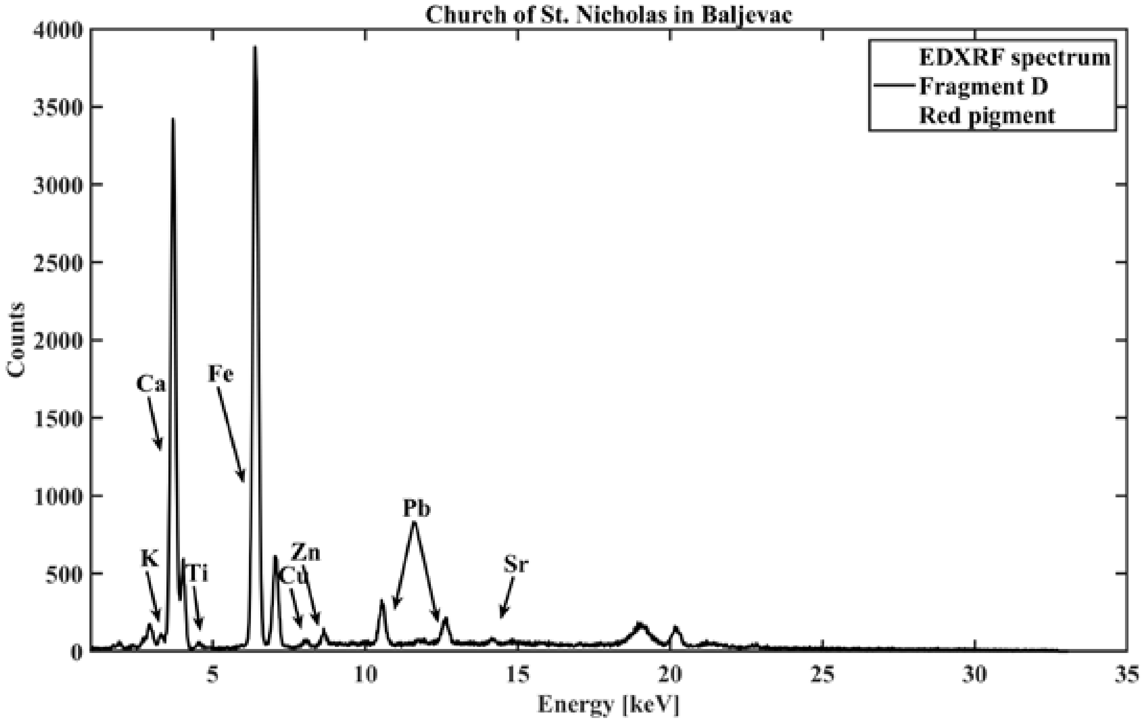

Fig. 14. EDXRF spectre of fragment D, red pigment.

Fig. 15. Sample 1, mortar with no traces of colour. Cross-section of the sample with a magnification of ca 180x, without a painted layer on the surface (Photo by T. Tripković).

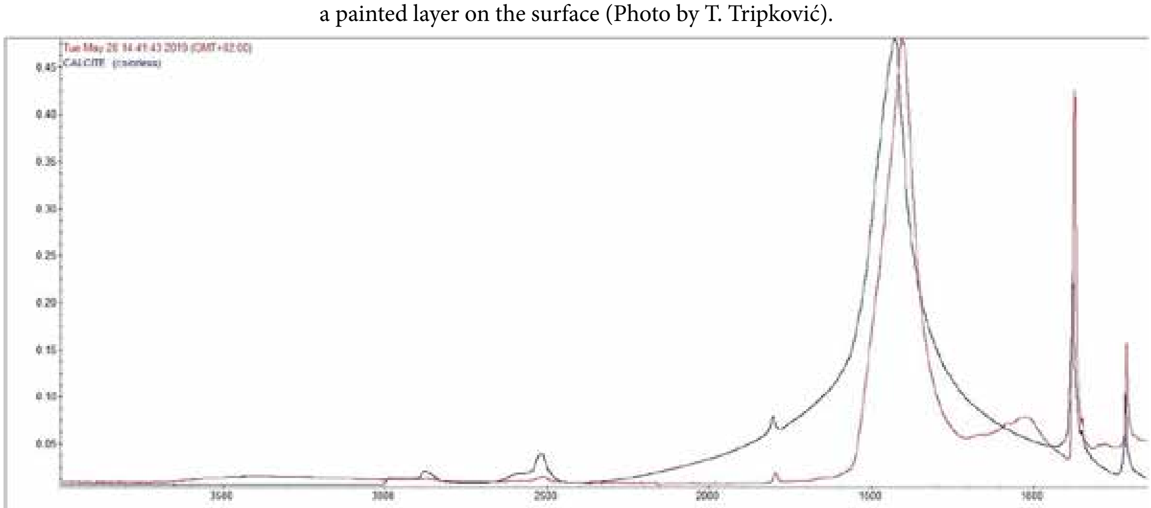

Fig. 16. Sample 1, FTIR mortar spectre shown in parallel with the calcite spectre.

Fig. 17. Sample 2, red painted layer. Cross-section of the sample with a magnification of ca 350x (Photo by T. Tripković).

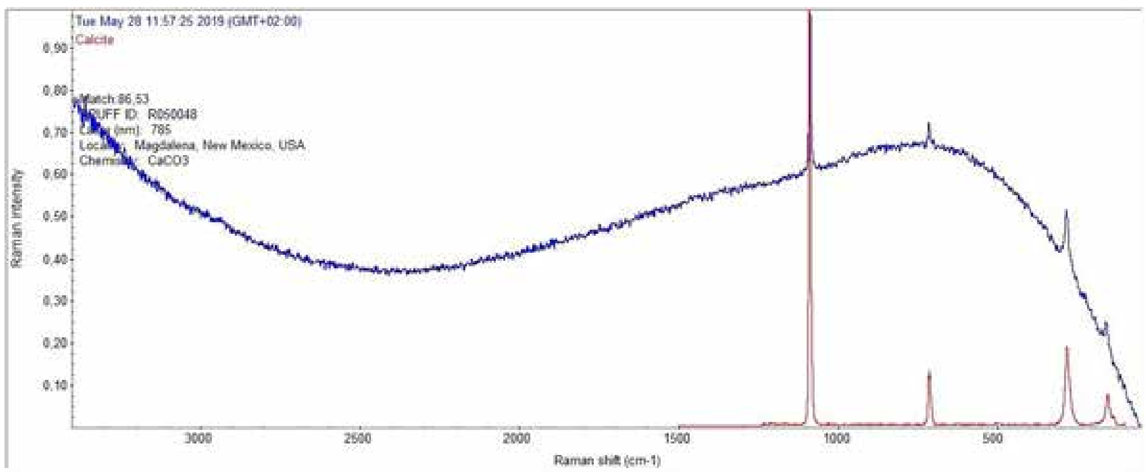

Fig. 18. Raman spectre of the white layer from sample 2 shown in parallel with the calcite spectre.

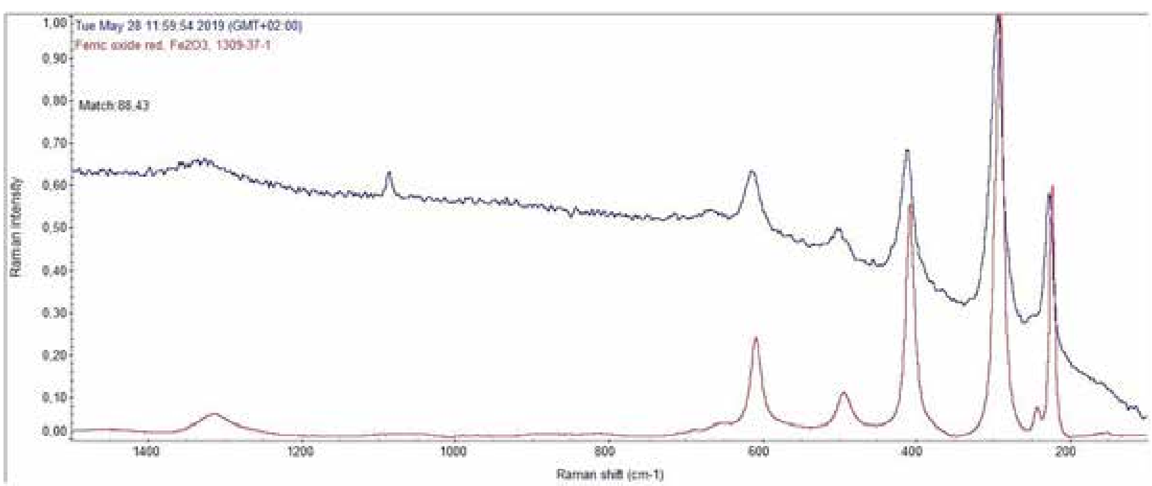

Fig. 19. Raman spectre of red pigment particles from sample 2 shown in parallel with the iron (III) oxide spectre.

earth red (as indicated by the trace elements K, Ti and Sr), as well as red lead – *minium* (with Cu and Zn as elements that can accompany lead).

In addition to these non-destructive analyses, optical microscopy and infrared spectroscopy (FTIR spectroscopy) were performed on one mortar sample (Fig. 15).[4] On the basis of the appearance of the cross-section of the sample, it can be concluded that the mortar is made of both a lime binder and limestone aggregate (Fig. 16). Based on the FTIR spectrum, it can be concluded that the composition of the mortar is calcareous (calcium carbonate) and that it contains aggregates of the same chemical composition. This analysis confirmed the XRF spectrometry findings, namely, that chalk was used.

using optical microscopy (Fig. 20). The result (Fig. 21) showed an interesting stratigraphy, which enables us to discuss the painting technique and the mixing of pigments. Two layers of paint are clearly visible on the cross-section of sample 3. The first layer above the fresco mortar contains more particles of red ochre (iron (III) oxide), while there is a whitish layer on the surface containing a smaller concentration of red ochre mixed with calcium carbonate.

Optical microscopy, as well as Raman spectroscopy, are excellent methods (when it is possible to take a sample) for identifying pigments that have chemical elements in their composition that cannot be detected by non-destructive XRF spectrometry, such as with parts of materials painted

Fig. 20. Sample 3, red or blue painted layer with a white coating. Cross-section of the sample with a magnification of ca 350x (photo by T. Tripković).

Another sample was analysed using destructive Raman spectroscopy and optical microscopy (Fig. 17), in order to learn about the painting technique and confirm the use of an iron-based red pigment. The cross-section of sample 2 is characteristic of the fresco technique. A darker layer of deposited impurities can be seen on the surface of the painted layer. On the basis of the Raman spectroscopy of the sample, it was determined that calcite, calcium carbonate, is present in the substrate (mortar) (Fig. 18), while red ochre was used as a red pigment for painting – iron (III) oxide (Fig. 19). Another sample of red paint was analysed by

black, as was the case with the sample in Fig. 21. The cross-section of the sample in Fig. 21 is characteristic of the fresco technique. The painted layer consists of black particles diffused into the layer of fresh plaster, so they give the appearance of a dark blue coloured layer. Using Raman spectroscopy, it was determined that the black pigment particles are amorphous carbon by composition (Fig. 22).

By means of the analytical techniques applied, it was discovered which aggregate was used for the preparation of the mortar, as well as which chemical elements and chemical compounds made up the pigments used for the wall paintings from the 13th century in the Church of St. Nicholas, in Baljevac. The composition of the mortar is lime (calcium carbonate) and it contains aggregates of the same chemical composition. Calcium carbonate was also used to lighten the tone of some

4 We would like to thank PhD Tatjana Tripković, chemist, adviser at the Republic Institute for the Protection of Cultural Monuments of Serbia - Belgrade for providing the results of the following analyses: optical microscopy, infrared spectroscopy and Raman spectroscopy.

Fig. 21. Sample 4, black. Cross-section of the sample with a magnification of ca 350x (photo by T. Tripković).

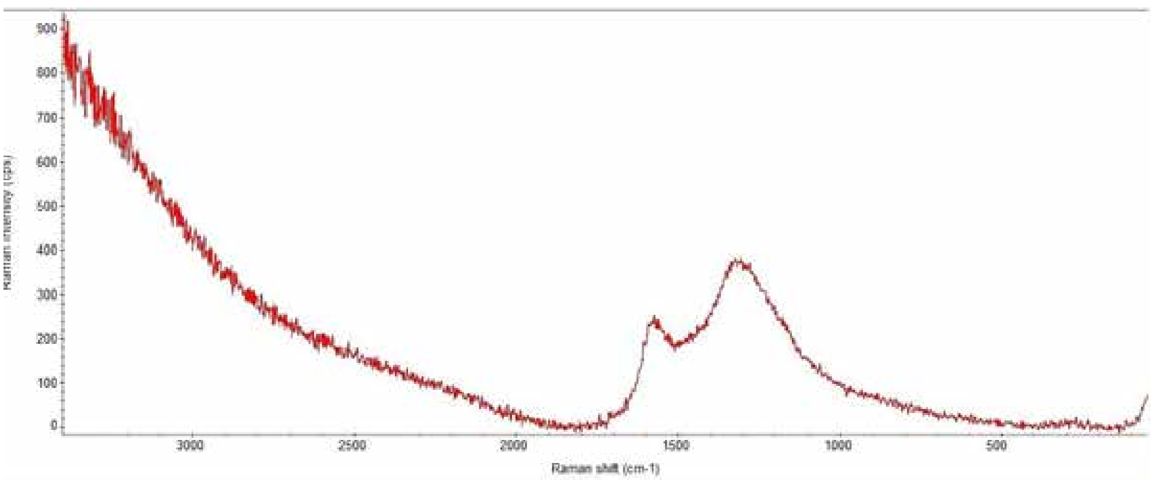

Fig. 22. Raman spectrae of the black layer in sample 4 contains peaks typical of amorphous carbon.

pigments, by being mixed with them. The most commonly used pigments are earth pigments of all colours: red – red earth, hematite, ochre – yellow ochre, brown – ochre and green – green earth. Darker red tones were obtained using red lead pigment – *minium*, while cinnabar was used for lighter red tones.

CONCLUSIONS

At the end of the 20th century, a wide-spread application of analytical techniques in the field of the study and protection of cultural heritage began in the world, resulting in a wide range of data on the physical-chemical composition and origin of various materials. In the past decades, during the research of wall paintings from both the Roman and the medieval period in the territory of Serbia, the emphasis was often on iconography and the archaeological context. In the past, analyses of materials were not available, and cooperation between experts from different fields in the process of the study and protection of the cultural heritage was rare. At that time, one could only guess at which pigments were used, based on the knowledge of painting technology. However, such conclusions were often wrong.

By means of physical-chemical analyses, it is possible to obtain exact data on pigments used.[5] The techniques applied in the analysis of painted layers are varied, and the following were used in this paper: pEDXRF, FTIR, and Raman spectrometry, as well as OM. For experts dealing with cultural heritage protection, it is most important to know what certain analytical techniques can reveal. Often, it is not necessary to apply a large number of different techniques, but rather to have a clear goal and choose those techniques that can provide the necessary data. Through a comparison of the results obtained by applying the aforementioned analytical techniques with knowledge from the field of painting technology, archaeology, history of art and architecture, scientifically invaluable conclusions can be reached (Mora, Mora, Philippot, 1984, 22). In order to obtain the most accurate results possible, it is important to choose an adequate sample, and to keep in mind that any information obtained from the sample must be additionally confirmed. It was noticed that samples with pure, intense and thicker colour layers yielded better results than lazure.

When it comes to the fragments from the Church of St. Nicholas, in Baljevac, the following colours were detected by visual observation: light and dark red, orange, pink, blue, green, various shades of ochre and brown, white and black, as well as various shades of mixtures of these colours. By using the analytical techniques of pEDXRF, Raman and FTIR spectrometry, it was concluded that the following pigments were used during the painting of the second phase of the Church of St. Nicholas, in Baljevac: yellow ochre, red earth, cinnabar, red lead, green earth, lime white and charcoal black. Unexpected results were obtained in two blue samples. Green earth was detected in one sample. Green earth can also have a bluish hue. In the case of the second sample, which seemed blue, it was concluded, on the basis of the obtained results, that charcoal black was used, making it seem blue due to the fresco technique and calcium carbonate. Iron oxide red – red earth with cinnabar and red lead, was also combined. The mortar consists of a limestone aggregate. Based on the cross-section of the fragments and microscope recordings, it can be concluded that the fresco painting technique was applied. The best comparison references for pigments from a similar period are those that were used to paint the monastery of Žiča.[6] Almost the same pigments were detected, the only difference being that no lapis lazuli was detected on the fragments from the Church of St. Nicholas, in Baljevac. It was interesting to note the use of cinnabar, a very precious and expensive pigment, even in the 13th century, which could represent additional research related to the historical and artistic context of these fresco paintings. Another finding that would be interesting for further research of these materials are the impurities from which elements detected in traces in the EDXRF spectrum of *minium* originate. By revealing information on the admixture types, it would be possible to discuss the technique of obtaining this pigment.

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5 For some of the first works on the analysis of painted layers from the Roman period in Serbia, see Rogić et al. 2012 and the unpublished PhD thesis by D. Rogić, “Tehnologija antičkog slikarstva na teritoriji Srbije” [Technology of antique painting in the territory of Serbia], 2014.

6 Physical-chemical analyses showed that iron oxides were used: hematite, goethite (red and yellow-ochre), cinnabar, lapis lazuli, charcoal or graphite black, magnetite brown and green earth. Холцлајтнер Антуновић, et al. 2015, 95.

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REZIME

PRIMENA ARHEOMETRIJSKIH TEHNIKA U ISTRAŽIVANJU ZIDNIH SLIKA NA PRIMERU FRAGMENATA FRESKO SLIKARSTVA IZ CRKVE SVETOG NIKOLE U BALJEVCU

KLJUČNE REČI: EDXRF, FTIR, RAMANSKA SPEKTROSKOPIJA, ZIDNE SLIKE ARHEOMETRIJA, KULTURNO NASLEĐE, FRAGMENTI, PIGMENTI, CRKVA SVETOG NIKOLE U BALJEVCU.

U radu su prikazane analitičke tehnike i rezultati koji su dobijeni njihovim korišćenjem prilikom ispitivanja izabranih fragmenata zidnih slika, pronađenih u Crkvi Sv. Nikole u Baljevcu. Prilikom arheoloških istraživanja crkve, u Jami br. 1, koja se nalazila u prostoru naosa, pronađeni su fragmenti zidnog slikarstva datovani u XIII vek. Odabrano je nekoliko fragmenata različitih i čistih tonova za ispitivanje sastava maltera i pigmenata, kao i tehnike oslikavanja.

Analitičke tehnike koje se primenjuju u ispitivanju zidnog slikarstva mogu biti nedestruktivne, mikrodestruktivne i destruktivne. Nedestruktivne i mikrodestruktivne analitičke tehnike su poželjne u radu sa arheološkim i muzejskim materijalom. Tehnike koje se primenjuju za analizu bojenih slojeva su raznovrsne, a u ovom radu su korišćene: pEDXRF, FTIR, i Ramanska spektrometrija, kao i OM. Za stručnjake koji se bave zaštitom kulturnog nasleđa najbitnije je da znaju šta pojedine analitičke tehnike mogu otkriti. Često nije neophodno primeniti veliki broj različitih tehnika, već imati jasan cilj i izabrati one tehnike koje nam mogu obezbediti potrebne podatke. Da bi rezultati bili što tačniji, važno je odabrati adekvatan uzorak. Poznato je da su uzorci čistih, intenzivnih i debljih slojeva boja daju jasnije razultate nego oni sa lazurnim slojevima.

Kod fragmenata iz Crkve Svetog Nikole u Baljevcu, upotrebom analitičkih tehnika pEDXRF, Ramanska i FTIR spektrometrija, zaključeno je da

su pri oslikavanju druge faze crkve korišćeni sledeći pigmenti: žuti oker, crvena zemlja, cinober, olovno crvena, zelena zemlja, krečno bela i crna od uglja. Malter je po sastavu krečni (kalcijum karbonat) i sadrži agregate istog hemijskog sastava. Kalcijum karbonat je korišćen i za posvetljavanje tona nekih pigmenata, tako što je mešan s njima. Na osnovu poprečnog preseka fragmenata i snimanja pod mikroskopom može se zaključiti da je primenjena fresko tehnika slikanja.

Kod dva uzorka plave boje dobijeni su neočekivani rezultati. Kod jednog od njih je detektovana zelena zemlja. Kod drugog uzorka, čija je boja označena kao plava, na osnovu dobijenih rezultata zaključeno je da je korišćena crna-ugljenik, koja zbog fresko tehnike i kalcijum karbonata stvara privid plave boje. Crvena boja – od oksida gvožđa je kombinovana sa cinoberom i olovno crvenom bojom. Najbolju analogiju za poređenje sa pigmentima iz sličnog perioda predstavljaju pigmenti korišćeni za oslikavanje manastira Žiča. U ovom manastiru su detektovani skoro isti pigmenti kao na ispitivanim fragmentima, osim lapis lazulija, koji je odsutan na fragmentima crkve u Baljevcu.

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THE EFFICIENCY OF CHEMICAL CLEANING OF DIFFERENT METAL ARTEFACTS FROM FELIX ROMULIANA AND GRADINA ARCHAEOLOGICAL SITES (SERBIA)

ABSTRACT

The research considers the effects of chemical cleaning of metal archaeological artefacts, made of silver, copper, bronze, lead and iron, from the archaeological sites in modern Serbia of Felix Romuliana (Gamzigrad) in the vicinity of Zaječar and Gradina (Jelica) near Čačak. Due to various corrosive products, artefacts were treated with different chemical solutions: citric acid, ethylenediaminetetraacetic acid sodium salts: EDTA-Na_2 and EDTA-Na_3. Corrosion products and surfaces before chemical treatments as well as products on various metal artefacts after chemical treatments were observed by SEM-EDS microanalysis. As expected, the EDTA-Na_2 solution removed all lead corrosion products (carbonates) within a very short period of time, whereas citric acid was most efficient in removing copper corrosion products (malachite, cuprite). As for the EDTA-Na_3 solution, impurities and corrosion products of silver (oxides) and copper (malachite and cuprite) were gradually removed, whereas the solution was partially selective in the silver sample. In iron deposits, corrosion layers such as goethite and magnetite were unevenly removed using the EDTA-Na_2 solution and citric acid. This research provides insights into the efficiency and risk estimation of the chosen chemical treatments, including the transformation of corrosion products, formation of chemical residual substances and the physical effects of the treatments.

KEYWORDS: SEM-EDS ANALYSIS, METAL ARTEFACTS, CORROSION, CONSERVATION.

INTRODUCTION

Archaeological metal artefacts can be exposed to complex physical and chemical decaying processes from the moment of production until the time of excavation or restoration. These physical-chemical processes induce various decaying processes, from the formation of layers of corrosion to a complete transformation (mineralization) into corrosion products (Schweizer 1994; Bertholon 2007). Deposits of both organic and inorganic composition are present on metal artefacts, and the latter, such as carbonates, oxides, hydroxides, phosphates, sulphides, sulphates, silicates, etc., are more difficult to remove (Gerwin and Baumhauer 2000; Kibblewhite et al. 2015). The choice of cleaning method is crucial for the effective preservation of the artefacts, since the cleaning is an irreversible reaction and it is, therefore, the most sensitive part of the conservation treatment (Casaletto et al. 2008). Cleaning methods are selected according to the physical, chemical and structural nature of both the original material of the artefact and the material that should be removed. By applying an appropriate cleaning technique and respecting the relevant ethical codes, i.e., the preservation of the cultural, historical and aesthetic value of the artefact (Brandi 2000), the stability and aesthetically acceptable form of the artefacts should be achieved.

Chemical cleaning is frequently applied in the corrosion treatments of metal artefacts with the purpose of removing deposits that occur in the form of massive corrosion products and impurities. It is especially used when the metal matrix of the artefact is highly preserved. Chemical cleaning is based on the use of chemical agents partially dissolving impurities and corrosion deposits, then rinsed and removed. The choice of solvents or solutions needs to be highly selective because only excess layers should be removed, whereas the original material and the structure of the artefact should be preserved. The excess layers are gradually removed, even in the case of inaccessible parts of the artefact, without any risk of causing sudden mechanical damage that may occur during mechanical cleaning (Pearson 1988; Bertholon and Relier 1990; Meyer-Roudet 1999; Cronyn 2004; Rodgers 2004; Selwyn 2004a). During the application of chemical methods, chelation agents have proved to be highly efficient in removing corrosion products and other impurities. During surface adsorption of chelate, the chelate binds specific metal ions, thereby releasing chelating complexes into the solution and weakening the structural integrity of the corrosion products (Meyer-Roudet 1999; Cronyn 2004; Casaletto et al. 2008; Abd-Allah 2013).

The disadvantage of chemical cleaning is reflected in the higher effort required in the control of chemical processes. It could significantly reduce the possibility to preserve any patina and protective layers. Also, the extent of the safe impact of chemical cleaning on certain parts of the artefacts, such as their original surface (metal substrate), is still uncertain. This is especially significant in the case of heterogeneous corrosion. Additionally, residual compounds that can cause dissolution or oxidation of metals may also occur, and thereby endanger the stability of the artefact. As chemical solutions act in microcracks, the integrity of artefacts can be endangered after the removal of corrosion products. Moreover, the residual substances can affect the stability of artefacts due to inadequate rinsing after chemical cleaning (Pearson 1988; Bertholon and Relier 1990; Meyer-Roudet 1999; Cronyn 2004; Rodgers 2004; Selwyn 2004a).

This research was performed on several selected archaeological metal finds from two archaeological sites in Serbia: Felix Romuliana (Gamzigrad) in vicinity of Zaječar and Gradina (Jelica) nearby Čačak, different in function and form, and made from various types of metals (silver, bronze as a copper alloy, lead and iron). The research aims to present all steps in the application of chemical treatments in the conservation process of metal artefacts, such as the analyses used for the determination of the condition of the artefact before treatment, the characterisation of the corrosion products, and the determination of the chemical cleaning surface effects before, during and after chemical cleaning. It includes non-destructive macroscopic examination, X–ray (radiography) image analysis, optical microscopy, and SEM-EDS analysis. The samples were treated with different chemical solutions, depending on the type of metal and corrosion products (citric acid, ethylenediaminetetraacetic acid sodium salts, EDTA-Na_2 and EDTA-Na_3).

This research shows the importance of choosing the appropriate chemical treatments, which is crucial for the both the efficiency of the cleaning process and the preservation of the artefacts. Furthermore, the research highlights the importance of traditional cleaning methods as part of the conservation process of the metal artefacts, which are easily available and applicable in the laboratories of local museums and institutions for the preservation of archaeological heritage.

FELIX ROMULIANA AND GRADINA SITES

Felix Romuliana (Gamzigrad) is an archaeological site with a continuity of life from the Neolithic to the Middle Ages, yet best known for the remains of a monumental fortified imperial residence from the beginning of the 4th century AD (Fig. 1a). In 2007, it became the first archaeological site in Serbia to be listed as a UNESCO cultural monument (Срејовић 1983; Поповић 2010). After excavations conducted in the second half of the 20th century, which were concentrated on the palace itself, research based on geophysical methods, started in 2004 in cooperation with the German Archaeological Institute, revealed the presence of a number of architectural units around the palace, which have yet to be examined in detail (Bülow et al. 2009; Pop-Lazić et al. 2014).

Thirty years of exploration of Gradina on Mt Jelica have shed light on the life of an early Byzantine city (6th century AD) that was an important regional centre of the Central Balkans (Milinković 2017) (Fig. 1b). Five churches and dozens of residential and economic buildings, as well as kilometres of ramparts have been unearthed so far. The daily life of the inhabitants of this urban settlement is documented by numerous finds of ceramic and glassware, some of which represent imports of Eastern origin (North African or Eastern Mediterranean). In addition, a large number of iron and bone tools were found, some of which were certainly produced in Gradina itself. Lead objects and lead as a raw material (ingots, lead strips) are relatively common finds in Gradina (Milinković 2017).

SAMPLES AND METHODS

Samples

From a total of 35 available metal archaeological finds excavated at the sites of Felix Romuliana and Gradina, seven were selected and stored in the depots of the National Museum Zaječar and the National Museum in Čačak under stable conditions after archaeological excavation and field cleaning (partial removal of soil). This includes the following samples: No. 1 – silver part of a bronze necklace - catch, No. 2 – part of a bronze brooch - pin, No. 3 – bronze coin, No. 4 – part of an iron key, No. 5 – iron fitting from a bag, No. 6 – fragment of a fitting - lead and No. 7 – lead plate. Samples Nos. 1, 2, 3, 4 and 5 belong to the Felix Romuliana site, whereas samples Nos. 6 and 7 are from the Gradina site, from the excavation of the Upper Town (Table 1). During the selection of the investigated collection of samples, the main adopted criteria were the diversity of the artefacts'

Fig. 1. Appearances of the archaeological sites: (a) Gamzigrad – Felix Romuliana (photo: K. Šarić), (b) Gradina – Jelica, (Narodni muzej Čačak, Gradina na Jelici, https://www.cacakmuzej.org.rs/gradina_na_jelici.html, accessed October 13th, 2022).

Sample label	Material	Sample	Archaeological site	Item, field number (C), dimension (cm)	Manufacturing technique, age*
1	**Ag**		Gamzigrad-Romuliana; Necropolis III	silver part of a bronze necklace, catch; C 1036/12; (3.27 x 0.58 x 0.64)	hammering, bending; second half of 4th -5th century
2	**Cu-Sn**		Gamzigrad-Romuliana; Northern rampart	part of a bronze brooch pin; C 1233/12; (length 6.88; spring 0.96)	casting, bending; 6th century, Early Byzantine Period
3	**Cu-Sn**		Gamzigrad-Romuliana; Tower 15	bronze coin; C 8/14; (R – 2.07)	hammering; M. Aurelius Probus (276-282)
4	**Fe**		Gamzigrad-Romuliana; Northern settlement	part of an iron key; C 1093/11; (length 7.59; ring end: 1.36)	hammering; Late Antiquity
5	**Fe**		Gamzigrad-Romuliana; Tower 15	bag fitting out of iron and bags; C 13/13; (10.68 x 1.98 x 0.34)	hammering; 6th century, Early Byzantine Period
6	**Pb**		Gradina - Jelica; Building II	fragment of a fitting – lead; C 8/96; (3.62 x 2.99 x 0.29)	casting; 6th century, Early Byzantine Period
7	**Pb**		Gradina - Jelica	lead plate; C 94/15; (4.06 x 2.22 x 0.46)	casting; 6th century, Early Byzantine Period

* Data on the technique of making the object and age are taken from the unpublished fund material of the National Museum Čačak

Table 1. Description and origin of samples, applied techniques and dating

composition, the degree of preservation of the metal matrix and the heterogeneity of the corrosion products.

Optical examination

Optical examinations were conducted in the Laboratory for Conservation and Restoration of the National Museum in Čačak. The method applied in the research included macroscopic and microscopic analysis, involving the use of lenses of different magnification and an optical microscope of the Carl Zeiss type (Jena).

Radiography

Radiographic methods such as X-rays and mammography were used to determine the degree of metal matrix preservation, which is one of the prerequisites for the application of chemical cleaning (Jones 2006). The X-ray results provide more accurate information about the original shape and surface details of the studied artefacts, that are hidden below the corrosion products. Comparative X-ray analyses were performed only for the iron samples, being the most damaged items in the collection (Nos. 2, 4, 5), using a SIEMENS Multix Fusion analogue X-ray system, digital Shimadzu FLEXAVISION X-ray system, and Siemens MAMMOMAT 1000 digital mammography system. The recording conditions were as follows: for the analogue X-ray system 81 kW and 0.93 mAs; for the digital mammography system 81 kW and 0.91 mAs, whereas for the digital X-ray system samples were recorded under various conditions: 9 kW and 1 mAs (sample 2), 54 kW and 4.3 mAs (sample 4) and 54 kW and 4.9 mAs (sample 5). The radiographic investigations were conducted in the Radiology Department of the Čačak Health Centre.

SEM-EDS analysis

The surface morphology and chemical composition of the samples were analysed before and after chemical cleaning. The analyses were carried out in the SEM-EDS Laboratory at the University of Belgrade – Faculty of Mining and Geology, using a JEOL JSM–6610LV scanning electron microscope that was connected to an X-Max energy dispersive spectrometer (SEM-EDS system). The images presented in the paper were obtained using secondary electrons (SE) and backscattered electrons (BSE) detectors. A tungsten filament was used as the electron source. The samples were not coated with carbon or gold, as metal objects are electrical conductors. Semi-quantitative chemical analyses of the samples before and after the chemical treatment were conducted, both on a selected area and in a specific spot of interest of the sample surface. Quantification of the elements was conducted using internal standards, and all analyses were normalized at 100%. The detection limit for all the analysed elements was approximately 0.1 wt.%. The content of light elements (atomic number from 1 to 5) was not determined.

Preliminary cleaning tests

Preliminary (spot) cleaning was conducted on bronze and lead finds using small wooden tools combined with distilled water and ethanol. The cleaning process was carried out on the selected minimal surfaces of finds (spot tests) in order to determine the preservation degree of the metal substrate, or the possible presence of metal coating on bronze finds.

Chemical cleaning method

Three substances were selected for chemical cleaning of the artefacts – citric acid ($C_6H_8O_7 \cdot H_2O$, *Fisher Chemical*) and disodium and trisodium salts of ethylenediaminetetraacetic acid (EDTA-Na_2: EDTA-$Na_2 \cdot 2H_2O$, *Fisher Chemical*; EDTA-Na_3: EDTA-$Na_3 \cdot xH_2O$, *Acros Organics*). The aqueous solutions were prepared with distilled water HPLC (Fisher Chemical) for all samples. Table 2 shows the concentrations and pH values of the selected solutions in detail. An AQUALYTIC - AL15 Set pH/Con instrument was used for determining the pH values of the solutions.

Chemical treatments were carried out in four daily cycles/chemical baths (4 days, 5 hours/one bath cycle). In the bronze sample (No. 3) and in the lead finds, the application period of two cleaning baths was affected by the nature of the corrosion products and the efficiency of the solutions, whereas the treatment of sample No. 6 was interrupted on the second day after two and a half hours. Without running the risk of damaging the metal matrix, a solution of higher concentration was initially applied on the iron sample No. 4 in order to accelerate the removal of hard surface corrosion products incorporated with additional substances from soil particles. The volumes of the solutions were from 100 to 200 cm^3 and were determined according to the size of the artefact (the artefacts were completely immersed in the solution). The treatment employed slight heating (the temperature of the magnetic stirrer – *Heidolph Instruments, Hei-Standard* ranged between 30 and 50 °C) with occasional solution stirring. Moreover, after daily chemical treatments, the soil deposits and encrustations, as well as surface corrosion products, were removed with cotton gauze in order to eliminate partially separated and dissolved corrosion products. Metal tools were not used in this phase, in order to avoid contamination and interference of the results.

Sample / Composition	Chemical solution (T = 30 - 50 °C)	Concentraction (%)	pH value (T = 25 °C)
1 / Ag	EDTA – Na_3	9.09	6.85
2 / Cu-Sn	EDTA – Na_3	9.09	6.85
3 / Cu-Sn	citric acid	4.74	1.40
4 / Fe	citric acid	9.01	1.83
	citric acid	4.74	2.24
5 / Fe	EDTA – Na_2	6.50	3.93
6 / Pb	EDTA – Na_2	6.50	3.90
7 / Pb	EDTA – Na_2	6.50	3.90

Table 2. Concentrations and pH values of selected solutions for cleaning metal artifacts

At the end of each cycle and after the final cleaning, a brief rinsing of the artefacts was carried out in slightly heated distilled water until a neutral reaction was achieved. The next step was drying in ethanol and acetone baths. A brief rinsing was carried out to avoid the possibility of interference of the chemical cleaning results. Interference of the results, or the formation of new compounds in the form of films or coatings, occurs if the artefacts are immersed in distillate water for a longer period. This particularly refers to the previously mentioned lead artefacts, on which a thin corrosion film is quickly formed in distilled water in the presence of dissolved gasses. Therefore, rinsing must be carried out in the shortest possible time (Selwyn 2004a). The artefacts were dried and stored in polyethylene zip bags, where they remained until the beginning of a new cycle of the SEM-EDS analysis.

RESULTS

Optical observations before treatments

An optical examination, both macroscopical and microscopical, indicated complete surface corrosion over all of the selected samples; additionally, layered corrosion had developed on the iron, bronze and lead findings. Although the items were stored for many years after excavation without any conservation, their stable condition was noted (the effect of active corrosion is not noticeable). The presence of impurities, like soil remains, was detected on the surface of all the artefacts. These particles are incorporated within the structure of the corrosion products (transformed medium) in the iron and lead findings.

On the surface of the silver sample No. 1, a thin, dark, transparent film, typical for silver, together with partially evident soil remains, was observed. Considering that the finds were not photo-documented immediately after the excavation, it is not possible to determine whether the dark film was formed in the soil (e.g., anaerobic conditions with the effect of sulphate-reducing bacteria activities) or whether it was partially formed after excavation, as a result of the atmospheric conditions (Bertholon and Relier 1990; Marchand et al. 2014).

On the basis of several parameters, the bronze coin (sample No. 3) was identified as silver during the archaeological excavations, even though the existing corrosion products indicated bronze (heterogeneous, uneven, corrosion layer with dark green parts). Soil remnants were also noticeable on the sample. Nevertheless, the cleaning test proved that sample No. 3 was made from bronze, and that it was possible that the coin was coated in silver, but the majority of the silver layer was lost over time. The relief structure of the coin is barely visible. On the bronze brooch-pin (sample No. 2), an incoherent layer of corrosion products occurred accompanied with visible soil remains. This artefact is dominantly featured by various layers of green shades with the partial appearance of dark layers.

On both samples made of iron (Nos. 4 and 5), layered deposits of the corrosion products typical for iron (shades of dark reddish-brown and orange) were present in both of the examined iron finds. The surface of the finds comprises a transformed medium, i.e., a mixture of corrosion products and components from soil.

The optical examination of the lead artefacts (samples No. 6 and 7) indicated the presence of an uneven and soft greyish–white layer.

X-radiographic screening

Radiographic images showed that sample Nos. 2, 4 and 5 had a highly preserved metal core (Fig. 2). Lighter parts on radiographic images indicate the presence of the metal matrix, whereas dark spots represent corroded or mechanically damaged parts of the artefact. The line shapes of the artefacts are irregular, due to mechanical deformations, damage and corrosion. The alternation of light and dark parts indicates the impacts of mechanical damage and corrosion (possibly pitting or some other form of local corrosion).

Chemical cleaning effects – macroscopic observations and SEM-EDS analyses before and after the treatment

The SEM-EDS analysis covered all seven selected finds analysed before and after the chemical treatment. The targeted parts of the surfaces were related to both the existing corrosion products and external material (soil) before the treatment, and the analysis of the artefact surfaces after the chemical cleaning.

Silver artefact. Soil particles and other impurities were removed from the silver find (sample No. 1) in the EDTA-Na_3 solution immediately after the first treatment, which was followed by the appearance of a smooth surface of the artefact. The intensity of patina significantly decreased after the first few treatments with the solution, but it gradually decreased later. The surface of the artefact contained an uneven, transparent film, which could be removed with polishing process.

The concentrations of Si, Al and other elements (Fig. 3a) before chemical treatment indicate the presence of aluminosilicate and silicate phases on the surface of the silver artefact, i.e., soil and sand remains, whereas the silver basis of the artefact was most likely covered with a dark film of silver sulphide – Ag_2S. Separate chemical analyses of particles within the aluminosilicate layer indicated the presence of quartz (SiO_2), alkali feldspar ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$), and some clay minerals.

Almost all the aluminosilicates were removed after the chemical treatment (Fig. 3b). Nevertheless, a thin film of silver sulphide remained unaltered on a large surface area. Individual spot chemical analyses, performed on the cleaned surfaces, indicated the presence of copper and gold in low concentrations (below 1%).

Bronze artefacts. Over a long treatment period of sample No. 2, the EDTA-Na_3 solution (pH ≈ 7) gradually dissolved corrosion products until the metal matrix was revealed. However, in sample No. 3, the citric acid solution dissolved almost all corrosion products in a short period of time. The surfaces of both artefacts obtained the expected appearance after chemical cleaning (the reddish-coloured bronze was covered with a thin uneven dark film). The cleaning process was completed with the necessary additional polishing in order to attain an aesthetically acceptable artefact

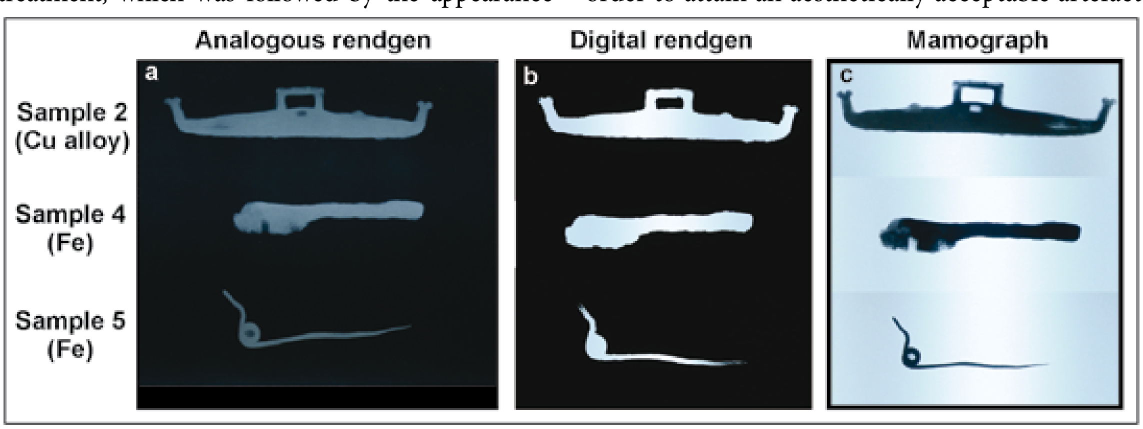

Fig. 2. Radiographic images of the examined samples 2, 4 and 5: a -analogue X-ray system, b - digital Xray system, c - digital mammography system.

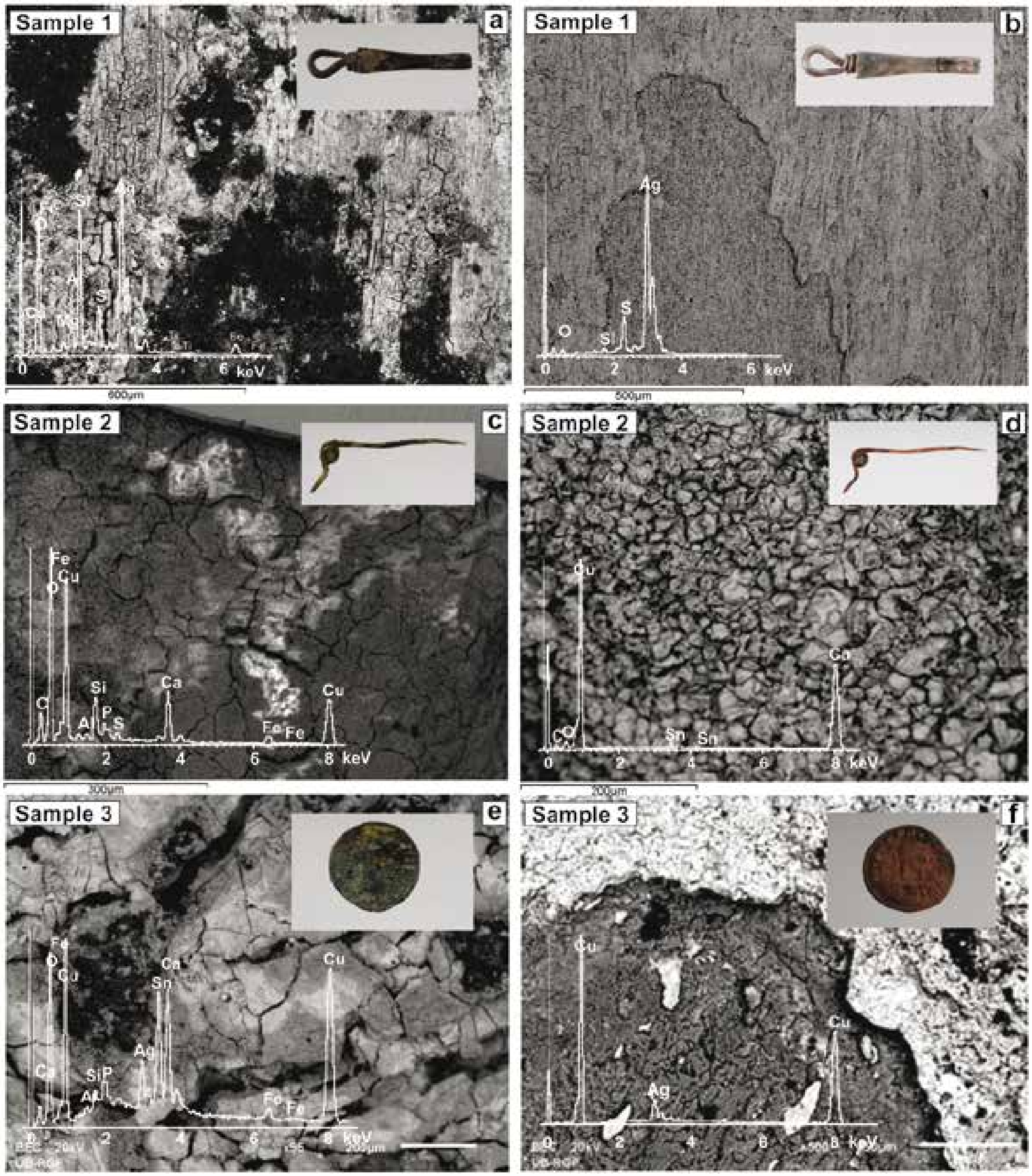

Fig. 3. BSE images and spectrums of the surface chemical analyses: Sample 1 (silver part of a bronze necklace): a - before treatment, b - after treatment; Sample 2 (part of a bronze brooch pin): c – before treatment, d - after treatment; Sample 3 (bronze coin): e - before treatment, f - after treatment.

appearance. In the bronze brooch-pin thread (the access of the solution to the metal surface was difficult due to thick corrosion layers), it was necessary to remove the additional corrosion products, which is usually performed in a mechanical way.

Before chemical cleaning, secondary copper phases were dominant in the samples of bronze brooch-pin and coin, and they mainly included copper carbonates and/or hydrated copper carbonates, such as malachite ($Cu_2CO_3(OH)_2$) and azurite ($Cu_3(CO_3)_2(OH)_2$). Besides carbonates, small amounts of copper oxide – cuprite (Cu_2O) could be traced, whereas the presence of sulphur (Fig. 3c) could indicate some of the copper sulphate phases. The presence of impurities (aluminosilicate and calcite) was negligible. After the chemical treatment, all impurities were removed, whereas the presence of copper carbonate was insignificant. The presence of tin (Fig. 3d) in some spot analyses on the cleansed needle confirms the hypothesis that the finds are made of bronze. Besides the previously mentioned copper carbonates, an increased amount of calcite ($CaCO_3$) could be traced on the bronze coin before the chemical treatment (Fig. 3e). Random silver accumulations on the surface of the coin were also detected (Fig. 3f). Illustration of the appearance of samples 1 to 3 before and after the treatment is given in Fig. 4.

Iron artefacts. For the iron items, a solution of citric acid solution (which had a significantly lower pH value than EDTA-Na_2 solution) proved to be more efficient. It should be noted that the first bath of sample No. 4 (a key) was carried out in a more concentrated citric acid solution, so that the initial remnants of soil and other materials could be easily removed. On a large surface area of the same sample, corrosion products were completely removed to the metal substrate. Additionally, a cleaning with a cotton cloth was performed on the key blade, due to the thin and corroded metal matrix, which carried a risk of losing the original shape of the artefact. On smaller surface areas of sample No. 5, an EDTA-Na_2 solution removed corrosion products to the metal matrix. The partially revealed metal surface possesses a characteristic stable silver–grey colour. Secondary iron phases are most dominant in the iron key sample,

Fig. 4. Illustration of cleaning effects: Sample 1 (silver part of a bronze necklace – catch), before (a) and after treatment (b); Sample 2 (part of a bronze brooch – pin), before (c) and after treatment (d); Sample 3 (bronze coin), before (e) and after treatment (f) (photos by M. Bojović).

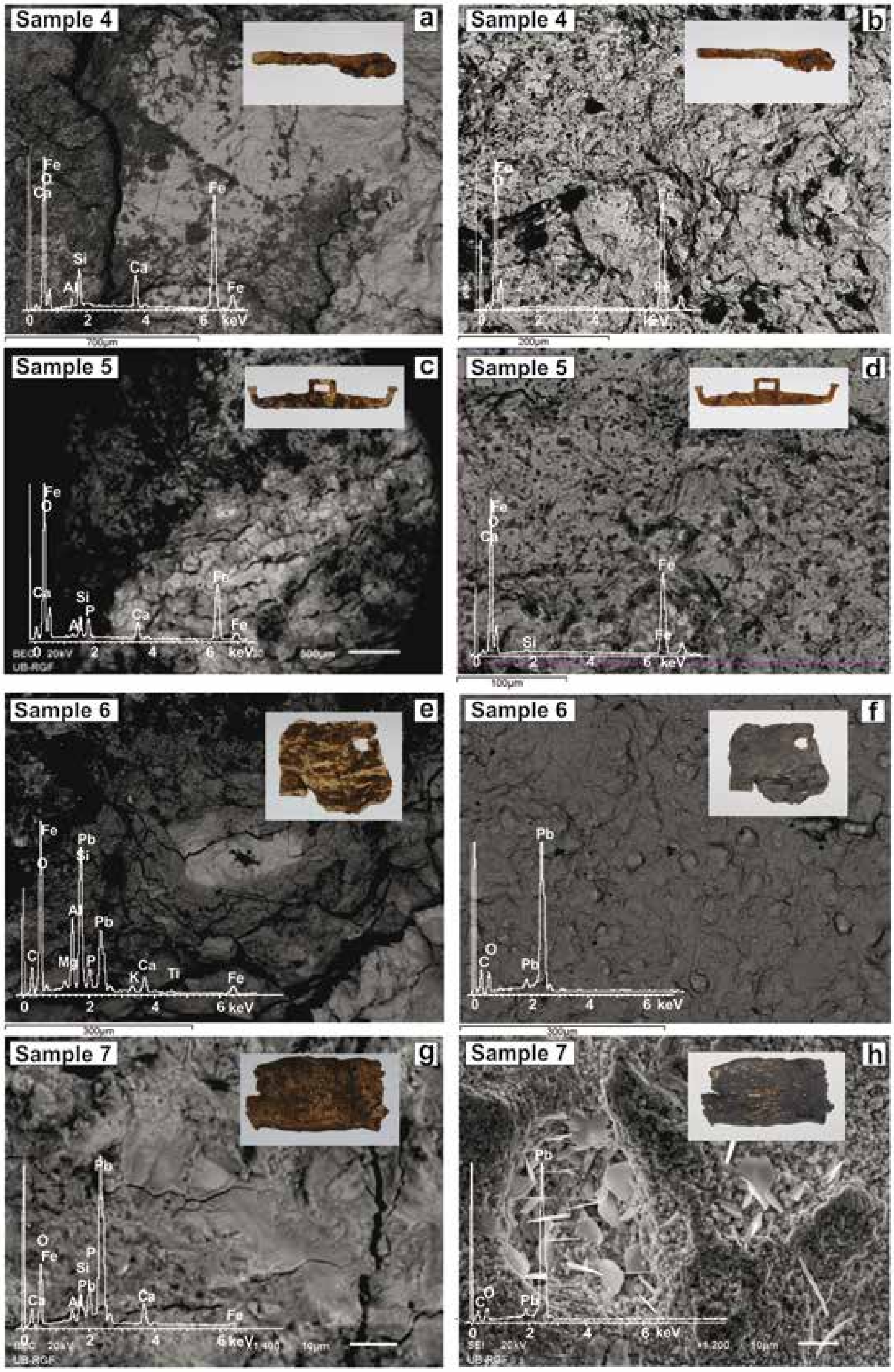

Fig. 5. BSE images and spectrums of the surface chemical analyses: Sample 4 (part of an iron key): a -before treatment, b - after treatment; Sample 5 (bag fitting out of iron and bags): c - before treatment, d -after treatment; Sample 6 (fragment of a fitting - lead): e - before treatment, f - after treatment; Sample 7 (lead plate): g - before treatment, h - after treatment.

whereas the presence of aluminosilicate is negligible (Fig. 5a). These phases are most likely present in the form of a mixture of various oxides and/or iron hydroxides. Chemical analysis of the surface after chemical cleaning shows that the aluminosilicates have been removed, whereas the mixture of oxides and/or iron hydroxides is still significantly present (Fig. 5b). Almost identical phases occurred in the case of the iron bag fitting sample (sample No. 5), both before and after chemical cleaning (Figs. 5c, 5d).

Lead artefacts. As expected, the EDTA-Na_2 solutions were highly efficient in removing corrosion products formed on sample Nos. 6 and 7. In sample No. 6, cleaning was mostly performed very quickly after the first bath. In the case of the second lead sample (No. 7), the solution reacted a bit slower owing to large recesses as well as to the deformed and curved structure of the lead plate. In both artefacts, corrosion products remained in the cracks. The cleaned surfaces of both finds were covered with a dark, thin film formed after the cleaning, i.e., during and after rinsing, or possibly as an effect of a short atmospheric corrosion. In the case of sample No. 6, cleaning was completed with the necessary additional polishing, which added the appropriate aesthetic look, whereas sample No. 7 required additional mechanical cleaning in hard-to-reach areas, such as recesses and the inner parts of the curved structure.

On both lead finds, very similar impurities were found, mostly in the form of various silicate and aluminosilicate phases (Fig. 5e). After chemical treatment, the surface of the lead finds mostly contained lead carbonates – cerussite ($PbCO_3$) and/or hydrocerussite /$Pb_3(CO_3)_2(OH)_2$/ – (Fig. 5f). The high concentration of phosphorus may be related to clayey fractions of the soil (Fig. 5g). After chemical treatment, lead carbonate crystals occurred in the cavities of the lead finds. These crystals displayed orthorhombic symmetry and this phase is most probably cerussite (Fig. 5h). Illustration of the appearance of samples 4 to 7 before and after the treatment is given in Fig. 6.

The results of the chemical analyses, after the chemical cleaning of all the treated artefacts, did not show any trace of characteristic elements that could refer to any possible residual compounds (reaction with the examined aqueous solutions).

Table 3 shows the summarised review of the identified phases, before and after the chemical treatment for all the studied artefacts.

DISCUSSION

A chemical cleaning treatment with the selected chelating agents was applied on various metal finds (silver, bronze, lead and iron) from two archaeological sites in Serbia. As expected, after the chemical treatment, silicates, aluminosilicates, and calcite ($CaCO_3$) – as usual constituents of

Sample/composition	Composition of untreated metal surfaces	Corrosion products after chemical treatment
Sample 1: Ag	- silicates and aluminosilicates from sand and soil - Cu sulphide	- Ag sulphide
Samples 2, 3: Cu-alloy (bronze)	- silicates and aluminosilicates from sand and soil - calcite - Cu carbonates and sulphates	- Minor quantity of Cu carbonate
Samples 4, 5: Fe	- calcite - silicates, aluminosilicates and phosphates from sand and soil - Fe oxides and hydroxides - Fe carbonates	- Fe oxides and hydroxides
Samples 6, 7: Pb	- silicates, aluminosilicates and phosphates from sand and soil - Pb carbonates	- Pb carbonates

Table 3. Effects of applied chemical cleaning

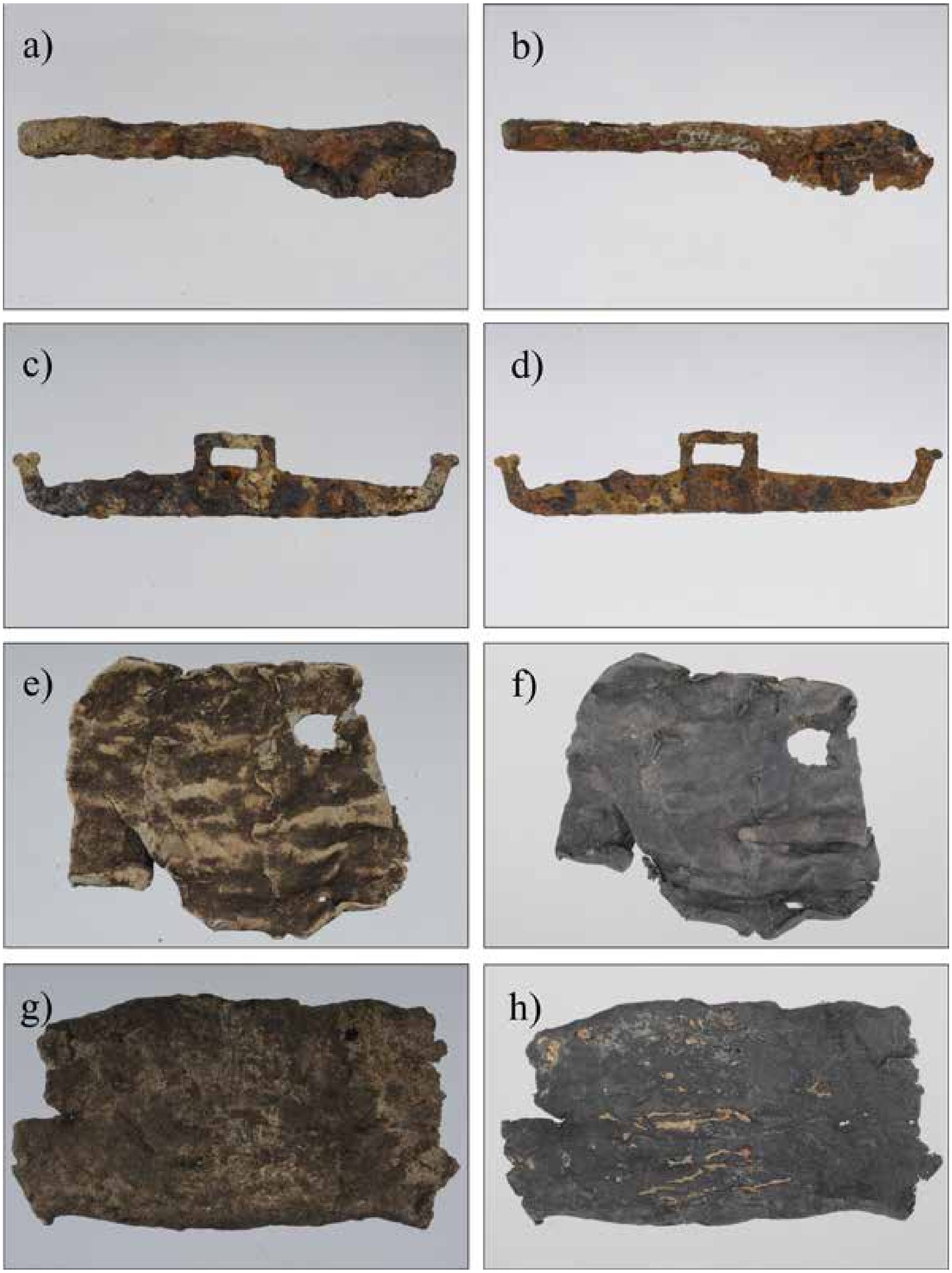

Fig. 6. Illustration of cleaning effects: Sample 4 (part of an iron key), before (a) and after treatment (b); Sample 5 (iron fitting from a bag), before (c) and after treatment (d); Sample 6 (fragment of a fitting – lead), before (e) and after treatment (f); Sample 7 (lead plate), before (g) and after treatment (h) (photos by M. Bojović).

sand and soil, were almost completely removed from all metal finds. Moreover, a significant part of the secondary phases formed from dominant metals were also removed from the artefacts.

Silver artefact. The main dark-greyish secondary phase of the silver find, which was, in addition to mechanical impurities, observed before chemical cleaning, was identified as silver sulphide (Ag_2S – possible phases are acanthite and/or argentite). The presence of silver sulphide on silver artefacts is a common corrosion product that usually occurs in the form of a thin, dark film formed in a reaction with hydrogen sulphide (H_2S) or carbonyl sulphide (OCS) in the environment, with moisture as an accelerator of reactions (reactions 1 and 2 – Selwyn et al. 1999; Graedel 1992; Polomar et al. 2016).

(1) $2Ag + ½O_2 + H_2S \rightarrow Ag_2S + H_2O$

(2) $Ag + OCS \rightarrow Ag_2S + CO$

Gases, such as hydrogen sulphide and/or carbonyl sulphide, which were necessary for the formation of silver sulphide on the examined artefact, most likely originated from the soil. Namely, the soil is highly significant both as a source and as a consumer of carbonyl sulphide. This type of gas plays a key role in the process of photosynthesis, since it is an analogue substrate of carbon dioxide (Masaki et al. 2016 and references therein), while bacteria and fungi release hydrogen sulphide during the decomposition of proteins that contain sulphur, as well as through the direct reduction of sulphates. Moreover, the final metabolic product of procaryotes that oxidise organic compounds using sulphate as a terminal acceptor of electrons is hydrogen sulphide (Lamers et al. 2013).

The analysis of the silver finds after the treatment shows that the silver sulphide was still present. However, this result, indicating partial remains of silver sulphide, was also found in a significant number of other silver cleaning treatments (Archi Olsoufieff et al. 2004; Ioanid et al. 2011; Marchand et al. 2014; Moreno-Suárez et al. 2016; Palomar et al. 2016). One of the main reasons this sulphide is not completely removed is its inability to dissolve in the slightly acidic environment of the heated EDTA – Na_3 solution (Table 2). Low oxygen concentrations without the presence of Si and Al (Fig. 3b), in the analyses after the treatment, may indicate the possible presence of silver oxide (Ag_2O). However, it is likely that, during the treatment, silver sulphide transformed into silver sulphate (Ag_2SO_4).

Some chemical analyses of the silver find show low concentrations of copper and silver (before and after cleaning). Bearing in mind that silver has often been alloyed with this element, the results of the analyses are not unusual (Goffer 2007; Artioli 2010).

Bronze artefacts. The applied chemical treatment with citric acid and EDTA-Na_3 solutions removed calcite and aluminosilicate in bronze finds (Fig. 3c), whereas the corrosion products such as copper carbonates were still present, but to a lesser extent, after the chemical treatment (Fig. 3d). Given that there are many hydrated copper carbonates – malachite /$Cu_2(CO_3)(OH)_2$/, azurite /$Cu_3(CO_3)_2(OH)_2$/, marklite /$Cu_5(CO_3)_2(OH)_6 \cdot 6H_2O$/, georgeite /$Cu_2(CO_3)(OH)_2 \cdot 6H_2O$/ etc., it is difficult to distinguish the exact phase or phases without the application of some destructive methods of identification (e.g. X–ray diffraction analysis). The presence of sulphur before chemical cleaning may indicate certain green hydrated copper sulphates, such as antlerite – $Cu_3(SO_4)(OH)_4$, brochantite – $Cu_4(SO_4)(OH)_6$ etc. These phases (carbonates and copper sulphates) may be formed in a reaction with oxygen, CO_2 and SO_2 from the air, in the presence of water at the place from which the artefacts originate.

The citric acid solution removed almost all corrosion products from sample No. 3 in a short period of time, whereas the EDTA-Na_3 solution (pH ≈ 7) gradually removed corrosion products to the metal matrix from sample No. 2 over a longer time period. The above-mentioned hydrated copper carbonates and hydrated copper sulphates are mainly dissolved in highly acidic conditions. Since the slightly acidic EDTA-Na_3 solution proved to be more efficient in removing corrosion products, it is possible that easily soluble secondary phases, e.g., chalcanthite – $CuSO_4 \cdot 5H_2O$, were also formed in these artefacts. In the natural environment it can be found as a secondary phase of copper and other metals (Moncur et al. 2015).

The content of tin (Fig, 3), as well as the minor lead content, identified in some analyses after the applied chemical treatment, originate from metal substrate, i.e., from the composition of the bronze alloy Cu–Sn–Pb (Goffer 2007; Artioli 2010), whereas the confirmed presence of silver (Figs. 3e, 3f) on the bronze coin shows that the coin was silver plated.

Iron artefacts. Small amounts of silicates, aluminosilicates and calcite occurring in the iron finds before the applied chemical treatment were removed to the greatest extent. Nevertheless, iron phases which show considerable concentrations in the form of the mixtures of oxides, hydroxides and iron carbonates, were still present in significant amounts in these iron finds (Figs. 5b, 5d). This layer is commonly called 'a thick corrosion layer' and it is characterised by the following phases: yellow–brownish goethite /$\alpha FeO(OH)$/ and black–greyish magnetite ($FeO{\cdot}Fe_2O_3$ – Fe_3O_4) (Neff et al. 2005; Neff et al. 2007; Wang 2007; Jegdić et al. 2012). Although some chemical analyses of cubic crystals confirm the presence of magnetite, the complete identification of all secondary phases could not be conducted without destructive X-ray diffraction analysis. The origin of phosphorus found in traces both in the corrosion layer and the metal substrate can be related not only to the soil in which the artefacts were found, but also to the slag inclusion (Neff et al. 2005). It is less likely that the presence of phosphorus indicates ferrous phosphate (vivianite) /$Fe_3(PO_4)_2{\cdot}8\ H_2O$/, either blue or white compound, frequently found in the excavated iron finds located near sources of phosphorus ions, such as bones or fish remains, or in the vicinity of landfills that are full of organic material (Selwyn 2004b). Although a series of chemical reactions is responsible for the formation of the corrosion layer, i.e., a mixture of various phases of iron, a simple mechanism for the formation of iron hydroxide can be described through the reaction between oxygen and water on the metal substrate, i.e., reaction 3.

(3) $4Fe + 3O_2 + 6H_2O \rightarrow 4Fe^{3+} + 12OH$
$\rightarrow 4Fe(OH)_3$ or $4FeO(OH) + 4\ H_2O$

The main reason for the partial removal of the iron secondary phases is primarily the thickness and inhomogeneity of the formed layer, whereas the long-term and more aggressive treatments could damage the metal matrix.

Lead artefacts. Uneven greyish-white and dark grey layers could be clearly seen on the lead findings before chemical cleaning, possibly due to contamination with the surrounding soil, or owing to the effect of atmospheric corrosion after the excavation (Mattias et al. 1984; Selwyn 2004a; Schotte and Adriaens 2006). The absence of chlorine and phosphorus shows that the corrosion phases cannot be constituted by chlorides and sulphates, but only by carbonates in the form of orthorhombic cerussite ($PbCO_3$) or by rarely found trigonal hydrocerussite $Pb_3(CO_3)_2(OH)_2$. It is well-known that a thin layer of lead carbonates can be quickly formed under atmospheric conditions in which the lead is rapidly coated with a thin corrosion layer of monoxide (reaction 4) that reacts with absorbed carbon dioxide, thereby forming lead carbonate (reaction 5), or lead carbonate hydroxide – hydrocerussite in an additional reaction with moisture (Selwyn, 2004b; Polić Radovanović et al., 2010).

(4) $Pb\ (s) + \frac{1}{2}O_2\ (g) \rightarrow PbO\ (s)$

(5) $PbO + CO_2 \rightarrow PbCO_3$

After the conducted chemical cleaning, silicates and aluminosilicates were mostly removed, while the dark greyish layer of lead carbonate occurred on the entire surface area of the lead finds (Fig. 5f). Plated orthorhombic crystals (Fig. 5h), formed in the cavities, indicate that lead carbonate occured in the form of cerussite.

CONCLUSIONS

The paper presents an analysis of the reactivity and efficiency of the chosen chelating agents (EDTA-Na_2 and EDTA-Na_3) and citric acid in the process of conservation treatments of metal archaeological artefacts made of silver, bronze, iron and lead. The chemical composition and the distribution of chemical elements on the surface of the artefacts before cleaning indicate the presence of characteristic corrosion products as well as some other foreign matter (soil).

As expected, the EDTA-Na_2 solution removed the lead corrosion products within a very short period of time, whereas citric acid was most efficient in removing copper corrosion products. Both solutions show a low level of selectivity and control, which further supports the fact that they can be mostly used for removing hardly soluble surface layers or entire corrosion layers. The reactivity of the EDTA-Na_3 solution on silver artefacts indicates a higher selectivity and control. Therefore, partial conservation of patina can be carried out simultaneously with the removal of impurities. In iron artefacts, corrosion layers were unevenly removed using the EDTA-Na_2 solution and citric acid. This was expected, taking into account the presence of hardly soluble iron compounds.

When the visual appearance is considered, it is necessary to carry out an additional mechanical cleaning, such as polishing, so that the artefacts can obtain an aesthetically acceptable appearance. In the case of iron artefacts (corrosion products are weakened and partially dissolved), it is necessary to carry out both chemical and mechanical cleaning.

SEM-EDS analyses of metal surfaces after cleaning did not indicate the presence of the characteristic chemical elements that could be related to possible residual compounds, as a result of reactions with the analysed aqueous solutions. Besides the necessity for further research, the overall conclusion is that the proposed chemical methods (chemical solutions) are highly efficient, easy to apply and easily available. Accompanied with the previous diagnostic examination of the artefacts' conditions, as prerequisites for the application of chemical cleaning, the proposed EDTA salts enable a wide range of possibilities regarding the selectivity and control of the chemical cleaning of archaeological findings.

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REZIME

EFIKASNOST HEMIJSKOG ČIŠĆENJA RAZLIČITIH METALNIH PREDMETA SA ARHEOLOŠKIH LOKALITETA FELIKS ROMULIJANA I GRADINA

KLJUČNE REČI: SEM-EDS ANALIZA, METALNI ARHEOLOŠKI PREDMETI, KOROZIJA, KONZERVACIJA.

U radu su razmatrani efekti hemijskog čišćenja metalnih arheoloških predmeta sa lokaliteta Feliks Romulijana - Gamzigrad i Gradina - Jelica. Studija je obuhvatila odabrane metalne arheološke nalaze, različite po funkciji i formi, izrađene od srebra, bakra - bronze, olova i gvožđa. Određivan je stepen efikasnosti različitih vodenih rastvora u kontrolisanim uslovima (pH vrednost, temperatura i vreme). Uzorci su u zavisnosti od vrste metala i korozionih produkata, kao i očuvanosti metalnog jezgra, tretirani različitim hemijskim rastvorima (limunska kiselina, natrijumove soli etilen diamin tetra sirćetne kiseline, EDTA-Na_2 i EDTA-Na_3). Makroskopska opservacija, rendgensko snimanje uzoraka (radiografija), optička mikroskopija i SEM-EDS analiza su korišćeni kako bi se utvrdilo zatečeno stanje predmeta pre tretmana, izvršila karakterizacija produkata korozije, ali i utvrdili površinski efekti hemijskog čišćenja na metalnim nalazima pre, u toku i nakon hemijskog tretmana. Rastvor EDTA-Na_2 je očekivano u vrlo kratkom roku uklonio olovne korozione produkte (karbonate), dok je limunska kiselina najveću efikasnost pokazala u uklanjanju bakarnih korozionih produkata (malahit, kuprit). Oba rastvora pokazuju nizak stepen selektivnosti i kontrole što potvrđuje činjenicu da se oni uglavnom mogu koristiti za uklanjanje kompletnih korozionih slojeva. Kada je reč o rastvoru EDTA-Na_3 nečistoće i korozioni produkti srebra (oksidi) i bakra (malahit, kuprit) su postepeno uklanjani. Ovim rastvorom u najvećoj meri je uklonjen srebro oksid u odnosu na sulfid što ukazuje na veći stepen selektivnosti i kontrole otvarajući mogućnost za očuvanje patine uz istovremeno uklanjanje nečistoća. Kod gvozdenih nalaza korozioni slojevi su neravnomerno uklonjeni pomoću rastvora EDTA-Na_2 i limunske kiseline, što je i očekivano s obzirom na prisutna teško rastvorna jedinjenja gvožđa (getit, magnetit). Kada je reč o površinskom vizuelnom izgledu neophodno je poliranje kako bi predmeti dobili estetski prihvatljiv izgled, dok je kod gvozdenih nalaza neophodno dodatno mehaničko čišćenje. Ovo istraživanje pruža odgovore vezane za efikasnost i procenu rizika izabranih hemijskih tretmana uključujući transformaciju korozionih proizvoda, formiranje hemijskih rezidualnih supstanci i uticaja fizičkih efekata tretmana na informacije sadržane u korozionim slojevima predmeta.

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LEITHA LIMESTONES’ PROPERTIES AND THEIR DEGRADATION – CASE STUDY OF BELGRADE FORTRESS

ABSTRACT

The availability and workability of limestones resulted in their extensive use throughout history for the construction or decoration of buildings, while their sensitivity to the aggressive environmental conditions initiated its degradation, leading to a loss of monumental integrity. Belgrade fortress was predominantly built of Badenian autochthonous corallinacean limestones, called “Leitha limestones” or “Lithotamnium limestones”. Since they contain red algae (Lithotamnium ramisissimum) fossils, molluscs, snails, sea urchins, corals, bryozoa and foraminifera, as well as clastic components, they are very heterogenous. This results in an uneven appearance and colour, but also mechanical properties and porosity. The mentioned features of limestones in conjunction with the influence of external factors - environmental and anthropogenic, results in their high degree of degradation. In this paper, the lithological mapping of six fortress gates dating from 15th to 18th century is shown. This determined the dominant existence of microfacies – grainstone and algal rudstone, but also the rare use of impure rudstone. Through field research and later laboratory studies, the petrological, chemical, physical and mechanical properties of these stones were examined. The results were used for the correlation of these features as intrinsic factors of decay with present weathering forms, and environmental influences as extrinsic factors. It enabled us to define the physicochemical degradation processes of limestone microfacies - cyclic dissolution, wetting/drying and freezing/thawing over a long period of time, causing the continuous progression of the intensity of decay and resulting in the present state of the studied limestone, which is in urgent need of conservation.

KEYWORDS: LITHOTAMNIUM (LEITHA) LIMESTONES, BELGRADE FORTRESS, INTRINSIC PROPERTIES, DEGRADATION, WEATHERING.

INTRODUCTION

The use of stone in construction is widespread throughout human history. From the moment of the extraction from the rock mass to the placing of the stone in a building, a long process of adaptation to the new environment begins. Physical-chemical processes that take place on the surface, but also inside the stone, can manifest themselves after a short or a very long time. The durability of the stone is reflected in its ability to resist decay over time and retain its original size, shape, hardness and appearance over a longer period of time (Bell 1993: 187–200).

The term "weathering" denotes changes in the physical-mechanical and chemical properties of stone under the influence of natural atmospheric agents (Vergès-Belmin 2008: 78). Weathering rate, on the one hand, depends on the intrinsic properties of the stone: mineral and chemical composition, structure and physical-mechanical properties. On the other hand, the degree and type of damage depends on the exposure of the stone to numerous extrinsic factors of the environment in which it is located. Within the group of extrinsic factors that aggressively affect the durability of the stone, the environment in which the building is located is of primary importance. The aggressiveness of the environment, regardless of the lithotype of the built-in stone, depends on the parameters that are defined as degradation factors: climatic, i.e., microclimatic parameters and composition of the atmosphere, with an emphasis on the presence of air pollutants, water, flora and fauna in the environment, effects of natural hazards (earthquakes, landslides, floods, etc.), but also equally significant anthropogenic influences. All these factors act synergistically on the stone and, depending on the intrinsic properties of the petrographic type, initiate certain processes of its weathering (McCabe et al. 2007: 77–86).

The manner in which intrinsic factors affect the durability of built-in stone is determined by its petrographic characteristics – mineral and chemical composition and structure, and then by its physical-mechanical properties, which are a reflection of the structure, texture, characteristics of the pore network, etc. The structural and textural heterogeneity of the stone results in its different reactions to extrinsic factors and, thus, also in different forms of decay (Mckinley et al. 2006: 1–12; Mckinley and Warke 2007: 950–969; Esbert et al. 2008: 87–95). The susceptibility of the stone to decay over time depends on all the discontinuities that exist in it, as well as on the heterogeneity in terms of shape, size and manner of interfusion of the constituents (Siegesmund and Torok 2014: 11–96), which are, all together, reflected in the porosity of the stone.

Porosity, as a textural parameter of stone, is the result of depositional and post-depositional processes and, as a physical property, it reflects the volume of pore space in the stone, type of pores (open/closed), pore size distribution, pore surface, and their interconnection and connection with the external environment (Fort 1996: 481–492). Bearing in mind the importance of the mentioned data, as well as the fact that porosity conditions the mechanical properties of the stone and determines its relationship to water, it is considered that porosity is a direct indicator of stone's sensitivity to physical, chemical and biological decay factors, even more significant than the mineral and chemical composition (Ordonez 1996; Esbert et al. 2008: 87–95).

Water, in any form, has a destructive effect on stone, by way of the crystallisation of salt or ice, biological colonisation and/or the process of dissolution of mineral components with a simultaneous decrease of hardness due to the loss of the cohesive bonds between minerals (Benavente 2006; Bell 2000). The degree of roughness of discontinuous stone surfaces (pore walls and microdiscontinuities) directly affects the level of fluid retention and adhesion of all components introduced into the stone by that fluid (soluble salts, aerosol, etc.). Greater roughness of the surface is directly proportional to a greater solution retention and, therefore, greater dissolution intensity, as well as a greater adhesion of all types of plants, from microorganisms to more complex rooted varieties. (Tomaselli et al. 2000: 251–258; Prietro and Silva 2005: 206–215; Scardino et al. 2006: 55–60, 2008: 45–53; Korkanc and Savran 2015: 279–294; Miller et al. 2012: 1–12).

Since the petrographic composition and structure of every type of stone has its own special interaction with the extrinsic factors of the environment in which it is located and, thus, different sensitivity to the physical and chemical decom-

Fig. 1. Position of the gates of Belgrade fortress subject to research (photo from Google Earth version 9.176.0.0 – Web Assembly, *Belgrade, 44°49′30″N 20° 27′40″E, elevation 79 m*, [online] available through: https://earth.google.com/web/, from November 10th, 2022, modified by M. Franković).

position processes, a detailed study of its internal nature is of extreme importance as a prerequisite for a correct selection and planning of the conservation treatment.

Among the numerous petrographic types of stone, limestones are rocks very suitable for exploitation and processing, which is why a significant number of buildings that are protected today as cultural monuments were built precisely from these rocks. While the high level of availability and workability of limestones resulted in them being abundantly used throughout all epochs of the development of civilizational heritage, their sensitivity to the aggressive environmental conditions, on the other hand, would initiate the decay process of the built-in limestone, damaging the integrity of monuments to a greater or lesser extent.

The subject of this research is the limestone used for the construction of Belgrade Fortress, which is categorised as a cultural monument of exceptional importance for the Republic of Serbia. Belgrade Fortress is located in Belgrade's old town, within Kalemegdan Park, forming a spatial cultural and historic ensemble with it. Because of its strategically important position on the border, the tumultuous history of Belgrade Fortress resulted in richness of cultural and historical layers that testify to the development of European military architecture from Antiquity to the end of the 18th century (Popović 2006: 335).

Within the architecture of Belgrade Fortress, its gates are prominent, due to their strategic function in communication routes within the fortress and as links with the main roads outside the fortress. Today, 26 gates have been preserved within Belgrade Fortress, dating from different periods of construction (Vulović 1972: 157–212). Their architecture is conditioned by their position and function within the fortifications, but also by the fortification styles that were current at the time of their construction. Considering the high frequency of circulation and the prominent placement within the fortification, aside from the utilitarian aspect, the gates also have a distinct aesthetic aspect. Special attention was paid to the decorative design of their façades, especially those on main communication routes and entrances into the fortified city. Due to the aforementioned features, the gates of Belgrade Fortress have an exceptional monumental value today and occupy a prominent place within the preserved parts of the fortification. The desire to preserve their authenticity, both stylistically and in terms of the materials they were built with, originated from the need to present them in a manner which would highlight their cultural and historical significance.

The aim of the research was to identify the main degradation processes of the limestone built into the buildings of Belgrade Fortress and to examine the role of the intrinsic properties of limestone on the form and intensity of their degradation. The research included six representative gates from different periods of construction, dating from the 15th up to the 18th century: Zindan Gate, Leopold's Gate, King Gate, Gate of Karl VI, Inner Stambol Gate and Dark Gate (Fig. 1).

In all construction phases of the fortification, mostly Badenian Lithotamnium limestones were used, the so-called *Leitha* limestones1 (Pantić 1988: 91–102). These are carbonate reef formations, deposited on the edges of coral reefs of the warm Pannonian Sea and, as such, represent a transition zone between coral reefs to non-reefal coral communities (Wiedl et al. 2013: 232–246). The former unique reef, which was later divided into smaller blocks by tectonic movements, extends from Tašmajdan to the northwest, emerging on the surface in the Kalemegdan section. These limestones have been exploited since ancient times, first at the site of the construction of the fortress, and later from the quarry of Tašmajdan. Today, the open profiles of *Leitha* limestones are visible at Tašmajdan, where they are massive, on Kalemegdan, under the monument of *The Victor* (*Pobednik*), in the form of banks, and near Belgrade Zoo, above the former Hammam, in the form of slabs or layers (Stevanović 1977: 107–162).

Due to the different nature of building organisms and variable participation of the clastic component, limestones are heterogeneous in composition and structure. This heterogeneity, as well as weak consolidation, are reflected in the physical-mechanical properties of the stone and affect the creation of different weathering forms. According to their spatial distribution and intensity, the most dominant registered weathering forms are crusts, both white calcite and black gypsum, followed by scaling, flaking and granular disintegration, which is especially present on newly exposed surfaces following crust detachment. The weathering processes result in the loss of material in the forms of backweathering and various forms of erosion. Depending on the lithotype, erosion manifests as rounding, loss of matrix, alveolisation or differential disintegration.

METHODOLOGY

The methodology of examining the intrinsic properties of the stone consisted of field surveys of selected gates of Belgrade Fortress with the aim of identifying the type of rocks (*in situ* mapping of the lithology of built-in stone blocks) and laboratory examinations: analyses of petrographic properties, chemical and X-ray analyses, determination of pore structure parameters by mercury intrusion porosimetry (MIP), and testing of physical and mechanical properties.

Considering the fact that the goal of this research is the understanding of the physical-chemical processes that lead to the degradation of limestone, samples for laboratory analyses were selected based on their susceptibility to degradation, i.e. sampling was done on stone blocks which were already affected by degradation processes. This is an important aspect for the interpretation of the results obtained. Samples were taken from the gates themselves, from blocks where the stone material had already detached, in the amount required for the preparation of petrographic thin-sections and a chemical analysis: eight samples of limestones built into the façades of the Dark Gate, four samples from the façade

1 The term "Leitha" comes from the German name *Leitha kalk* for the Vienna Basin rocks. They were named after Leitha Hills, where they were first discovered and studied.

Fig. 2. Location of sampling points on facades: a) Southeast facade of the Dark gate; b) Inner Stambol gate (Franković 2021: 48).

of the King Gate and one sample from both the Leopold's Gate and the Inner Stambol Gate (Fig. 2). For the testing of the physical and mechanical properties, it was necessary to take larger stone blocks from which the test specimens would be obtained, and they were selected from the disposal area for stone blocks at Belgrade Fortress.[2] Initially, a total of 33 stone blocks were sampled. Following identification of their petrographic characteristics, an analogy was made with the limestones built into the façades of the gates, after which seven blocks were selected to form test bodies for the purpose of testing of the physical and mechanical properties.

The mapping of the lithology of the built-in stone blocks was carried out by macroscopic observation of their structural characteristics with the application of Dunham's classification (Dunham 1962: 108–121).

The mineralogical-petrographic analysis included optical examinations of petrographic thin-sections on a *Leica DMLSP* Transmitted Polarizing Light Microscope connected to a *Leica DFC 290HD* digital camera. On the basis of the obtained results of the petrographic analysis, a structural/genetic classification of the type of limestone was carried out using Folk's classification (Folk, 1959: 1–38).

The chemical analyses included complexometric determination of CaO and MgO content by using 1 M-EDTA complex (Ethylene-diaminetetraacetic acid), and separation of the carbonate phase – by using HCl 1:3. For the test, 0.5 g of the test sample was used (if the sample showed a violent reaction with HCl) or 1 g (if the sample did not show a reaction). On the basis of the obtained contents of Ca and Mg oxides, the contents of $CaCO_3$ and $MgCO_3$ were recalculated and the rock type was determined. The content of organic matter was determined colourimetrically, by titrating the solution with $KMnO_4$ (1N), with the addition of oxalic acid.

Rock samples where an elevated MgO content was identified complexometrically, were subjected to X-ray analyses. The determination of the phase composition of the limestone samples was performed by means of an X-ray analysis of the powder, with the use of a *Philips PW-1710* diffractometer. The samples were analysed in the imaging range from 50° to 750° 2θ by using radiation obtained from a copper anticathode CuKa (1.54178 Å). The current was 30 mA and the voltage was 40 kV. Recording was performed at a step of 0.02° 2θ (2.45°/min) and a time delay of 0.5 s. The X-ray analysis of the powder can identify only the phases that occur in the examined material in amounts greater than 2%. The analyses were performed in the Laboratory of Crystallography at the Faculty of Mining and Geology, University of Belgrade.

Examinations of the physical properties of the stone were carried out in accordance with standardised methods (defined by national standards SRPS EN) with a correction of the number of test specimens due to the limited amount of sampled material (tests were performed on four instead of six samples). The following physical properties were determined: bulk and real density, open and total porosity (SRPS EN 1936:2006), water

2 At Belgrade Fortress, which has been subject to continuous renovation for the past few decades, a disposal area for stone blocks used for restoration purposes was formed. The origin of the blocks is twofold: from the ramparts of the fortress that underwent restoration phases or from archaeological excavations at Belgrade Fortress.

absorption at atmospheric pressure – immersion method (SRPS EN 13755:2009) and capillary water absorption (SRPS EN 1925:2009).

In order to determine the parameters of the pore structure of limestone, the mercury intrusion porosimetry (MIP) method was used, carried out on an *AutoPore 9500* device (Micromeritics, USA), with the maximum applied pressure of mercury intrusion of 228 MPa in the range of pore diameter sizes from 150 to 0.005 µm. The measuring was carried out at the Laboratory for Materials in Cultural Heritage of the Faculty of Technology, University of Novi Sad. Due to the limited possibilities of the scope of the research, the examination was only conducted on four samples.

The determination of pulse velocity and ultrasonic elastic constants was performed according to the SRPS B.B8.121:1990 standard. The measurement of pulse velocity of longitudinal and transverse waves – Vp and Vs was performed on two samples, on three cube-shaped test bodies (50 ± 5), with previously known values of bulk density (ρb). Measurements were performed on a *SONIC viewer – MODEL 5210* device (reading accuracy of the smallest time unit 0.10 µs).

The determination of uniaxial compressive strength (SRPS EN 1926:2010) was performed in the Laboratory for Stones and Stone Aggregates of the Highway Institute, Belgrade. The test was carried out on cube-shaped stone samples (50 ± 5 mm) in a dry state, at a constant pressure increase of 1 ± 0.5 MPa/s.

RESULTS

During the field lithological mapping of the façades, a macroscopic differentiation of the rocks was carried out on the basis of structural properties, size of the constituents and dominant type of allochem (Dunham's classification), as well as the colour of the built-in stone. Built-in lithological types were classified into three limestone facies: grainstone (Fig. 3a), algal rudstone (Fig. 3c), and impure rudstone (Fig. 3e). The overall results of the lithological mapping of the gates show an almost equal representation of grainstone and algal rudstone microfacies. Impure rudstone is rarely present, suggesting that it might have been used in the reconstruction phases of the fortress. The precise lithological determination of the examined limestones was carried out by means of an optical analysis of petrographic samples with the application of Folk's classification.

Grainstone is the dominant lithotype built into the façades of the gates of Belgrade Fortress. These are bioclastic limestones of arenitic character, with a medium to densely packed allochem made of fragments of various microfauna, mainly algal fragments, foraminifera, shells, gastropods and other types of organic detritus bound by microsparite and, rarely, sparite orthochem. Aside from bioclasts, ooids and intraclasts occur in this limestone microfacies, and according to their composition, algal biomicrosparites, oobiosparites, biosparites, intrabiosparites, as well as all transitional forms, can be distinguished. In addition to the mentioned allochems, the rocks often contain a terrigenous component in the form of quartz, mica, feldspar and rock fragments. The size of the allochem gives the rocks an arenitic character (Fig. 3b). According to their textural properties, they are characterised by occasionally noticeable thin layering, a pronounced difference in the coarseness of the allochems and regularly present porosity of the type: intergranular, intragranular, or mould-type porosity, but also secondary porosity in the form of cracks and cavities.

Algal rudstone is characterised by a porosity texture with poorly consolidated coarse allochem – algal fossil fragments with round to nodular cross-sections, measuring over 2 mm, which give the rock a rudite character. Bioclasts of other types of macro- and microfauna are usually intergrown with the algal fragments, but they are all poorly consolidated with microsparite to sparite cement, which affects the high porosity of the type of cavities, channels and cracks (Fig. 3d). Additionally, primary inter- and intragranular porosity and porosity linked to skeletal growth are also regularly present. According to the type of allochem present, these rocks are characterised as algal biosparrudites, rarely biolithites.

Impure rudstones are characterised by an increased content of the terrigenous component (> 10%), the size of which varies from arenite to rudite. The identified authigenic constituents, of sandy to gravelly fractions, are quartz, feldspars, muscovites, and rock fragments dominated by quartzites (Fig. 3f).

The results of the chemical characterisation of

Fig. 3. Limestone microfacies: a) grainstone of the northern facade of the King's Gate; b) photomicrograph of grainstone - oval to ellipsoidal forms of algal fragments, with chambers filled with sparry calcite, sample 34 of the southeast facade of the Dark Gate; c) algal rudstone of the southern facade of the Karl VI Gate with visible algal macrofauna; d) photomicrograph of algal rudstone - algal skeleton in weakly consolidated rudstone, sample 41 of the Inner Stambol Gate; e) impure rudstone of the southwest facade of the Dark Gate; f) photomicrograph of coarse lithoclast with bioclasts of impure rudstone - sample 36 of the southern facade of the Dark Gate (Franković 2021: 70, 73, 75, 76).

the examined limestones show that chemically pure limestones, with a carbonate content ($CaCO_3$) of 91.41 % to 96.27 %, dominate among the examined samples. The content of insoluble residue in the four tested samples varies from 11.12 % to 23.75 %, classifying these rocks in the group of sandy limestones (the prefix "sandy" was assigned based on the results of the optical analysis, which confirmed the presence of a terrigenous – sandy component). Only one sample was classified as impure dolomite

Sample	ρ_b (Mg/cm^3)	ρ_r (Mg/cm^3)	Po (%)	Pt (%)	Ab (%)	C (g/m$^{2 \cdot s^{-0.5}}$)
Grainstone						
S-3	1.88	2.68	/	29.8	11.05	/
34	1.84	2.68	24.30	31.21	11.61	527
37	1.84	2.70	24.69	31.85	13.44	/
42	1.68	2.70	27.84	37.42	16.90	997
43	1.90	2.70	21.17	29.70	11.17	∥ 325
						⊥ 395
44	1.87	2.70	21.85	30.46	11.68	255
	1.83	2.70	23.97	31.74	12.64	500
min	1.68	2.68	21.17	29.70	11.05	255
max	1.90	2.70	27.84	37.42	16.90	997
Stan.Dev.	0.08	0.01	2.64	2.90	2.25	
KV	4.33	0.38	11.03	9.14	17.85	
Algal rudstone						
Z-1	1.95	2.68	/	28.05	7.39	/
Z-2	1.50	2.59	/	41.00	14.11	/
K-4	1.84	2.71	25.17	32.10	13.60	/
K-5	1.81	2.74	23.60	33.90	13.00	/
K-7	1.94	2.75	20.76	29.50	10.70	/
K-9	1.80	2.74	26.97	34.30	15.13	/
38	1.98	2.72	18.42	27.10	9.29	/
S-1	1.75	2.67	/	34.40	12.52	/
S-2	1.82	2.70	/	32.80	11.20	/
41	1.76	2.70	27.96	34.99	15.94	415
8	1.85	2.71	21.90	31.33	11.85	215
11	1.74	2.69	24.08	35.40	13.86	513
15	1.79	2.70	25.83	33.57	14.40	434
23	1.89	2.69	23.57	29.71	12.48	219
	1.82	2.70	23.83	32.73	12.53	359
min	1.50	2.59	18.42	27.10	7.39	215
max	1.98	2.75	27.96	41.00	15.94	513
Stan.Dev.	0.12	0.04	2.89	3.54	2.32	
KV	6.50	1.44	12.14	10.84	18.52	
Key: – mean value; min – minimal measured value; max – maximal measured value; Stand.Dev. – standard deviation; KV – coefficient of the variation.						

Table 1. Physical properties of grainstone and algal rudstone samples (according to Franković 2021: 97, 108)

limestone, due to the high presence of MgO, i.e., dolomite mineral (12.72 %). In all the examined samples, the content of organic matter is extremely low and varies from 0.03 % to 0.08 %.

The presence of dolomite was also confirmed by an X-ray analysis. Diffractograms indicate that calcite is the main mineral phase (078-4615; ICDD PDF Standard), and that, aside from the presence

Sample	P_{om} (%)	V_p (ml/g)	PP (m^2/g)	D (μm)	D_c (μm)	S_c (%)	D_u (μm)	S_u (%)
Grainstone								
34	33.12 (24.3)	0.189	0.728	1.04	29	31.24	40	9.59
42	35.01	0.205	1.149	0.71	38	20.32	60	7.69
Algal rudstone								
41	32.54	0.184	1.127	0.65	40	36.76	60	20.88
8	29.51	0.162	1.219	0.53	18	27.94	50	5.83

Table 2. Parameters of the pore structure for grainstone and algal rudstone samples (according to Franković 2021: 100)

Sample	Pore volume (%)				
	Macro-pores D > 0.05 μm			**Meso-pores D** = 0.05-0.002 μm	
	Large pores 1000-100	Pores 100-10	Large capillaries 10-0.05	Medium capillaries 0.05-0.01	Small capillaries 0.01-0.002
Grainstone					
34	2.52	58.22	38.40	0.85	0.00
42	3.26	62.09	32.98	1.67	0.00
Algal rudstone					
41	6.36	56.81	35.54	1.28	0.00
8	2.92	37.01	58.38	1.68	0.00

Table 3. Volumetric distribution of the pores by their size in the grainstone and algal rudstone samples (according to Franković 2021: 101)

of dolomite (074-7800) in sample 34 and Mg-calcite (089-1304) in sample 37, the rocks regularly contain quartz (087-2096) and feldspar-albite (009-0466). It is important to point out that the presence of a small amount of the gypsum mineral (076-8728) was registered in both samples, which is certainly a secondary product of limestone degradation.

The results of the physical properties (bulk density – ρb, real density – ρr, open porosity – Po, total porosity – Pt and water absorption – Ab) of the examined limestone samples are shown in Table 1.

The results of the testing of parameters of the pore structure using the MIP technique on the grainstone and algal rudstone samples are expressed in the values of open porosity (Pom), total pore surface (PP), mean pore diameter (D), critical pore diameter (Dc), entry pore diameter (Du), volumetric content of pores with diameters larger than the critical diameter (Sc) and larger than the entry pore diameter (Su), and distribution of defined pore size classes (Tables 2 and 3).

The grainstone samples are characterised by close values of Pom (33.12 % and 35.01 %, Table 2), PP shows small variations in the examined samples, i.e., it is slightly higher in sample 42 compared to sample 34, which is consistent with the size ratio of the mean pore diameter. Differences are also evident in the pore size distribution, i.e., the representation of the defined classes of the corresponding range of pore diameters (Table 3). The grainstone samples have a unimodal pore size distribution with a dominant presence of the 10–100 μm pore diameter size class and the almost twice as small presence of the 0.05–10 μm pore diameter size class (Table 3). The content of large pores (100–1000 μm) is extremely small (2–3%), and the content of pores <0.05 μm is almost negligible (0–2%). The range of variation of Dc values also shows uniformity in the examined grainstone

3 The open porosity value of 33.12% is significantly different from the value of 24.3% obtained by the laboratory test procedure using the immersion method according to the SRPS EN 1936:2006 standard (all other samples have close values). The difference is due to the textural heterogeneity of sample 34.

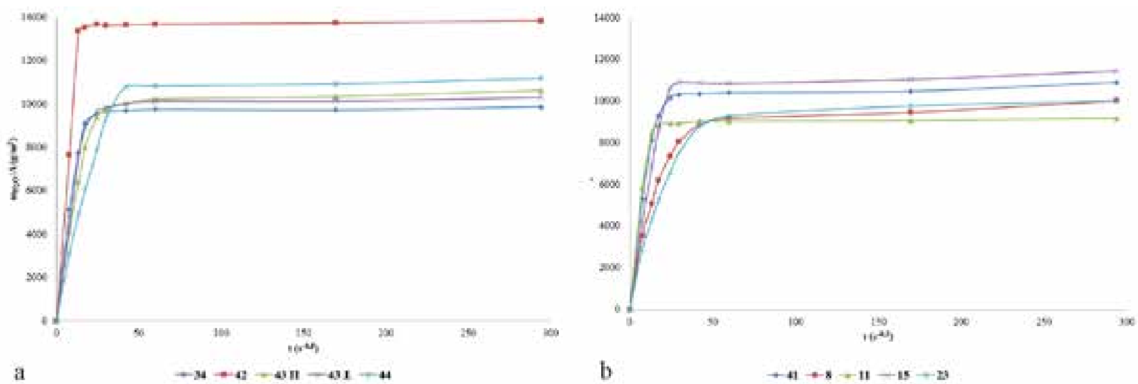

Fig. 4. Curves of capillary water absorption: a) grainstone; b) algal rudstone. (according to Franković 2021: 109, 111)

samples (22–50 μm), with an average value of 34 μm for all analysed samples.

Algal rudstone samples have close Pom values, little difference in PP values, and close mean pore diameter values (Table 2). However, differences are prominent in the pore size distribution (Table 3). Both samples have a unimodal pore distribution, but with different modes. While the dominant population of pores in sample 41 has a size of 100–10 μm (56.81 %), sample 8 is in the 10–0.01 μm size class – 58.38 %. Both samples are characterised by a small presence of medium capillaries and an absence of small capillaries. Despite the similarity in mean pore diameter values, the size of the critical pore diameter varies from 50 μm in sample 41 up to 15 μm in sample 8, indicating a difference in the pore network available for fluid movement.

The mode and trend of capillary water absorption are represented by diagrams of the ratio of the mass of absorbed water per unit area as a function of the square root of time (Fig. 4). In addition to the graphical presentation of capillary absorption curves, the results are also shown by the capillary absorption rate, expressed by the capillary absorption coefficient (C) (Table 1). For the sample with pronounced thin layering (43), test results are shown in parallel, or perpendicular to the anisotropy plane. Capillary absorption curves, of both limestone varieties, initially have asymptotic flow that, after a certain time, passes into a stationary absorption mode. The capillary uptake curves are linear, which indicates that the pore network is homogeneous (Beck et al., 2003: 1151–1162), while the C values indicate different kinetics of capillary absorption. The high value of C – 997 $g/m^{2 \cdot s^{-0.5}}$ in sample 42 indicates extremely fast absorption, while the values of the other samples vary from 225 to 527 $g/m^{2 \cdot s^{-0.5}}$. In algal rudstone, C varies from 215 to 513 $g/m^{2 \cdot s^{-0.5}}$ and the curve shows a slight increase in the last time interval, indicating the process of extrusion of air trapped in the pores (Beck et al., 2003: 1151–1162).

Based on the measurement of the velocity of propagation of longitudinal and transverse waves, the values of the dynamic elasticity module (Edyn) and Poisson's coefficient (μdyn) were calculated as parameters representing the hardness of the porous stone, especially its internal structure. Grainstone has ~26% lower propagation values for both types of waves compared to algal rudstone (Fig. 5). The difference is twice as great if we compare the mean values of the dynamic elasticity module, which is 3.19 GN/m^2 for grainstone, and 6.74 GN/m^2 for algal rudstone, which is in agreement with the porosity results of the examined samples (the open porosity of sample 42 is higher than the open porosity of sample 8 – see Table 1). The volumetric presence and pore size did not affect the value of Poisson's coefficient, which is 0.35 for both the microfacies. Based on the results of compressive strength measurements of the selected representative samples, it is concluded that the grainstone and algal rudstone samples have low, but similar, uniaxial compressive strength values (7.2 MPa grainstone and 6.35 MPa algal rudstone), which is in agreement with the close values of other properties such as, for example, total porosity. It is characteristic for all tested samples that the fractures were subtle, without any special sounds, and the form of destruction was along the cracks that intersect the axis of the sample at an angle.

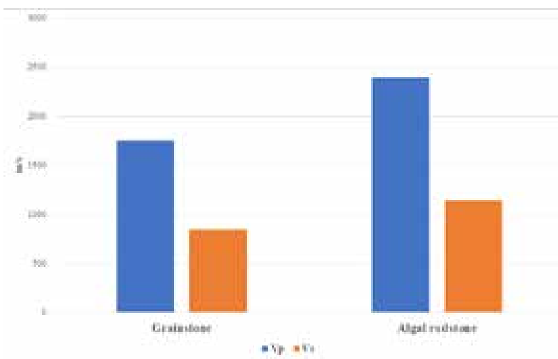

Fig. 5. Histograms of the results of measuring the velocity of longitudinal waves of grainstone and algal rudstone samples

DISCUSSION

Limestones built into the gates of Belgrade Fortress show signs of weathering in various individual decay forms: granular disintegration and scaling, alveolisation, flaking and splintering, the appearance of light and black crusts, biological colonisation and others. The observation of the mentioned decay forms and correlation with petrological and physical-mechanical properties established the influence of intrinsic factors of built-in limestone on the representation of individual decay forms, without major differences in the intensity of degradation.

The results of petrological analyses and lithological mapping of stone blocks built into the façades of the gates at Belgrade Fortress quantitatively showed the distribution of limestone microfacies. From the aspect of the genetic type of rock, i.e., the dominance of limestone as the building lithotype used, the gates of the fortress are petrologically and mineralogically homogeneous. From a chemical point of view, the most common type are pure limestones ($CaCO_3$ content ~95%) and less common impure limestones with variable $CaCO_3$ content (76–89%). Dolomitic limestones were also identified, rather sporadically, in which the dolomite component is prominent (12.72% $MgCO_3$). When it comes to the structure, however, the heterogeneity of the incorporated limestones is notable. These are allochemical sediments, classified into three microfacies according to the ratio, packing and size of allochem: grainstone, algal rudstone and impure rudstone.

Although structurally different, the physical properties of the examined grainstone and algal rudstone are very similar. According to the values of the bulk and real density, both varieties of limestone are medium-heavy rocks, i.e., soft limestones with a coarse-porous texture. The total porosity values classify them as extremely porous rocks. Both limestone lithotypes have almost the same values of open porosity and mean pore diameter (G-0.9 μm, AR-0.6 μm), very close values of critical pore diameter (G-34 μm, AR-29 μm), with the inlet pore diameter in the range of 40–60 μm. The grainstone pore network is homogeneous with a unimodal pore size distribution, a dominant class of pores with the size of 10–100 μm (~60%) and a significant participation of large capillaries (30–40%). Algal rudstone shows heterogeneity in the pore structure, with pores and large capillaries alternating as dominant classes.

According to the pore structure, the examined lithotypes are characterised by high water absorption, with a high capacity for capillary water absorption. Grainstone samples have an average coefficient of capillary water absorption of 376 g/m2·s-0.5,[4] while in algal rudstone it is 359 g/m2·s-0.5, which can be defined as a high coefficient of capillary absorption, and at the same time an indicator of the rock's susceptibility to decay (Snethlage 2005; Graue et al. 2011: 1799–1822).

A large amount of capillary pores with a unimodal character of distribution, as well as the small difference between total and open porosity in both lithotypes, indicate a good interconnection of pores, capable of absorbing and retaining water and enabling its transport through the interior of the built-in limestone. Pore size is a crucial parameter that regulates fluid movement through the stone pore system. While pore sizes of 1 mm – 1 μm enable a high degree of water absorption, pore sizes below 1 μm and their interconnections are considered critical for the stone's susceptibility to decay. They enable easy capillary movement of fluids, and when they are additionally well connected, they facilitate the diffuse movement of solutions along with a simultaneous increase in the intensity and surface of stone dissolution. A high content of capillary pores conditions a larger specific surface, which represents, at the same time, the surface available for capillary condensation and moisture retention and, thus, the ag-

4 The extreme value of sample 42 was excluded from the statistical analysis.

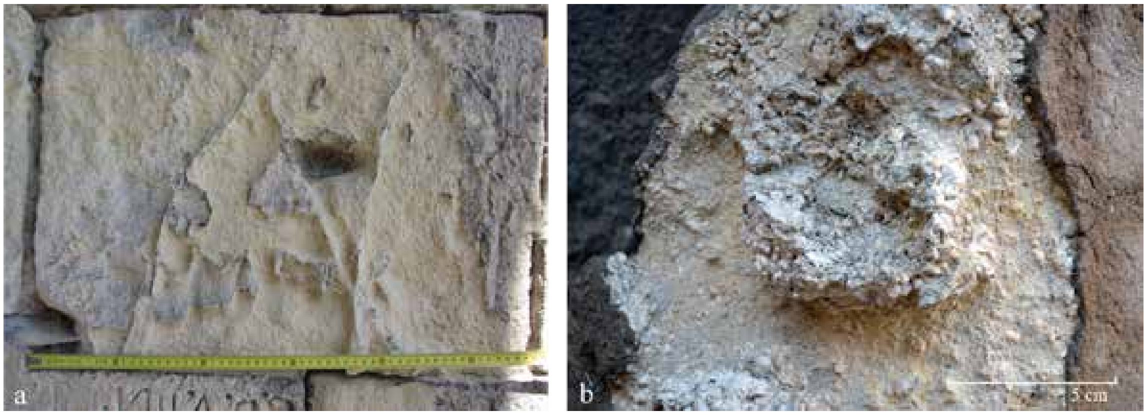

Fig. 6. Differential weathering of the same damage category – manifestation according to structural characteristics of the microfacies: a) grainstone; b) algal rudstone (Franković 2021: 70, 81).

gressive action of all components that enter the stone with the fluids. Additionally, when it comes to pores with sizes of 0.1–1 μm, the crystallisation and hydration pressure of ice and salt represent a regular destructive factor to the stone (Benavente 2006; Bugani et al 2007: 316–320; Benavente 2011: 41–42). High coefficients of capillary water absorption indicate the ability of both lithotypes to absorb water in an amount that enables long-term moisture retention and consequent dissolution and migration of soluble salts (Graue et al. 2011: 1799–1822). The overall pore network of the examined limestones enables unhindered water circulation and consequent chemical dissolution, primarily of the orthochem. Therefore, the pore structure of both lithotypes enables the physical and chemical decomposition processes to take place, which led to the present state of the built-in limestones.

According to their mechanical properties, both varieties of limestone can be characterised as soft rocks with a low propagation velocity of ultrasonic waves and very low to low compressive strength. Since it has been proven that the compressive strength of porous limestone decreases significantly in a water-saturated state compared to the values in a dry state (Vásárhelyi 2005: 69–76; Torok and Vásárhelyi 2010: 237–245), and the pore network of the examined limestones enables long-term water retention, it can be considered that the mechanical resistance of the limestones built into the gates of Belgrade Fortress is very weak, which makes them sensitive to all types of physical destruction.

When considering the morphology of the degradation in relation to the lithotype, the petrological (structural-textural) influence on the decay forms is evident in the manifestation of individual decay forms. Cavities and the presence of coarse allochem in algal rudstone favours biological colonisation, as well as the formation of deposits on surfaces. The higher content of the limonite component in grainstone, under the influence of high temperature, causes chromatic changes. The textural characteristics of the grainstone cause the detachment of centimetre-thick scales, which has not been observed in the algal rudstone. The thickness of the crust corresponds to the difference in the size and packing of the allochem, the position of structurally different layers, which further affects the movement of the drying and wetting fronts, and the generation of hydration and crystallisation pressures of salt or ice. All of the above leads to scaling. Backweathering of grainstone occurs with greater intensity precisely due to scaling, compared to algal rudstone, where it is a consequence of the crust detachment or splintering. Erosion, in the form of alveolisation and differential weathering, is a more common characteristic of grainstone. Differential weathering is a consequence of the existence of areas with harder, firmer and more compact constituents, which are, thus, more resistant to decay over time. While this form occurs in grainstone due to the existence of structurally different layers and/or locally deposited secondary calcite, when it comes to algal rudstone, especially biolithite, Lithotamnium algae remain prominent due to the granular disintegration of softer parts of the limestone (Fig. 6).

Granular disintegration and flaking mostly occur with equal intensity and, therefore, in the same damage categories in both lithotypes. The different intensity that can occur even within one block of stone is, on the one hand, a consequence of the heterogeneous microstructure of the examined limestone blocks, and on the other, the intensity of the degradation processes. Granular disintegration is intense in those parts where the cement binder has been washed away or mechanical microdamage has occurred due to the action of hydration and crystallisation pressure, on newly opened surfaces after the detachment of the surface crust/ scale. In the zones of surface crusts, this weathering form has not been registered, due to the compaction of intergranular spaces with dissolved calcite and/or gypsum.

In contrast, significant differences in the intensity of individual weathering forms in relation to the lithotype have not been recorded. The presence of all damage categories on both lithotypes, with great similarity of physical-mechanical properties, generally indicate their equal susceptibility to weathering processes, while the degree of damage on individual stone blocks is related to their exposure to extrinsic decay factors.

CONCLUSIONS

Based on everything presented previously, in the complex mechanism of weathering of the limestone at Belgrade Fortress, key intrinsic factors have been identified that enable the physical-chemical weathering processes to take place. The carbonate composition, i.e., the presence of mineral calcite, which is soluble in water and weak acids, enables the chemical dissolution of limestone. The diagenesis of the studied limestones caused weak cementation, which results in low mechanical strength and high porosity. The pore network allows for an unhindered circulation of water and the consequent chemical dissolution of poorly cemented algal rudstone and sparite grainstone cement, weakening the stone from within. Dissolved calcite recrystallises on the surface in the form of a thin white crust, while black gypsum crusts form on protected stone blocks, created by the chemical reaction of calcite with atmospheric pollution. The porosity of the limestone, and the type and distribution of the pores also allow for unhindered freeze/thaw cycles, which result in physical damage in all forms of detachment. The repeating of dissolution, wetting/drying and freezing/thawing cycles over a long period of time causes a continuous progression of the intensity of decay and the appearance of very prominent damage in various forms of loss of the stone material. The simultaneous action of the mentioned principal decay mechanisms on built-in limestones, otherwise susceptible to decay, results in the present condition and is a clear indicator of the urgent need for conservation.

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REZIME

SVOJSTVA LAJTOVAČKIH KREČNJAKA I NJIHOVA DEGRADACIJA − STUDIJA SLUČAJA BEOGRADSKE TVRĐAVE

KLJUČNE REČI: LITOTAMNIJSKI (LAJTOVAČKI) KREČNJACI, BEOGRADSKA TVRĐAVA, INTRINZIČNA SVOJSTVA, DEGRADACIJA, ATMOSFERSKO RASPADANJE.

Predmet ovog istraživanja su litotamnijski (lajtovački) krečnjaci korišćeni za izgradnju Beogradske tvrđave, koja je kategorisana kao spomenik kulture od izuzetnog značaja za Republiku Srbiju. Istraživanje je imalo za cilj identifikaciju glavnih procesa raspadanja ugrađenih krečnjaka i ispitivanje uloge intrinzičnih svojstava krečnjaka na formu i intenzitet njihovog raspadanja. Istraživanjem je obuhvaćeno šest reprezentativnih kapija iz različitih perioda gradnje, datovanih od XV do XVIII veka: Zindan, Leopoldove, Kralj kapije, kapije Karla VI, unutrašnje Stambol kapije i Mračne kapije.

Metodologija ispitivanja intrinzičnih svojstava kamena sastojala se od terenskog rekognosciranja odabranih kapija Beogradske tvrđave sa ciljem identifikacije vrste stena (*in situ* mapiranja litologije ugrađenih kamenih blokova) i laboratorijskih ispitivanja: ispitivanja petrografskih karakteristika, hemijskih i rendgenskih ispitivanja, određivanja parametara porne strukture živinim porozimetrom (MIP), te ispitivanja fizičkih i mehaničkih svojstava.

Rezultati petroloških analiza i litološkog mapiranja kamenih blokova ugrađenih u fasade kapija Beogradske tvrđave, kvantitativno su pokazali distribuciju izdvojenih mikrofacija krečnjaka. Sa aspekta genetske vrste stene, odnosno dominacije krečnjaka kao ugrađenog litotipa, kapije tvrđave su petrološki i mineraloški homogene. Hemijski posmatrano, najzastupljeniji su čisti krečnjaci i manje prisutni nečisti krečnjaci sa varijabilnim sadržajem $CaCO_3$ (76-89 %). Sasvim sporadično su identifikovani i dolomitski krečnjaci u kojima je markantno učešće dolomitske komponente. Strukturno posmatrano, međutim, izražena je

heterogenost ugrađenih krečnjaka. To su alohemijski sedimenti koji su prema odnosu, pakovanju i veličini alohema svrstani u tri mikrofacije: *grainstone*, algalni *rudstone* i nečisti *rudstone.*

Iako strukturno različiti, fizička svojstva ispitivanih *grainstone* i algalnog *rudstone* su veoma slična. Prema vrednostima prividne i stvarne zapreminske mase oba varijeteta krečnjaka su srednje teške stene, odnosno mekani krečnjaci gruboporozne teksture. Vrednosti ukupne poroznosti svrstavaju ih u ekstremno porozne stene. Porna mreža *grainstone* je homogena sa unimodalnom distribucijom veličine pora, dominantnom klasom pora veličine 10-100 μm (~60 %) i značajnim učešćem velikih kapilara (30-40 %), dok algalni *rudstone* pokazuje heterogenost u pornoj strukturi gde se kao dominantne klase smenjuju pore i velike kapilare. Saglasno pornoj strukturi, ispitivane litotipove karakteriše veliko upijanje vode, sa velikom sposobnošću kapilarne apsorpcije vode. Prema mehaničkim svojstvima, oba varijeteta krečnjaka se mogu okarakterisati kao meke stene sa niskom brzinom prostiranja ultrazvučnih talasa i vrlo niske do niske čvrstoće na pritisak.

U složenom mehanizmu raspadanja krečnjaka Beogradske tvrđave, identifikovani su ključni intrinzični faktori koji omogućavaju odvijanje fizičko-hemijskih procesa raspadanja. Karbonatni sastav, odnosno prisustvo minerala kalcita koji je rastvorljiv u vodi i slabim kiselinama, omogućava hemijsko rastvaranje krečnjaka. Dijageneza ispitivanih krečnjaka uzrokovala je slabu cementaciju, što za posledicu ima nisku čvrstoću i veliku poroznost. Porna mreža omogućava nesmetanu cirkulaciju vode i posledično hemijsko rastvaranje slabo cementovanog algalnog *rudstone* i sparitnog cementa *grainstone*, slabeći kamen iznutra. Rastvoreni kalcit rekristališe na površini u formi tanke bele kore, dok se na zaštićenim kamenim blokovima formiraju crne gipsane kore, nastale hemijskom reakcijom kalcita sa atmosferskim zagađenjem. Poroznost krečnjaka, tip i distribucija pora omogućavaju i nesmetano odvijanje ciklusa mržnjenja/otapanja koje rezultira fizičkim *oštećenj*ima u svim oblicima odvajanja. Ponavljanje ciklusa rastvaranja, vlaženja/sušenja i mržnjenja/otapanja tokom dužeg vremenskog perioda, izaziva kontinuiranu progresiju intenziteta raspadanja i pojavu veoma jakih oštećenja u različitim formama gubitka kamenog materijala. Simultano delovanje navedenih glavnih mehanizama raspadanja na ugrađene krečnjake, inače podložne raspadanju, rezultira današnjim stanjem i jasnim indikatorima urgentne potrebe za konzervacijom.

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THE RUDIMENTS OF TRADITIONAL MORTAR PREPARATION AND USE

ABSTRACT

This paper seeks to summarise recent major shifts in the understanding of the nature and provenance of traditional mortars, the nature of the lime most used for the preparation of these mortars, as well as the methodology of the crafts in their preparation. It draws upon the author's experience of designing and using such mortars over a 20-year period, but also upon extensive research into old texts about lime and mortars written over the last 2,000 years, as well as upon extensive analysis of primary building accounts from England and elsewhere. It also references an expanding body of academic research in the characterisation of composition, as well as of the performance of such mortars, itself a significant shift in focus and understanding. It will set out the primacy of the quicklime slaking method in the delivery of successful mortar performance, optimal in the context of traditional building technology, and will reiterate the absolute importance of observing traditional lime choices, slaking method, rules and mortar proportion in the achievement of durable mortars of optimal performance for the like-for-like and compatible repair of traditional buildings of all kinds and status.

KEYWORDS: QUICKLIME, LIME MORTAR, EARTH-LIME MORTAR, HOT-MIXING METHOD, LIME SLAKING, POZZOLANS, MORTAR PROPORTION.

INTRODUCTION

As it becomes increasingly understood that most historic mortars were hot mixed with quicklime, and as increasing numbers of craftspeople around the world are rediscovering and routinely using such mortars in the care and repair of traditional buildings, it is important to set out the fundamental principles of lime slaking and mortar making methodologies, drawing upon the extensive historic texts on the subject of building, as well as upon building accounts and material science, with a view to avoiding simple mistakes with less than simple consequences. Much detail remains to be discovered, not only by the crafts themselves, but by professionals, researchers and academics in the field – intellectually as well as, crucially, by practical experience and observation. The author has worked with traditional earth-lime and hot mixed lime mortars for 20 years as a stonemason and building conservator and has conducted an extensive review of historic texts and archived building accounts ranging over the last 2,000 years. The story that these tell is generally consistent over this period - and is consistent with the experience of those using hot mixes again today - but is a very different story from that told, even by advocates for the use of lime mortar, over the last 50 years (Copsey 2019 a & b).

HOW DO WE CHARACTERISE HOT MIXED LIME OR EARTH-LIME MORTARS?

After many years of confusion within academic circles and beyond, it is now beyond dispute that, in most cases, the presence of residual inclu-

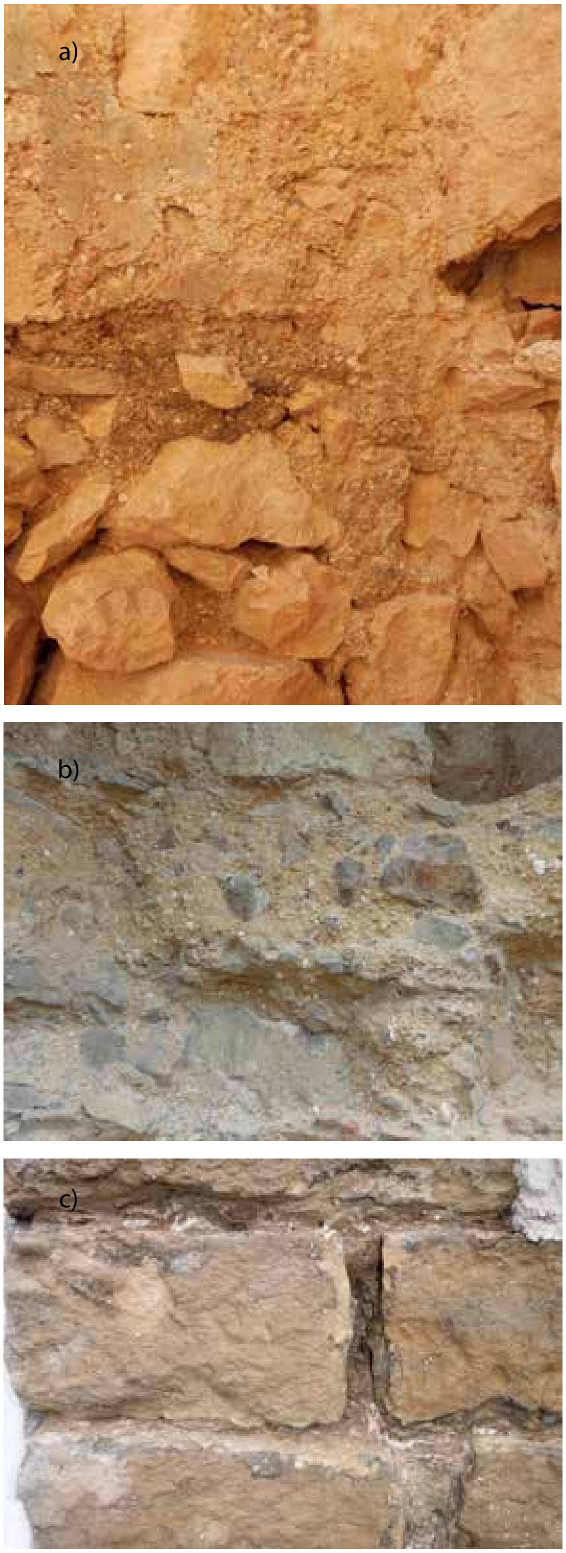

Fig. 1. The presence of residual lime lumps in earth-lime mortars from different periods and geographies: a. Masada, Israel, 2,000 years old; b. Rievaulx Abbey Cloister, North Yorkshire, 12th century; c. bedding mortar in the wall of calcareous sandstone, Wrench Green, North Yorkshire, 19th century (all photos by N. Copsey; c. from Copsey 2019c).

Fig. 2. Earth-lime mortar and remnants of pure lime basecoat plaster, medieval dovecot, Calvados, Normandy (photo by N. Copsey).

sions of lime – sometimes underburned quicklime, sometimes over-burned, sometimes simply slaked, unmixed and subsequently carbonated lumps, of variable dimension, but typically angular – indicates the preparation of the mortar to have been performed using a hot mixed method (Hughes, Leslie, Callebaut 2001), which is to say, that quicklime is slaked and mixed with intended aggregates as soon as the slaking is substantially complete, the quicklime remaining hot from the slake. When powdered or pulverized quicklime was used, the quicklime and sand would be mixed prior to or during the slaking of the quicklime, without generally leaving lime lumps in the mortar, but typically rich in lime (Revie 2019a). Figures 1a – 1c illustrate the presence of residual lime lumps in three earth-lime mortars from different periods and geographies, demonstrating not only their essential commonality, but also their dura-

Fig. 3. Hot mixed lime mortar with basalt beach sand, Vancouver Island, British Columbia, 1864 (photo by N. Copsey).

bility in significantly different climates. Figure 2 illustrates earth-lime mortar and remnants of pure lime basecoat plaster, in Normandy, while Figure 3 illustrates a typical hot mixed lime-sand mortar, in this case in British Columbia.

Callebaut (2000) was the first in a laboratory context to make a connection already made by numerous craftspeople such as Patrick McAfee (1997; 1999), disproving previous opinions (Bakolas et al 1995) that residual lumps were comprised of the thin, soft calcite crust that would form upon the surface of laid down lime putty, incorporated when this putty was mixed with aggregates to form a mortar. How such low volumes of soft calcite crust might account for such high volumes of hard residual lime lumps in actual mortars was seemingly not considered.

The possibility of hot mixing was long ignored in favour of a long-standing cognitive bias that held that most mortars historically had been made using matured lime putty, which the technical evidence, as well as the evidence of most historic literature and material science, indicates that they were not. Lime putty was always made, of course, although the period of repose would vary from days to weeks to months and even years, but for very specific purposes and for uses that made the continued presence of residual lime lumps problematic – such as fine plaster and stucco finish coats and the finest brick or stone ashlar jointed bedding mortars, within which lime putty was used as the mortar itself, on its own, and without the typical addition of sand or other aggregates (Langley 1750; Millar 1898). For more than these particular uses, lime putty was generally distrusted and considered to be lacking in binding qualities, compared to those that existed in a hot mixed lime mortar, which is not to say that it was never used in combination with aggregates, of course, depending upon practical circumstance. Beyond this, the preparation, storage, and later use of lime putty required much more handling and labour, reducing its efficiency when compared to a mortar that might be mixed and used immediately, even when that mortar might itself be laid down for a week or two, or sometimes longer, to allow for late-slaking to occur before a plaster was laid upon a wall (Higgins 1780; Millar 1898), although even this was not as common as many suppose (Langley 1750, Pasley 1826, Lazell 1915). A properly slaked lime putty ('just sufficient' water added to effect the slake, before some further water addition once the slake was complete, and whilst the heat of the slake endured) produced a material universally described in the past as having been of 'bread-dough' consistency, and of much greater immediate and subsequent density (and lower water content) than most commercially produced 'lime putties' available today. Lime putty so-slaked was a mouldable, plastic material (that resembled linseed oil window putty in character) that enjoyed excellent internal bonds and into which water was typically 'locked' and effectively invisible and unavailable to promote the 'swimming' of stones laid upon it, for example, or the staining of masonry substrates during use – much like a hot mixed lime: an aggregate mortar, in fact.

At Viminacium in modern-day Serbia, the former capital of Upper Moesia, the vast majority of Roman mortars so far revealed, whether pure, feebly hydraulic, or more hydraulic mortars according to purpose, retain lime lump inclusions consistent with the mortars having been hot mixed from quicklime, in the author's observation (Nikolic & Rogić 2018), as were the vast majority of sampled and analysed mortars from Roman Britain (Vindolanda mortar analysis in Revie 2019b; www.hotmixedmortars.com). Ottoman Empire mortars in Serbia and elsewhere were similarly processed in the author's observation and assessment. In the lands of modern-day Israel, mortars of all kinds (including earth-lime mortars) from every period – from as early as 10,000 BC, where hot mixed earth-lime and lime mortars were deployed as grave covers, as well as wall plasters– were hot mixed from quicklime and are considered to display a sophistication in processing that might indicate an already mature technological understanding during the Pre-Pottery Palaeolithic Era (Friesem et al 2019). In Greece, analysis of 1,300 mortars used during at least the last 2,000 years, offers a very similar picture, with the overwhelming majority of Hellenistic, Roman, Byzantine, Ottoman and medieval mortars, as well as those still used during the earlier 20th century, displaying residual lime lumps consistent with their having been hot mixed directly from quicklime (Stefanidou and Pappyianni 2011).

A similar picture may be seen in the British Isles, as in most places across the world. Lime putty formed the binder in a small minority of over 4,000 mortars analysed by the Scottish Lime Centre Trust (Historic Environment Scotland 2020), (Fig. 4), and even this may represent a misinterpretation, given that the not uncommon use of powdered quicklime historically would leave no residual lime lumps in the mortar. A long laid down hot mixed plastering mortar, knocked up before use, might display very few residual lime lumps.

Alternatively, hot mixed mortars might be laid down after mixing, subsequently used whilst cold – although there was a broad consensus historically that the majority of mortars, for the majority of purposes, should be used within a week of preparation; this consensus only becoming less firm as the 20th century wore on, and during which same period, lime putty came to be used much more as a binder, often in association with low level Portland cement addition to otherwise air lime mortars, uniquely delivering a mortar of similar workabili-

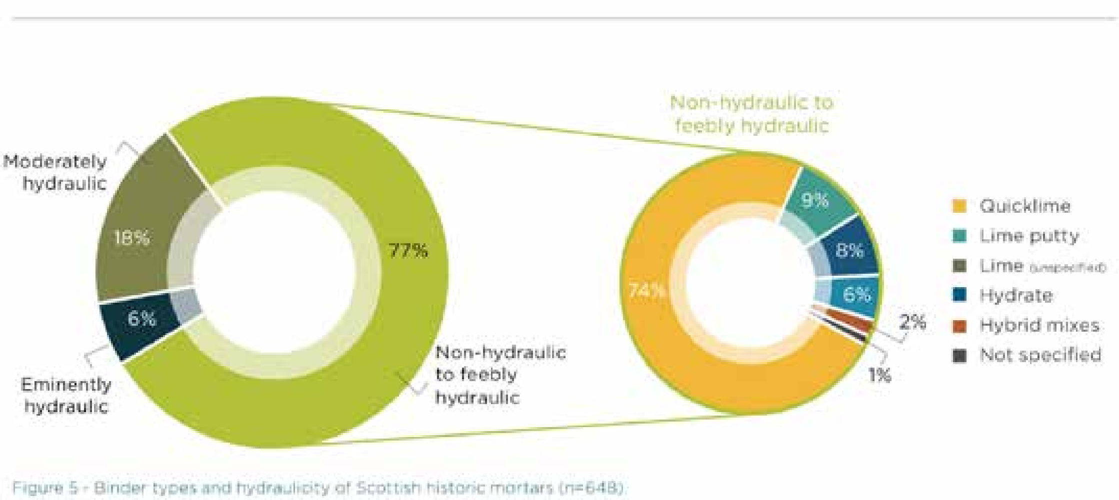

Fig. 4. Collated analyses of over 4,000 samples held by the Scottish Lime Centre. (Historic Environment Scotland Technical Paper 32, 2020).

HOT MIXING METHODS

The precise hot mixing method might vary between dry-slaking (common for plastering mortars, the larger unslaked lumps sieved out- along with larger aggregate inclusions – after mixing with sand, or immediately after slaking and immediately prior to mixing with aggregates, if not used on its own after sieving and mixing with water, and with fibres added to control shrinkage) – or wet slaking, straight through to a useable mortar.

These mortars might be used whilst still hot, which offered significant advantages to the crafts in terms of initial shrinkage behaviour and general efficiency, as well as – recent research would suggest (Koeberle 2020) - forming a stronger immediate bond with substrates and delivering early stiffening in situ due to the immediate and rapid evolution of Portlandite crystal structures within the mortar, as well as offering greater durability over 'cold-mixed' alternatives.

ty to a traditional hot mixed mortar (Totten 1842, Geeson 1952, Copsey 2019 a & b). The lime putty typically 'matured' for days (plasterer Ray Warley, pers. comm.) or for several weeks, or sometimes only a week (Nicholson 1841, Millar 1897).

The particle size and character of a dry-slaked lime differs somewhat from a wet-slaked lime paste, as well as from that of a lime putty; this was known intuitively by the crafts, so that the slaking method was often determined by the intended purpose. Dry slaked lime forms an irreversible crystalline (and larger) particle, whereas wet slaked lime (or lime putty) forms a platelet structure with a finer particle size and significantly greater surface area (Rodriguez-Navarro et al 2005). The smaller and more malleable the particle size, the greater the likely bond with aggregates will be. This difference affects their workability and behaviour in use. A plaster mortar made with a dry slaked lime – even of similar lime-to-aggregate proportion – will typically shrink less than a wet-slaked or lime putty mortar, although it will also be typically less workable, of lesser adhesiveness and cohesiveness., in use. Before the 20th century, dry-slaked lime would be produced on site. Vicat (1837) discusses the immediate placement of such lime into barrels for storage. However, in most cases, prompt, if not immediate, use will have been the norm.

LIME PURITY

Contrary to many prevailing narratives today, and since the widespread promotion and use of initially Portland cement and, more recently, natural hydraulic lime, (usually coupled with a dismissal of the value and usefulness of fat limes for any purpose), the quicklime that was preferred, in all periods and in all regions of the world, was as pure as might be found. 'Pure or nearly pure' would be the most accurate description. This understanding, made evident in all reviewed texts about lime and craft practice historically (see Copsey 2019b, Appendix 10), runs contrary to recent narratives concerning the historic use of natural hydraulic limes, which were, in fact, rarely used for much beyond the making of concretes, lest, like the Blue Lias lime used in the UK, (Smeaton 1791; Taylor & Levon 2021) they were of unusually high free lime content, offering more workability, when they might be used for waterworks, although always with the addition of pozzolan to consume the excess of free lime, consistent with their purpose. In Scotland, where far fewer pure limestone deposits were available, and where natural hydraulic limestones were more common, the desired pure lime was derived from sea-shells, abundant along an extensive coastline, or were imported by sea and river from Northumbria or from Cumbria, across the border in England, whilst indigenous sources of pure or feebly hydraulic lime were exploited wherever they existed, as is evidenced by the building accounts of the Royal Works before the 1709 union with England (Accounts of the Masters of Works Vols 1 & 2 1957). This picture is demonstrated in Fig. 4, above. Even in the first recorded use of lime mortars, by the Natufian culture in the Palaeolithic Era, at the excavated burial site of NEG II, the immediate geology was of dolomitic limestone and the mortars were made with a high calcium lime carried from further afield for the purpose (Freisem et al 2019). The Romans were aware of impure limestones that delivered strongly hydraulic mortars – Pliny (2015) calls it 'silex' – but preferred to use hot mixed pure lime and pozzolan mortars for waterworks and in other inherently wet situations. The most hydraulic pozzolanic mortar, which would ultimately consume all free air lime, offered a workability in use – delivered by the free lime before its consumption to form (primarily) di-calcium silicate, otherwise known as belite - that was little different than that of a pure lime and sand mortar; it enjoyed excellent initial water retentivity, contributing to optimal bond formation (Boynton & Gutschick 1964) and was, anyway, considered more reliable and more stable during its life-time, when compared to a mortar made from natural hydraulic lime (Totten 1842). Indeed, masons would frequently reject NHLs (Biston 1828), in favour of fat lime mortars that offered a workability that NHL mortars did not and which did not dry too quickly (the countering of which demanded significant on-going hydration, which fat limes did not, and significantly more time-consuming aftercare, as well as the extensive wetting of building units). Vicat (1837) says that these must be saturated and kept that way for a long period prior to use, compromising the necessary bond formation and promoting the swimming of newly laid building units, thereby hampering building progress. When using a fat lime mortar, only the initial rate of suction (Hall & Hoff 2009) needed to be satisfied to prevent over-rapid drying of the mortars. This allowed for immediate and sufficient bond, as well as the full extent, of durable bond and it was generally enough to dip a brick or stone in water immediately prior to bedding it, or to splash an existing mortar joint before pointing it, after which no more on-going hydration would generally be required. Fat limes need to lose their excess of water to begin to set, but will lose this slowly and steadily; NHLs need water to set, but will lose what water they contain very quickly in the absence of long-term and on-going hydration.

Pure or nearly pure lime was predictable and of generally similar behaviour and performance wherever it was found. Many limes contained small volumes of clay or other impurities, and these may or may not have been reactive silicas or aluminas. Even if they were, in small volumes, these might have made a mortar feebly hydraulic, but their slaking behaviour and ultimate strength would have been only marginally different from a pure lime, and might, in fact, ultimately have delivered a slightly weaker mortar than their pure lime equivalents (Dibdin 1911). Any advantage that there was, was in the initial shrinkage behaviour, it being significantly reduced. This same advantage could be won by the addition of small volumes of brick or of wood ash, or another pozzolan, to an otherwise pure lime mortar. Such additions were common at the craft level in all periods and places, particularly, perhaps, for pointing mortars. The addition of even 10% pozzolanic material (as a proportion of the slaked lime) would leave 80% of the binder as pure lime, continuing to offer high – if not quite optimal – effective porosity. Most often, around 5% pozzolanic addition is found in analysis. (Revie 2019b; www.hotmixedmortars.com). After the laboratory research of Roman mortars in Serbia, there is an ongoing study into the possibility of using natural pozzolanic materials and lime with hydraulic properties at the provincial sites of the Roman Empire - Viminacium and Lederata, for the mortar production (researcher Emilija Nikolić, pers. comm). Romans at Viminacium abundantly used brick in mortars in humid and water environments, and there is also an indication that some red fragments in mortars were actually 'natural brick' formed by the spontaneous combustion of shallow coal-seams that lay beneath the clay soil in the nearby hill, since the laboratory research confirmed its pozzolanic features (Nikolić, Tapavički-Ilić, Delić-Nikolić 2022). In Israel, brick, cocciopesto and wood ash were used for a similar purpose, the routine use of wood ash as a pozzolan arriving in the region with the Romans (Van Zuiden & Asscher 2021) and this, along with other Roman practices were swiftly adopted by King Herod. Hydraulic quicklime and wood ash mortars, as well as hot mixed cocciopesto mortars, used to plaster water cisterns in Masada remain intact today, 2,000 years after placement, in the author's observation, and as assessed by Tal Hayut, the lead conservator at the site. A recently excavated lime kiln at Masada (Figs. 5 and 6), built to a typical Roman pattern, which contained in situ air-slaked and carbonated lime, as well as unburned limestone, would indicate not only chemical purity but also the burning

Figs. 5 and 6. Masada lime kiln and associated lime slaking area just below, where the slaked lime was discovered (photos by N. Copsey).

of limestone from without the local geology, suggesting its careful selection and carriage. Analyses of both are currently underway

Natural hydraulic limes are eminently variable (and unpredictable) materials (Figueiredo 2018; Seo Jun 2020), not only between sources, but within the same source (Fig. 7). Boynton (1980) saw this as the primary obstacle to the use of NHLs for building, although as early as 1777 Le Sage, in France, had called for the prohibition of NHLs for general building purposes for the same reason (Vicat 1837). Their initial setting times vary significantly from one batch to the next, and this would always have alarmed the building crafts (as it still does today). It may be considered a basic principle of building that the mortars of construction should be of the same strength and character throughout the build, and certainly above ground. NHLs do not deliver this certainty whilst, at the same time, they have been shown to continue to gain strength over an unknown, but possibly indef-

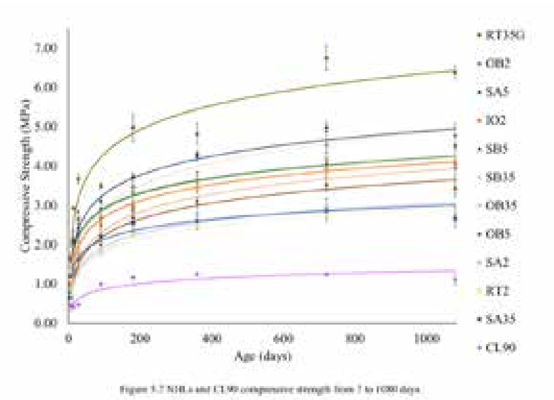

Fig. 7. NHLs and CL90 compressive strength from 7 to 1,080 days (Figueiredo 2018).

inite, period after placement, each gain in strength indicating an increase in density and an associated diminution in an already low effective porosity. This, with the ongoing hydration necessary for them to set properly. In the absence of such ongoing hydration, over a period that might need to be 6 months – their period of maximum strength-gain – they are unlikely to set properly, remaining (behind an apparently set and hardened face) as a mush or as a powder within a masonry joint, in the authors' observation, as well as that of others (Roger Curtis, Historic Environment Scotland, Technical Research team, pers. comm.). This latter behaviour is commonly seen in the UK, where many give little to no hydration after placement, leaving the mortars to rely upon received rainfall and frequently high relative humidity only. At the same time, NHL-pointed traditional buildings in the UK and elsewhere tend to display permanently elevated moisture levels in their fabric, which will peak during the winter months, but only slightly diminish during the summer, once more, in the author's observation.

In contrast, traditional buildings that retain their original pointing mortars, or which have been repointed with non-hydraulic hot mixed lime mortars (often after years of suffocation by sand: cement or NHL mortars) quickly dry after wetting and remain perennially dry in their fabric in all seasons. (Figs. 8-12)

Effective porosity – like appropriate and useful workability – is primarily delivered by a high free/air lime content (Wiggins, in Copsey a 2019). A mortar that enjoys a high level of air lime will possess a high proportion of capillary-active pores held within an inter-connected pore structure. Whilst the fundamental laws of physics indicate that the penetration of received water will be but

Figs. 8 and 9. Marske Hall; porous Jurassic sandstone' Repointed with NHL. Winter and summer, the latter image taken after five months without significant rainfall (photo by N. Copsey).

Fig. 10. A humbler building of similar geology, pointed with hot mixed air lime mortars, Pockley, North Yorkshire (photo by N. Copsey from Copsey 2019c).

minimally absorbed into an essentially dry capillary-active material (Pender 2012) – a behaviour known to all masons who work on old buildings, who might soak existing traditional mortars before repointing, to find that this water has been absorbed to a very shallow depth, in fact. This received water, as well as that which might be generated by interstitial condensation, and by moisture generated within a building interior, or from the ground, will be quickly released into the atmosphere due to wind or air movement powered capillary activity, so that a fabric that retains its original or otherwise air lime-rich mortars will tend to be perennially dry and resistant to water penetration – all the more so because a mortar rich in air lime will have retained enough water during and immediately subsequent to its application for optimal bond formation with the substrates or the masonry units, thus offering high resistance to water penetration (ASTM 2007; Johnson 1926). In addition, such bonds will be durable – they will not be disrupted by expansion and contraction during wetting and drying, or during thermal cycles (Palmer 1931 - US Bureau of Standards Research Paper 321). Hydraulic mortars are not stable in such cycles and this characteristic will compromise the bond has been formed in mortars lacking in water retentivity, such as sand and cement, and natural hydraulic lime mortars without any, or much reduced, free air lime content (Johnson 1926).

Beyond this, and as demonstrated by the US Bureau of Standards (Palmer 1931 - Research Paper 321) as long as 100 years ago, the initial shrinkage of a fat lime mortar happens at a moment when the mortars remain plastic, allowing easy closure of such shrinkage, this being the only shrinkage such a mortar will exhibit in its lifetime. The Bureau further demonstrated that, although hydraulic mortars exhibit much less, or no apparent initial shrinkage, they will shrink by up to four times the extent of the initial shrinkage in a fat lime mortar in their life-span, but only after they have set hard. Even unclosed initial shrinkage in a fat lime mortar (the leaving of which was not unusual in craft practice at a time when most buildings were routinely limewashed upon completion and throughout their life-time) will not present a structural or performance issue – received moisture will quickly evaporate away. Shrinkage in a much less effectively porous hydraulic mortar will always be a problem, allowing the ingress of re-

Fig. 11. Archbald Moffat House, Moffat, two years after repointing with NHL 5.0 mortar (photo by N. Copsey from Copsey 2019a).

Fig. 12. Archbald Moffat House, Moffat, two weeks after repointing with a hot mixed air lime mortar and after 12 hours of rainfall (lean-to on the right still retains NHL pointing) (photo by N. Copsey).

ceived water that will find its egress much less immediate or straightforward, leading to cumulative dampness.

In this context, the addition of relatively small volumes of air lime to a clay-bearing subsoil, was sufficient to counteract the swelling of clay particles upon wetting (and their subsequent shrinkage upon drying), enhancing the durability of their bond to the substrates as well. The addition of 10 or 20% of pure lime was the norm, not only for plasters and bedding mortars, but for solid-wall earth construction also (Vegas et al 2014), in very many cases. Sometimes more lime than this was added, depending upon the situation and purpose. At the Atlit Crusader fortress near Akko, in modern-day Israel, earth-lime mortars are found below the water-line, in excellent condition and still fit for purpose (Eli Sklar, pers. comm.), exploiting the feebly hydraulic reactions that can occur between the lime and clay components (Boynton 1980).

Experience and observation in the UK (as well as in Israel, where similar NHL mortars have been used over the same 25-year period for routine conservation and repair) has shown that most masonry buildings repointed or otherwise repaired with NHL mortars quickly become wet in their fabric, and that this wetness tends to become cumulative – very similarly, in fact, to that which occurs when sand and cement mortars are used. (Figs. 8-12). Over 20-year time spans (and frequently sooner), such mortars tend not to behave sacrificially in the presence of salts or other decay mechanisms, and the stones or bricks decay exponentially. (Figs. 13-15).

Ongoing wetness of the fabric has also promoted frost damage – at Lincoln Castle, for example, where limestone faces regularly fall off during winter months (the specifying architect, pers. comm.). The pore size distribution of NHL mortars is similar, in tests, to that of cement and sand mortars, and both mortars (Wiggins 2019), which are of similar overall porosity, are low in capillary-active pore sizes, meaning that received water is slow to be removed from the fabric, as well as being encouraged to combine with already present water molecules, to penetrate and to linger. In Israel, the low effective porosity of pointing mortars has facilitated significant decay of masonry units in the presence of salts, in the author's observation, whilst the NHL mortars remain largely intact (Figs. 13-14). A similar situation is increasingly observed in the UK (Fig. 15) – much as Smeaton observed about the use of NHLs in association with Bath stone, as long ago as 1756:

Figs. 13 and 14. Akko, Israel. Exponentially decaying calcareous sandstone after repointing with NHL premixed mortar (photo by N. Copsey).

"The Bath freestone is of the pure calcareous kind, and it is remarked that when it is walled with this kind of mortar (*blue lias NHL, with high free lime content*), which is *frequently,* if not generally, used for the purpose, the joints are more permanent, and resist the weather better, than the stone itself…" (Smeaton, account of Edystone etc p115 1791)

In Israel, as in most parts of the world, including North America, per the author's understanding, only naturally feebly hydraulic limestones exist (and existed) in an accessible form – their routine use has never been and cannot be a like-for-like response to the care and repair of traditional buildings, even had NHLs been extensively used in those regions with the limestones that might deliver them hydraulicity, which they

Fig. 15. Pennine sandstone, 20 years after repointing with St Astier 3.5 mortar. Salt-induced decay of the sandstone; no sacrificial behaviour in the mortars, Studley Royal, North Yorkshire (photo by S. Baxter from Copsey 2019a and 2019c).

were not. For building above ground, NHLs may be seen as generally defective in their behaviour, character and performance and, in their low capillarity and high strength (by comparison with traditional mortars), generally incompatible with the porous construction mortars and especially incompatible with porous stone or brick, and with earth construction generally.

By contrast, in my own (and other practitioners') experience and observation, hot mixes made with pure or nearly pure; pure or feebly hydraulic quicklimes, and made to historic lime: sand proportions are efficient and economical to produce. They offer mortars of eminent workability, encouraging good and efficient workmanship. They also offer optimal water retentivity and excellent bond strength as well as a consistent, full extent of the bond. Additionally, they demand much less after-care than other forms of lime. They are tenacious and they offer appropriate durability. As long as traditional building details are respected and maintained, may can be expected to last indefinitely. The addition of small (or even large) volumes of pozzolan enhances the tenacity and speed of the initial set without compromising workability, water retentivity or other essential mortar characteristics. They offer highly effective porosity, keeping the building fabric dry and thermally efficient and reducing the need for repair or replacement of building elements.

WORKABILITY

As is evident in innumerable historic texts (Copsey 2019b, Appendices 4, 10 & 11), workability was the standard, historically. If a mortar was workable, it was considered fit for purpose. This essential mortar property was substantially forgotten during the 20th century, as less than workable mortars – specified by individuals who did not themselves use them, their design frequently driven by abstract laboratory testing - have come to dominate building practice, encouraging the addition of chemical additives, such as air entrainment, in pursuit of a semblance of workability. These additions will often serve to eliminate the necessary capillarity.

Surprisingly, perhaps, although due, one might suggest, to the legacy of extensive research into mortars carried out by the US Bureau of Standards during the 1920s and 1930s, and to the work of Robert Boynton in the USA more recently (1964; 1980), historic understandings are perfectly expressed in the modern ASTM guidance:

"X1.5.1 *Workability* – Workability is the most important property of plastic mortar. Workable mortars can be spread easily with the trowel into the separations and crevices of the masonry unit. Workable mortar also supports the weight of the masonry units when placed and facilitates alignment. It adheres to vertical masonry surfaces and readily extrudes from the mortar joints when the mason applies pressure to bring the unit into alignment. Workability is a combination of several properties, including plasticity, consistency, cohesion, and adhesion, which have defied exact laboratory measurement. The mason can best assess workability by observing the response of the mortar to the trowel. …Good workability is essential for maximum bond with masonry units…. (p6)" (ASTM International C270-07. 2007).

This bonding characteristic is due to workability's indication of excellent water retentivity (Boynton & Gutschick 1964)).

Furthermore, C270-07 emphasises the importance of lime for the formation of durable bonds that will most effectively resist water penetration, as well as removing excess moisture that might promote frost damage. "X1.6.4 *Durability*....The coupling of mortars with certain masonry units, and design without exposure considerations, can lead to unit or mortar durability problems. It is generally conceded that masonry walls, heated on one side, will stand many years before requiring maintenance…Parapets, masonry paving, retaining walls, and other masonry exposed to freezing whilst saturated represent extreme exposures and thus require a more durable mortar. (p7)…. A wall containing [a straight Portland cement and sand mortar] would be strong but vulnerable to cracking and rain penetration….A wall containing… [a straight sand-lime mortar] would have lower strength, particularly early strength, but greater resistance to cracking and rain penetration" (ASTM International C270-07. 2007).

According the author's perception, and feedback from the crafts who recently re-embraced the use of traditional mortars, most masons and other building crafts throughout most of history would agree with the statements above. The question has only been which kind of mortar best meets these demands. Until very recently, there was no debate or discussion about this within the crafts. It was an earth-lime or a hot mixed fat or feebly hydraulic lime mortar, amended, according to exposure, by the addition, as necessary, of pozzolanic additives to the same.

As late as 1910, in France, Champly succinctly expressed the hierarchy of building mortars: "We differentiate mortars thus: fat lime, used for raising walls, hydraulic lime for foundations, substructures, basement and works meant to be immersed. Slow (Portland) or prompt (natural) cement for underwater works or in very humid places" (p.54)

There was no obsession about strength or, indeed, with drawing real-world conclusions about practice on site from generally unrepresentative laboratory experiments. Palmer and Parsons (1934) described typical laboratory freeze-thaw tests as 'meaningless' in the context of real buildings and their mortars in the 1930s. In the United Kingdom, there was no standard for the compressive strength of building mortars until 1938 (Stewart 1997). Before the ascendancy of modern, thin-wall construction technology, there had been no perceived need to know – traditional mortars routinely delivered between 1 and 2 MPa and recent research strongly indicates that a typical and properly proportioned hot mixed lime mortar will reliably achieve 2 MPa after 3 months (Truschik 2018), (See Fig. 16), and a typical earth-lime mortar, 1 MPa over a similar period (Rashmi et

Table 2 Compressive Strength Development

Mortar Mix	Vicat Cone (mm)	Air (%)	Compressive Strength(MPa)			
			28d	56d	90d	6 months
P1	32	3.5	-	0.75	1.01	1.55
P2	22	3.75	-	0.80	1.20	1.94
W1	12	-	0.90	1.28	2.02	-
W2	24	4	0.82	1.53	1.98	-
W3	18	5.25	0.80	1.48	2.05	-
W4-X	19	7.5	0.22	1.22	1.27	-
W4	31	5.5	-	1.21	1.21	-

Note: 1MPa = 145 psi

W1 1:3 Graymont kibbled quicklime from Quebec: Nesbitt sand
W2 1:3 Graymont powdered quicklime ditto; Nesbitt sand
W3 1:3 Indiana limestone fired on site: Nesbitt sand.
P1 and P2, sand-slaked but not hot mixed.

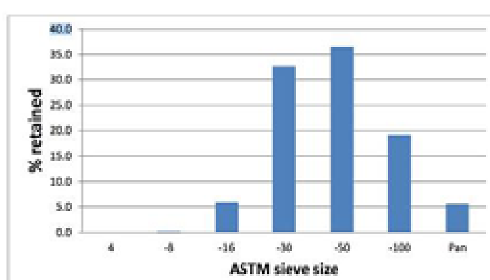

Fig. 16. Tested lime mortar samples. W1, 2 & 3 sampled whilst still hot (Truschik 2018).

al 2014). Both of these were more than sufficient to ensure the structural soundness and integrity of a traditional building of solid wall construction, and, indeed, included a generous redundancy to such mortars and structures. In 1911, Dibdin doubted the utility of laboratory testing of mortars, suggesting that experienced observation and the inability to crush a small sample of original mortar between thumb and forefinger would be sufficient to demonstrate its fitness for purpose (Dibdin 1911).

Over the last eight years, there has been a major revival in the routine use of hot mixed pure and feebly hydraulic limes (Henry 2018), as well as – to a somewhat lesser, but also growing extent, the use of earth-lime mortars - in the UK and Ireland, across Scandinavia and in parts of central Europe, as evidenced by the Gatherings of the Building Limes Forums in these regions. This revival continues to grow and to expand into North America, Australasia and, most recently, across Israel, where the Antiquities Authority has initiated seven major research streams into all aspects of traditional mortars and their use (Carmel Y, presentation to the Building Limes Forum Ireland, 4th September, 2022), whilst the conservation crafts themselves have begun to explore and to deploy like-for-like mortars for perhaps the first time. This change has been substantially driven by the crafts, assisted by some more enlightened structural engineers and other professionals, as well as by the research teams of Historic England and Historic Environment Scotland, the latter of which have commissioned and published seven Technical Papers (numbers 25 – 33) dealing with different aspects of traditional mortar preparation, use and performance. As has become clear during numerous conversations with the author in recent years, many craftspeople had become frustrated by the widespread commercially driven use of natural hydraulic lime mortars, and associated pre-mixes, which their own experience suggested were inappropriate, unpredictable and potentially damaging to traditional buildings not at all built or, until recently, repaired with more than feebly hydraulic mortars. This renewed embrace of substantially like-for-like materials – the existence and nature of which had been largely forgotten by the building trades and substantially ignored until recently by the conservation community internationally, as well as by academics and professionals working within this community – has been met with resistance from vested interest, both commercial and intellectual, but has gained a seemingly unstoppable momentum. For all of us craftspeople, it has been, and continues to be, a steep but deeply satisfying and empowering re-learning curve, after years of focus on materials that were not so much used for the purposes to which we have sought to put them – particularly lime putty (frequently improperly slaked) and natural hydraulic limes. The best teacher of all, of course, has been, and will always be, the material itself and the methodology by which it should be processed.

"In all the regions of France and Italy I have travelled to study the way of building, I questioned workers, the ones who seemed the smartest. I found that their knowledge came, from a practical side, from use and experience. There are many differences in materials; it is not possible to prescribe specific methods, because every rule requires uniform qualities and properties in the materials, which does not happen. A worker of long experience knows how to judge if the mortar is fat enough, beaten enough, if it has the right consistency - he almost never makes a mistake; he crushes and mixes the different materials until it feels right. This is why it is not enough to propose methods, we need to train workers to understand and modify them on account of the materials and buildings intended to be built. There is an infinity of things that cannot be said nor prescribed in advance. We can only indicate the general precautions to take for the most important operations, which are the methods of slaking lime and the methods of mixing it with sand and cement *(pozzolan)* to make a good mortar." (Rondelet 1803 p.301)

It is essential to the successful performance and anticipated longevity of traditional mortars, whether used in the context of repair of existing buildings and fabric, or in the context of new build (and this, not only in the context of the inherent good sense and fitness for purpose of traditional building technology, but of its essentially sustainable nature in the context of mounting climate chaos), that historic methods of preparation and historic binder to aggregate proportions are observed. These rules and prescriptions were consistent for thousands of years, the condensed wisdom and experience of craft practice over millennia. They have been substantially departed from, in terms of preferred binders and binder to aggregate proportions, for not much more than 120 years in some parts of the world, and for fewer years than this in other parts. Indeed, in some parts of the world, less touched by the constrictive tentacles of global capitalism, it is likely that the knowledge and practice of hot mixing has never been lost.

MORTAR PROPORTION

During the 20th century, typical mortar proportions changed significantly, lime mortars becoming leaner in binder content than at any time before. In the cement-lime mortars that dominated mid-20th century practice (a compromise between traditional mortars and modern, thin-wall building methods, as well as the growing rate of exploitation of the building crafts and the demand for rapid construction (Searle 1935, Powell 1980), after the realisation that cement and sand mortars led to leaky building fabric and to the accelerated decay of masonry units) the typical binder to aggregate proportion was 1:3. The binder might comprise 1 part Portland cement to 3 parts air lime (which might be industrially hydrated air lime or, if an especially workable version was demanded, lime putty or quicklime) to 12 parts aggregate. It might be 1:2:9 or, for especially exposed situations, 1:1:6. (Mitchell 1947). Common to all of these (and many other local variations) was a 1:3 binder to aggregate proportion. In this case, this reflected the increased power of Portland cement, as well as a saving in cost. In the observation of the author and as has been researched by Yotam Carmel and Eli Sklar, conservators, the majority of buildings of Tel Aviv were built with such mortars, as were very many brick and stone buildings across the UK and North America. The vast majority remain in a sound and healthy condition, although this can quickly unravel when such fabric is repaired with sand and cement or, indeed, NHL mortars. A lime rich cement-lime mortar offered a good and durable bond, as well as good functional performance and such mortars tend to behave sacrificially when required. The free lime content of even a 1:1:6 exceeds that of most currently available NHLs, many of which also exhibit tri-calcium silicate (alite) content, unlike historic NHLs, which were burned to deliver only belite into their composition (Davy 1802, Eckel 1922, Figueiredo 2018).

The 'Lime Revival', which originated in Sweden (Holmstrom 1996) and very soon afterwards began in the UK, continued this 1:3 proportion, typically using lime putty, a significant volume of which was water, not lime, potentially increasing the already unprecedented leanness of such mortars dramatically, unless this was accounted for in the gauging (which it frequently was not). Around 30% of the volume of even a properly slaked, dense lime putty, will be water, not lime. (Boynton 1980). The failure in situ of many (although not all) lime-lean lime putties across the UK in the early years of the 'Lime Revival' unquestionably led to the overly eager and unresearched embrace of NHLs in the UK, following the clear encouragement of its use by English Heritage after 1997 (Ashurst 1997). NHLs, too, were mixed at 1:3, with little attention paid to the variable bulk density of these materials between and within brands (Figueiredo 2018), or to traditional mixing proportions for such binders.

In both cases, such mortars, whether NHL or lime putty, were mixed at a significantly lower lime content than their historic equivalents, when such were used, and most certainly with at least half the lime content of the leanest hot mixed lime mortar in the past.

If a traditional, hot mixed lime mortar as lean as 1 part lime to 3 parts aggregate exists, it has yet to be discovered and analysed. The leanest ratio at which such mortars were mixed, as evidenced by innumerable mortar analyses across the world, (Revie, material scientist, pers. comm. and example mortar analyses Revie 2019b) and of mortars from every period, was 1 part quicklime to 3 parts aggregate, when fat limes were used. A pure or nearly pure quicklime will typically at least double in volume during slaking, delivering a binder to aggregate proportion of at least 2 parts lime to 3 parts aggregate, although some of this lime content will be in the form of residual lumps, and be aggregate, not binder. A ratio of 1 part lime to 1 part aggregate (made by mixing 1 part quicklime with 2 parts aggregate) is as commonly found. Many lime mortars historically were even richer in lime than this. Typical lime pointing over earth-lime building mortars in North Yorkshire were hot mixed but were 2 parts lime to 1 part aggregate (in this case, finely sieved limestone aggregate) ('Stonehouse' mortar analysis in Revie 2019b) (Fig. 17). Such mortars have been shown to have lasted 400 years or more. In 18th century London, bricklaying mortars might have been hot mixed at 2 parts quicklime to 1 part sand, delivering a mortar that was 4 parts lime to 1 part sand (Langley 1750). It was in response to such apparent profligacy with the most expensive ingredient (the lime), that Charles Pasley was prompted, in 1826, to set parameters on the essential lime to aggregate proportion (Pasley 1826). He concluded that 1 part quicklime to 3 parts sand was the most sand that might be carried without compromising either workability or performance, and that the most lime-rich mortar that might be generally required was made with 1 part quicklime to 2 parts sand. He considered any more lime than this to be wasteful (he was a military engineer keen to control Government expenditure) and a reflection of the desire of the crafts for the stickiest, most cohesive and adhesive mortar they could get. That said, the most commonly found lime to aggregate proportions on analysis, from the Roman period onwards, has been 2:3 or 1:1.

Fig. 17. Dry hot mix pointed building, "Stonehouse", Thornton-le-Dale (subject of a referenced mortar analysis by Revie) (photo by N. Copsey).

NHLs, when used, were also made from quicklime (at least until 1896, when Lafarge in France began to produce slaked, dry hydrated NHL lime (Gillmore 1871)). These expanded less on slaking, the less so, the greater their hydraulicity, and were mixed at 1:2 or 1:1, quicklime to aggregate.

When already slaked lime was used or specified, this was never leaner than 1:2 (Vicat 1837, Pasley1826), except in the case of concretes, when the quicklime to aggregate proportion could be as lean as 1:7 (when NHL was initially displaced as a binder for concrete, the proportion was often 1: 8). (McKay 1938; Mitchel 1912)

A further error of the 'Lime Revival' was to condemn the use of dry hydrated lime, a form of slaked lime that had a much longer historically pedigree as a binder than had lime putty. Lime sieves (indicating dry slaking of quicklime) appear routinely in building accounts in the UK in all periods (Copsey 2019b). Dry slaking allowed for the screening of mortars after mixing, removing larger lumps of unslaked lime, as well as of aggregate. It was less cohesive and adhesive than a wet-slaked mortar, but still more adhesive than most modern mortars. It tended to promote less initial shrinkage on application as a plaster, and tended to be richer in residual lime lumps than a wet slaked equivalent, which may or may not be significant.

SLAKING

The temperature of the slake is the single most important aspect of the hot mix method, as it is of all kinds of lime production. Simply put, the temperature of the slake needs to reach at least 100 °C (Hassibi 2011). This temperature inevitably produces steam and, in most hot mixing methods, this steam will slake at least some of the lime, in tandem with liquid water. The significance and effect of this is currently being researched at Northumbria University (Pesce 2021). In the commercial lime industry, dry hydrated lime is typically produced by the steam slaking of powdered quicklime, and a slaking temperature of between 100 and 120 °C is demanded (Lafarge-Tarmac, Buxton, pers. comm.).

Historically, it is said repeatedly, by numerous authors, that lime which slakes the fastest and the hottest is the best. Moxon (1703) and others stress the need to 'keep the steam' in, as well as the, perhaps more mystical, 'spirit of the lime'. Both requirements indicate that temperature and steam were essential parts of the equation. The purer a quicklime is, the more quickly will its slake begin, on receipt of the necessary water, and the more rapidly will its slake complete.

According to the author's experience, and the consensus of numerous texts (Copsey 2019b, Appendix 11), if too much slaking water was used, the lime might be 'drowned', which is to say, that it would not reach a temperature during the slake of 100 °C or more. Whilst the quicklime would typically turn to a paste even so, it would not acquire the necessary tenacity in use; it might be weak, particularly in its bonds, both within the mortar and on building substrates. In the case of a limewash, it might disaggregate on contact, dusting off to the touch. In the author's experience, hot limewash, slaked at the necessary temperature, does not dust off, and may be applied at a greater thickness without crazing and cracking than one made from diluted lime putty, especially if this lime putty has itself been drowned during slaking. The superior behaviour of a limewash made from quicklime, in terms of thicker coats, minimal crazing after application, better bond and greater durability (Koeberle 2019), comes, to some extent, from typically having been applied whilst still hot, but also from the simple fact of having been slaked at the correct minimum temperature. Experiments by the author would indicate that the advantageous properties remain, even after a hot limewash has cooled, indicating that the advantage is delivered by the slaking method itself, as is the tenacity of a properly hot mixed mortar. "Aggregated limewashes", more usually described as sheltercoats are similarly superior when made from quicklime and applied whilst still hot (Figs. 18a and 18b).

Historically, writers about lime stressed the need to slake the quicklime with 'just sufficient' water. Once slaking was complete, then more water could be added according to the intended purpose, but the 'short-cut' of adding all the necessary water at the onset was condemned. It was an 'iron rule' that water should always be added to the quicklime, and that quicklime should not be added to water. The 'Lime Revival' inverted this rule, although by the mid-20th century, the addition of quicklime to water had become the norm, perhaps in response to the high reactivity of 'scientifically' burned quicklime. The slaking water to quicklime ratio, however, remained the same (British Standard Code of Practice 1951).

How much water is 'just sufficient'? It was not until the late 19th century that precise volumes of slaking water were explicitly articulated (Richardson 1897). This knowledge was very much held by the crafts before then, consistent with Campbell's assertion in 1747 (Campbell 1747) that central to the stonemason's craft was that he was 'the Judge of all Kind of Cements, and the Secret of preparing them for Use' (The London Tradesman, 158), a situation that had been increasingly eroded during the second half of the 19th century in the UK and

Figs. 18a. and 18b. Hot lime sheltercoat to a 12th century doorway (with recycled Roman columns), St Michael's Church, Foston, near York (photos by N. Copsey from Copsey 2019a).

North America, mortar design being increasingly co-opted by architects, surveyors or, indeed, others, unfamiliar with using the materials themselves (Powell 1980), (Clarke L 2012).

Limestone fired in a kiln will lose between 30 – 40% of its weight during firing. This equates to an enforced and unnatural loss of 'molecular' water and carbon dioxide. Quicklime desperately wants back the water it has artificially lost, so much so that it will begin to slake in moist air; it will re-absorb carbon dioxide much more slowly after application. It was a common demand historically that quicklime should be slaked as soon as possible after burning.

If a dry-slaked lime is required, then the quicklime will require around 1/3 of its weight in water to slake (Richardson 1897). This typically equates to an equal volume of water to that of the lime. If the intention is to make a mortar immediately, and to 'wet-slake,' then between 2 and 3 volumes of water to the volume of the quicklime will be added. Any more than this will suppress the temperature of the slake (as will the addition of more than 3 parts of sand to a powdered quicklime, many modern pre-mixed hot mixes being mixed at 1 part quicklime to 5 or 6 parts sand, also suppressing temperature, when the powdered quicklime is mixed directly with this sand before slaking). If boiling water is used to slake the quicklime, then greater volumes of slaking water will have no ill-effect (Miller 1960). If too little water is added in the first instance, then the temperature of the slake may quickly exceed 400 or 500 °C, it will be 'burned', in traditional parlance. In and of itself, this is not as problematic as it may sound, except that the addition of the necessary water (usually cold water) to an only partially slaked quicklime will 'chill' it. The consequence of burning, followed by chilling, will be the arresting of any further slaking and the delivery of a 'short' and lime-lean mortar. Generally, however, it is important to note that the residual lime lumps in traditional mortars are not a consequence of this.

SLAKING AND MIXING METHODS

In most parts of the world, the most common method, using lump quicklime, was to form a 'basin' with the sand or other aggregate into which the lump lime was placed. This was the same for both dry and wet slaking. Necessary volumes of slaking water were then poured onto the quicklime all in one go. The slaking quicklime was immediately banked over with sand, to retain heat and steam. As the quicklime expanded in volume, the sand covering would crack and open up. These cracks would be closed down, again to retain as much heat as possible. The slaking of a pure quicklime takes as little as two minutes; a feebly hydraulic (or old) quicklime might take five or six minutes (Miller 1960). This progress might be considered substantially complete once expansion and cracking of the sand cover ceases. At this point, the sand and the hot lime would be mixed and beaten together to form a mortar. (Figs. 19-22). More water might be required, although the more vigorous the beating, the less this might be necessary to achieve a similar workability, and the less water that is added at this stage, the lesser might be initial shrinkage in use. Beating of a freshly made mortar was a common requirement historically. Extensive beating will certainly improve the workability of an initially dry-slaked mortar. In all parts of the world, this method was called the 'ordinary' or the 'common' method, indicating its ubiquity (Copsey 2019b Appendix 11) Its primary practical purpose was to reduce lump quicklime to a size that might be readily incorporated with the sand.

This early incorporation of the hot lime with the sand or other aggregate may also be considered essential to hot mixing. Quicklime slaked but left to cool before mixing with the sand will offer a mortar of significantly different character, one that would be somewhat less workable, although extensive beating would improve this, whilst requiring more labour.

Lump quicklime might alternatively be slaked alone in a box or a pit, with similar slaking water volumes, before either sieving or, more commonly, being slaked to a thick paste, before being promptly mixed with sand in the same or another box or pit.

Dry hydrated lime might alternatively be slaked alone, by immersion in water whilst inside a basket, held beneath the water until it has absorbed all of the water it can, before being tipped out into a pile to slake (or into a barrel, as Vicat (1856) describes, to 'cook') and to fall to a powder. This might be sieved before mixing with sand, although it might be mixed without sieving, or it

Figs. 19 - 22. The Ordinary Method (all photos by N. Copsey, photos left and top right from Copsey 2019a).

might be used on its own. In a variation on this, the quicklime might be laid out on the ground and water poured from a watering can over the whole, after which it, too, would fall to a powder.

All of these methods guaranteed the minimum necessary temperature of the slake and, therefore, maximised the potential of the material.

One possible reason for the common distrust of lime putty was the suspicion that too much slaking water would be used. Vicat (1837) and other engineers expressed this anxiety. However, the procedure for making lime putty in the past was not so different from the procedures set out above. Lump lime would be given between two or three volumes of water in one tank or basin, the slake allowed to substantially complete, before more water might be added to allow the lime putty to pass from an upper tank into a lower tank. (Biston 1828). Between the two tanks there would be a grill to remove larger unslaked lime, or lumps of under- or over-burned quicklime. Lime putty could be stored in the lower tank (or in a pit in the ground, as Vitruvius (2015) De L'Orme (1567) and others describe), or it could be immediately mixed with sand, in which case, this method would be simply another hot mixing method.

De L'Orme (1567), and others describe the slaking of lime to a thick paste in a pit, beneath a covering of sand, typically for storage. The sand was laid on to preserve the lime in an 'unctuous' condition (De L'Orme 1567) after water had been poured through the sand covering to effect its slake. The sand may, or may not, have been mixed with the lime at a later time. The lime may have been used on its own for plastering or it may have been mixed with sand to form a mortar. Ware (1756) describes a similar procedure in England. Hassenfratz (1825) also makes clear that the sand and the lime were kept separate and were not necessarily subsequently mixed together, indicating that woven wattle hurdles separated the two. The sand (or earth) was to keep the lime from drying out and to maintain it in a fresh, cohesive and adhesive state.

A common variation on the ordinary method as described above, and which was common, perhaps more so in Central Europe and the Balkans in more recent history (Koeberle 2019), would be to lay the lump quicklime onto a bed of some of the sand to be mixed with it. The quicklime would then itself be covered with the remainder of the aggregate. Slaking water, in similar proportions to those above, would then be poured – or drizzled – through the sand covering to unite with and slake the quicklime, either to a dry hydrate or to a wetter paste, or, indeed, to a mixture of the two. A heap of material treated in this way could then be cut away incrementally to be mixed together in an accurate lime to aggregate proportion. This (as above methods) might only be defined as hot mixing if the sand and slaked lime are mixed together immediately. If the lime is left in situ to cool before mixing, then the method should properly be termed 'sand-slaking' and would deliver a mortar of somewhat different character. The 'ordinary method' may be reproduced in modern pan mixers, quicklime is evenly spread over a bed of part of the aggregate within a stationary mixer. Necessary volumes of water are then be poured over the quicklime and the mixer covered to retain steam. Once slaking is substantially complete, the mixer is set in motion and the remainder of the aggregate added, more water is added as mixing proceeds, according to the intended purpose.

Although frequently seen today as being a 'modern' and somehow 'inauthentic' form of quicklime, powdered or pulverised quicklime was used historically. When roller mills were used, which they were from an early period, built into the ground before free-standing machines became the norm, the lump quicklime would be thrown into the mixer and crushed, before slaking water was added, followed by the sand or other aggregate (Wright 1845). Performed manually, pulverisation inevitably involved additional labour, but was considered to deliver the 'strongest' mortar of all (Dossie 1771), as well as the most adhesive and cohesive (De la Faye 1777). The perception of greater strength was probably due to the absence of residual lime lumps; the total volume of the quicklime being binder after its slaking, although Dossie's assertion might usefully be tested. Dossie indicates that powdered quicklime should be mixed with the aggregate before the incremental addition of water, the mix being kneaded as each increment of slaking water is added. He suggests the mixing of small batches, with a trowel, and indicates that this should be done whilst still hot. Powdered quicklime is currently the most commonly used form of quicklime today and has been the most commonly used form during the recent revival in hot mixing. It being the most readily available in the UK has been the primary reason for this, although for those new to the material, its method of preparation – whether mixed by shovels, or mechanically – is little different from the mixing of dry hydrated binders of all kinds, although it remains essential to observe the initial slaking water to quicklime volumes. The use of powdered quicklime avoids any risk of late-slaking, removing anxiety about hot use, especially for plastering. Elsewhere in Europe and across the world, although they are scarce, small-scale traditional lime burners remain and traditional lump lime is more readily available, in the author's observation.

The initial pulverisation of natural hydraulic limes, when these were used, was common in the UK during the late 18th and 19th centuries. This accelerated what could otherwise be a very slow slake (sometimes up to 12 hours), as did the use of hot slaking water. Pasley (1826) states that whilst such powdering of the quicklime was routine for Blue Lias NHL (used for concretes and for some water works), it was also, at that time, becoming increasingly common for fat quicklimes as well. It is possible, if not likely, that many of the mortars interpreted as having been made with lime putty – due to the general absence of residual lime lumps – were, in fact made with powdered quicklime. For all that, these still represent a relatively small minority of analysed mortars. (HES Technical Paper 32). Plaster mortars can be similarly interpreted, where a hot mixed plaster has been laid down to allow for late slaking to occur, and knocked up immediately before application. That said, the author has seen very few historic plasters the mortars of which were not hot mixed, and which do not display a multitude of residual lime inclusions; lime putty being reserved for the fine finish coats

Fig 23. Hot limewashed exterior, reinstating original coating and pigment (iron sulphate). Bishop Burton Old Hall. Limewash offers moisture buffering and capillary activity across the whole surface area of building elevations (photo by N. Copsey).

over these hot mixed backing coats, whether these coats were of earth-lime or of lime and sand.

Earth-lime mortars would have been generally prepared using the ordinary method. Although the quicklime proportion tended to be less, it remained important that the lime was slaked at the necessary temperature prior to mixing with the clay-bearing subsoil or loam.

Limewashes (and grouts) would have been prepared similarly to lime putty, as described above, the former diluted somewhat after initial slaking and poured through a sieve to remove unslaked lumps prior to application whilst still hot. Such sieving was also common for the making of lime putty for bricklaying (when the joints were very fine); the lime putty pressed through a hair sieve and used as a bedding mortar whilst still hot (Langley 1750, Pasley 1826). This avoided the need to lay the lime putty down and allowed for hot use, when the lime putty remained 'flowing' and very straightforward to use. Hot limewash takes similar advantage of the easy flow of lime when it remains hot, and before it thickens on cooling (See Fig. 23).

CONCLUSIONS

Pure and nearly pure lime mortars and earth-lime mortars were essential elements – perhaps the *most* essential elements – of building technology and construction over many thousands of years. As a system, traditional building technology was relatively simple and straightforward, generally sustainable and made good and sensible use of locally available natural materials, and these were often processed and altered, typically by the use of fire. Mortars were critical to the success and longevity of such systems and were generally porous, as were most other building materials. Most were built by practical men and women drawing upon centuries and more of learning and experience. That hot mixed lime and earth-lime mortars were the ubiquitous mortars of construction for so long as humanity built structures at all is, quite simply, because they were the fittest materials for purpose and delivered dwellings and other structures that were healthy in themselves and healthy for those who occupied them. As modern craftspeople around the world are increasingly coming to understand, they remain the mortars most fit for purpose, for new builds, so long as the buildings themselves are designed within similar parameters and to similar principles as traditionally, and for the conservation and repair of existing structures applying rational principles of 'like-for like' and compatibility.

"The technical evidence does not point to short cuts in the achievement of good building; it points consistently to the discovery by scientific means of the rationale of established building traditions, which should be altered only with the full knowledge of the consequences…" (RIBA 1946).

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REZIME

RUDIMENTI TRADICIONALNE PRIPREME I UPOTREBE MALTERA

KLJUČNE REČI: ŽIVI KREČ, KREČNI MALTER, BLATNO-KREČNI MALTER, VRUĆI POSTUPAK, GAŠENJE KREČA, PUCOLANI, PROPORCIJE MALTERA.

Zaključak koji se može dobiti iz zanatskog iskustva o kome svedoči mnoštvo postojećih konstrukcija, kao i međusobno doslednih tekstova o kreču i malteru pisanih tokom poslednjih 2.000 godina, a najmanje do 1925. godine, iz obilja arhiviranih građevinskih izveštaja i specifikacija tokom sličnog perioda, kao i iz savremene nauke o materijalima, je taj da je živi kreč sa visokim sadržajem kalcijuma bio osnova za većinu tradicionalnih maltera. Specifični agregati ovih maltera mogu varirati u zavisnosti od dostupnosti i geologije, kao i od predviđene namene, a metodologija i razumevanje načina njihove pripreme i upotrebe su bili izuzetno postojani od najmanje 10.000 pre nove ere, da bi bili prekinuti i obezvređeni tokom XX veka. U to vreme tradicionalna zanatska praksa i znanje postaju sve više izazvani i podriveni unutar građevinske industrije, a uspostavlja se nova i prethodno nepostojeća građevinska tehnologija, omogućena razvojem sve više globalizovanog industrijskog kapitalizma i uz promenljivu ravnotežu klasnih snaga unutar industrije. Ovo tradicionalno znanje i razumevanje je dodatno umanjeno i kompromitovano – iako sa najboljom namerom – greškama, nesporazumima i kognitivnim predrasudama u okviru različitih pokreta za ponovno uspostavljanje upotrebe krečnih maltera za očuvanje i sanaciju starih građevina, a nakon „preporoda kreča“ u Skandinaviji i Velikoj Britaniji posle 1975. godine. Tradicionalni malteri pripremljeni tradicionalnim metodama gašenja i uz tradicionalne proporcije, izuzetno su pogodni za ovu namenu. Optimalno su obradivi u upotrebi, nude odgovarajuću trajnu vezu i odličnu efektivnu poroznost, dok su slični i kompatibilni sa postojećim tkivom građevine, nudeći održivije opcije ne samo za sanaciju ovog tkiva, već i za nove konstrukcije. Iako nam ostaje još mnogo istraživanja o nijansama i detaljima tradicionalnih maltera, mora se reći da znamo da oni “funkcionišu”, kao što su to znali i u prošlosti, sve dok poštujemo i primenjujemo znanje i razumevanje o njima - onih koji su ovde bili pre nas, i sve dok priznajemo, pre svega, da stojimo na ramenima divova, od kojih su većina poznati samo po građevinama i strukturama koje su stvorili.

* * *

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MASTER CONSERVATION PLAN FOR THE ARCHAEOLOGICAL SITE OF STOBI: GOALS AND OUTCOMES

ABSTRACT

The Master Conservation Plan for the archaeological site of Stobi was created in cooperation between NI Stobi (RN Macedonia) and the Balkan Heritage Foundation (Bulgaria), with the generous support of the J. M. Kaplan Fund (USA). The plan was produced in the period between 2019 and 2021, involving professionals from the partnering institutions as well as foreign and local experts. The Master Conservation Plan for Stobi is a strategic document created with the main goal of offering directions and recommendations for the better preservation and presentation of the diverse cultural heritage of the site, to promote a modern methodological approach in the assessment of the potential risks, damage and problems, to offer the best possible solutions, to foster the usage of the proper conservation materials and methods, and to point to the importance of building institutional capacity and using skilled professionals in the field of cultural heritage preservation. The plan also offers directions for the improvement of the tourist presentation of the site, as well as guidelines for the development of a fundraising strategy, with a list of potential donors, programmes, funds and grants. The plan especially emphasises the recommendations concerning two segments of our work: authentic preservation and preventive conservation during ongoing excavations, practiced worldwide, which is crucial for the preservation of the excavated structures. Also to diminish the disbalance between excavations and conservation, for which wholesale changes in the legislation, especially concerning archaeological remains, are needed. In fact, the Master Conservation Plan is a basic tool for present and future managers of the archaeological site of Stobi to better plan short- and long-term activities related to preservation, presentation and maintenance, thus providing opportunities for the sustainable development of the site.

KEYWORDS: STOBI, CONSERVATION, PLAN, MANAGEMENT, MAINTENANCE, PRESENTATION, FUNDRAISING.

The ancient city of Stobi was the largest city in the northern part of the Roman Province of Macedonia (Fig. 1). It is located at the confluence of two largest rivers Axios and Erigon (today's Vardar and Crna Rivers) and on the crossroads of major trading routes north-south and east-west. Known as *oppidum civium Romanorum* in the time of Augustus and later as a *municipium* of citizens who were granted *Ius Italicum,* the city flourished in the Roman imperial period. An imperial mint was established at Stobi during the reign of Vespasian, which produced coins until the reign of Caracalla. In Late Antiquity, Stobi became an important Early Christian centre and for a short time the capital of the newly established province of Macedonia Secunda. Surviving the barbaric raids in the 5th and 6th centuries, earthquakes, climate changes, famine and plague in the 6th century, as well as the general decline of the empire, the city exist-

Fig. 1. Archaeological site of Stobi, aerial view from SW, 2009 (Archive of the National Institution Stobi).

ed until the end of the 6^{th} or early 7^{th} century, when it was abandoned.[1]

Excavations at Stobi began a century ago, during the First World War, forty years after Leon Hezey and Georg von Hahn independently located the ruins of the ancient city (Hezey 1873:25-42; von Hahn 1867: 158–160). To date, 23 buildings of secular and religious character, a theatre, a library, baths, a temple of Egyptian deities, civil and Early Christian basilicas, residential buildings with rich architectural decoration, cemeteries and a large collection of finds have been discovered (Wiseman 1973; Микулчиќ 2003; Blaževska 2021: 189-215).[2] The site was proclaimed as a cultural heritage property of the first category of national

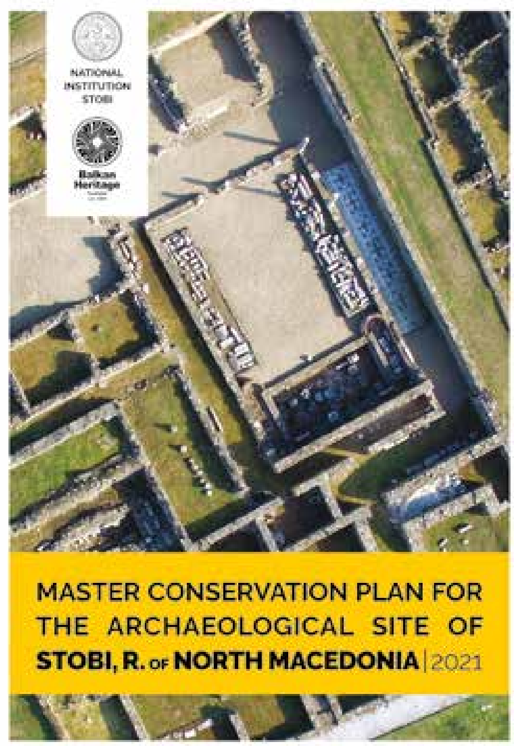

Fig. 2. Master Conservation Plan for the archaeological site of Stobi, cover page (Blazhevska et al. 2021).

1 For the general history of the city and its urban development, see: Wiseman 1986: 37-50; Микулчиќ 2003. Blaževska 2021: 189-215 with quoted earlier bibliography. For the final moments of life in the city and causes of its abandonment see: Wiseman 2006: 225-261; Wiseman 2007: 85-110; Snively 2009: 37-44; Pavlovski and Blaževska 2017-2018: 49-83.

2 For extensive bibliography of the excavations at Stobi and discovered buildings until 1973, see: Radošević 1973, 233-268. The updated bibliography on Stobi will be published in the forthcoming Studies in the Antiquities of Stobi vol. 5 (forthcoming).

Fig. 3. Risk from flooding: rise in the level of subterranean waters and flooding in the Building with Arches, 2010 (Archive of the National Institution Stobi).

interest in 1956 and 1971, and in 2016 evaluated as a cultural heritage of especial significance, subcategory - great, based on UNESCO's criteria for the significance, authenticity, integrity, diversity and rarity incorporated in the national legislation.[3] Since the discovery of Stobi, the excavations, preservation and presentation of the site have been under the jurisdiction of various institutions: National Museum in Belgrade, Council for Stobi, Archaeological Museum in Skopje, National Museum in Veles and the Republic Institute for Cultural Heritage Protection (National Conservation Center). The National Institution for Management of the Archaeological Site of Stobi (National Institution Stobi / NI Stobi) was established in 2008 as an independent governmental institution under the Ministry of Culture, with the main goal of taking care of the site from every possible aspect: excavation, preservation and presentation (Службен весник 2008; Службен весник 2009).[4] The different policies and strategies implemented by the various institutions responsible for the site in the past have resulted in the present condition of the ancient remains, moveable finds and infrastructural facilities.

Conservation and preservation of the discovered buildings started in the 1930s, under the patronage of the National Museum in Belgrade, focused on presentation of the richly decorated phase of the residential buildings. For that purpose, the later walls built of sandstones and mud mortar were removed and the remaining walls were protected with a cement-based capping, some of which is still visible at the site. After World War II, the conservation of the architectural remains was undertaken by the Republic Institute for Cultural Heritage Protection (National Conservation Center) until 2008, when NI Stobi took over the jurisdiction of the site.[5] In most cases, cement-based mortars were used for conservation and restoration of the architectural remains, for consolidation of the mosaic and stone slab pavements throughout the site, as well as for restoration and anastylosis of the architectural marble elements. NI Stobi made significant efforts to improve the condition of the site through permanent maintenance and the implementation of various conservation projects of the ancient structures and their elements, taking into consideration available human and funding resources and national legislation. Besides the professional team of NI Stobi, many experts from other institutions in the country and abroad were involved in the projects. A strong collaboration has been established with the Balkan Heritage Foundation (BHF), from Bulgaria[6], in the organisation of international field schools in archaeology, conservation of pottery, glass, mosaics and a variety of other educational initiatives.

In 2018, NI Stobi received an invitation for funding from the J. M. Kaplan Fund through the partnering institution the Balkan Heritage Foundation,

3 The Document for evaluation of Stobi is still pending in the Ministry of Culture.

4 For the activities of NI Stobi see the official web site of the institution: http://stobi.mk.

5 See: http://www.stobi.mk/Templates/Pages/Excavations.aspx?page=3315

6 For the activities of the Balkan Heritage Foundation see the official web site: http://balkanheritage.org.

Fig. 4. Risks from atmospheric influences: degradation of the discovered buildings caused by rain water, The House of Polycharmos (Archive of the National Institution Stobi).

when members of the family and board visited the site.[7] The decision was made that for the sustainable preservation and presentation of the archaeological site of Stobi, a Master Conservation Plan (MCP) (Blazhevska et al. 2021) was urgently needed. The plan was designed between 2019 and 2021 and besides the professional team from NI Stobi and the BHF, local and foreign experts in conservation, presentation and fundraising were involved in its creation. With the completion of the MCP, NI Stobi and the BHF celebrated the 11th anniversary of their institutional collaboration at Stobi.

The MCP for Stobi (Fig. 2) is a strategic document created with the main goal of offering directions, recommendations and strategies for the better preservation and presentation of the diverse cultural heritage of the site, considering its importance, integrity and authenticity and the necessity for sustainable development within its natural environment. It aims to promote a modern methodological approach to the assessment of the potential risks, damage and problems, to offer the best possible solutions, to foster the usage of the proper conservation materials and methods, and to point out the importance of building institutional capacity and skilled professionals in the field of cultural heritage preservation. The plan also offers directions for the improvement of the tourist presentation of the site, as well as guidelines for the development of a fundraising strategy with a list of potential donors, programmes, funds and grants. It is aimed at serving as a basic tool for short- and long-term planning for present and future managers of the NI Stobi and its professional team and as a basis for the creation of additional action and strategic plans, and working protocols.

The MCP contains six chapters, twelve appendixes and numbered illustrations, following the text. The first three chapters contain an introduction of the plan's goals, structure and phases of its development, followed by a basic description of the site's history, discovered buildings and other infrastructural facilities, the significance of the site, as well as a historical overview of its excavations, conservation activities and management in-

7 See: https://www.jmkfund.org/wp-content/uploads/2014/11/HC-GRANTS-LIST_12.2021-1.pdf. https://www.bhfieldschool.org/news/jm-kaplan-fund-grant-awarded-to-bhf-and-ni-stobi-for-master-conservation-plan-for-the-archaeological-site-of-stobi.

Fig. 5. Poor quality building material – soft sandstone, lichens and the use of cement-based mortar for conservation, Small Bath (Archive of the National Institution Stobi).

stitutions. A brief description is also provided of the collections of movable finds, the infrastructure and the existing documentation.

The next three chapters deal with conservation policy and practice, visitor management, interpretation and presentation, and fundraising and resource development. They are the key elements in the plan. Conservation Policy and Practice is the most important chapter in the document, starting with the condition and a significance assessment of the excavated and presented buildings and their decorative elements, of the infrastructure and storage facilities, and of the moveable finds. During the assessment process the priority buildings and interventions were identified, as well as reasons for their current condition and the risks facing their further existence.

The condition assessment of ancient features (stone masonry and pavements), observed in the context of the current conservation practices, has detected various problems and risks for the ancient structures at Stobi (Figs. 3-6):

Natural hazards such as seismic activity in the region and floods caused by the rise in the level of subterranean water or the level of the rivers Vardar and Crna;

Salts and vegetation, especially lichens;

Atmospheric influences and pollution from traffic on the nearby motorway (the latter especially refers to the marble parts of the theatre);

Poor original construction material (most of the buildings at Stobi are built of sandstone and lime mortar, which easily deteriorates after being exposed to atmospheric influences and temperature differences after excavations);

Lack of a conservation policy, imbalance between the excavations and conservation and restoration vs conservation as it is discovered, and a lack of maintenance;

Lack of professional training and use of inappropriate conservation materials. The larger conservation issues detected at Stobi are the use of cement-based mortars in most of the conservation and restoration works of the stone masonry, the pavements and architectural decoration, and the use of aluminium honeycomb plates as bedding for mosaic pavements outdoors;

Current legislation and administrative issues, such as long and complicated procedures,

Fig. 6. Risk from air pollution: black surface on marble blocks at the Theatre, caused by exhaust gases from vehicles on the nearby motorway (Archive of the National Institution Stobi).

especially for preventive and emergency conservation.

Recommendations for improving the condition of the excavated structures are the most important part of the document and they include:

Establishing routine conservation processes and protocols for interventions that are crucial for a proper assessment of the priorities and preventive interventions, based on the importance and risk assessment.

Establishing a substantial database and set of documentation for all processes;

Establishing protocols for routine maintenance and monitoring that are important for long-term preservation of the ancient structures;

Defining a proper conservation policy: philosophy, standards and guidelines: (for example: a balance between excavation and conservation and preventive conservation vs conservation and restoration, the use of the proper conservation materials based on the contemporary standards, securing the buildings and the excavated areas, defining the role and type of wall capping and shelters in order to authentically preserve ruins in their natural environment, etc.);

Defining reburial (for example: short- and long-term proper reburial of ancient pools, basins and pavements, especially for those that are not on the visitor's path, to facilitate their better preservation;

Defining interdisciplinary investigations and technical conservation research for which the establishment of partnerships with scientific institutions is needed (for example: analysis of the effects of pollution or lichens in the processes of stone deterioration, analysis of the original stone and mortar composition, etc., in order to establish a proper conservation approach);

Building professional capacities through training.

The plan especially emphasises the recommendations concerning two segments of our work: authentic preservation using original materials and preventive conservation during the ongoing excavations, such as wall capping or repointing, or replacement of severely deteriorated sandstones to preserve the stability of the walls. These activities, which are practiced worldwide, are crucial for the preservation of the excavated structures, but due to rigid legislation are not possible in our country without prepared conservation projects. Therefore, wholesale changes in the national legislation are recommended, especially concerning the preservation of the archaeological remains. The chapter is supplemented with four Appendices where details are provided for performing various surveys of the masonry types and a significance assessment, the seasonal protection of pools, of maintenance and reburial examples, shelter design, wall capping, and repointing, all using examples from other sites in the world (Herculanum, Sagalassos, etc.), and supported by a comprehensive list of references available on line. This chapter also contains an assessment of the storage facilities for the preservation of moveable finds at Stobi and recommendations for their improvement, based on the *RE-ORG* Model, a method for reorganising museum storage, available at the ICCROM (ICCROM 2022).

Besides the condition of the ancient features at the site, an assessment of current visitor management, and the presentation and interpretation of the site was made. A similar analytical methodological approach has been applied to analyse the site's presentation in various media, social networks, educational projects and visitor's infrastructure. Through an evaluation of the current condition of the site's promotion and the activities of NI Stobi, recommendations are given for improvement, stressing the need for a careful approach to visitor management and avoiding events for promotional needs, because of the high risk of damaging the vulnerable archaeological remains. The necessity for the development of a visitor's management plan was emphasised, which will contain directions for the interpretation of various other topics and not just simple explanations of the site's history and ancient buildings.

One of the most serious problems in the work of professionals and institutions in the field of preservation around the world is undoubtedly securing funding for excavations, technical research, conservation, maintenance and preservation. The very last chapter of the plan suggests recommendations for creating a fundraising strategy with opportunities for funding diverse aspects of excavations and scientific based research, and preservation and presentation from different sources: state institutions, European funds, philanthropic organizations and individual donors from around the globe.

At the end of the MCP there are detailed descriptions of the excavated buildings, with brief details of the history of the excavation, conservation and condition assessment of each building, the condition assessment of the collections of finds and infrastructural facilities, as well as a list of ongoing and planned future projects of NI Stobi.

We hope that MCP for Stobi will serve not just as a basic tool for the effective and sustainable protection and management of Stobi, but will also serve as an example for the creation of similar documents for other archaeological sites in the country and in the region. Our goal is that this plan will not remain just a paper document, but that its implementation will result in the sustainable and systematic maintenance and preservation of Stobi for future generations. We are happy to announce that the first step in its implementation comes courtesy of the J. M. Kaplan Fund, who will fund conservation of the Theodosian Palace at Stobi in the following three years, during which time a training course for professionals will be included, under the guidance of foreign experts in architectural, mosaic and stone conservation.

On behalf of the National Institution Stobi and the Balkan Heritage Foundation, we would like to express our enormous gratitude to the international and local experts and editors and all colleagues who have participated in the creation of this plan, and for their useful advice and constructive discussions during both round tables, organized at Stobi. The Master Conservation Plan for the Archaeological site of Stobi is available to download from the websites of both the National Institution Stobi[8] and the Balkan Heritage Foundation[9].

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REZIME

MASTER PLAN KONZERVACIJE ZA ARHEOLOŠKO NALAZIŠTE STOBI: CILJEVI I REZULTATI

KLJUČNE REČI: STOBI, KONZERVACIJA, PLAN, MENADŽMENT, ODRŽAVANJE, PREZENTACIJA, FANDREJZING.

Antički grad Stobi je bio najveći grad u severnom delu rimske provincije *Macedonia*, kasnija prestonica provincije *Macedonia Secunda* i važan gradski, administrativni, trgovački i religiozni centar tokom rimskog i kasnoantičkog perioda. Smešten na izuzetno značajnom mestu, na ušću dve najveće reke Aksios i Erigon (današnji Vardar i Crna Reka) i na raskršću glavnih trgovačkih puteva koji su vodili od severa ka jugu i od istoka ka zapadu, grad je imao sve preduslove za značajan rast i razvoj. Preživevši varvarske napade u V i VI veku, zemljotrese, klimatske promene, glad i kugu u VI veku, kao i opšte slabljenje carstva, grad je opstao sve do kraja VI ili ranog VII veka, kada je napušten.

Arheološka iskopavanja grada Stobi započeta su pre jednog veka, tokom Prvog svetskog rata, a sprovode se i danas, dok su prve aktivnosti na zaštiti otkrivenih antičkih ostataka pokrenute tokom tridesetih godina prošlog veka. Do danas su otkrivene dvadeset četiri bogato ukrašene građevine javnog, privatnog, svetovnog ili religioznog karaktera: pozorište, biblioteka, hram posvećen egipatskim božanstvima, civilna i ranohrišćanske bazilike, stambene građevine, kao i velika kolekcija predmeta.

Nalazište je proglašeno kulturnim dobrom od nacionalnog interesa prve kategorije, 1956. i 1971. godine, a 2016. godine je vrednovano kao posebno kulturno nasleđe od velikog značaja, i to prema Uneskovim kriterijumima za značaj, autentičnost, integritet, raznolikost i retkost, koji su uključeni u nacionalno zakonodavstvo Republike Severne Makedonije.

U proteklh sto godina, iskopavanja, zaštita i prezentacija nalazišta su bili pod nadležnošću različitih institucija. U 2008. godini je osnovana Nacionalna institucija za upravljanje arheološkim nalazištem Stobi (National Institution Stobi / NI Stobi), kao nezavisna vladina institucija pod okriljem Ministarstva kulture, sa ciljem brige o nalazištu sa svakog mogućeg aspekta: iskopavanja, očuvanja i prezentacije.

Različitost politika i strategija primenjenih od strane različitih institucija odgovornih za nalazište u prošlosti dovela je do sadašnjeg stanja antičkih ostataka, pokretnih nalaza i infrastrukturnih objekata.

Glavni problemi zabeleženi na nalazištu su:

- Upotreba neadekvatnih materijala za konzervaciju – maltera na bazi cementa u konzervaciji i restauraciji arhitektonskih ostataka, mozaika i podova od kamenih ploča, kao i u restauraciji i anastilozi mermernih elemenata arhitekture;
- Nedostatak balansa između iskopavanja i konzervacije;
- Nedostatak održavanja;
- Politika konzervacije koja se zalagala za neumerenu restauraciju umesto konzervacije ostataka u obimu u kom su pronađeni.

U cilju prevazilaženja ovih glavnih problema, a u saradnji Nacionalne institucije za upravljanje arheološkim nalazištem Stobi i Balkan Heritage Foundation iz Bugarske, i uz velikodušnu podršku fonda J. M. Kaplan Fund (SAD), izrađen je *Master plan konzervacije za arheološko nalazište Stobi* (*Master Conservation Plan for the Archaeological Site of Stobi*) tokom perioda od 2019. do 2021. godine, uz učešće stručnjaka iz partnerskih institucija, kao i inostranih i lokalnih eksperata.

Master plan konzervacije za arheološko nalazište Stobi je strateški document pripremljen sa osnovnim ciljevima pružanja uputstava i preporuka za bolje očuvanje i prezentaciju raznolikog kulturnog nasleđa na ovom nalazištu, promocije savremenog metodološkog pristupa oceni po-

tencijalnih rizika, oštećenja i problema, pružanja najboljih mogućih rešenja, negovanja upotrebe adekvatnih metoda i materijala u konzervaciji i isticanja značaja građenja institucionalnih kapaciteta i obučenih stručnjaka u oblasti očuvanja kulturnog nasleđa. Plan takođe pruža uputstva za unapređenje turističke prezentacije nalazišta, kao i smernice za razvoj strategije fandrejzinga sa listom potencijalnih donatora, programa, fondova i grantova.

Plan posebno naglašava preporuke vezane za dva segmenta našeg rada: očuvanje i preventivnu konzervaciju tokom tekućih iskopavanja koji se praktikuju širom sveta, a što je ključno za očuvanje iskopanih struktura, ali i za umanjenje neravnoteže između iskopavanja i konzervacije, za šta su potrebne ozbiljne promene u zakonodavstvu, a posebno u njegovom segmentu vezanom za arheološke ostatke.

Zapravo, *Master plan konzervacije za arheološko nalazište Stobi* predstavlja osnovni instrument za sadašnje i buduće upravljače arheološkim nalazištem Stobi, kako bi bolje planirali kratkoročne i dugoročne aktivnosti vezane za očuvanje, prezentaciju i održavanje ovog nalazišta, i na taj način obezbedili mogućnosti za njegov održivi razvoj.

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CONTEMPORARY APPROACHES TO THE REVITALISATION, PRESENTATION AND PROMOTION OF THE CULTURAL AND NATURAL HERITAGE OF THE PART OF THE ROMAN LIMES - CASE STUDY OF THE LATE ANTIQUE TOMB IN BRESTOVIK

ABSTRACT

The Roman Limes is recognised as a serial cultural property of exceptional universal values of international importance by UNESCO. In the Republic of Serbia, it includes the Danube Valley. The protection, revitalisation, presentation and promotion of sites along the Danube in Serbia is a prerequisite for the entry of this part of the Roman Limes on the UNESCO World Cultural and Natural Heritage List. Bearing in mind the current state of a large number of sites, the question of their protection, revitalisation, presentation and promotion in a contemporary context arises. Referring to the principles of international charters and conventions, the main goal of this paper is to spread knowledge about the possibilities of the protection, revitalisation, presentation and promotion of the cultural and natural heritage of the Roman Limes in Serbia, all for the integration of cultural and natural heritage into the contemporary environment and the establishment of sustainable landscape development. The results are presented through a case study of the late antique tomb in Brestovik, through the conceptual solutions of architecture students, within which the possibilities of integrating contemporary architecture into spaces of natural and historical values were examined. The expected results include raising awareness of the possibilities of integrating natural and cultural heritage into a contemporary context, as well as considering the natural and cultural heritage as a driver for establishing sustainable landscape development.

KEY WORDS: ROMAN LIMES, CULTURAL AND NATURAL HERITAGE, LATE ANTIQUE TOMB, CONTEMPORARY REVITALISATION AND PRESENTATION, SUSTAINABLE DEVELOPMENT

INTRODUCTION

Roman Limes

The Roman Limes represents the former border between the Roman Empire and other, the so-called, "barbarian territories". Considering the dominant position of the Roman Empire throughout history, which is supported by the evidence of the territorial spread of the Roman Empire on three continents – Africa, Europe, and Asia, the Roman Limes represents a significant testimonial of the existence, development, intertwining, and alternation of different and various social and cultural influences that shaped life over time on the border of the Roman Empire. Nowadays, the remains of the former Roman Limes consist of many sites of different periods of origin (prehistoric, classical antiquity, and the Middle Ages). It also includes different types of sites such as, fortlets and watchtowers, legionary and auxiliary forts, settlements, and necropolises (Mrđić and Golubović, 2014:101). The rediscovery and study of the site of the Roman Limes enables a revival and understanding of the customs, cultures, and traditions of the people who were an inseparable part of the Roman Limes and who shaped life on the border of the Roman Empire.

Within the borders of the European continent, the natural border of the former Roman Empire includes the courses of large rivers, among which the Rhine and Danube rivers stand out. Along the banks of the Rhine and Danube, an elaborate defensive system was built. As a result of the existence of these numerous fortifications, the rivers became a sort of first defensive shield against enemy attacks on the territory of the Roman Empire (Mrđić and Golubović, 2014:101). Although primarily in the role of protecting the border of the Roman Empire, the built defence facilities enabled the emergence and development of life on the Roman Limes, as seen in the evidence of the remains of many settlements and necropolises. The Roman Limes is, therefore, not only a testimony to the power and wealth of the former Roman Empire, but also a testimony to the former life along the border, which is rediscovered through the study of the remains of the natural and cultural heritage of the Limes itself.

The importance of the study, protection, presentation, and promotion of the Roman Limes on an international and global level has been recognised by UNESCO. Based on the UNESCO initiative, a transnational project for the protection, presentation, and promotion of the cultural and natural heritage of the Roman Limes was launched, under the name "Frontiers of the Roman Empire" (Cvjetićanin 2013; Mrđić and Golubović, 2014:102-103). This project aims to preserve the remains of the Roman Limes in Europe, Asia, and Africa. The project began with the inscription of the Antonine Wall in Scotland to the UNESCO List of World Cultural Heritage, in 2008 (Breeze 2009: 39-72). Germany, Great Britain, The Netherlands, Austria and Slovakia, on whose territories the sites belonging to the remains of the Roman Limes can be found, have entered sites on the UNESCO List of World Cultural Heritage and numerous other countries are in the process of registering (Cvjetićanin 2013; Mrđić and Golubović, 2014:102-103). The Republic of Serbia, through whose territory the Danube river flows and which is part of the Roman Limes, is in the process of registering as well (Cvjetićanin 2013; Mrđić and Golubović, 2014:102-103). However, in order for sites to be included in the UNESCO List of World Cultural Heritage, they must be properly protected, presented, and promoted, as laid out in the "Operational Guidelines for the Implementation of the Convention on World Heritage", verified by the UNESCO organisation (UNESCO 2021:42-43).

Consequently, this paper aims to highlight the necessity of studying the natural and cultural-historical values of the part of the Roman Limes located on the territory of the Republic of Serbia. The length of the Danube river through the Republic of Serbia is 588 kilometres and it keeps the testimony of the natural and cultural heritage of the part of the Roman Limes that requires a certain type of protection, presentation, and promotion in the contemporary context, in order to enter the UNESCO List of World Cultural Heritage as part of the heritage of the border of the Roman Empire. In 2015, a tentative list of sites in Serbia was submitted and adopted, while in 2020, the list was revised by Serbia, and now includes 35 sites (UNESCO 2020).

Roman Limes in Serbia

Within the territory of the Republic of Serbia, the Roman Limes includes the course of the Danube river. Geographically and spatially, the study of the part of the Roman Limes in the territory of the Republic of Serbia can be divided into three sections: the Pannonian section, the Moesian section, and the Iron Gates section (Figure 1) (Korać et al, 2014:37)

The Pannonian section includes the area along the banks of the Danube on the territory of Vojvodina – Srem, Banat and Bačka, and extends to Belgrade. This part of the Roman Limes stands out for its large number of fortifications and watchtowers, which were built for the needs of the Roman garrisons. The evidence of their existence are numerous remains of former buildings, but also the remains of settlements and necropolises that point to the

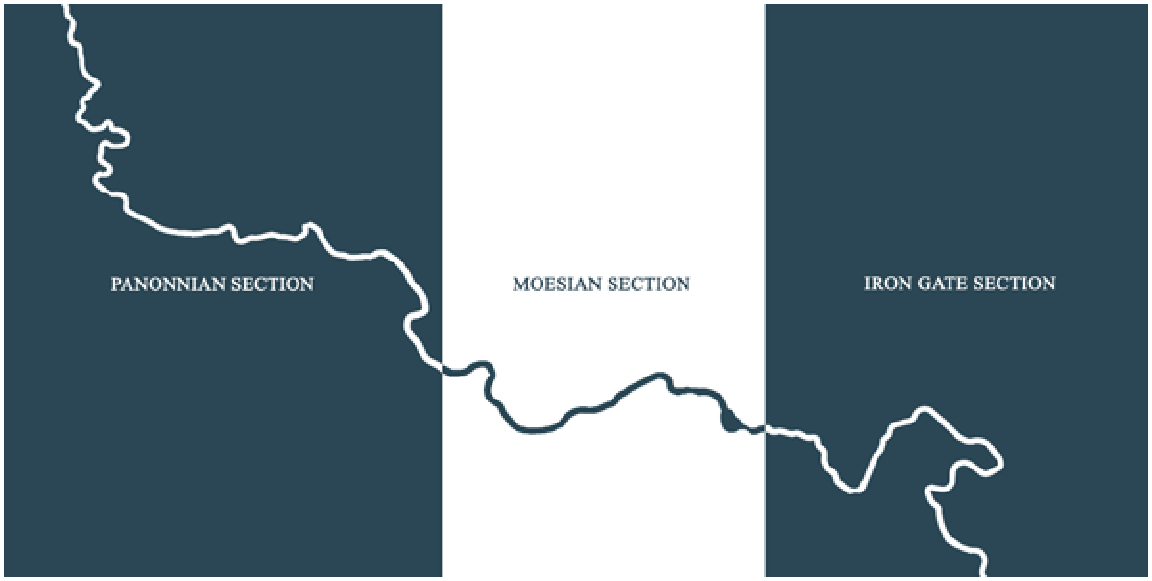


Fig. 1. Roman Limes in Serbia (map by J. Šćekić).

origin and development of life on the border of the Roman Empire (Korać et al, 2014:47-49). Among the discovered and explored sites, those that stand out are: the Dumbovo site (remains of a settlement,), the sites in Susek and Neštin (watchtowers), the Bač site (fortification and port), the Ilok site (fortification), the site in Begeč (*Castelum Onagrinum* – fortification), the site near Čortanovci (*Ad Herculem* –fortification), the site at Petrovaradin (*Cusum* – auxiliary fort), the site near Stari Slankamen (*Acumincum* – ancient fortification under the medieval fortification), the site in Surduk (*Rittium* –fortification), and the site in Zemun (*Taurunum* –fortification, settlement, and necropolis) (Đorđević 2007).

The Moesian section extends geographically between Belgrade and Golubac, including the course of the Danube river and its embankment. Given the geographical and morphological characteristics of the Moesian section, which is dominated by wide valleys, this part of the Roman Limes within the territory of today's Republic of Serbia was part of the border among those most exposed to enemy attacks. Consequently, the Moesian section was the most important part of the border of the Roman Empire in the defence system (Korać et al. 2014:50-53). Confirmed sites of the Moesian section are the one located under today's Belgrade (*Singidunum* –Roman city and legionary fortress), a site in Višnjica (*Castrum Octavum* – auxiliary fort), sites in the area of Ritopek (*Castra Tricornia* – auxiliary fort), site near Grocka (Brestovik – a tomb), a site in Seone (*Aureus Mons* – a settlement), a site in Dubravica (*Margum* – a settlement and a fort), a site in Stari Kostolac (*Viminacium* – the capital of the province of Upper Moesia and the legionary fortress), two sites in Ram (Roman road with the inscription and *Lederata* – auxiliary fort), and a site in Golubac (*Cuppae* – auxiliary fort) with the remains of the Roman road below the Golubac fortress (Korać et al. 2014:50-53).

The section of Iron Gates includes the course of the Danube river within the Iron Gates gorge. Bearing in mind the geographical and morphological characteristics of the Iron Gates gorge, which represents a composite river valley composed of four gorges (Golubac, Gospođin vir, Kazan, and Sip) and four valleys (Ljupkova, Donji Milanovac, Oršavska, and Wallachia-Pontic lowlands), the Iron Gates section of the Roman Limes represented is one of the most challenging parts of the border of the Roman Empire from the perspective of defence infrastructure (Korać et al, 2014:54). As a result, smaller military fortifications for auxiliary troops of the Roman army were built in the Iron Gates gorge, while larger settlements, fortifications, and ports were built in the valleys where the space for construction was more accessible (Korać et al, 2014:54). Explorations of the Iron Gates section began in the 19th century, and numerous books and travelogues indicate the existence of more than 80 archaeological sites, among which Roman fortifications prevail (Korać et al, 2014:55). The most extensive protective research of this part of the Roman Limes, the results of which can be found in the publications of the Institute of Archaeology in Belgrade – "Đerdapske sveske (Cahiers des Pontes de Fer) I, II, III, IV", were carried out in the 20th century (Kondić, 1980, 1984, 1986, 1987). After the beginning of the work of the Iron Gates Hydroelectric Power Plant, numerous sites were submerged and, as a result, almost forgotten. The sites still visible and partly accessible in this section are Čezava (*Novae* – auxiliary fort) in Dobra, a site named Hajdučka Vodenica (auxiliary fort), a site in Miroč (*Gerulata* – auxiliary fort), Trajan's tablet (imperial rock inscription with the section of the Roman road), a site in Karataš (*Diana* – auxiliary fort), a site in Kostol (*Pontes* – auxiliary fort with Trajan's Bridge), a site in Rtkovo (*Glamija* – fortlet), a site in Brza Palanka (*Egeta* – three auxiliary forts), a site in Mihajlovac (*Mora Vagei* – fortlet), a site in Prahovo (*Aquae* – city), and a site in Radujevac (Ćetaće – fortlet). (Korać et al, 2014:67-87; UNESCO 2020).

Cultural and historical values of the Moesian section

As already mentioned in this paper, the Moesian section (Figure 2) represented one of the most vulnerable parts of the Roman Limes on the territory of today's Republic of Serbia, because of which more attention was directed towards its protection. The Moesian section is characterised by a large number of sites that are the remains of military fortifications and settlements built in their surroundings (Figure 3).

Singidunum is a Roman legionary fortress around which a settlement and necropolis developed. According to its geographical position, at the confluence of two rivers, the Danube and the Sava in Belgrade, *Singidunum* represented an important military stronghold, but also a town, a trade and economic centre. Many discovered archaeological remains testify to its multi-layered importance (Đorđević, 2019:38-41). Based on the decision from the Institute for the Protection of Cultural Monuments of the City of Belgrade, ancient *Singidunum* was recognised as and declared an immovable cultural asset in 1964 (Rešenje 1964).

The site of *Viminacium* includes the remains of a legionary fortress and a Roman city, the capital of the province of Upper Moesia. Its location is in the village of Stari Kostolac, just 12 kilometres from the town of Požarevac (INSKD 2020b). Considering its role as a former military and administrative centre, *Viminacium* is recognised as an archaeological site of exceptional importance. Based on the decision on determining immovable cultural assets of exceptional and great importance, the *Viminacium* site was declared a cultural asset of exceptional importance for the then Socialist Republic of Serbia in 1979 (Odluka 1979).

The site of *Lederata* is located on the right bank of the Danube river, near the village of Ram. It represents the remains of an auxiliary fort from the end of the 1st century and later building phases up to the 6th century. The fort's hilly position above the river predetermined the function of *Lederata* as a defensive fortification for the protection of the river crossing (INSKD 2020a). The fortification's significance was also recognised by the then Socialist Republic of Serbia. The site of *Lederata* was declared a cultural asset of great importance in 1987, based on the decision regarding the determination of immovable cultural assets of exceptional and great importance (Odluka 1987).

The shown sites indicate the cultural and historical values of the Moesian section as part of the Roman Limes that is located on the territory of the Republic of Serbia. Above all, it also showed its defensive importance in the military protection system of the borders of the Roman Empire. However, although it is mainly dominant in its defensive role, the Moesian section includes sites of other functions. One of them, which, from the perspective of the protection, presentation, and promotion of cultural heritage, has been unduly neglected, is the late antique tomb in Brestovik, chosen as a case study within this paper. The Brestovik tomb represents a kind of testimony of social and cultural values, but also beliefs, customs, and traditions of the time.

Fig. 2. Cultural and historical values of Moesian section
a. Remains of old Roman castrum of Singidunum (@Crnibombarder/Wikimedia Commons/CC BY-SA 3.0, https://upload.wikimedia.org/wikipedia/commons/thumb/9/92/Singidunum_ostaci1.jpg/350px-Singidunum_ostaci1.jpg, accessed October 9th, 2022);
b. Mausoleum in Viminacium (Perpetuum Mobile, Viminacium: Grad careva, grobova, mamuta i brodova, @2014-2022 Milan Mirković, https://www.perpetuummobile.blog/2020/08/viminacijum.html, accessed October 9th, 2022)
c. Remains of Lederata fort tower (Boom93, Kakve se još tajne kriju u Ramu, @Narodni muzej Požarevac, https://boom93.rs/info/drustvo/kakve-se-jos-tajne-kriju-u-ramu/, accessed October 9th 2022)

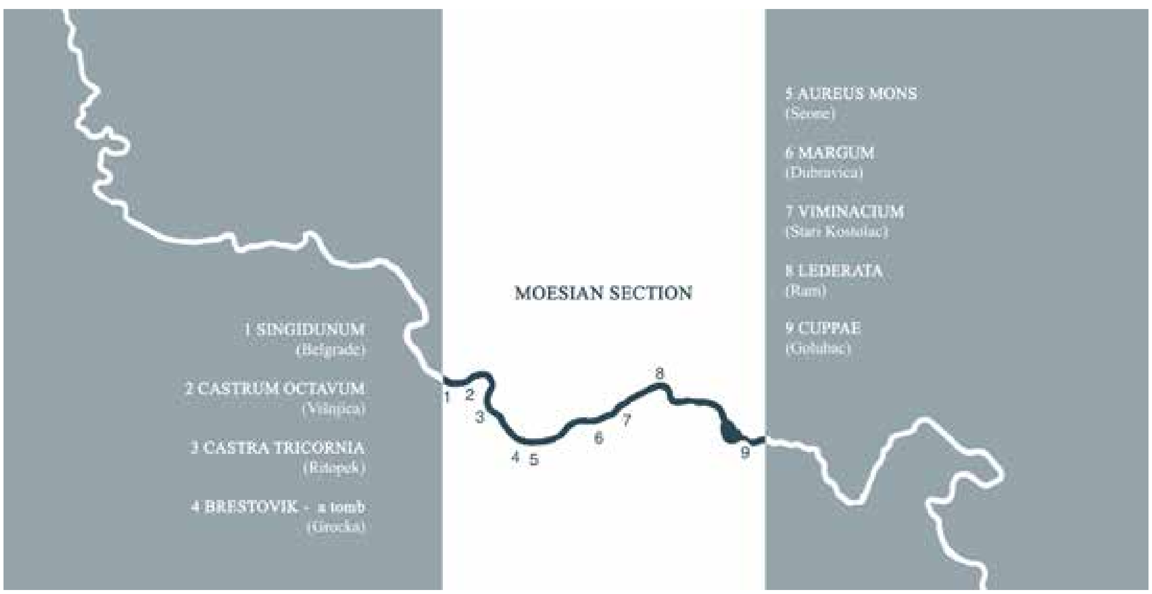


Fig. 3. Moesian section - archaeological sites source (map by J. Šćekić, October 2022).

NEW APPROACHES TO THE PROTECTION, PRESENTATION AND PROMOTION OF CULTURAL AND NATURAL HERITAGE IN THE CONTEMPORARY CONTEXT

The previous analysis of the Roman Limes, as well as the overview of important sites that belong to different historical periods and with different purposes, indicates its multi-layered importance, both on the level of the Republic of Serbia as well as on the global level. Consequently, the necessity of adequate protection, presentation, and promotion of the cultural heritage of the Roman Limes as a piece of heritage of the entire humanity, in accordance with the needs and ways of contemporary life, is highlighted. In that regard, the importance of studying international documents, charters, and declarations, verified by relevant organisations working on the protection, presentation, and promotion of cultural and natural heritage on the global level, is emphasised, among which are UNESCO (United Nations Educational, Scientific and Cultural Organisation – a United Nations organisation specialising in education, science and culture throughout the world), the Council of Europe and international non-governmental organisations, such as: ICOMOS (International Council on Monuments and Sites), ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Properties) and Europa Nostra (Europa Nostra – The Voice of Cultural Heritage in Europe) (Nikolić 2022:50). Within the framework of documents, declarations, and charters that are important for the study of cultural and natural heritage, principles and guidelines for their protection, presentation, and promotion in the contemporary context are defined, aligned with the imperative of preserving their natural and cultural and historical values. Therefore, their study is a prerequisite for any dealings with cultural and natural heritage in the contemporary context. Bearing in mind the subject and problem of this research paper, which refers to the contemporary principles of the revitalisation, presentation, and promotion of cultural and natural heritage researched in the case study of the late antique tomb in Brestovik, the importance of studying the Florence Landscape Convention (Council of Europe, 2000), the Charter on Cultural Routes from Quebec (ICOMOS 2008), and the Nara Document on Authenticity is particularly emphasised (ICOMOS 1994).

Within these documents, the concepts of cultural and natural heritage, cultural landscape, and cultural routes are more closely defined. Also, the potential of viewing cultural and natural heritage through the concept of the protection, presentation, and promotion of the authenticity of cultural and natural heritage, as well as the presentation and promotion of landscapes and cultural routes, allows cultural and natural heritage to be seen as an inseparable part of the environment in which they are located.

The importance of studying the authenticity of cultural and natural heritage is especially highlighted from the aspect of recognising the value of the cultural and natural heritage that should be protected, presented, and promoted in the contemporary context (Nikolić 2022:111-116). The term authenticity defined this way indicates the complexity of authenticity as a quality of heritage, but also its importance in the process of preserving heritage, which requires a comprehensive consideration of all its values, both material and immaterial, but also a dedicated search for the truth that should be preserved and appropriately presented and promoted in the contemporary context. The importance of the Nara Document on Authenticity is particularly emphasised when integrating contemporary architecture into spaces with pronounced natural, cultural, and historical values, where the preservation of all existing cultural and historical layers that built the identity of the cultural heritage over time and influenced its current state is an imperative in the process of the protection, presentation, and promotion of cultural heritage in the contemporary context (Roter Blagojević et al, 2013:20-24).

The use and respect of the principles of protection, presentation, and promotion of cultural and natural heritage defined in the framework of internationally recognised documents, charters, and declarations, with an examination of the possibility of their implementation within the project framework of the protection and revitalisation of natural and cultural heritage through contemporary architectural expression, represents a possible method for the integration of natural and cultural heritage into contemporary trends, and seeing them as an integral part of the space in which they are located, something that is also sought in the case study of the late antique tomb in Brestovik.

TEACHING IN THE FIELD OF THE STUDY AND PROTECTION OF ARCHITECTURAL HERITAGE AT THE UNIVERSITY OF BELGRADE – FACULTY OF ARCHITECTURE

Within the Faculty of Architecture's teaching process at the University of Belgrade, the successful and long-term development of the teaching programme in the field of the study and protection of architectural heritage, in compulsory as well as optional subjects, is noticeable. These programmes are in line with the guidelines adopted for education and training for the conservation of monuments, ensembles, and sites by ICOMOS in Colombo in 1993 (Roter Blagojević i Nikolić, 2013: 45). These guidelines stipulate that in the educational system and training for conservation, it is a necessity to transfer all the necessary knowledge to those who directly or indirectly affect the cultural heritage. According to that, the basic recommendations defined by the guidelines have been incorporated in various ways into the system of education and improvement of conservation practices in certain European countries, as well as at the Faculty of Architecture in Belgrade.

The methodology of the elective course History and Theory 3 – Ancient Heritage in the Region

During classes in the autumn term of 2020/2021 at the University of Belgrade's Faculty of Architecture, a course was part of a syllabus in the second year of the master studies, i.e., in the fifth year of integrated academic studies in architecture, entitled History and Theory 3 – Ancient Heritage in the Region, led by Assistant Professor Dr Marko Nikolić and Teaching Assistant Ena Takač. A total of 28 students from the master's academic studies in architecture and 12 students from the integrated academic studies actively attended the course (Nikolić i Takač, 2021: 202). The teaching process in this subject consisted of lectures and exercises, during which students had the opportunity to become acquainted with modern methodological approaches to research and the valorisation of ancient heritage in the world, as well as on the territory of the Republic of Serbia, and to address the problems and methods of defining the potential and possibility of restoration of the ancient heritage in accordance with contemporary needs. The topic of the research in the subject was related to the study of the ancient heritage on the territory of the city of Belgrade, through the study of the late Roman tomb in Brestovik and the possibilities of its protection, revitalisation, and presentation.

Cultural and historical values of the late Roman tomb in Brestovik and its surroundings

The village of Brestovik is located 28 km east of Belgrade, within the boundaries of Grocka borough, near the Danube river. Like many small towns in Serbia, Grocka was organised in an oriental manner, with a busy bazaar in the centre of the settlement. The settlement consists of houses that are made of bondruck (houses with a wall construction made of a visible skeleton of wooden beams), and which, with their architectural and ethnographic values, represent the largest domains of construction, housing, and local culture in our national architecture. Houses in the Grocka style are spacious single-family dwellings of different types of bondruck country houses, with three to four rooms, a porch, and a veranda (Вујовић 1994: 341). Brestovik has a similar character to the municipality to which it belongs, a spontaneous character, created on hilly terrain, Brestovik, like Grocka, has village-type buildings that are in very bad condition. (Figure 4)

The late Roman tomb in Brestovik represents evidence of life in Brestovik even in Roman times. It represents one of the most precious monuments from the ancient period, not only on the territory of Belgrade but also on the whole territory of Serbia. The late Roman tomb is located right next to the village cemetery, on the site that locals call Vukašin's church. The tomb is positioned in a diverse landscape on a hill that had a potential of viewing the entire landscape and creating a visual connection with the Danube river, which, due to contemporary construction, does not exist now. Emphasizing the potential of the natural environment is one of the key aspects of connecting this site with its visitors (Nikolić i Takač, 2021: 206).

Fig. 4. Brestovik - late Roman tomb and its surroundings (photo by P. Marjanović, June 2021, from Nikolić, Takač 2021).

The tomb's layout and the found artifacts indicate the connection of the tomb with pagan heroes and sanctuaries of the imperial cult. Considering that, this tomb represents a link in the chain of development between ancient and early Christian cult buildings. The tomb was built in the second half of the 3rd or at the beginning of the 4th century AD (Вујичић-Вуловић, 1967:85). It represents the type of building from which complex Christian buildings related to the tombstone cult would later develop (Симић 2009:3). Today, the entrance to the late Roman tomb is located on private property, in a back garden. In other words, it requires the visitor to pass through private property, an inappropriate and impractical way to visit this cultural asset, which should be publicly approachable and open to all visitors (Figure 5).

The current approach to the protection of the late Roman tomb in Brestovik

The late Roman tomb in Brestovik was discovered in 1895 by the then owner of the property on which it is located. In the same year, the first explorations of the tomb were conducted by the architect Mihajlo Valtrović. He made detailed notes about the remains and artifacts that he found there. Based on the discovered remains, consisting of three brick sarcophagi – for two adults and one child, parts of two figures of the Genius of Death, and two lions guarding the tomb entrance, together with one life-sized statue of a Roman, Valtrović pointed out in his report that they were the remains of a Roman tomb. After further excavations, it was determined that this tomb dates back to the 3rd century and that it represents the first example of a multi-chambered tomb from the ancient era to be found on

Fig. 5. Brestovik - late Roman tomb (photo by P. Marjanović, June 2021, from Nikolić, Takač 2021).

Fig. 6. Brestovik – Appearance of the late Roman tomb (photo by Institute of Archaeology, May 2022, December 2019, from Nikolić, Takač 2021).

the territory of the city of Belgrade (Валтровић, 1906: 130). The study of the painted decoration in the late Roman tomb was described by Mihajlo Valtrović in 1905, while research and revision excavation works on the tomb were carried out much later in 1955 by the Institute of Archaeology of the Serbian Academy of Sciences and the researcher Đorđe Stričević. Research concluded that the room with the remains of the sarcophagus on the west side is older than other parts of the building (Стричевић 1957: 412).

The report after all completed research and works on renovation, which was published in 1967 by the architect Mila Vujičić-Vulović, did not clearly state exactly which interventions were included in the conservation of the painting inside the tomb, which was carried out by Radomir Gašić. After the completion of the works carried out in 1964, which are not clearly stated, the tomb was restored to the state it is in today, which is accessible to the public (Вујичић-Вуловић, 1967: 91) (Figure 7).

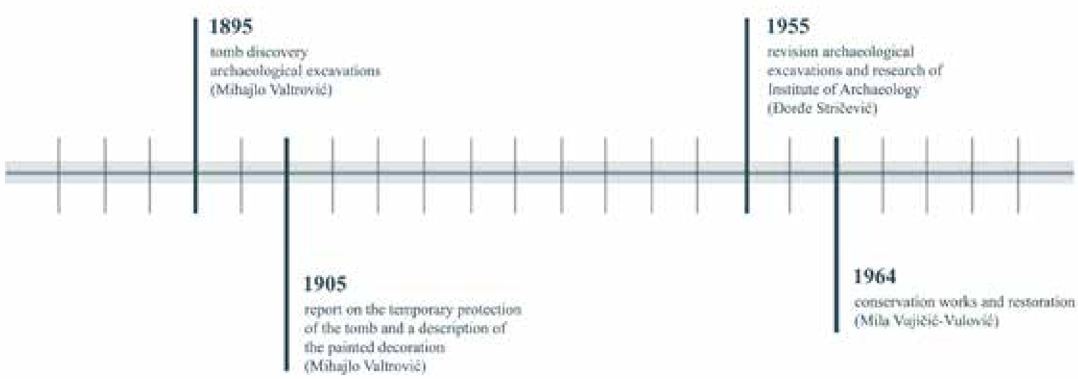


Fig. 7. Chronological overview of the archaeological research of the late Roman tomb in Brestovik (scheme by E. Takač, modified from Nikolić, Takač 2021).

Research and conservation efforts on the remains of the tomb continued in 1964 under the supervision of the architect Mila Vujičić-Vulović (Nikolić, Rogić i Anđelković Grašar, 2018: 198). The focus of the work was centred on the conservation and restoration of the tomb's architecture and painting. The condition of the tomb in 1964 was very similar to that of 1955, before the works were carried out. It was noted that the walls of the building were damaged and that the frescoes had disappeared in several places due to exposure to atmospheric changes (Вујичић-Вуловић, 1967: 89). The renovation works in 1964 were conducted on the architecture, that is, on the entrance wall of the burial chamber, the walls of the apse, and the walls of the approach area, as well as on the floors in front of the chamber and inside the porch. In addition to the above-mentioned efforts, the renovation also included access paths, as well as a plateau in front of the tomb. (Figure 6)

With its architectural and constructional characteristics and religious-cultural features, the tomb represents an outstanding example of Roman sacral architecture on the territory of the Republic of Serbia. Consequently, in 1979 it was declared a cultural asset of great importance.

THE POSSIBILITIES OF THE PROTECTION, REVITALISATION AND PRESENTATION OF THE LATE ROMAN TOMB IN BRESTOVIK – ACHIEVED RESULTS

After researching the cultural-historical and natural values of the site and its development over time, the conducted research and the current state – based on the collected, systematised, analysed, and valorised data, the students started working on conceptual solutions for the protection, revitalisation, presentation, and promotion of the observed values of the late Roman tomb in Brestovik, with the aim of integrating it into the contemporary environment.

Project 1 – Proposed by students Milena Ristić, Eli Janja Stojanović and Emilija Savić

The proposal for the revitalisation of the late Roman tomb project is formed by emphasising the solution to the main problem of accessibility and the specific morphology of the terrain, in order to preserve the ambiance. Accordingly, the basic concept of moving around the site is designed to be carried out by using a system of ramps that reach all points on the site and allow unhindered movement and viewing of its complete content. The ramp system extends over several levels and, as it were, "collects" each object with all their functions and, thus, following the route of the system, visitors can create a story and enjoy all the possibilities that the site offers. (Figure 8)

The revitalisation plan of this project envisages the creation of a visitor centre, located at the beginning of the ramp system, where visitors would receive basic information about the site, then, via the ramp, reach the vineyard, which includes a wine store, a coffee bar, a viewpoint, pavilions containing a souvenir shop and, finally, they come to the tomb, where conservation is planned. Newly designed buildings are fully integrated into the natural environment, emphasising their character. By using stone, wood, and glass in shaping the new content, a balance between the old and the new is achieved, which enables the preservation of the authenticity and ambiance of this monument. (Figure 9)

The project, in addition to the introduction of new complementary content, foresees the formation of a protective structure serving as a lapidarium, the main motive of this project, which also integrates a ramp. The formation of the lapidarium points to the tomb as an important location for the development of the space for education. The construction of the protective building was shaped to emphasise the connection of the natural environment with the tomb itself, which is reflected in the formation of a semi-open structure which, by the exclusion of one wall, enables a clear view towards the Danube river. (Figure 10)

Project 2 – Proposed by students Teodora Simonović, Ana Srebro, Jelena Stanisavljević, Milica Miljković and Jelena Šćekić

The proposal for the revitalisation of the late Roman tomb in this paper is based on improving access to the site and its better presentation, and

Fig. 8. Proposal for arranging the parterre around the late Roman tomb (drawing and models by M. Ristić, E. J. Stojanović and E. Savić, from Nikolić, Takač 2021).

Fig. 9. Preliminary project of the visitor centre (models by M. Ristić, E. J. Stojanović and E. Savić, from Nikolić, Takač 2021).

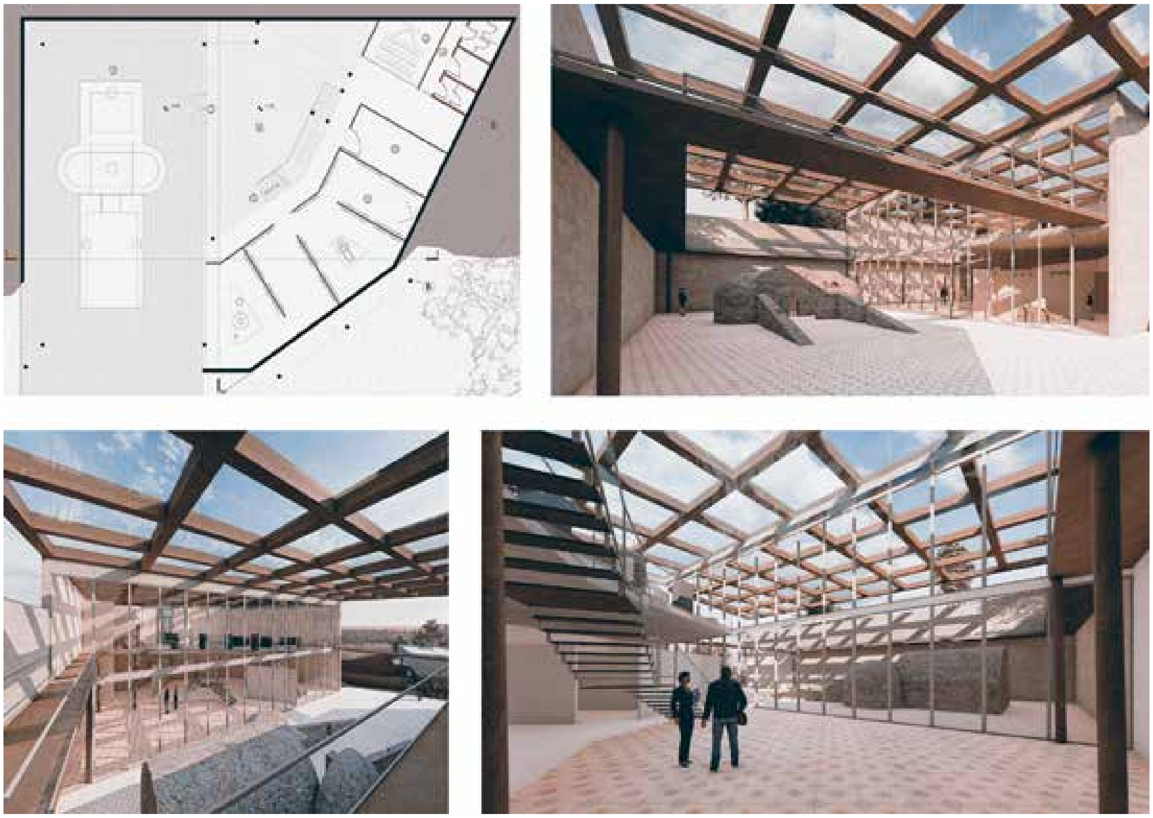


Fig. 10. Preliminary project of the lapidarium (drawing and models by M. Ristić, E. J. Stojanović and E. Savić, from Nikolić, Takač 2021).

also its tangible and intangible values. Establishing such an approach in order to revitalise the site, indicates that its goal is to find a balance between the old and the new in order to preserve the authenticity and ambiance of its archaeology.

By recognising the main problem that is reflected in the access to the site, the students proposed arranging the traffic infrastructure and the surroundings of the site itself. The development plan foresees the existing access to the site being moved to the side of the plot where the tomb is located, thus, preventing the need to go through the properties of nearby buildings. (Figure 11) After rearranging the site's access, the next step related to the position of the first content that will indicate the importance of the site is the formation of the visitor's centre. The centre is designed as an exhibition space with a lecture hall, which would offer visitors their first information about the site. The ground-floor of the centre is designed in a simple geometric form, which, with its appearance and realisation, indicates the consistency of the revitalisation project with its aim of not jeopardising the perception of the tomb's architecture and its ambiance. (Figure 12)

The revitalisation of the central part of the plot creates a piazza as the main gathering spot from which paths branch off to other complementary contents, such as: a wine cellar, amphitheatre, lapidarium, and the tomb itself. In addition to everything mentioned above, in the piazza, we would form some prefabricated pavilions, which would represent a space for the presentation of the intangible heritage, as well as a gathering place for the local population. Within the pavilion, it is foreseen that it would provide content to inform the site's visitors, in addition to including some information about the architecture of Grocka – about its cultural heritage and natural resources. (Figure 13)

In addition to the piazza as an organised public space, an amphitheatre would also be created, located next to the tomb itself. It is placed so it can follow the fall of the terrain and it represents a natural deflection from the village cemetery, which is located behind the tomb itself. Above the amphitheatre and the remains of the tomb, which is being conserved, a steel protective structure is formed so that it can protect the frescoes and the interior of the tomb

Fig. 11. Proposal for arranging the parterre around the late Roman tomb (drawing and model by T. Simonović, A. Srebro, J. Stanisavljević, M. Miljković and J. Šćekić, from Nikolić, Takač 2021).

Fig. 12. Preliminary project of the visitor centre (models by T. Simonović, A. Srebro, J. Stanisavljević, M. Miljković and J. Šćekić, from Nikolić, Takač 2021).

Fig. 13. Preliminary project of the piazza with pavilions (models by T. Simonović, A. Srebro, J. Stanisavljević, M. Miljković and J. Šćekić, from Nikolić, Takač 2021).

itself. By positioning the amphitheatre next to the late Roman tomb itself, visitors are given the opportunity to observe the landscape as a whole, and it can also be used for open-air lectures. (Figure 14)

To additionally point out the importance of the presentation of the intangible heritage of this area, the students, in addition to prefabricated pavilions, envisioned a wine cellar. Bearing in mind the dominant natural environment of the location near private family houses, the wine shop was designed to fit into the existing landscape. By positioning the wine shop within this site, a presentation of wine and local products is made possible, which enables the nurturing of the culture of wine production that is a characteristic of this region. (Figure 15)

Project 3 – Proposed by students Nevena Petrović, Emilija Radenković, Jovan Jovanović, Teodora Jeremić, Una Korica and Milica Jovančević

By analysing the environment in which the monument is located, to activate it and bring it closer to visitors, this group of students approached the solution of its approach and the use of the specificity of its disposition by proposing three options. (Figure 16)

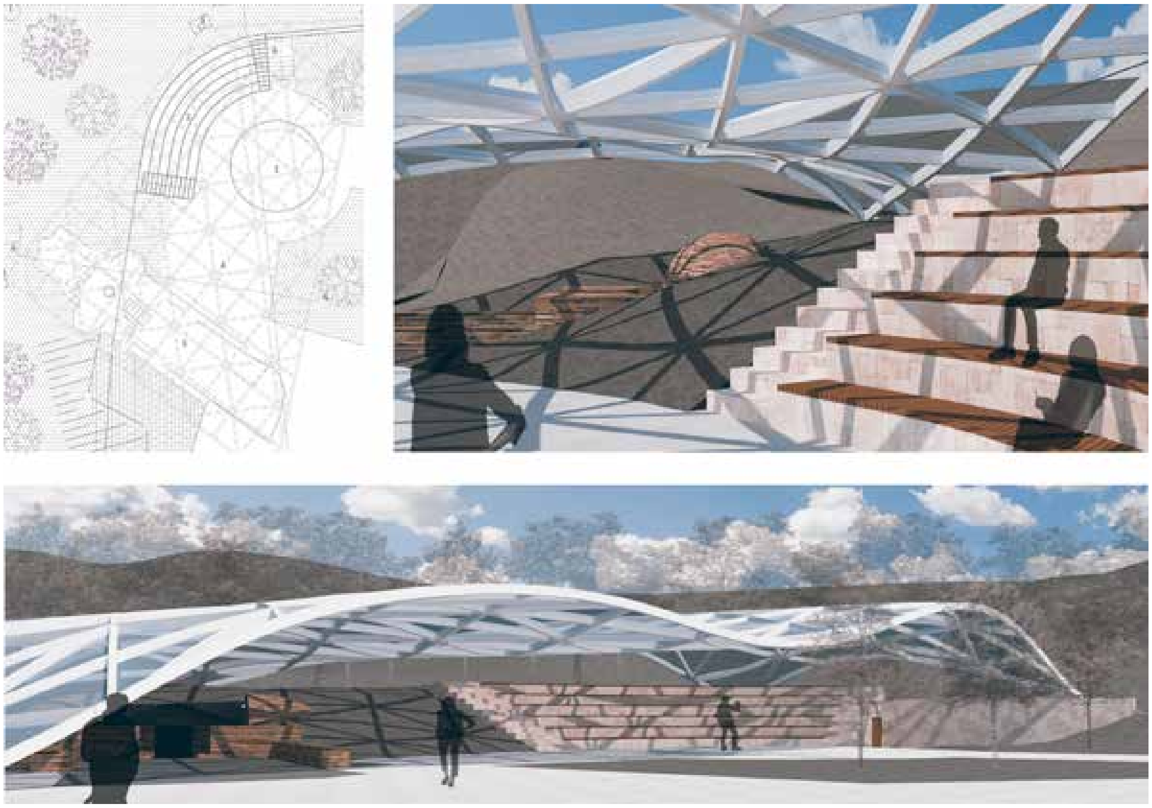


Fig. 14. Project of the amphitheatre and protective structure above the late Roman tomb (drawing and model by T. Simonović, A. Srebro, J. Stanisavljević, M. Miljković and J. Šćekić, from Nikolić, Takač 2021).

Fig. 15. Preliminary project of the winery (models by T. Simonović, A. Srebro, J. Stanisavljević, M. Miljković and J. Šćekić, from Nikolić, Takač 2021)

Option 1 represents a proposal that considers the formation of new content at the current position of the entrance to the site itself. Based on this option, it was established that the privacy of properties in the immediate proximity of the tomb is being compromised and, for this reason, it is additionally conditioned that future interventions on this site must be of a closed nature. Looking back to the previous option, option 2 was formed to indicate that it is necessary to avoid close contact with residential buildings by relocating the entrance to the complex to the centre of the plot. This option envisions a smaller building being positioned south on the street itself and this could be used as an information centre after the revitalisation. Similar to option 1, this solution would be primarily linear, and would create a climb to the tomb, which would include exhibits along its route. Option 3 does not resemble the previous two concepts, as accessing the tomb is possible from a secondary road leading to the village cemetery. The advantage of this solution is that the private plots would not be disturbed, but the connection to the tomb itself would be formed on a path that lies on the divisions of the plots. The proposed form of the new facility may seem inconsistent and

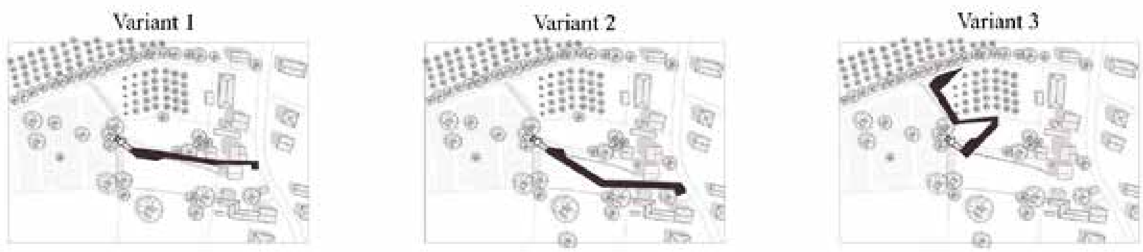


Fig. 16. Diagram of variations of the parterre in front of the late Roman tomb (drawings by N. Petrović, E. Radenković, J. Jovanović, T. Jeremić, U. Korica and M. Jovančević, from Nikolić, Takač 2021).

invasive at first glance. However, this structure is justified by the division of new content. In addition to the above, the embankment that separates the new building from the village cemetery could be used and, thus, a part of the building could be subterranean. By considering all the variations, the students concluded that the best solution for the regeneration of this area is variant 3, which, with its unique solution enables the undisturbed use and presentation of the tomb.

After solving the main problem of accessing the site itself, the students considered the concept of the architectural project. The concept of new content was formed in relation to the importance of the cult of the dead, which was present during the late Roman period. Following that concept, the students envisioned a multi-functional facility designed as intertwining above-ground and underground spaces, simulating the cycle of life through the experience of the exhibition. Consequently, an object of four broken tracts that follow the isohypses of the terrain was formed. The first tract of the building is located above ground and contains an information centre with a gallery space where visitors can learn about the intangible heritage of Brestovik. The second tract is located underground and introduces visitors to the tangible heritage. Within the third tract, which is

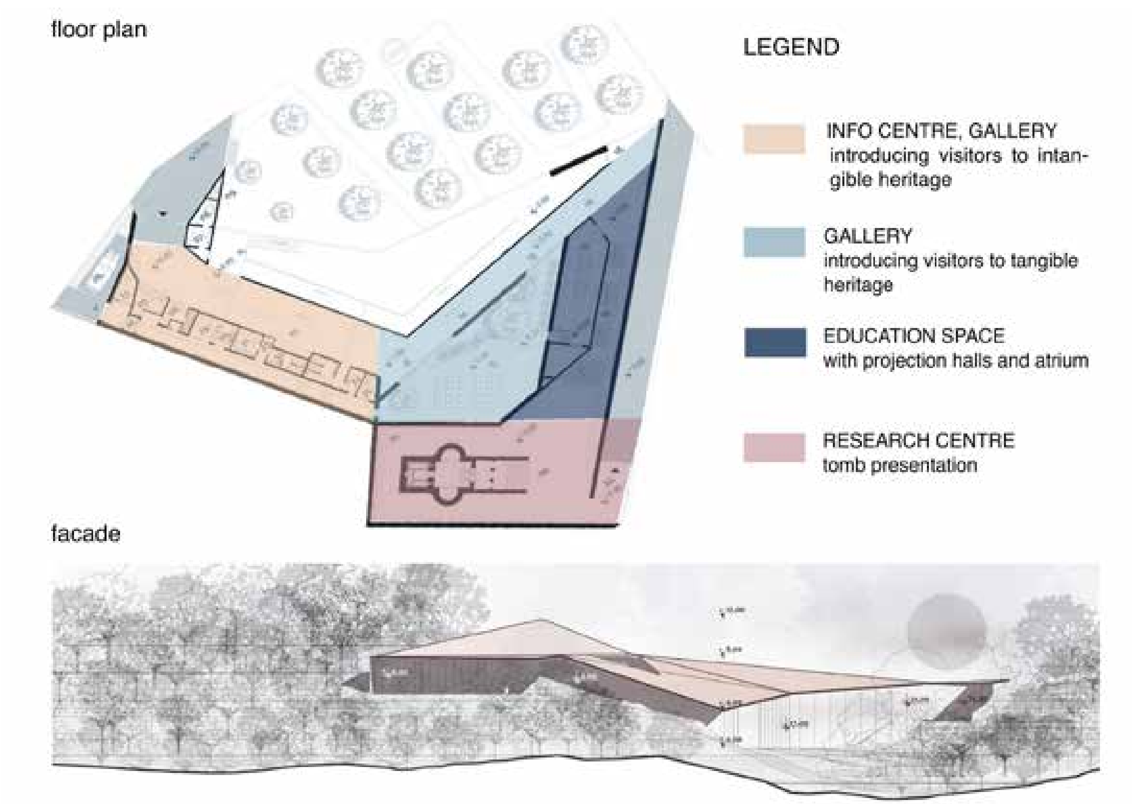


Fig. 17. Floor plan and facade of the object (drawings by N. Petrović, E. Radenković, J. Jovanović, T. Jeremić, U. Korica and M. Jovančević, from Nikolić, Takač 2021).

found above ground, there is an educational hall which, in addition to the projection room, also has an atrium where lectures are held that teach visitors about the importance and preservation of archaeological sites. The fourth and final tract, located underground, forms the centre for scientific research with the purpose of presentation of the late Roman tomb itself. (Figure 17)

Analysis of achieved student results in the field of the protection, revitalisation and presentation of the late Roman tomb in Brestovik

The rich range of offered solutions speaks, on the one hand, of the complexity of all the problems encountered by students during the work and, on the other hand, about the breadth and creativity of the students with which it is potentially possible to improve and restore the site of the late Roman tomb in Brestovik. Accordingly, the relevance and success of the protection, revitalisation, and presentation projects of the late Roman tomb in Brestovik are viewed with regard to three important criteria: the relationship to protected cultural-historical and natural values (Table 1), the introduction of new complementary content (Table 2), and the use of contemporary materials in the architectural expression (Table 3).

The protection and preservation projects of the late Roman tomb in Brestovik envisage the conservation of the remains (in situ) and the formation of a protective structure that, with its structure and materialisation, does not damage the cultural-historical and natural values of this site. The specificity that distinguishes the approaches in the presentation of the remains of the late Roman tomb in the presented projects is their relationship to the environment. With its proposal for a protective structure, Project 1 envisages the formation of a semi-open protective structure that integrates the environment with the remains of the tomb itself. That is not the case with Project 3, which presents the remains of a tomb in a closed structure buried underground. Complete contact with the environment was made possible within the framework of Project 2, by forming a protective structure whose shape fully follows the configuration of the terrain.

The students' works, in addition to considering the protection the remains of the late Roman tomb site itself, also realise the importance of its presentation. As the first problem in solving the site's presentation, they encountered the problem of its accessibility and disposition, which all projects solved by proposing new access to the site and creating new public spaces within which new cultural and educational content was formed. These allow visitors to learn about the importance of the late Roman tomb in Brestovik (Table 2).

The students' work that dealt with designing new content at the site of the late Roman tomb in Brestovik envisages the use of stone, steel, wood,

	REMAINS OF A LATE ANTIQUE TOMB				
	Relationship with the environment	Technical protection measure	Protective construction / purpose	Materialisation	Project
PROJECT 1	The protective building integrates with the environment with its open plan	Conservation of remains in situ	Protective structure in a massive system with the purpose of a lapidarium	The building was made from a combination of stone, steel and glass	
PROJECT 2	The protective structure was created to follow the morphology of the terrain	Conservation of remains in situ	Protective structure as a skeletal system in the form of a canopy	Protective structure was made from a combination of steel and glass	
PROJECT 3	The protective structure is partially buried in the ground and allows the synergy of the interior and the natural environment	Conservation of remains in situ	Protective building in a massive system with the purpose of a scientific research and visitor centre	The building was made from a combination of steel and glass	

Table 1. Relationship between protected cultural-historical and natural values (table by E. Takač).

	NEW STRUCTURES ON THE SITE				Project
	Public spaces	Accessibility	Cultural - educational contents	Catering facilities	
PROJECT 1	A ramp system like a street gallery	Moving the original access to the side street. Creating new pedestrian paths and ramp systems	Lapidarium Visitor centre Gallery	Cafe Restaurant	
PROJECT 2	Forming a piazza with prefabricated pavilions	Moving the original access to the side street. Creating new pedestrian paths	Lapidarium Visitor centre	Winery Cafe Restaurant	
PROJECT 3	Formation of inner courtyards with the character of a park area	Moving the original access to the side street	Lapidarium Gallery Research centre Visitor centre	Cafe Restaurant	

Table 2. Formation of new complementary content at the site (table by E. Takač).

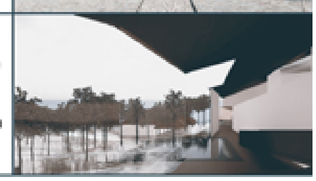
	MATERIALISATION OF NEW STRUCTURES ON THE SITE				Project
	Public spaces	Accessibility	Cultural - educational content	Catering facilities	
PROJECT 1	Corten steel ramp system	Access to the building paved with stone slabs	Walls built of a combination of stone and steel Roof covered with glass and sheet metal	Walls built of a combination of stone and steel Roof covered with glass and sheet metal	
PROJECT 2	The piazza is paved with stone slabs Pavilions built of light wooden construction	Access to the building paved with stone slabs	Walls built of a combination of stone and wood Roof covered with glass and sheet metal	Walls built of a combination of stone and wood Roof covered with glass and sheet metal	
PROJECT 3	The floor is formed of stone slabs	Access to the building paved with stone slabs	The walls are made of steel in combination with glass Roof covered with corten steel	The walls are made of steel in combination with glass Roof covered with corten steel	

Table 3. Use of modern materials in architectural expression (table by E. Takač).

and glass, enabling their integration into the environment. (Table 3)

Based on the established criteria, we can conclude that, in the creation of their solutions, the students have a clear definition and relocation of the access to the site, as well as the aspiration to, through the introduction of new artistic and educational content, retain the primary cultural-educational character of the site and, thus, make it more attractive for visitors, as a common characteristic. By forming this approach for the revitalisation of this ancient heritage, the students pointed out the importance of presenting archaeological sites and monuments, primarily their tangible and intangible elements and, in this way, the authenticity and integrity of the site to be preserved is enabled.

CONCLUSIONS

Through theoretical and practical teaching in the elective course History and Theory 3 – Ancient Heritage in the Region, students were able to become acquainted with the methodology of planning and modern planning approaches in protected areas. Based on the student projects of the protection, revitalisation, and presentation of the late Roman tomb in Brestovik, we can conclude that archaeological sites and monuments represent good training grounds for the development of various cultural and artistic content that enrich both the sites and their surroundings, as well as society as a whole. The presented projects indicate the monitoring of the dynamic concept of constant enrichment of the authenticity of the historical location, through the changes and layers brought by time, with the necessary respect for the guidelines and principles of architectural heritage preservation, in accordance with the recommendations established in international documents, charters, and conventions.

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REZIME

SAVREMENI PRISTUPI REVITALIZACIJI, PREZENTACIJI I PROMOCIJI KULTURNOG I PRIRODNOG NASLEĐA DELA RIMSKOG LIMESA − STUDIJA SLUČAJA KASNOANTIČKE GROBNICE U BRESTOVIKU

KLJUČNE REČI: RIMSKI LIMES, KULTURNO I PRIRODNO NASLEĐE, KASNOANTIČKA GROBNICA, SAVREMENA REVITALIZACIJA I PREZENTACIJA, ODRŽIVI RAZVOJ.

Rimski limes prepoznat je kao kulturni predeo izuzetnih univerzalnih vrednosti međunarodnog značaja od strane relevantne organizacije za zaštitu kulturnog i prirodnog nasleđa - UNESCO. Na prostoru Republike Srbije, Rimski limes obuhvata dolinu reke Dunav gde se nalaze lokaliteti različitih istorijskih perioda (praistorije, antike, srednjeg veka), koji predstavljaju svedočanstvo o kontinuitetu života na granici Rimskog carstva. Zaštita, revitalizacija, prezentacija i promocija lokaliteta duž reke Dunav predstavlja preduslov za upis dela Rimskog limesa na prostoru Republike Srbije na Listu svetske kulturne i prirodne baštine Uneska. Ovaj prostor se trenutno nalazi na Tentativnoj listi Uneska od 2020. godine. Imajući u vidu trenutno stanje velikog broja lokaliteta, postavlja se pitanje njihove zaštite, revitalizacije, prezentacije i promocije u savremenom kontekstu. Pozivajući se na principe međunarodnih povelja i konvencija, među kojima se ističu Dokument o autentičnosti, Evropska konvencija o predelu i Povelja o kulturnim rutama, osnovni cilj ovog rada jeste širenje znanja o mogućnostima zaštite, revitalizacije, prezentacije i promocije kulturnog i prirodnog nasleđa dela Rimskog limesa na prostoru Republike Srbije kroz primenu principa definisanih u međunarodnim poveljama i konvencijama, a radi integracije kulturnog i prirodnog nasleđa u savremene tokove i uspostavljanja održivog razvoja predela.

Rezultati istraživanja prikazani su kroz studiju slučaja arheološkog nalazišta kasnoantičke grob-

nice u Brestoviku, kroz idejna rešenja studenata arhitekture, u okviru kojih su ispitivane mogućnosti integracije savremene arhitekture u prostore izraženih prirodnih i kulturno-istorijskih vrednosti, uz istovremeno očuvanje identiteta prirodnog i kulturnog nasleđa koje iziskuje određeni stepen zaštite, ali i prezentacije i promocije. Kroz proces edukacije studenata arhitekture, budućih graditelja, pruža se mogućnost svestranog sagledavanja problema očuvanja kulturnog i prirodnog nasleđa, njegovog istorijskog i urbanog konteksta, nastanka, razvoja, kulturnih, urbanističkih i arhitektonskih vrednosti, te ispitivanja mogućnosti i komparacije različitih pristupa prezentaciji i savremenog korišćenja. U koncipiranju budućeg pristupa prezentaciji i uključivanja u savremeni život kasnoantičke grobnice u Brestoviku i njene okoline, u studentskim analizama akcenat je stavljen na sveobuhvatno istraživanje njenog života, od vremena nastanka do savremenog doba, te otkrivanju specifične kulturne vrednosti i karaktera koji su osnov očuvanja u budućnosti. Cilj je bio da se osmisle održiva rešenja koja će sa jedne strane očuvati razvojne faze, autentičnost i integritet kompleksa kasnoantičke grobnice u Brestoviku, a sa druge strane obezbediti njenu reaktivaciju i kvalitetnu integraciju u neposredno okruženje, koje je i pored brojnih neadekvatnih savremenih intervencija očuvalo pojedine elemente prepoznatljivog istorijskog ambijenta. Kroz svoje predloge, studenti su kompleks ispunili brojnim savremenim kulturnim, edukativnim i umetničkim sadržajima koji su u korelaciji sa njegovim karakterom i značajem, a obezbeđuju mu i aktivan život u budućnosti. Očekivani rezultati istraživanja obuhvataju podizanje svesti o mogućnostima integracije prirodnog i kulturnog nasleđa u savremeni kontekst, te sagledavanje prirodnog i kulturnog nasleđa kao pokretača za uspostavljanje održivog razvoja predela.

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DOCUMENTATION OFFICE OF THE INSTITUTE OF ARCHAEOLOGY IN BELGRADE AS AN ORGANISATIONAL UNIT

ABSTRACT

In the first segment of this paper, the stages of development of the field documentation of the Institute of Archaeology in Belgrade were processed. Special attention was paid to the history of the collecting, recording and inventorying of field documentation materials, starting from the establishment of the aforementioned scientific institution up to the present day. In the process of the reconstruction of these elements, the greatest source of data is provided by work biographies and annual reports of previous associates who performed the work of keeping the documentation, as well as the archival material of the Institute of Archaeology, which is located in the State Archives of Serbia. In the final parts of the text, the current state of the documentation and the proposed plans with the main goals for the next period are discussed, along with the presentation of new proposals in the fields of systematisation, digitisation and consolidation.

KEYWORDS: INSTITUTE OF ARCHAEOLOGY, FIELD DOCUMENTATION, RECORDING, ARCHAEOLOGY, SYSTEMATISATION, HISTORY, DATABASE.

INTRODUCTION

The research of archaeological sites has the goal of obtaining knowledge about the entire human life, society, economy and culture through material monuments and antiquities from the past. For archaeological science, fieldwork related to field survey of sites (reconnoitring and marking) is of basic and multifaceted significance because it represents the foundations of subsequent archaeological activities: excavations, study and maintenance, with the aim of creating a true picture of the previous state of archaeological sites (Грбић 1953: 28, 70). This is how Dr Miodrag Grbić, research associate of the Archaeological Institute at SAS, described the tasks of archaeological science in 1953 in his work *Fundamentals of Archaeological Site Research*. In the same year, another significant work on this topic was published by Milutin Garašanin and Draga Garašanin, then young members of the Institute, called the *Manual for Archaeological Excavations*, which points out the importance of keeping field archaeological documentation: "Along with archaeological research carried out according to all the principles of modern archaeological work, there is also archaeological documentation, which must be carried out with full attention and in all its details. Without documentation, even the most carefully conducted excavations have no value" (Гарашанин и Гарашанин 1953: 61).

An archaeological site is visible to researchers for only a short time, because during further work, most of it is destroyed. Documenting the data obtained during archaeological work enables a complete and correct use of archaeological materials necessary for further processing (Vinski 1948: 194–196; Гарашанин и Гарашанин 1953: 61). All data must be recorded with a clear idea of possible issues that may be raised in later stages of the work. Such an approach, as Kevin Green states, allows the director of the excavations to impose standardised recording methods, which greatly reduce the possibility of error or omission.


Fig. 1 Vladimir Petković (1874–1956) (Taken from: SASA Library -Ф 259, 259/1-2).

The time invested during the compilation of field documentation will pay off, e.g., at the time of writing the excavation report, because a comprehensive site database can be organised in various ways and, thus, present specific information arranged in the desired order (Грин 2003: 150, 152). The documentation of archaeological excavations basically consists of: a diary, technical drawings, a levelling book, photographs (during the 20th century also film negatives or photo-plates), as well as processed, classified record cards for mobile archaeological material. Financial reports (transportation costs, accommodation fees, field work consumables, etc.) or video tapes can be added to this. This type of material represents a recorded source of archaeological information or reproduced documentation material, which is of particular importance for scientific researchers whose main task is to reconstruct the past and cultural heritage (Гарашанин и Гарашанин 1953: 61; Бошковић 2017: 268).

The beginnings of work to collect and arrange the field documentation of the Institute of Archaeology were recorded in the first years of its establishment. To this day, this scientific institution has implemented a number of large projects that have resulted in extensive field documentation. According to the reports compiled by documentarians during the second half of the 20th century, this organisational unit of the Institute represents the most numerous archaeological materials of its type collected, catalogued and available in one place in the entire territory of Serbia (including the former republics of the SFRY) (Бошковић 2017: 267). To date, little and insufficient attention has been paid to the published reports and scientific papers, especially when it comes to the history of recording the field archaeological documentation of the Institute. A few years ago, a documentarian of this scientific institution, Zoran Bošković, published a brief overview of the work in the field of history and development of documentation (Бошковић 2017), which represents the sole paper dealing with this topic so far, but also the basis for further research endeavours when it comes to this topic.

FOUNDING OF THE INSTITUTE OF ARCHAEOLOGY

The idea of founding the Institute of Archaeology in these regions originated in 1927 by Prof. Dr Miloje M. Vasić. The then professor of archaeology at the Faculty of Philosophy in Belgrade, published an article entitled *Institute of Archaeology of Serbs, Croats and Slovenes*, printed in the *Serbian Literary Herald* XXII-1 (Васић 1927: 33-34). This paper mentions that there was a need to create such an institution in the Kingdom of SCS. However, for reasons unknown thus far, this idea was not put into practice at that time (Васић 1997: 9).[1]

The first scientific institution in this area that was engaged in the study of archaeological material, certainly as a secondary plan, was the Kon-

1 It is interesting to note that, as early as 1908, as the director of the National Museum, Vasić indicated that the Museum should be freed from certain obligations and that a "special institute for archaeological research" should be established. This document has not been preserved, but a trace of it and its contents can be found in the book of administrative protocols of the Ministry of Education of the Kingdom of Serbia for the year of 1908 (ДАС, Министарство просвете, Деловодни протокол за 1908, бр. 4408).

dakov Institute for Byzantology and Archaeology. This Institute was founded in the Kingdom of Yugoslavia in 1938, after it was moved from Prague to Belgrade. Prof. Dr Georgije Ostrogorski was appointed as the first director (AJ, 66-84-245; 66-569-892). One of the members of the Kondakov Institute was Đurđe Bošković, later the long-term director of the Institute of Archaeology.[2] During 1941, the Institute ceased to operate (AJ, 66-3272-2469) and was never restored.

The next attempt to establish the Institute of Archaeology, which would bear fruit, would occur in the post-war period. It was announced in the Yearbook SAS, vol. LIV that the Institute of Archaeology at the Serbian Academy of Sciences was founded on May 31, 1947 (*Годишњак* САН 1947: 41).[3] At that time, the president of the Serbian Academy of Sciences was Prof. Dr Aleksandar Belić, while the vice president was Prof. Dr Milutin Milanković. By a decree of the Committee for Scientific Institutions, Universities and Colleges of the Government of the People's Republic of Serbia, number 563, Prof. Dr Vladimir Petković (1947–1954) (Fig. 1) was appointed the first director of the Institute, with Prof. Đurđe Bošković (Fig. 1) as his deputy (*Годишњак* САН 1947: 41, 113, 115). At first, the premises of the Institute were located in the building of the Serbian Academy of Sciences. However, due to the need for more space for work, and at the suggestion of V. Petković, at the 6th Session of the Institute Commission of the Presidency of the Serbian Academy of Sciences, the Institute received approval for the transfer of the staff to Princess Ljubica's Residence (*Годишњак* САН 1947: 112, 122, 274, 277-278), which was carried out in January 1948 (*Годишњак* САН 1948: 236). The Institute continued to operate in this place until October 1952, when it moved again to the Academy building, where it remains today (*Годишњак* САН 1952: 316; Васић 2017: 9).

Fig. 2 Đurđe Bošković (1904–1990) (Taken from: Documentation of the Institute of Archaeology, Belgrade).

Under the leadership of its first director, the Institute aimed to gather collaborators from the university, museums and other scientific institutions in Belgrade who were engaged in the study of archaeological problems in various ways. By the end of 1947, a group of nineteen eminent experts was formed, which gathered once a week to solve numerous issues of the Institute (*Годишњак* САН 1947: 41-42, 115, 122, 131, 191-192; Бошковић 1969: 1-2). One of the goals, which was set after its formation, was the definition of work plans in which the study of the development process of human life on the basis of archaeological materials in the country and the Balkans was emphasised. By studying those material remains, the aim was to provide a reconstruction of the way of life, culture, art and scope of human thought in the mentioned regions (Бошковић 1959: 1).

In 1961, the Institute of Archaeology became an independent institution, as was confirmed by the *Decree on the Foundation of the Institute of Archaeology*, published in the *Official Gazette of the People's Republic of Serbia*. According to Article 1 of the

2 Documentation from the Legacy of Đurđe Bošković at the Institute of Archaeology in Belgrade.

3 The draft for the establishment of the Institute of Archaeology was first submitted to the Committee for Scientific Institutions, University and Higher Education of the People's Republic of Serbia, which was initially decided at the IV Session of the Committee for Managing the Affairs of the Serbian Academy of Sciences, held on May 23rd, 1947. The session was chaired by M. Milanković, with C. Petrović, P. Kolendić and P. Savić attending (*Годишњак* САН 1947: 108-110).

АРХЕОЛОШКИ ИНСТИТУТ
Бр. 816
5.XI. 1952 год.
БЕОГРАД

Asistentima Arheološkog instituta SAN

Beograd

U smislu preporuka rukovodstva SAN da asistenti akademijinih Instituta,uporedo sa individualnim naučnim radom i usavršavanjem u svojoj užoj specijalnosti,obavljaju i one stručne poslove koji stoje u neposrednoj vezi sa izvršenjem opštih zadatka Instituta,Naučni savet Arheološkog instituta doneo je na svojoj sednici od 4 o.m.odluku da će asistenti Arheološkog instituta biti obavezni da,prema svojoj stručnosti,tri sata dnevno posvete radu na sistematskom sredjivanju naučne dokumentacije o objektima koji se u Institutu proučavaju.Ovaj rad odnosiće se prvenstveno na sredjivanje materijala kojim institut raspolaže/rukopisi,izveštaji,terenski zapisnici,planovi,crteži,kopije,fotografije itd./.Bliža uputstva za izvršenje ovih zadatka asistenti će dobiti od Naučnog saveta Arheološkog instituta.

S.F.-S.N.

UPRAVNIK
Arheološkog instituta

/dr Vlad.Petković/

Primili znanju:
1.arh.Nevenka Spremo
2.Djordje Stričević
3.arh.Vojislav Korać

Fig. 3 Document on the decision on naming an assistant for the classification of scientific documentation in the Institute of Archaeology at SAS (Taken from: State Archives of Serbia – Fond of the Institute of Archaeology, Д-9).

Regulation, the Institute was jointly founded by the Executive Council of the National Assembly of the People's Republic of Serbia, the Serbian Academy of Sciences and Arts, and the Faculty of Philosophy and History of the University of Belgrade (*Службени гласник* НРС XVII-18: 1961, 269). The head of the newly formed institution was Đ. Bošković, who was elected the director of the Institute in 1954. He would continue to hold this position, with great success, until 1977 (Шарић и Бикић 2017: 52).

STAGES OF THE DEVELOPMENT OF RECORDING THE FIELD DOCUMENTATION OF THE INSTITUTE OF ARCHAEOLOGY

Stage I: from the founding of the Institute until 1962

Based on the written material from the Fund of the Institute of Archaeology in the State Archives of Serbia[4] and the published annual reports

4 On this occasion, I would like to sincerely thank

of the Serbian Academy of Sciences since 1947, the beginnings of work in documenting field archaeological documentation within the scientific institution that is the topic of this paper can be reconstructed to a large extent. Judging by the available material, from the moment of its establishment until 1955, as we will see later, the Institute did not have a dedicated documentarian to carry out tasks related to the collection, arrangement and recording of field archaeological material (*Годишњак* САН 1947: 41, 115‒116; *Годишњак* САН 1952: 316; Бошковић 2017: 265).

In the year the Institute was founded, archaeological excavations of sites, field surveys of terrain, thematic tours, as well as the protection of certain archaeological finds were all carried out.[5] The management of documentation during these first campaigns is certainly unquestionable, and it is likely that, after the research was completed, it would have been kept for some time by the excavation director (*Годишњак* САН 1948: 232; *Годишњак* САН 1952: 323). Today, in the Documentation Office of the Institute, there is no inventory book from the first years in which the inventory of documentation of archaeological fieldwork would be listed.

The first data related to the plan for organising the field documentation can be found in the records of the 11th Session of the Institute of Archaeology SAS, held on November 8, 1947. At that time, a decision was made, under the second point of the meeting agenda, regarding cooperation between the Institute for the Protection and Scientific Study of Cultural Monuments of the Republic of Serbia and the Institute for the creation of a file archive and photo files, as well as the procurement of the necessary photo material (ДАС-ФАИ, Д-3). As early as the following year, we find information about the arrangement of documentation by Prof. Đurđe Bošković, Prof. Aleksandar Deroko, Ivan Zdravković and others, at the moment when they were engaged in the organisation of and joint work on the archives of the Institute of Archaeology and the above-mentioned Institute for the Protection and Scientific Study of Cultural Monuments. On that occasion, they handed over their previously collected scientific data and drawings (from the field), noting that they worked on supplementing and improving the files whenever necessary (*Годишњак* САН 1948: 235; Бошковић 2017: 265). Data on documentation management for the following years is also scarce. It is known that the work plan for 1950 included the production of technical drawings, as well as photographs for the album and photo collection. In the report of the Institute for the following year, there is information about the creation of a photo archive and the arrangement of negatives and photographs (Бошковић 2017: 265). During those years, work in the field increased intensively, so the volume of documentation material became more and more extensive and complex (*Годишњак* САН 1948: 234‒237; *Годишњак* САН 1952: 320‒321). The year of 1952 was certainly a turning point in the attempt to engage professional staff in the work of arranging the Institute's field documentation. The work plan for that year provided for the following, under point four: "Work on the photo archive, files of miniature plans and other records". In the annual work report, when the systematisation of workplaces was carried out at the suggestion of the leadership of the Serbian Academy of Sciences, it was stated that the assistants of the Institute would perform the work of arranging scientific and technical documentation, registering photographs, negatives, copies and drawings, for 3 hours a day. At that time, architects Nevenka Spremo and Vojislav Korać, as well as art historian/archaeologist Đorđe Stričević, held the title of assistant (Fig. 3)

senior archivist Gordana Vukasović and archival assistant 1st class Svetlana Lekić, for their help and advice during their work in the processing of archival material from the Fund of the Archaeological Institute, which is kept in the State Archives of Serbia.

5 A fairly good picture of the first field research activities of the Archaeological Institute, in the year of its establishment, is provided by the reports published in the first issues of the magazines *Starinar* (n.s) (1950) and *Muzeji* (1948). In addition, it is worth looking at the *Yearbook* SAS, vol. LIV about the early works (*Годишњак* САН 1947: 328‒329). Archaeological excavations in 1947 were carried out at the following locations: Gradište near Kikinda, Belgrade fortress, Orašje (*Margum*) near Požarevac, Caričin Grad (*Ivstiniana Prima*) near Lebane and Najeva Ciglana near Pančevo. As for the archaeological field survey activities, they were carried out in the area of eastern and south-western Serbia. It is interesting that some members of the Institute took part in the first rescue research aimed at transporting the inscription originating from the church in Padež near Drenova in the vicinity of Prijepolje to a safer location.

(*Годишњак* САН 1952: 40, 316–317; ДАС-ФАИ, Д-9, бр. 816/1952). Their first work in the organisation of field documentary materials was related to the recording of the photographic, plan and copy funds, through the use of inventories and files (ДАС-ФАИ, Д-2, бр. 28/1953, 3). The assistants performed that work in the Academy building, where the Institute got its new premises in the end of 1952 and, thus, somewhat better working conditions, though it should be noted that it was still necessary to acquire furniture for the file archive, photo archive and plans archive (*Годишњак* САН 1952: 316, 322).

However, during 1952, the assistants were often engaged in field research and performing personnel related work at the Institute and, as a result, the work of arranging documentation material was most likely not continuous and dynamic (*Годишњак* САН 1952: 320–321; ДАС-ФАИ, Д-2, бр. 36/1953). We should mention here the budget proposal of the Institute for 1953, drawn up on October 15, 1952 at the request of the management of the Serbian Academy of Sciences, which states: "Recording of the entire business, field and publishing, has become more difficult and insufficient. Under these conditions, the library is also suffering heavily, and the cataloguing of the Institute's extensive scientific and documentary material, photographs, plans, reproductions, drawings and copies, which represents a material value measured in millions, without an increase in administrative, professional and technical staff in the next year, will hardly be possible" (ДАС-ФАИ, Д-2, бр. 777/1952, 1).

Information related to the arrangement of the Institute's documentation by assistants for 1953 is somewhat scarce. The question is whether they really continued that work since, in addition to their obligations to prepare their doctoral theses, they were also engaged in many field research activities, as well as in writing scientific papers, which, for their young years, was certainly extensive and difficult work (See ДАС-ФАИ, Д-2, бр. 486/1952; ДАС-ФАИ, Д-2, бр. 28/1953, 1; Стричевић 1952; Стричевић 1953; Спремо Петровић 1955; Кораћ 1956). However, in the work plan for 1953, a complete record of the photographic, plan and copy fund was foreseen through the use of inventories and files with the aim of starting their final arrangement (ДАС-ФАИ, Д-2, бр. 28/1953, 3). Perhaps we should mention the Explanation of the Budget Proposal for 1954, which was compiled by Đ. Bošković, where the idea of hiring a typist, who would perform the work of the technical arrangement of documentation collections collected during fieldwork, is presented. In addition, the work team needed a photographer who would carry out the technical processing of field material and photography in the field (ДАС-ФАИ, Д-2, бр. 600/1953, 2). Taking into account the already mentioned tasks of various types that the assistants performed, the idea of the need to hire new associates in the field of organising the Institute's documentation, in this case typists and photographers, becomes quite clear and justified.

The year of 1954 is also significant for the development of the Institute's documentation. On the payroll of annual expenses there is a 1st class typist – registrant, as well as a qualified technician – photographer (ДАС-ФАИ, Д-2, бр. 600/1953). As it was already announced in the work plan for this year that a typist and a photographer would perform the tasks of the technical arrangement of documentation collections, as well as the technical processing of field material and photographs, it is highly probable that in 1954 they were engaged in the entire arrangement of the Institute's documentation material. It should be noted that from the beginning of August of the same year, data entry of inventoried field documentation began in the Inventory Book of the Archaeological Institute SAS, which still exists today in the Documentation Office.

The increase in the amount of documentation material obviously influenced the Institute's administration to take the final step in the realisation of the systematisation of archaeological field documentation. The numerous attempts of the previous years were obviously only a basis for a temporary rather than a permanent solution. A very complex influx of voluminous, now multi-year field documentary material, of various forms, content and scope, indicated to the Institute's management new priorities in the final, permanent decision to hire a documentarian. On March 10, 1955, the daily newspaper *Politika* first announced a competition for the position of "registrant for scientific and technical documentation" of the Institute of Archaeology SAS (*Политика*, March 10, 1955, ad. no. 2450-Б). From as many as 22 registered candidates, Ljubica Zotović (Fig. 4), then a graduate archaeologist, was selected for this position by an expert committee consisting of Milutin Garašanin, Svetozar Radojčić and Đurđe Bošković (ДАС-ФАИ, Д-9, бр. 443/1955). Officially, as the first documentarian of the Institute, she initially performed the tasks of recording and publishing photos and plans, and, after work-hours, advanced professional training followed (Бошковић 2017: 265-266). In addition to the aforementioned activities, Lj. Zotović kept an inventory book, quite meticulously. Based on that book, it is possible to chronologically follow her work in the entry and inventory of documentary field material and the newspaper archive, which dates back to 1962. By hiring a documentarian, at a time when Bošković was the manager, the foundation was laid for the systematisation and preservation of the Institute's archaeological field documentation, defining the tasks for a specially allocated professional staff.

Fig. 4 Ljubica Zotović (1931–2021) (Taken from: Documentation of the Institute of Archaeology, Belgrade).

Stage II: 1962-1992

By introducing a central archive for site files, plan files,
photo files and other forms of data registration,
Ljubica Prodanović not only indebted us all,
but also erected a permanent monument to herself.
Academician Prof. Dr Vladislav Popović

The new stage in managing the archaeological documentation of the Institute brought new personnel changes and consolidation (Бошковић 2017: 266). In 1962, Lj. Zotović left her post of document management and focused her career on field research as a research associate. In the same year, Ljubica Prodanović, a graduate archaeologist, took her place as the new documentarian (Fig. 5). In this position, where she remained for thirty years, she introduced a new system of managing field archaeological documentation that still functions today. At the time when Lj. Prodanović started working, the Institute had already participated in several large archaeological projects (Iron Gates I, Ulcinj, *Sirmium*, etc.). Research at the Iron Gates was particularly important because the Republican Commission for Scientific Research and Protection of Cultural and Natural Monuments in the Iron Gates insisted on well-prepared and modern scientific documentation, as the research was managed by a large number of experts from various specialties (Трифуновић 1984: 1).

Until 1970, when the Iron Gates project was completed, Lj. Prodanović had before her the task of introducing a unique system for the manage-

Fig. 5 Ljubica Prodanović (1935–1992) (Taken from: Documentation of the Institute of Archaeology, Belgrade).

ment of field documentation to the Institute.[6] In the realisation of this undertaking, her participation in several field investigations of archaeological sites of different cultural and chronological affiliations was also important. Along with that, Lj. Prodanović introduced a system of keeping data through central registers, where the following are separated: files of archaeological sites, dossiers, plans archive and photo archive (Поповић 1995: 227; Бошковић 2017: 266), and today, each of them contains the following:

Central file archive – data files related to archaeological sites;

Dossiers – binders with data from field surveys and documentation from archaeological excavations;

Photo archive – records of negatives, photographs and slides;

Plans archive – record of plans on tracing paper and ozalid.

The central file archive is arranged in two wooden boxes, which contain data from archaeological sites from the former Yugoslavia (SFRY) (box 1) and abroad (box 2). In these boxes, for easier search and inspection, there are cardboard record cards. They contain basic information about the archaeological site that was the subject of research by the Institute's experts, whose sections can be formally divided into two groups: general data on the archaeological site and numerical content of the field documentation. It should be noted that each card has a registration number that matches the file and photo archive numbers. Under general data, the name of the site and the object that was the subject of the research, chronological focus (e.g., Roman or Byzantine era), time of the research and the research directors are entered on the card. Within the numerical content of the field documentation, the total recorded number of photographs, negatives, slides, plans, diaries and other field records (e.g., inventory[7], etc.) is entered.

Dossiers or binders today are larger marked cardboard boxes that are placed in display cases. They contain diaries, notes, sketches, technical drawings, financial reports and inventories originating from field surveys or archaeological excavations. Each binder is labelled with a number that matches the number on the central file card in the upper right corner. In addition, the name of the archaeological site, as well as the year of research, are entered on them. It should be noted that each content in the file has an inventory number, certified by the seal of the Institute, which is entered in the inventory book.

The photo archive includes three important segments of the Institute's documentation, in which they are recorded: negatives, photographs and slides. This inventory group represents the largest collection of documentation. The photographs are placed in metal drawers, marked with numbers that match the numbers of the central filing cabinet. They are mounted on cardboard, containing: inventory number, object number (that is, the card of the central file), as well as general information about the photographs: time and place of creation, author, short presentation of the photographs, as well as the identification of the negative. This last piece of information is important because, based on it, we can find the negatives of the corresponding photographs, also arranged in separate metal drawers. The slides are placed in wooden boxes that are marked with numbers on the outside. Each slide is marked with a serial number, which, together with the number on the wooden box, is entered on the cardboard of the central filing cabinet for easier searching. The serial number of the slides is recorded in a separate slide inventory book, which contains basic data: time and place of creation, and a description of the presentation on the positive.

The plans archive contains records of technical plans on tracing paper and ozalid, on which immovable archaeological finds are presented, of different scales and representations (situational plans, bases, views, sections, etc.) and necropoles, which were investigated during archaeological excavations. The plans are held in metal drawers that are marked with inventory numbers on the outside. Each plan is authenticated with a seal containing the inventory number of the plan, which matches the number of the metal drawer.

The plans are arranged in drawers according to the names of the archaeological sites, wrapped in

6 An example in keeping field documentation in those years was suggested by V. Popović, citing the method of the *Centre for Documentary Archaeological Analysis*, which was founded in Paris in 1957. See Popović 1966.

7 The term "inventory" refers to the files in which data on mobile archaeological findings discovered during the research were entered.

rolls or laid flat in larger cardboard frames, with the inventory numbers of the plans written on them, as well as the number of plans in a roll/cardboard frame – e.g., the site of *Pontes* 6254-6389. Also, the inventory numbers of the plans are listed in a special inventory book, in which the following are also entered: location, file number, inventory number of the main inventory book, drawing scale, subject and year when the plan was created.

There are 33,954 photographs, 1,000 slides, 2,548 plans and 562 reports from field archaeological research that were registered in the reports on the work of the Institute's documentation for 1967. During 1979, an audit was carried out and the entire collection of documentation was re-inventoried, which at that time numbered 1,756 sites in the central file, 12,600 slides, 86,182 photographs, 5,260 negatives, 5,804 plans and 1,257 sectional maps in various scales (Бошковић 2017: 266).

During the 1970s, Ljubinka Babović, a graduate archaeologist, performed the work of managing documentation, together with Ljubica Prodanović, for a certain period of time.[8] The 1980s brought new management changes within the Documentation Office as an organisational unit of the Institute. In 1982, Sofijana Stojković, a graduate archaeologist, joined as a new documentarian. She would perform this job until 1994. In 1985, the Institute hired Nebojša Borić, also a graduate archaeologist, to take the position of the photographer, and he performed this job until 2016. It is worth pointing out that in 1985 S. Stojković went to Paris for six months for professional training in managing documentation from the field of archaeology (Бошковић 2017, 266–267). At that time the director of the Institute was Borislav Jovanović (1977–1986) (Шарић и Бикић 2017: 52).

Stage III: 1992–2020

In the new stage of documentation management, personnel changes took place first. From 1992 to 1994, when the director was Vladimir Kondić (1986–1994), only Nebojša Borić was employed in the Documentation Office (Бошковић 2017, 267; Шарић и Бикић 2017: 52). In 1994, at the time when Petar Petrović was the director (1994–1997), Zoran Bošković, a graduate archaeologist, replaced the documentarian. A more prominent use of personal computers and the improvement of software created new conceptual possibilities for digital data processing, however, it went no further than initial attempts. At this stage, the documentation was still manually processed, recorded and maintained, i.e., according to the unique system established by Lj. Prodanović (Бошковић 2017: 267–268).

Z. Bošković worked as a documentarian until 2020. His work is primarily remembered because he recognised the importance of information technology and digitisation of the Institute's complex and voluminous documentation. He was the first to attempt automatic processing of archaeological documentation and to create an archaeological information database for the entire territory of Serbia. The goal was the easy availability of information for documentation users. Regardless of the fact that those attempts did not bear fruit, Z. Bošković remains remembered as the originator of a great idea that represents a challenge to the next generations. During his work within this organisational unit of the Institute, the Rulebook of the "Centre for Documentation of the Institute of Archaeology" was prepared, while the inventory of field documentation material was increased and filed (Бошковић 1993; Бошковић 1996; Бошковић 2017: 268–296; Илић 2020: 293).

THE CURRENT STATE OF THE FIELD DOCUMENTATION OFFICE AS AN ORGANISATIONAL UNIT OF THE INSTITUTE OF ARCHAEOLOGY

Today, the field documentation of the Institute of Archaeology is kept in several separate rooms. It has been managed by the author of this text since March 2021, as a professional associate. In the beginning, the work was carried out with the organisation and arrangement of the work space, as well as the procurement of office materials necessary to perform the work in the Documentation Office. For easier management and recording of field archaeological documentation, work biographies and annual reports of previous collaborators who performed the work of documentarians, as well as the Institute's archive material, were used.

8 Documentation of the Institute of Archaeology in Belgrade.

In the main office, there are inventory books, files, a central file archive, slides and a newspaper archive.[9]

The central file archive, which has data on sites from the former Yugoslavia (SFRY), has about 1,400 files, arranged in alphabetical order. When it comes to the record cards in the central file archive, in which the sites outside of Yugoslavia are registered, there are 393 of them, also arranged in alphabetical order. The slides, which are in wooden boxes, are divided by format into two groups: smaller ones, of which there are 19,242, and large formats, of which there are 1,795.

The Institute's reading room houses a photo archive (photographs and negatives) which is stored in the already mentioned metal drawers. Some 6,881 negatives were recorded, while there are over 150,000 photographs. In the corridor of the Institute, there are metal cabinets that contain the plans archive, that is, technical plans originating from archaeological research, as well as section maps, of which there are more than 1,350. The number of processed original plans and copies is ca. 12,000.

The Documentation Office, as an organisational unit of the Institute, today functions according to the manual system created by Lj. Prodanović during her fruitful working career. When issuing documentation, the users, i.e., the employed experts of the Institute, must sign a receipt, marked with numbers and the current year. The approval of the Scientific Council is required for the issuance of documentation to persons who do not belong to the working scientific staff of the Institute.

During the year, the associates of the Institute submit documentary material from field research, which, according to the Rulebook created by Z. Bošković, consists of: diaries, reports, photographs (formerly, negatives), cardboard inventory cards and technical drawings. Newly received documentation is certified with a stamp, on which the inventory number is written. This information is then entered into the main inventory book and the card of the central file, and the entire set of documentation is placed in a separate file that receives a new registration number. Photos and technical drawings also receive registration numbers and, after certification, they are placed in the drawers of the photo archive and the plans archive.

During the working years of 2021 and 2022, attention was mostly focused on the digitisation of the Institute's documentation, with the aim of creating adequate conditions for the creation of a central database in the future in which users will more easily and quickly be able to access the necessary field material of this type. This process is also self-imposed in the future because this is how the protection of the material is carried out. A certain part of the field documentation is damaged today, while older drawings and typewritten texts have begun to fade. This is being scanned in the Documentation Office or in copying offices in Belgrade that have larger scanners that can capture longer and broader technical plans. At the end of the year, the documentarian submits an annual work report to the competent authorities of the Institute.

PROPOSED WORK PROGRAMME FOR THE NEXT PERIOD IN MANAGING THE FIELD DOCUMENTATION OF THE INSTITUTE OF ARCHAEOLOGY

The primary goal of the organisational unit for field documentation of the Institute of Archaeology in the coming period is the formation of a central information database, the conceptual creator of which was Z. Bošković. At this moment, it is difficult to say what the future database will look like, being formed for easier searching and availability of information for users. It is necessary for the documentarian to first familiarise himself/herself with the entire documentary material of the Institute, in order to create a clear picture of the overall condition, content, scope, typology and degree of preservation of the field material of this type. Based on that, the type and scope of metadata by which the database will be searchable will be determined. Preliminarily, it can be said, with a degree of caution, that the database will be created according to a search system based on excavation sites and the year of research, within which data on the results of excavations and the

9 According to Z. Bošković, the archive of the Institute of Archaeology SAS was maintained until 1962 (Бошковић 2017: 269). Today, in the Institute's Documentation Office, there is the *Inventory Book of Newspaper Clippings* II (99/1), which records archaeological content in the press from the period from 1957 until 1962.

content of field materials (diaries, photos, technical plans, etc.) will be obtained. During the realisation of that undertaking, we believe that consultations and advice from senior experts, as well as associates from other related sciences – architects, art historians, then experts from the fields of informatics, archival and documentary studies – are necessary, so that the final approach to the digital information database will be as clear and high-quality as possible.

A special type of documentation management, which is self-imposed, will involve the use of new digital tools that are used to process movable and immovable archaeological findings during field work. In recent times, more and more different models have been created, on the basis of which we can obtain certain data and a clear insight into the archaeological material: 3D, geotiff and DEM (*Digital Elevation Model*). These models are obtained with the help of the computer program *Agisoft Metashape Professional*. In addition, work in GIS (*Geographic Information System*) has become indispensable during field research. In this program, indicators are obtained related to the generation of altitude and cartographic projections, followed by the display of interconnections, spatial analysis and possible visual communication of archaeological sites, within the geographical area that is the subject of research.

Before excavation, geophysical tests of the terrain are planned, which most often comprehend magnetometer and radar guidance, with the help of which we obtain the distribution of immovable archaeological finds and necropoles. These research activities have recently become an indispensable factor in fieldwork. Manual drawing in the field nowadays has been greatly surpassed due to the use of 3D tools and AutoCAD programs, in which drawing, model processing and exporting of archaeological field materials is faster, simpler, clearer and more accurate. A revolution in field research was certainly provided by the use of GPS (*Global Positioning System*), thanks to which we can obtain the geographical positioning of archaeological finds and altitude.

The new approach in the methodology of archaeological research, for which we outlined the main terms, will also condition a special way of compiling the field documentation of the Institute. Digital inventory of movable and immovable archaeological finds, 3D models, the generation of data obtained by the GIS method and geophysical interpretations indicate the need to create a new, unique operational documentation consolidation in the registration of archaeological data, which may also represent one of the basic goals in managing the field documentation at the Institute in the next period.

CONCLUSIONS

By analysing the stages of development and recording of the field documentation of the Institute of Archaeology, the current situation and plans for further work, certain conclusions can be drawn. The earliest data on the arrangement of field documentation, which represents the first stage of development, were recorded in the first years after the establishment of the Institute, at which time several experts worked together on the processing of files and photo files. As the documentation increased over time, since the Institute was conducting extensive archaeological research of various types, the need for new personnel arose, finally resulting in the hiring of a professional associate in the position of documentarian. After Lj. Zotović, who was the first documentarian at the Institute, a new stage was marked by the work of Lj. Prodanović, who introduced a unique system of keeping field archaeological documentation, with the use of central registers, where the following are separated: files of archaeological sites, files archive, plans archive and photo archive. In the third development stage, which lasted from 1992 to 2020, there was an attempt to digitise and create an informational database, the conceptual creator of which was Z. Bošković. Today, field archaeological documentation is managed by the author of this text.

In the coming period, an attempt will be made to realise several of the defined goals. Among the first is the formation of a central digital information database, which will most likely be created according to a search system based on archaeological sites and the year of research, within which data on the results of excavations and the content of field materials will be obtained. A new approach in the methodology of archaeological research, which nowadays is gaining more and more importance during field work, including geophysical studies, will condition a special way in managing the field documentation of the Institute by applying various operational programmes and digital methods. The goal is to increase access to documentation to a higher level in the future with the help of innovative IT technologies, which will enable better insight into the documentation, as well as protection of the original material from damage.

ABBREVIATIONS

АЈ – Архив Југославије (Arhiv Jugoslavije)
Д – Досије (Dosije)
ДАС – Државни архив Србије (Državni arhiv Srbije)
НР Србија – Народна Република Србија (Narodna Republika Srbija)
Годишњак САН – *Годишњак Српске академије наука* (Godišnjak Srpske akademije nauka)
Краљевина СХС – Краљевина Срба, Хрвата и Словенаца (Kraljevina Srba, Hrvata i Slovenaca)
САН – Српска академија наука (Srpska akademija nauka)
САНУ - Српска академија наука и уметности (Srpska akademija nauka u umetnosti)
Службени гласник НРС – *Службени Гласник Народне Републике Србије* (Službeni Glasnik Narodne Republike Srbije)
СФРЈ – Социјалистичка Федеративна Република Југославија (Seocijalistička Federativna Republika Jugoslavija)
ФАИ – *Фонд Археолошког института* (Fond Arheološkog instituta)

ARCHIVES

Архив Југославије, Фонд 66, Министарство просвете Краљевине Југославије.
(Arhiv Jugoslavije, Fond 66, Ministarstvo prosvete Kraljevine Jugoslavije).

Државни архив Србије, *Фонд Археолошког института*.
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INSTITUTE DOCUMENTATION MATERIALS

Документација Археолошког института у Београду.
(Dokumentacija Arheološkog instituta u Beogradu)

LEGATES

Легат Ђурђа Бошковића Археолошког института у Београду.
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REZIME

DOKUMENTACIJA ARHEOLOŠKOG INSTITUTA U BEOGRADU KAO ORGANIZACIONA JEDINICA

KLJUČNE REČI: ARHEOLOŠKI INSTITUT, TERENSKA DOKUMENTACIJA, EVIDENTIRANJE, ARHEOLOGIJA, SISTEMATIZACIJA, ISTORIJAT, BAZA PODATAKA.

Najraniji podaci o sređivanju terenske dokumentacije Arheološkog instituta u okviru prve etape razvoja, zabeleženi su u prvim godinama nakon osnivanja (1947) kada je nekoliko stručnjaka zajednički radilo na obradi kartoteke i fototeke. Kako se vremenom dokumentacija povećavala, budući da je Institut sprovodio obimna arheološka istraživanja različitog tipa, ukazala se potreba za novim kadrovima, što je konačno rezultiralo angažovanjem stručnog saradnika na radnom mestu dokumentariste 1955. godine. Posle Ljubice Zotović, koja je bila prvi dokumentarista u Institutu, novu etapu obeležio je rad Ljubice Prodanović koja je uvela jedinstven sistem vođenja terenske

arheološke dokumentacije kroz centralne registre, gde su izdvojeni: kartoteka arheoloških nalazišta, dosijei, planoteka i fototeka. U trećoj razvojnoj etapi, koja traje od 1992. do 2020. godine, javlja se pokušaj digitalizacije i stvaranja informativne baze podataka, čiji je idejni tvorac Zoran Bošković. Danas terenskom arheološkom dokumentacijom rukovodi potpisnik ovih redova.

U narednom periodu izvršiće se pokušaj u vidu realizacije nekoliko definisanih ciljeva. Među prvim je formiranje centralne digitalne informativne baze podataka, koja će najverovatnije biti napravljena po sistemu pretrage arheoloških lokaliteta i godine istraživanja, u okviru koje će se dobijati podaci o rezultatima iskopavanja i sadržaju terenske građe. Nov pristup u metodologiji arholoških istraživanja, koji u današnje vreme dobija sve više na značaju tokom terenskih radova, uključujući i geofizička proučavanja, uslovljavaće i poseban način u vođenju terenske dokumentacije Instituta primenom različitih operativnih programa i digitalnih metoda. Cilj je da se u budućnosti pristup dokumentaciji podigne na viši nivo uz pomoć inovativnih informatičkih tehnologija, koje će omogućiti kako bolji uvid u dokumentaciju, tako i čuvanje originalne građe od oštećenja.

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EU CYBER INITIATIVES AND INTERNATIONAL CYBERSECURITY STANDARDS – AN OVERVIEW

ABSTRACT

The paper presents the legal directives, decisions, instruments, and policies as the holder of the strategic development of the EU digital transition. EU initiatives and international cybersecurity standards are covered through the EU Strategic initiatives and international cybersecurity standards. Cross-sectoral standards of cybersecurity and cross-sectoral good cybersecurity practices are particularly emphasised. The recommendations of the security standards in the energy, transport, financial and banking sector, health sector, water supply and drinking water distribution sector, and digital service providers sector have been provided. This also represents the ultimate goal of the NIS directive, which implies ensuring the network and information security of the systems in the mentioned sectors.

KEYWORDS: INFORMATION SECURITY, CYBER INITIATIVES, INTERNATIONAL SECURITY STANDARDS.

INTRODUCTION

EU cyber initiatives

The European Union sees digital transformation as one of the basic features of the future. This transformation is of key importance for realising the transition towards climate-neutral, circular, and resilient economies. In the wider context, it brings to the Union prosperity, security and competitiveness, as well as the well-being of European societies.(1)

The strategic direction of the Union's digital transition development is a long-term process that includes a broad spectrum of legal directives, decisions, instruments and policies:

- Data Governance Act(2),
- Digital Services Act(3),
- Digital Markets Act(4),
- Cybersecurity Strategy for the Digital Decade (5)
- The Union Budgetary Instruments: Cohesion programmes, Technical Support Instrument, Digital Europe Programme6, Horizon Europe7 and InvestEU (8).
- Security Union Strategy (9),
- Skills Agenda of the EU,
- Digital Education Action Plan (10)
- 2021 Strategic Foresight Report (11)
- Green deal package (12).

EU digital decade

The European Commission adopted the decision named “2030 Digital Compass: The European way for the Digital Decade” (“Digital Compass Communication”) (13) on 9 March 2021, which presents the vision, goals, and methods for the successful digital transformation of the European Union by 2030.

The “Path to the Digital Decade” programme aims to ensure that the European Union accomplishes its goals in the direction of the digital transformation of society and economy in accordance with EU values, reinforcing digital management, and promoting the digital policy that strengthens citizens and companies. The digital targets for 2030 are based on four fundamental points: digital skills, digital infrastructure, digitalisation of companies, and public services.

Solving the massive staff shortage in cybersecurity is vital for protecting the EU from internet threats. In accordance with the Social Rights Action Plan, the plan of the EU is the training of 20 million employed specialists in information and communication technology.

Governments have the role of initiators of the new platforms for building safe public services.(14)

EU INICIATIVES AND INTERNATIONAL CYBERSECURITY STANDARDS

EU strategic initiatives

The central place in the new EU Cybersecurity Strategy (adopted on 16/12/2020) are three initiatives whose integral parts are:

Critical infrastructure protection,

Small and medium-sized enterprises protection, and

Cyber diplomacy.

Extreme exposure to cyber threats (15-17) initiated the launch of a whole set of initiatives to find solutions for the strategic weaknesses of internet technologies, with a particular focus on DNS service vulnerabilities (18-21).

The establishment of the so-called EU Cyber Diplomacy Network is intended to “promote the EU vision of cyberspace, exchange of information and coordination of development.” In addition, it has been announced that the EU will develop the “EU External Cyber Capacity Building Agenda” that will be in line with the “External Cyber Capacity Building Guidelines” (22) and the 2030 Agenda for Sustainable Development. (23)

The EU will continue to work in the UN on introducing consensus on cyberspace and responsibility in cyberspace. (24-25) The so-called “Programme of Action to Advance Responsible State Behaviour in Cyberspace (PoA)” (26) is under preparation in the UN. The PoA provides a legal platform for cooperation and the exchange of information.

International cybersecurity standards

According to Directive (EU), 2016/1148 published by the European Parliament and Council of Europe, the directive regarding the security of *Network and Information Systems* (“NIS”) (27) refers to the security framework that provides necessary services to the European market.

The ultimate goal of the NIS directive is to ensure network and information system security in all sectors (energy, transport, water and food, banking, financial market infrastructure, healthcare, and digital infrastructure) that are of vital social and economic importance and which depend on ICT [*Information* and *communication technologies]* (Article 5, 2-6, NISD). Operators identified by the Member States as OES (Operators of Essential Services) should undertake appropriate and proportional technical and organisational measures for risk management intended for network and information systems security (Article 14, 51, NISD).

With the adoption of the directive on the security of Network and Information Systems (NIS) in 2016, a basic security level of network and information systems should be achieved at the EU level. This will support the wider vision of the Digital Single Market of the EU (28), protecting European society’s interests and providing essential services to European citizens.

Cross-Sector Cybersecurity Standards:

ANSI/ISA, Series “ISA-62443: Security for Industrial Automation and Control System”

ISO 27001 Information Technology Security Techniques Information Security Management Systems Requirements

NIST Framework for Improving Critical Infrastructure Cybersecurity

ISO/IEC 27002:2013: Code of practice for information security controls

ISO 27003 - Information technology -- Security techniques -- Information security management system implementation guidance

ISO/IEC 27004:2016 Information technology -- Security techniques -- Information security management -- Monitoring, measurement, analysis and evaluation

ISO/IEC 20000-1:2011 Information technology -- Service management -- Part 1: Service management system requirements

ISO/IEC 27010:2015 Information technology -- Security techniques -- Information security management for inter-sector and inter-organizational communications

ISO/IEC 21827:2008 Information technology -- Security techniques -- Systems Security Engineering -- Capability Maturity Model® (SSE-CMM®)

ISO/IEC 10181-2:1996 Information technology -- Open Systems Interconnection -- Security frameworks for open systems: Authentication framework

ISO/IEC 27013:2015 Information technology -- Security techniques -- Guidance on the integrated implementation of ISO/IEC 27001 and ISO/IEC 20000-1

ISO/IEC 27014:2013 Information technology — Security techniques — Governance of information security

ISO/IEC 27032:2012 Information technology -- Security techniques -- Guidelines for cybersecurity

ISO/IEC 27033-1:2015 Information technology -- Security techniques -- Network security -- Part 1: Overview and concepts

ISO/IEC 27034-1:2011 Information technology -- Security techniques -- Application security -- Part 1: Overview and concepts

ISO/IEC TR 19791:2010 Information technology -- Security techniques -- Security assessment of operational systems

European Telecommunications Standards Institute (ETSI) Cybersecurity Standards

TR 103 303 - TR 103 309 CYBER series

TR 103 331

TR 103 369

TS 103 487

IT Infrastructure Library (ITIL) v3

NIST SP 800-53

Information Assurance for SMEs (IASME)

ISF Standard of Good Practice for Information Security

ITU X series: Information security management framework

Cross-Sector Cybersecurity good practices:

The CIS Critical Security Controls

Organisation for Economic Co-operation and Development (OECD), Guidelines for the Security of Information Systems and Networks, 2002,

Generally Accepted Information Security Principles (GAISP) – ISSA

The Open Group Open Information Security Management Maturity Model (O-ISM3)

ISACA BMIS

IT Baseline Protection Manual Standard Security Measures – BSI

UK Cyber Essentials (CREST)

Cyber Defence Capability Assessment Tool (CDCAT®) – CESG

HMG Security Policy Framework (SPF) – CESG

NIST/NSA/DISA/DoD Security Technical Implementation Guides (STIGs)

Carnegie Melon Capability Maturity Model (CMM)

The list of standards for assessing and managing cybersecurity risks is in Annex 1.

Energy sector

The NIS directive divides the energy sector into 3 subsectors:

Electricity subsector

Oil and gas subsector

Energy subsector

For the electricity subsector, the following security standards are recommended:

NIST SP 800-82 Rev. 2 (Guide to Industrial Control Systems (ICS) Security (29) provides guidelines on how to secure Industrial Control Systems (ICS). EU operators usually use this as a good practice;

ISO 27019 is a guideline for information management (30) based on ISO/IEC 27002 for process control systems specific to the energy utility industry;

NERC CIP (North American standard, focus on electric reliability and critical infrastructure protection) (31) The standard is followed by EU operators who expand their business activity in the United States.

For the oil and gas subsector, the following security standards are recommended:

The most well-known security framework associated with the oil and gas sector is the Chemical Facility Anti-Terrorism Standards (CFATS) programme, the standard for chemical capacity security with the highest risk in the United States. However, CFATS does not consider cybersecurity but physical and operative security.

The most applicable cybersecurity standards in the energy industry are: ISO 27001, NIST Cyber Security Framework and ISA/IEC 62443.

Traffic (transport) sector

The transport (traffic) sector is divided into the following subsectors: air, rail, river and sea traffic, and road traffic.

a) Air traffic subsector:

Due to the increased spectre of threats, the cybersecurity and physical security of the transport sector can no longer be treated separately (32). The "Roadmap to Secure Control Systems in the Transportation Sector" stands out among the good practices for the transport sector. (33)

The most applicable cybersecurity standards are: ISO 27001, NIST Cyber Security Framework и ISA/IEC 62443. Other standards (that do not include cybersecurity): *ARINC 811* Commercial Aircraft Information Security Concepts of Operations and Process Framework

ICAO Aviation Security Manual - Document 8973 (Restricted Access) (34)

EUROCAE ED-201 – 204 Aeronautical Information System Security (AISS) Framework

RTCA DO-326 Airworthiness Security Process Specifications

Good practices that include cybersecurity:

AIAA (The American Institute of Aeronautics and Astronautics) The Connectivity Challenge: Protecting Critical Assets in a Networked World35

Information Security Certification and Accreditation (C&A) Handbook – FAA

FAA Issue Paper, Aircraft Electronic Systems Security Protection from Unauthorised External Access

FAA Aircraft systems information security protection overview

b) Rail traffic subsector:

Most of the security standards in the domain of rail transport refer mainly to the broader security aspects, not the cybersecurity challenges, that could ultimately influence the security of modern signalisation systems and train control. The applicable cybersecurity standards are ISO 27001 and ISA/IEC 62443.

The UK Rail Cyber Security Guidance to Industry should be emphasised as cybersecurity good practices in this subsector.

c) River and Sea traffic subsector:

The ICT systems supporting river and sea traffic, from port management to ship-to-ship/ship-to-shore communication, are generally very complex and use various ICT technologies. In this sector, there is no particular holistic consideration of cybersecurity. The applicable cybersecurity standards are ISO 27001 and ISA/IEC 62443.

Standards pertaining to security:

International Safety Management (ISM) Code (36)

IMO interim guidelines on maritime cyber risk management

International Ship and Port Facility Security (ISPS) Code

IEC 62351:2017 SER - Power systems management and associated information exchange - Data and communications security

IEC 61162 - Digital interfaces for navigational equipment within a ship

ISO 13613:2011 - Ships and marine technology -- Maintenance and testing to reduce losses in critical "systems for propulsion

Good practices that include cybersecurity:

BIMCO Guidelines on Cyber Security Onboard Ships - The Guidelines on Cyber security Onboard ships

DNVGL-RP-0496 (DNV-GL, 2016) Cyber security resilience management for ships and mobile offshore units in operation

Cyber-enabled ships: ShipRight procedure – autonomous ships

Cyber-enabled ships: Deploying information and communications technology in shipping – Lloyd's Register's approach to assurance

United States coast guard – Cyber Strategy Draft Guidelines on maritime cyber risk management

d) Road transport:

Several initiatives (37) led to defining the guidelines and regulations for implementing security in the automotive industry (38), and other initiatives sought cooperation in the automotive industry security topics (39). Even though some of them are ahead in *development*, such as ISO/AWI 21434 (40), the broadest security initiative is currently led by the TC22/SC3/WG16 committee within the development of ISO 262626 (41).

Road Transport Security Standards:

SAE J3061 Cybersecurity Guidebook for Cyber- Physical Vehicle Systems

SAE J3101 Requirements for Hardware- Protected Security for Ground Vehicle Applications (WiP)

ISO 15031 Road Vehicles - Communication between vehicle and external equipment for emissions-related diagnostics. Part 7: Data link security

ISO 15764 Road Vehicles - Extended data link security

ISO/AWI 21434 - Road Vehicles -- Automotive Security Engineering

ISO 26262-1:2011 - Road vehicles -- Functional safety

TS 102 940 Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management

TS 103 096-1 to TS 103 096-3: Intelligent Transport Systems (ITS);

TR 103 061-6 Intelligent Transport Systems (ITS); Testing; Conformance test specifications for ITS Security; Part 6: Validation report

Best practices:

ENISA Cyber Security and Resilience of smart cars – ENISA

Auto ISAC, Automotive Information Sharing and Analysis Center, Best Practices

Five Star Automotive Cyber Safety Framework

Guideline on cybersecurity and data protection of connected vehicles and vehicles with ADT – UNECE

Finance and banking sector

Finance and Banking Sector Security Standards:

ISO/TR 13569:2005

Gramm–Leach–Bliley Act

Sarbanes–Oxley Act

Payment services (PSD 2) - Directive (EU) 2015/2366

EBA on the security of internet payments (42)

ISO/IEC 27015:2012 Information technology - Security techniques – Information security management guidelines for financial services

American National Standards Institute *(ANSI) X9 series*

Cybersecurity good practices:

Payment Card Industry Data Security Standard (PCI DSS)

Basel II

Draft Guidelines on the security measures for operational and security risks of payment services under PSD2 43

CPMI-IOSCO Guidance on cyber resilience for financial market infrastructure (44)

SEC OCIE Cybersecurity (45)

ISO/TR 13569:2005 Financial services — Instructions for information security (46) provide guidelines for developing the information security programme in the financial services industry. Implementation of the security controls is processed, as well as the elements necessary for managing the information security risk within the framework of the modern financial services institution.

Gramm–Leach–Bliley Act (GLB Modernization Act or GLBA) (47), also known as the Financial Modernization Act of 1999, is the federal law passed in the United States to control how financial institutions deal with the private information of individuals. It is required of the financial institutions, companies offering consumers financial products or services such as credits and financial or investment counselling, to be obliged to explain their company practices or information exchange to their clients and to protect sensitive data.

Sarbanes–Oxley Act from 2002 (SOX) (48) is the act adopted by the American Congress in 2002 to protect investors from the possibility of fraudulent accounting activities by corporations. The SOX Act ordered strict reforms to improve corporate financial disclosures and prevent accounting fraud.

Basel II, or International Convergence of Capital Measurement and Capital Standards, is a series of recommendations issued by the Basel Committee on Banking Supervision Basel II. The Basel Committee believes that risk assessments of banks' internal systems, as investments in capital budgets, are critical. (49)

Payment Services (PSD 2)- Directive (EU) 2015/2366 (50) tends to improve existing EU regulations for electronic payment. It takes into account emerging and innovative payment services, such as internet and mobile payments. It sets rules related to strict security conditions for electronic payment and the protection of consumer financial data, guaranteeing secure identity confirmation and reducing the risk of fraud; transparency of conditions and information requirements for payment services; rights and obligations of users and payment service providers

The Payment Card Industry Data Security Standard (PCI DSS) (51) represents the security standard of information for organisations handling branded credit cards. The PCI DSS standard is provided by card brands and managed by the Payment Card Industry Security Standards Council. The standard is created to increase data controls about the card owner to reduce credit card fraud.

Healthcare sector

ISO 27799:2008 Health informatics - Information security management in health using ISO/IEC 27002

Health Insurance Portability and Accountability Act (HIPPA)

ISO 13485:2003 Medical devices -- Quality management systems – Requirements for regulatory purposes

ISO 80001-1:2010 Application of risk management for IT networks incorporating medical devices

ETSI eHealth Standard TR 102 764 eHEALTH; Architecture; Analysis of user service models, technologies and applications supporting eHealth (52)

Digital Imaging and Communications in Medicine (DICOM)

EC Medical Devices Regulation (text agreed by EP and Council – in adoption process)

NIST SP 800-66 An Introductory Resource Guide for Implementing the Health Insurance Portability and Accountability Act (HIPAA) Security Guide

Healthcare Cybersecurity Best Practices:

Royal Australian College of General Practitioners (RACGP) Computer Information Security Standards (CISS)

ISO 7799:2016 (53) provides guidelines for standards of organisation security information and practices for information management, including selection, implementation, and control management. It defines the guidelines for the support of interpretation and implementation of the healthcare information code of practice ISO/IEC 27002.

Health Insurance Portability and Accountability Act from 1996 (HIPAA) (54). The United States Department of Health and Human Services (HHS) developed regulations to protect the privacy and security of certain health information. With the rule called "*Security Standards for the Protection of Electronic Protected Health Information*", abbreviated to "Security Rule") (55), the national package of the security standards for the protection of certain health information that is saved or transferred in the electronic form was established. The security standard includes technical and non-technical protection measures that health organisations must implement to secure the "electronic protected health information" of individuals. (e-PHI) (56).

Water supply sector and drinking water distribution

Regarding drinking water operators, the most applicable cybersecurity standards for this sector are ISO- 27001 and ISA/IEC 62443

However, it is worth mentioning the standard ANSI/AWWA G430-09 "Security practice and waste management", published by the American Association for Water Supply, which aims to define minimal conditions for the water protection programme that will improve security protection of the employed, public health, public security, and public trust.

Digital service providers sector

According to the directive on security of Network and Information Systems (NIS) (57) (EU)2016/1148, Member States should adopt the common security requirements package for Operators of Essential Services (OES)58 and Digital Service Providers (DSP) (59).

- The EU strategic directives regarding the Digital Service Providers:
- NIS Working Group, security measures for OES60;
- ENISA report on the security measures for DSP[61]; and

- European Commission Act on implementation of measures for DSP (62).

The list of the Digital Service Providers security standards:

ISO/IEC 27011:2008 Information technology -- Security techniques -- Information security management guidelines for telecommunications organisations based on ISO/IEC 27002

List of good practices:

- *Technical guidance on the security measures for Telcos in Article 13a*, ENISA

*ISO/IEC 27011:2008 (***63)** refers to the security information management guidelines for telecommunication organisations, and is based on ISO/IEC 27001:2013.

CONCLUSIONS

The aim of all of the aforementioned standards is to ensure that the European Union (with the "Path to Digital Decade" programme) accomplishes its goals in the direction of the digital transformation of society and the economy in accordance with EU values, reinforcing digital management, and promoting the digital policy that strengthens citizens and companies. The ultimate goal of the NIS directive is to ensure network and information system security in all sectors (energy, transport, water and food, banking, financial market infrastructure, healthcare, and digital infrastructure) that are of vital social importance and the economies that depend on ICT. This paper provides insight into the standards aiming to increase protection against Internet threats in different sectors.

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58) ANNEX II NISD. The operators of the essential services are public and private entities stated in Annex II of the Directive that meet the criteria from Article 5(2).

59) ANNEX III Directives

60) http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=53643

61) https://www.enisa.europa.eu/publications/minimum-security-measures-for-digital-service-providers/

62) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.026.01.0048.01.ENG

63) ISO/IEC 27011:2008 - Information security management guidelines for telecommunications organisations based on ISO/IEC 27002; URL: https://www.iso.org/standard/43751.html

REZIME

SAJBER INICIJATIVE EU I MEĐUNARODNI STANDARDI IZ OBLASTI SAJBER BEZBEDNOSTI – PREGLED

KLJUČNE REČI: INFORMACIONA BEZBEDNOST, SAJBER INICIJATIVE, MEDJUNARODNI STANDARDI BEZBEDNOSTI.

U radu je dat prikaz zakonskih direktiva, odluka, instrumenata i polisa kao nosioca strateškog razvoja digitalne tranzicije EU. Inicijative EU i međunarodni standardi iz oblasti sajber bezbednosti obuhvaćeni su kroz strateške inicijative EU i međunarodne standarde iz oblasti sajber bezbednosti. Posebno su istaknuti međusektorski standardi sajber bezbednosti i međusektorske dobre

prakse iz oblasti sajber bezbednosti. Date su preporuke bezbednosnih standarda iz oblasti energetike, saobraćaja, finansijskog i bankarskog sektora, zdravstvenog sektora, sektor snabdevanja vodom i distrubucija pitke vode i sektora pružalaca digitalnih usluga. Ovo ujedno predstavlja i krajnji cilj NIS Direktive koja podrazumeva da se osigura mrežna i informaciona bezbednost sistema u pomenutim sektorima.

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INFLUENCE OF ARTIFICIAL INTELLIGENCE ON HUMAN RIGHTS

ABSTRACT

Today, artificial intelligence has a direct impact on not only the economy, politics, education, culture and democracy, but human rights as well. Its development and appearance in our everyday life opens up a series of new issues: from the issue of the legal subjectivity and responsibility of robots with artificial intelligence, to the issue of threats to human rights and democracy from artificial intelligence systems. Through the prism of the concepts of human rights and artificial intelligence, the impact of artificial intelligence on human rights is discussed. Given that artificial intelligence systems that are based on biased information can cause algorithmic discrimination in work, legal and non-legal means of protection against algorithmic discrimination are highlighted.

KEYWORDS: ARTIFICIAL INTELLIGENCE, HUMAN RIGHTS, ALGORITHMIC DISCRIMINATION

INTRODUCTION

Artificial intelligence has already had a direct impact on the economy, politics, education, culture, democracy and human rights. We can only guess what impact artificial intelligence will have on our lives in the future. Its development and appearance in our everyday life opens up a series of new issues today: from the issue of the legal subjectivity and responsibility of robots with artificial intelligence, to the issue of threats to human rights and democracy from artificial intelligence systems. The number of human rights that are threatened because of the development and application of artificial intelligence is increasing on daily basis. It is necessary for the law to respond to that challenge and protect basic human rights and freedoms. The adoption of new rules and changes to existing ones should create a legal system that will successfully protect the highest values, guided by justice, morality and ethics. That legal system, both at the national and international level, must be made up of binding and non-binding rules that are mutually agreed upon. Law is required to respond to the development of new technologies and limit the possibility of their abuse and protect human rights and freedoms.

In the past five years, the Council of Europe and the European Union have adopted a series of documents related to certain aspects of the legal regulation of artificial intelligence, including aspects of the protection of human rights as well.

In February 2017, the European Parliament adopted the Resolution on Civil Law Rules on Robotics (European Parliament, "Resolution on Civil Law Rules on Robotics", 2015/2103 (INL) https://www.europarl.europa.eu/doceo/ document/TA-8-2017- 0051_EN.html.), which opened up many issues related to the use of artificial intelligence in products that appear on the market, and especially issues regarding their safety. In March 2018, the European Commission established a High-Level Expert Group on Artificial Intelligence, gathering experts from various fields of expertise. The initial task of the expert group was to gather stakeholders in the "European AI Alliance", support the implementation of the European initiative for artificial intelligence, prepare a draft of guidelines for the ethical development and use of artificial intelligence based on EU law, and to consider issues regarding fairness, security, transparency, the impact on democracy and basic rights of individuals. In June 2018, the EU Commission appointed fifty-two experts to the High-Level Expert Group on Artificial Intelligence. On April 10th, 2018, the members of the European Union signed the *Declaration on Cooperation in the Field of Artificial Intelligence*, in order to solve the most important issues raised by artificial intelligence together: from the issue of ensuring competitiveness in the research and application of artificial intelligence, all the way to the consideration of social, economic, ethical and legal issues in areas such as health care, education, climate changes, cyber security, migrations, etc.

On April 25th, 2018, the European Commission adopted the strategic document *Artificial Intelligence for Europe* (European Commission, "Artificial Intelligence for Europe", COM (2018) 237 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2018%3A237%3AFIN). In this first strategic document, attention is focused on strengthening the technological and industrial capacities of the EU and introduction of artificial intelligence into the entire economy, on the preparation of social and economic changes caused by the development of artificial intelligence, on the creation of an appropriate ethical and legal framework for the use of technologies based on artificial intelligence and on joint action and mutual exchange of experiences of the EU countries in connection with the development and use of artificial intelligence. Based on this adopted strategic document, the *European AI Alliance* was founded in June 2018 as a broad forum that would discuss all aspects of the development of artificial intelligence and its impact on society and the economy. It brought together representatives of companies, consumer organisations, trade unions, and of civil society. Several thousands of participants within the European AI Alliance exchange opinions, documents and information on events related to artificial intelligence. Members of the European AI Alliance can also discuss various issues, draft documents, etc. with the members of the High-Level Expert Group on Artificial Intelligence. The most important questions about the future perspective of building the European Union's approach to artificial intelligence are discussed at the annual meetings of the European AI Alliance.

The first annual meeting of the European AI Assembly was held in June 2019, and the second was held in October 2020. *The Coordinated Plan on Artificial Intelligence* was adopted by the European Commission in December 2018 (European Commission, "Coordinated Plan on Artificial Intelligence", COM (2018) 795 final, https://digital-strategy.ec.europa.eu/en/policies/european- approach-artificial-intelligence). In February 2019, the European Parliament adopted the *Resolution on a Comprehensive European industrial policy on Artificial intelligence and robotics* (European Parliament, "Resolution on a Comprehensive European industrial policy on Artificial intelligence and robotics", 2018/2088 (INI), https://www.europarl.europa.eu/doceo/document/TA-8-2019-0081_EN.html). *Ethic Guidelines for Trustworthy AI* (European Parliament, "Resolution on a Comprehensive European industrial policy on Artificial intelligence and robotics", 2018/2088 (INI), https://www.europarl.europa.eu/doceo/document/TA-8-2019-0081_EN.html) were presented by the High-Level Expert Group of the European Commission in April 2019. In February 2020, the European Commission adopted the *White Paper – A European approach to excellence and trust* (European Commission, "White Paper – A European approach to excellence and trust", COM (2020) 65 final, https://ec.europa.eu/info/files/white-paper-artificial-intelligence-european-approach-excellence-and-trust-en), which clearly indicated the need to adopt a new legal framework for the regulation of artificial intelligence, with basic directions for the development of that legal framework. *The Impact Assessment of the Proposed Regulation on Artificial Intelligence* (European Commission, "Commission Staff Working Document Impact Assessment Accompanying the Proposal for a Regulation of the European Parliament and the Council Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts", SWD (2021) 84 final, https://digital-strategy.ec.europa.eu/en/library/impact-assessment-regulation-artificial-intelligence), as a working document of the European Commission, was prepared in April 2020 and published together with the *Proposal of a Regulation on Artificial Intelligence* in April 2021. In June 2020, the European Parliament established a *Special Committee on Artificial Intelligence in a Digital Age*, with the task of analysing the future impact of artificial intelligence in the digital age on the EU economy and to determine future EU priorities. A series of resolutions related to artificial intelligence was adopted by the European Parliament in October 2020: *Resolution on a framework of ethical aspects of artificial intelligence, robotics and related technologies* (European Parliament, "Resolution on a framework of ethical aspects of artificial intelligence, robotics and related technologies", 2020/2012 (INL), https://www.europarl.europa.eu/doceo/document/TA-9-2020-0275_EN.html), *Resolution on a civil liability regime for artificial intelligence* (European Parliament, "Resolution on a civil liability regime for artificial intelligence", 2020/2014 (INL), https://www.europarl.europa.eu/doceo/document/TA-9-2020-0276_EN.html), *Resolution on intellectual property rights for the development of artificial intelligence technologies* (European Parliament, "Resolution on intellectual property rights for the development of artificial intelligence technologies", 2020/2015 (INI), https://www.europarl.europa.eu/doceo/document/TA-9-2020-0277_ EN.html). In April 2021, the European Commission brought a package containing:

- Communication on a European approach to artificial intelligence (European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Fostering a European approach to Artificial Intelligence", COM (2021) 205 final, https://www.digital-strategy.ec.europa.eu/en/library/communication-fostering-european-approach-artificial-intelligence);

- Coordinated plan from member countries (European Commission, "Coordinated Plan on Artificial Intelligence 2021", COM (2021) 205 final Annex, https://digital-strategy.ec.europa.eu/en/library/coordinated-plan-artificial-intelligence-2021-review);

- Proposal of a Regulation on artificial intelligence (European Commission, "Proposal for a Regulation of the European Parliament and of the Council Laying Down Harmonised Rules on Artificial Intelligence (Artificial intelligence Act) and Amending Certain Union Legislative Acts", European Commission, Brussels, 21.4.2021. COM (2021) 206 final, https://www.eur-lex.europa.eu/resource.html?uri=cellar:e0649735-a372-11eb-9585-01aa75ed71a1.0001.02/DOC_1&format=PDF).

In April 2021, the European Parliament adopted the *Report on artificial intelligence in education, culture and the audio-visual sector* (European Parliament, "Report on artificial intelligence in education, culture and the audiovisual sector", 2020/2017 (INI), https://www.europarl.europa.eu/doceo/document/A-9-2021-0127_EN.html). In June 2021, the European Parliament adopted the *Report on artificial intelligence in criminal law and its use by the police and judicial authorities in criminal matters* (European Parliament, "Report on artificial intelligence in criminal law and its use by the police and judicial authorities in criminal matters", 2020/2016(INI), https://www.europarl.europa.eu/doceo/document/A-9-2021-0232_EN.html.).

The Council of Europe has also been considering certain issues regarding the regulation of legal aspects of the use of artificial intelligence for several years. It adopted new standards related to artificial intelligence and data protection, bioethics, cybercrime, human rights, democracy and the rule of law. In 2019, it founded the *ad hoc* Committee on Artificial Intelligence (CAHAI), which investigates the elements of the legal framework for the development, design and application of artificial intelligence, based on European standards in the field of human rights, democracy and the rule of law. The Committee has a unique structure, which brings together member countries and observers, as well as observers from the civilian society, and the academic and private sector, and works in close cooperation with other international institutions, such as UNESCO, OECD and the European Union.

All previous activities of national and international participants indicate that the legal system that will regulate artificial intelligence in the future must be a part of the global legal mechanism that regulates digital technologies in general, and must include a coherent set of binding and non-binding rules, which will regulate the everyday use of artificial intelligence in different areas of people's life and work in a fair, moral and ethical manner.

The mutual relationship between law and artificial intelligence is not a one-way street, that is to say, it's not only the law that affects artificial intelligence, but this relationship is more like a two-way street, because artificial intelligence also affects the law in different ways. In many aspects, artificial intelligence can influence a different and better way of applying law. Some of those ways are automatic translation, decision-making, especially in the judiciary, risk prediction, resource management, form filling and expert systems.

Human rights and freedoms, as universal values, must be protected from possible threats from products and services based on algorithms, i.e., artificial intelligence. The best way for this to actually happen is to develop a set of legal norms, which will guarantee the effective exercise of rights and freedoms for all individuals without any differences.

The concept of human rights

The origin of human rights stems from the theory of natural law. Human rights as natural rights are acquired by every human being by birth. Human rights apply equally to all people, regardless of their race, sex, language, religion, economic status, education, political or other opinion, in any circumstances. Regardless of the diversity among societies and people, human rights form the thread that binds them together. They represent universal values, which are common to all (Grahovac 2020: 11).

The rights that every human being has, by virtue of being a human being, independent of the state and without a state, are human rights (Dimitrijević and Paunović 1997: 26). They belong to all human beings without any distinction and are based on values that modern humanity acknowledges for all human beings (Paunović, Krivokapić and Krstić 2021: 23). It can be said that human rights are a set of inalienable rights and freedoms of individuals (Gajin 2011: 15).

The core of the concept of human rights is the aspiration to protect human dignity. It puts the personality of an individual at the focal point and is based on a shared general value system (Benedek and Nikolova 2003: 18).

The history of the development of human rights is linked to the American and French revolutions in the 18th century, when human rights were promoted and recognised in the acts of the USA and France, namely, in the Declaration of Independence in 1776 and the Declaration on the Rights of Man and Citizen in 1789. In the 20th century, the foundations of today's human rights system were laid in numerous international and national legal acts. These are, first and foremost: UN Declaration of Human Rights from 1948, European Convention on Human Rights from 1950, UN Convention on the Elimination of All Forms of Racial Discrimination from 1965, International Covenant on Civil and Political Rights and International Covenant on Economic, Social and Cultural Rights of the UN from 1966, Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data of the Council of Europe from 1981, UN Convention on the Elimination of All Forms of Discrimination against Women from 1981, Convention on Cybercrime of the Council of Europe from 2001, and EU Charter of Fundamental Rights from 2009.

In many international and national legal acts, some of the rights and freedoms comprehended by human rights are specifically stated, such as the right to life, and freedom of movement, the right to a fair trial, the right to privacy, freedom of expression, freedom of assembly and association, the right to vote, the right to work, the right to health, the right to an education, the right to a healthy environment, etc. It should be emphasised that the list of human rights given in any international or national legal act is not limited and that it expands over time in accordance with the values accepted by today's societies. The process of including certain new rights and freedoms to the list of human rights that belong to individuals is never-ending.

Human rights and freedoms are most commonly listed by being classified into three generations of rights.

The first generation of rights and freedoms consists of civil and political rights. Civil and political rights usually include: the right to life, equality before the law, freedom of speech, freedom of religion, property rights, the right to a fair trial, and voting rights.

right to equality,	group of rights for participants in judicial proceedings,	property rights,
prohibition of discrimination,	right to privacy,	freedom of thought, belief and religion,
freedom from slavery, torture and inhuman or degrading treatment and punishment,	freedom of movement,	freedom of thought and expression,
right to legal subjectivity,	right to sanctuary,	freedom of assembly and association,
right to judicial protection,	right to citizenship,	right to participate in the management of public affairs, and
right to liberty and security,	right to marry and start a family,	right to participate in free elections.

Table 1. The first generation of rights and freedoms

The second generation consists of economic and cultural rights and freedoms. Economic and cultural rights and freedoms include:

right to work,	right to a suitable compensation for work,	right to an education,
right to the freedom of choice of employment,	right to rest and limited work hours,	rights of mother and child,
right to just and satisfactory work conditions,	right to union organisation and membership in a union,	right to participate in cultural, artistic and scientific life of the community, and
right to protection from unemployment,	right to a life standard which provides health and well-being for individuals and their families,	right to protection of scientific, literary and artistic works.
right to equal pay for equal work,	right to social security,	

Table 2. The second generation consists of economic and cultural rights and freedoms

The third generation consists of the right to development, right to peace and right to a healthy environment.

This division into three generations of human rights has no greater significance today for at least two reasons. The first is because no human rights differ in importance, that is to say, they all have equal importance. There are no human rights and freedoms that are more important or significant, i.e., there are no human rights and freedoms that have greater legal force. The second reason is that the division into three generations of human rights and freedoms is certainly not final, since human rights and freedoms are continuously expanding due to the development of social communities and the development of notions about particular social values that should be protected. A good example is the right to data protection, and soon also the right to protection against artificial intelligence

(Gajin 2011: 131–141), (Paunović, Krivokapić and Krstić 2021: 25–27).

In order to fully comprehend the concept of human rights, it is necessary to consider two more important questions: who are the beneficiaries of human rights and who are the guarantors of the real application of human rights?

In principle, it is claimed that the beneficiaries of human rights and freedoms are all human beings, but not all human beings can enjoy all human rights and freedoms. Some human rights and freedoms are intended exclusively for certain groups of human beings. The reason for this may be their specific characteristics:

- age (children's right, right to marry),
- sex (women's rights),
- occupation (media rights),
- citizenship (right to vote),
- status of refugee or stateless person, etc.

Aside from natural persons, users of human rights and freedoms can also be organisations, such as political parties, trade unions, religious organisations, non-governmental organisations, professional associations, foundations, faculties and universities, companies and other subjects of commercial law. Not all organisations can enjoy all human rights and freedoms either. The application of some human rights is reserved only for some of the organisations, such as the right to submit the so-called "organisational lawsuits" for protection against discrimination, which is reserved for organisations for the protection of human rights and the rights of discriminated categories of persons (Gajin 2011: 182–184).

The question regarding those who guarantee the enjoyment of human rights and freedoms is extremely important for the very concept of human rights and for anyone whose human rights, any of them, are threatened. The guarantors are countries, on one side, and international organisations, on the other. By signing international legal acts and adopting national legal acts, countries have committed themselves to respect human rights and freedoms and to provide mechanisms for unhindered enjoyment of fundamental rights and freedoms. In exceptional cases, countries have the right to limit certain rights and freedoms in given situations. This is the case when there are extraordinary circumstances, hence, for reasons of national security, protection of public order or protection of health and morals, countries can suspend certain human rights and freedoms for a certain period of time while those circumstances last.

International organisations, on the other hand, have mechanisms for monitoring the exercise of human rights by countries.

Individuals initiate the procedure for the protection of human rights with an individual petition (lawsuit, appeal, application) by fulfilling certain conditions (legitimate interest, exhaustion of domestic remedies, etc.). Countries rarely initiate procedures for the protection of human rights for political and economic reasons. So far, not a single country has addressed the UN Human Rights Committee with a request for the protection of human rights, and there were a dozen cases before the European authorities in which countries sued other countries for endangering human rights (Paunović, Krivokapić and Krstić 2021: 113–118).

We can note that, despite a large number of international and national acts, the concept of human rights and freedoms is not precisely defined, because it is actually not identical for all societies due to the numerous specificities of individual social organisations. In some countries, for example, same-sex marriage is acceptable and falls within the scope of human rights, while it is not acceptable in other countries and does not fall within the scope of human rights. Regardless of these individual differences, a large number of human rights and freedoms is similarly protected in different countries.

Numerous international and national legal acts continuously expand the list of protected human rights; therefore, it is practically impossible to create a definitive list of human rights and freedoms. A typical example of the expansion of the list of human rights and freedoms are legal documents of the European Union. They have significantly expanded human rights and freedoms in the areas of consumer protection, intellectual property protection, natural environment protection, data protection, and labour rights protection, and legal acts of the European Union have already been prepared that would expand the list of human rights and freedoms to the areas of protection from artificial intelligence and algorithmic discrimination.

THE CONCEPT OF ARTIFICIAL INTELLIGENCE

As with the definition of rights, there is no universally accepted definition of artificial intelligence. Some authors believe that the definitions of artificial intelligence can be divided into rationalistic ones and those that focus on humans. Supporters of rationalistic theories believe that artificial intelligence can be defined as a type of agent, created by man, that can make decisions and perform actions based on its perception. Supporters of the definition of artificial intelligence that puts humans at its centre believe that artificial intelligence exists when it can perform a task, the execution of which would otherwise require human intelligence (Turing test). In 2019, the European Union's High-Level Expert Group defined an artificial intelligence system as a software or hardware system created by humans, which, in relation to a set goal, acts with perception in the physical or digital dimension, collecting data, interpreting the collected structured or unstructured data, explicating information and knowledge obtained by processing this data and deciding on the best action or actions to be taken to achieve a given goal. Artificial intelligence systems can use symbolic rules or learn a numerical model, and can adapt their behaviour according to an analysis of how the environment is affected by their previous actions (Ben-Israel et al. 2020: 22).

Artificial intelligence, which is considered a scientific discipline, appeared shortly after the invention of the first computers. Skills characteristic of humans, i.e., intelligent beings, are attributed to artificial intelligence, including proving hypotheses, reasoning and playing games (Bialko 2005).

The first definition of artificial intelligence, presented by John McCarthy, referred to the unity of the "science and engineering of making intelligent machines" (https://www.artificial-solutions.com/blog/homage-to-john-mccarthy–the-father-of-artificial-intelligence), i.e., the creation of particularly intelligent computer programmes (http://35.238.111.86:8080/ jspui/ bitstream/123456789/274/1/McCarthy _ John _What %20is % 20artificial% 20intelligence.pdf).

Definitions that appeared somewhat later can be grouped by taking into account two main criteria. One group of definitions refers to the process of thinking and reasoning, while the other group of definitions takes into account the category of success (Furmankiewicz, Sołtysik-Piorunkiewicz and Ziuziański 2014).

The focus of definitions that include rationally acting systems and those systems that behave like humans (thinking, reasoning), is behaviour. They measure success in the context of matching human performance, while others measure success in comparison to ideal concepts of intelligence that we call rationality. A system is rational if it does the "right thing", considering the things it knows. This means that the system is expected to have full awareness of the goal, i.e., formally speaking, that there is an implicitly or explicitly defined criterion function, which measures, in a given metric system, the success of the action of an intelligent system in its work environment (Milosavljević 2015).

Although this division is characteristic of the period up to the mid-1990s, it is comprehensive in its purpose. Modern definitions generally present artificial intelligence as a simulation of human intelligence processes by a suitable algorithm, code or technique, with the help of machines or computer systems. Artificial intelligence systems are actually systems that enable machines to perform activities that are similar to human intelligence (Mitchell 1997). The subjects of study of artificial intelligence are actually management rules of the so-called intelligent human behaviours and the creation of formal models of these behaviours, with the help of computer programmes that will simulate this behaviour. Some intelligent behaviours are: speech recognition, shape recognition (letters, drawings, photos), proving theorems, playing board games, translating from one natural language to another, creativity (creating musical compositions, drawing), formulating a medical diagnosis, etc. (Sroka and Wolny 2009: 171–173).

Artificial intelligence technologies today are increasingly present in various fields, bringing a large number of benefits. In its beginnings, artificial intelligence was conceived as a replacement for experts in certain fields (medicine, informatics, finance), only to evolve, so that now it can offer great opportunities for improving people's quality of life. In perspective, for certain tasks that automated artificial intelligence systems would perform better than humans, there will be no need to engage the human factor any more, but on the other hand, there will be need for the human factor in new areas that automation would bring (control, management, legal regulations, etc.).

INFLUENCE OF ARTIFICIAL INTELLIGENCE ON HUMAN RIGHTS

The use of products and services based on artificial intelligence leads to the possible endanger-

right to dignity,	right to freedom of expression and free assembly,	right to consumer protection,
right to respect of private life,	right to an efficient legal remedy,	rights of children and disabled,
right to data protection,	right to a fair trial and presumption of innocence,	right to a healthy environment, and
right to non-discrimination,	right to good management,	right to health and safety of people.
right of suffrage,	right to fair and just work conditions,	

ing of the basic rights and freedoms of individuals:

The right to freedom of expression was drastically threatened when Facebook and Cambridge Analytica distributed partially correct or inaccurate information and, thus, threatened the human right to freedom of expression, i.e., the right of citizens to freely participate in the management of public affairs and voting processes. Millions of people were jeopardised who could not protect their right to freedom of expression with an adequate legal remedy (Desierto 2020).

The use of artificial intelligence systems in the judiciary can negatively affect the *right to a fair trial*, if the decision is made with the use of an algorithm, and judicial employees do not have a sufficient level of understanding of artificial intelligence to ensure that decisions made with the help of artificial intelligence are non-discriminatory. A system for biometric face and voice recognition can threaten the *privacy of individuals*. Artificial intelligence systems that collect and analyse large amounts of data about individuals can predict their behaviour, influence changes in their behaviour, threaten their privacy, e.g., by revealing their facial expression, emotional state, heart rate, physical location, etc. Biometric facial recognition systems can prevent citizens from exercising their right *to freedom of expression, association and assembly* and, thus, can have a negative effect on social solidarity and participation in democratic processes. The activities of *chatbots* (computer programmes that simulate people conversing via voice or text messages. This way, people can be misled into believing that they are communicating with other people when they are, in fact, communicating with a computer programme based on artificial intelligence) and the creation of undoubtedly falsified content (*deepfake* - false information created by the digital alteration of photos or videos so that a person appears to be someone else, that is, to have done or said something that they did not actually do or say. This way, false information is spread maliciously) by systems based on algorithms and artificial intelligence can affect an individual's ability to build attitudes based on reliable information. This way, individuals are manipulated and their *right to be informed* is threatened, necessary for them to be able to participate in democratic decision-making processes.

Artificial intelligence systems that control sophisticated weapons, such as robot snipers or drones with the purpose of killing individuals or groups of people, are already in use and threaten the most important of human rights, *the right to life*.

A particularly negative impact of artificial intelligence products and services on human rights and freedoms is achieved through algorithmic discrimination, endangering the *right to data protection*, but also endangering many other human rights and freedoms.

ALGORITHMIC DISCRIMINATION

The quality of our everyday life increasingly depends on the use of artificial intelligence. Artificial intelligence manages traffic and energy supply, recognises speech, filters spam, analyses X-ray images and affects our daily life in many other ways, and the economic development of the entire society as well. In all these processes, artificial intelligence works using algorithm-based software, making decisions that usually involve a large number of individuals. Those decisions should be rational, neutral, impartial and equal for all affected. Practice shows that decisions made in artificial intelligence systems based on algorithms are often not so, but cause some form of discrimination called algorithmic discrimination. An algorithmic decision-making system can be defined as a computer process, including one derived from machine learning, statistics or other data processing or other artificial intelligence techniques, that makes decisions on its own or supports human decision-making (European Law Institute, "Model Rules on Impact Assessment of Algorithmic Decision Making Systems Used by Public Administration", European Law Institute, Vienna, 2022, 16).

An algorithm can be described as an abstract, formalised description of a computational procedure. An algorithmic decision is the result, finding, or outcome of that procedure. Sometimes the algorithm decides in a completely automatic way. It is necessary to distinguish between decisions made on the basis of an algorithm that are fully automated and those that are only partially automated. This is important because of the determination of responsibility in the case of human rights violations and because of how changes can be made to the automatic decision-making system, so that human rights violations would not occur in the future. In algorithmic decision-making systems with partial human participation, a tendency to minimize one's responsibility by simply following the computer's recommendations has been observed. This phenomenon is called automation bias (Zuiderveen Borgtesius 2018: 11).

The rights possessed by human beings derive from the fact that they are human beings, and for this reason the acceptance of human inequality actually destroys the entire concept of human rights (Dimitrijević and Paunović 1997: 181). The principle of equality is the basic principle of human rights, hence, the principle of non-discrimination derives from it – in other words, *the prohibition of discrimination* between people.

In recent legal documents, discrimination based on gender, sexual orientation, gender identity, age, health status, disability, marital status, migrant or refugee status, or other status is prohibited, which means that this list is not exhaustive either (Gasmi 2016: 149–167).

One of the most frequently reported negative impacts of artificial intelligence on human rights is the impact on the prohibition of discrimination, i.e., on the *right to equal treatment* (Ben-Israel et al. 2020: 28).

Artificial intelligence systems based on biased information can cause algorithmic discrimination, i.e., discriminatory algorithmic decisions or behaviours. If an artificial intelligence system learns on the basis of previous data, founded on discriminatory decisions, then it can also make discriminatory decisions, on the basis of "feedback loops", meaning, it can threaten human rights.

LEGAL MEANS FOR PROTECTION AGAINST ALGORITHAMIC DISCRIMINATION

Binding and non-binding norms are the main obstacles to algorithmic discrimination. First of all, there are binding regulations at the international and national level on non-discrimination and data protection, but also many other regulations, standards and rules of conduct. The UN Universal Declaration of Human Rights from 1948 guarantees freedom and equal rights to all people in its first article, and guarantees non-discrimination in the second article. The European Convention on Human Rights and Fundamental Freedoms, in accordance with the UN Universal Declaration of Human Rights, prohibits discrimination in article fourteen. The EU directive from 2000 on the implementation of the principle of equal treatment among persons regardless of their racial or ethnic origin recognises two forms of discrimination: direct and indirect discrimination. In the case of algorithmic discrimination, indirect discrimination often occurs, so that a seemingly neutral provision leads to a particularly unfavourable position for a certain group of people. Therefore, it is not relevant whether the discriminator had the intention to discriminate, the effect that algorithmic decision-making had in practice is what is important instead. This indirect discrimination happens much more often than the direct one. For example, algorithmic decisions that force people of a particular racial background to pay higher prices for products or services violate the prohibition of indirect discrimination (Zuiderveen Borgtesius 2018: 34).

Artificial intelligence systems base algorithmic decision-making on the large amount of data they collect about individuals. *Data protection regulations* aim to ensure respect for all fundamental rights and freedoms, to ensure equal rights and, thus, non-discrimination as well, for all those whose data is processed.

The EU General Data Protection Regulation (Regulation 2016/679 of the European Parliament and of the Council of 7 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), *Official Journal of the European Union* L 119/2016) from 2016, which began to be applied in 2018, largely influenced the changes in the data protection system in the EU and worldwide. It requires the raising of the level of transparency in all cases of data processing, especially when it comes to automated decision-making by artificial intelligence systems, as stated in article thirteen, point f. In that point, it is stated that individuals will be given information about the logic by which decisions were made, as well as the significance and the consequences of such data processing and such decision-making for individuals. Transparency is required when personal data is collected, used, disclosed or otherwise processed.

Based on the principle of transparency, in point thirty-nine of the Preamble of the EU General Data Protection Regulation, it is required that any information and communication related to the processing of personal data be easily accessible and understandable, that clear and simple language be used. Point seventy-one of the Preamble, as well as article twenty-two of the EU General Data Protection Regulation, directly covers algorithmic decision-making. It establishes the right of an individual to request that he/she would not affected by a decision made solely on the basis of automated data processing that produces legal consequences for him/her or significantly affects him/her (Regulation 2016/679 of the European Parliament and of the Council of 7 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), *Official Journal of the European Union* L 119/2016). Such automated data processing includes the creation of a profile, that is to say, an assessment of an individual's personal traits, especially those related to work results, economic status, health, personal preferences or interests, reliability or behaviour, location or movement, when it produces legal consequences related to the individual or that affect him/her. However, decision-making based on such processing, including profiling, may be permitted if allowed by EU law or the law of a member country to which the data processor is subject, among other things, for the purposes of monitoring and preventing fraud and tax evasion, in accordance with regulations, standards and recommendations of EU institutions or national authorities (Regulation 2016/679 of the European Parliament and of the Council of 7 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), *Official Journal of the European Union* L 119/2016). The prohibition of such automated discriminatory algorithm-based decisions does not apply in cases where the individual has given consent, when it is stipulated in the contract between the data handler and the individual and when it is stipulated by law.

In these cases, as stipulated in article twenty-two of the EU General Data Protection Regulation, it is necessary for the data handler to implement appropriate measures to protect the rights and freedoms and legitimate interests of individuals, especially the right of people to participate in decision-making, the right to express personal opinion and the right to challenge a decision. Based on article twenty-four of the EU General Data Protection Regulation, data handlers are required to *take into account risks* of different levels of probability and severity that may threaten the rights and freedoms of individuals. This certainly includes the risk of discrimination against individuals during data processing. Data handlers are obliged to take appropriate technical and organisational measures in order to eliminate these risks. This is especially necessary when it comes to the application of new technologies, such as artificial intelligence and algorithmic decision-making, if the handler has not carried out an *impact assessment* on data protection, as stated in point eighty-nine of the Preamble of the EU General Data Protection Regulation. Article thirty-five of the EU General Data Protection Regulation established the handler's obligation to carry out an impact assessment regarding data protection, in cases of high risk to the rights and freedoms of individuals.

Examples of automated algorithm-based decisions with legal consequences are court decisions or decisions of state authorities on social benefits provided by law, such as pensions and various other social benefits. Automated decisions with similar consequences are also those made by banks when approving loans or decisions made by private companies on the prices of products or services that put individuals and groups of individuals in an unequal and disparate position in relation to others.

Point seventy-five of the Preamble of the EU General Data Protection Regulation also refers to algorithmic discrimination. In that point, it is emphasised that the processing of personal data may cause physical, material or non-material damage (Regulation 2016/679 of the European Parliament and of the Council of 7 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), *Official Journal of the European Union* L 119/2016).

The EU General Data Protection Regulation has great importance in the prevention of discrimination in terms of the processing of personal data, but even so, a part of algorithmic decision-making that does not relate to the processing of personal data remains outside the scope of this legal regulation (Zuiderveen Borgtesius 2018: 44–45).

The Proposal for an EU Directive *on improving working conditions in platform work* from 2021 contains a separate chapter on algorithmic management, divided into five articles (Proposal for a Directive of the European Parliament and of the Council on improving working conditions in platform work, COM(2021) 762 final, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0762&from=EN):

- Transparency on and use of automated monitoring and decision-making systems,
- Human monitoring of automated systems,
- Human review of significant decisions,
- Information and consultation,
- Persons performing platform work who do not have an employment relationship.

In addition to regulations on the prohibition of discrimination, regulations on data protection, and regulations on improving the working conditions of platform workers, there is a large number of other regulations in legal systems that can be helpful when it comes to fighting algorithmic discrimination. These are regulations on consumer protection, competition, free access to information of public importance, freedom of information, etc.

There is an increasing number of non-binding rules on ethical principles regarding the use of artificial intelligence, which are formulated by international organisations and professional associations, and which can serve as a good basis for formulating binding legal regulations.

NON-LEGAL MEANS OF PROTECTION AGAINST ALGORITHMIC DISCRIMINATION

In addition to strictly legal means to fight against algorithmic discrimination, there are a number of other measures that can help in this fight. These measures are education, risk assessment and mitigation, public sector transparency, strengthening of equality bodies, strengthening of human rights monitoring organisations, etc. (Zuiderveen Borgtesius 2018: 51–60).

A large number of people, such as computer scientists, lawyers and economists, are not aware of the risks brought on by the use of artificial intelligence, hence, it is necessary to direct attention at all levels of education to the acquisition of new knowledge, which can help fight against algorithmic discrimination.

CONCLUSIONS

Risk assessment and mitigation is essential for all projects involving the use of artificial intelligence. Any institution that intends to create a product or service based on artificial intelligence, i.e., algorithms, should form a team made up of IT specialists, lawyers and economists, who will assess the possible risks and impact on the rights and freedoms of individuals. This is not only necessary in the creation phase of the artificial intelligence system, but also needs to be done later, during the testing and implementation phase of the artificial intelligence system. Special responsibility when using artificial intelligence systems exists when such systems are used by public services and state bodies. Their decisions often affect a large number of individuals, endangering human rights, so it is necessary to exclude all possible forms of discrimination in such algorithmic decision-making. In order to achieve fairness and equality in the use of artificial intelligence and algorithmic decision-making in the public sector, it is necessary to constantly monitor and control the functioning of these artificial intelligence systems.

Institutions that deal with equality and those that deal with the protection of human rights should handle issues of algorithmic discrimination, but in order to successfully deal with those issues, they should acquire new knowledge and use special expert analyses. Additionally, the task of these institutions is to work on raising public awareness regarding the risks brought on by algorithmic decision-making. Cooperation between institutions that deal with equality and institutions that deal with human rights, on one hand, with institutions that deal with data protection and consumer protection, on the other, can also contribute to a more successful fight against endangering human rights due to the consequences of algorithmic discrimination.

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REZIME

UTICAJ VEŠTAČKE INTELIGENCIJE NA LJUDSKA PRAVA

KLJUČNE REČI: VEŠTAČKA INTELIGENCIJA, LJUDSKA PRAVA, ALGORITAMSKA DISKRIMINACIJA.

Veštačka inteligencija danas ima direktan uticaj kako na ekonomiju, politiku, obrazovanje, kulturu, demokratiju tako i na ljudska prava. Njen razvoj i ulazak u naš svakodnevni život danas otvara niz novih pitanja: od pitanja pravnog subjektiviteta i odgovornosti robota sa veštačkom inteligencijom, do pitanja ugrožavanja ljudskih prava i demokratije od strane sistema veštačke inteligencije. Kroz prizmu pojmova o ljudskim pravima i veštačkoj inteligenciji obrađen je uticaj veštačke inteligencije na ljudska prava. S obzirom da sistemi veštačke inteligencije koji su zasnovani na pristrasnim informacijama mogu prouzrokovati algoritamsku diskriminaciju, u radu su istaknuta pravna i nepravna sredstva zaštite od algoritamske diskriminacije. Tema rada je aktuelna i prikazuje kako međusobni odnos veštačke inteligencije i ljudskih prava ima ne samo praktičan uticaj na naš svakodnevni život, već će utiče i na kvalitet pravne regulative u ovoj oblasti. Sa jedne strane utiče se na ubrzavanje ili usporavanje primene najnovijih tehnoloških dostignuća iz oblasti veštačke inteligencije, a sa druge strane opredeljuje stepen dostojanstva i stvarne slobode pojedinca u sajber prostoru.

* * *

PRIKAZI - REVIEWS

Anthony Harding, SALT White Gold in Early Europe, Cambridge University Press – The European Association of Archaeologists, serija Cambridge Elements – The Archaeology of Europe, Cambridge 2021. Knjiga sadrži 94 stranice (osam poglavlja, bibliografija i 29 ilustracija).

Publikacija predstavlja rezultate do kojih su arheološka istraživanja dosegla vezano za pitanje proizvodnje soli u drevnoj Evropi, od najstarijih perioda do srednjovekovnog doba. Autor predočava odgovore na pitanja šta je so, gde se pronalazi, za šta se koristi i značaj soli za zdravlje ljudi i životinja. Posebna pažnja posvećena je pisanim izvorima koji svedoče o značaju soli u grčkom i rimskom svetu. kao i najznačajnijim mestima njene proizvodnje u Mediteranu i šire. Ekonomski i društveni značaj soli za ljudske zajednice ogledao se u tomo šro je ona predstavljala vrlo važan (u nekim slučajevima i najvažniji) činilac u trgovini i razmeni tokom milenijuma, dok je mogla označavati i pokazatelj pojedinačnog i društvenog stepena zdravlja i statusa. Navedene činjenice inspirisale su autora da, u naslovu svoga dela, so nazove „belim zlatom drevne Evrope".

Na stranicama Uvoda, autor nam sugeriše da, iako so danas predstavlja deo naše svakodnevice koju prihvatamo „zdravo za gotovo", takav slučaj nije bio tokom proteklih epoha. Antički autori često, u svojim delima, pominju so, ali nam ne govore dovoljno o mestima njenog porekla i načinu proizvodnje, verovatno zato što su smatrali to poznatom činjenicom o kojoj nije potrebno davati bliža objašnjenja. Drugačiju situaciju pronalazimo na stranicama napisanim od strane srednjovekovnih i renesansnih pisaca. Autor posebno naznačava značaj podataka zabeleženih od strane Georgija Agrikole u XVI veku, budući da je on spasao od zaborava veliki broj podataka vezanih za proizvodnju i promet soli iz vremena koja su mu prethodila.

Iz navedenih razloga, publikacija posebnu pažnju posvećuje proizvodnji soli na evropskom prostoru od najstarijih vremena do rimskog perioda.

Započinjući svoju studiju, autor predočava značaj i opasnosti upotrebe soli za ljude i sve vrste životinja. Posebno je naglašena uloga soli u predindustrijskim zajednicama, kada su njena antibakterijska svojstva korišćenja za potrebe očuvanja hrane.

Potom sledi osvrt na glavna ležišta soli u svetu. Najveće zalihe nalaze se u na prostoru sva tri američka kontinenta, Sahari i delovima Azije (Kina i Himalaji). U današnje vreme najveći proizvođači soli su Kina, SAD i Indija. Što se tiče Evrope, najveća proizvodnja beleži se u Nemačkoj, dok autor naglašava resurse u Španiji, Poljskoj, Rumuniji i Velikoj Britaniji (uz naglasak da je reč o jednom od retkih rudnih potencijala koji se na Ostrvu pronalaze u dovoljnoj meri da mogu zadovoljiti lokalne potrebe). U okviru istog poglavlja, predstavljena su najznačajnija savremena pisana dela i autori posvećeni ovoj problematici.

Autor ističe da se priča o soli na prostoru Evrope može pratiti milenijumima unazad, pri čemu su se procesi njene eksploatacije i proizvodnje tokom protoka vremena često menjali i usložnjavali, čemu će biti posvećena naredna poglavlja publikacije.

Predočeni su osnovni pojmovi šta zapravo predstavlja so (natrijum hlorid), kao i glavna ležišta i načini eksploatacije ovog minerala. Autor posebnu pažnju posvećuje nalazištima soli u Evropi i predstavlja geografsku kartu kao pokazatelj lokacija najznačajnijih zaliha natrijum hlorida na Starom kontinentu.

Naglašeno je da se so može proizvoditi na više različitih načina, od kojih su mnogi bili poznati još u praistorijskom periodu. Način korišćen za eksploataciju i preradu najviše je zavisio od vrste ležišta minerala. Sa arheološke strane, oba osnovna načina dobijanja soli, putem vađenja kamene soli ili kuvanja slane vode, ostavili su trag u nalazima. Procesi koji se ne mogu dokumentovati arheološkim metodama, rekonstruišu se putem etnografskih svedočanstava.

Autor zatim predstavlja faze u razvoju rudarenja soli, počev od prvobitnih eksploatacija površinskih ležišta, pa sve do razvoja rudarenja na većim dubinama, što predstavlja rimsko dostignuće. U okviru poglavlja, predstavljeni su i najznačajniji lokaliteti na kojima su utvrđeni tragovi drevne eksploatacije soli, kao i raznovrsni načini rudarenja na većim dubinama. Navedeni postupci ilustrovani su kvalitetnim i edukativnim fotografijama i planovima.

Drugi način dobijanja soli, putem isparavanja morske vode, predstavljen je u narednom poglavlju. Nakon objašnjenja pocesa, navedeni su lokaliteti na kojima je utvrđeno postojanje antičkih solana. Citirani su i odlomci dela antičkih pisaca (Rutilije Namacijan i Marko Manilije), na čijim stranicama se pažnja posvećuje ovom pitanju. Predstavljene su i paralele sa antičkim načinima dobijanja soli, putem primera i danas korišćenim u solanama na atlantskoj obali Francuske.

Na narednim stranicama detaljno se razrađuju saznanja o tehnikama eksploatacije i proizvodnje soli u različitim arheološkim epohama, počev od mezolita do srednjovekovnog perioda. Narativ je ilustrovan brojnim planovima, fotografijama i crtežima arheoloških lokaliteta (navedena su brojna mesta sa utvrđenom eksploatacijom soli širom Evrope) i nalaza vezanih za proizvodnju soli (alatke, posude, rimski epigrafski spomenici...), kao i pokušaji idealne rekonstrukcije rudnika i solana.

Publikacija se zaokružuje iscrpnom bibliografijom citirane literature.

Istraživački rad Entoni Hardinga, publikovan na stranicama predstavljene knjige, predstavlja veoma značajan doprinos za proučavanje do sada nedovoljno istražene teme i biće od velike koristi prilikom proučavanja brojnih aspekata života tokom arheoloških epoha.

Ljubiša VASILJEVIĆ

MANJŠA RIMSKA NASELJA NA SLOVENSKEM PROSTORU / MINOR ROMAN SETTLEMENTS IN SLOVENIA, Jana Horvat, Irena Lazar, Andrej Gaspari (ur.), izdavač ZRC SAZU, Inštitut za arheologijo, Serija: Opera Instituti Archaeologici Sloveniae 40, Ljubljana 2020. Publikacija sadrži 420 stranica (predgovor, 21 tematski članak i zaključak sa uporednim pregledom i klasifikacijom manjih rimskih naselja u Sloveniji i bibliografiju serije).

Pubikacija je posvećena manjim rimskim naseljima, otkrivenim na prostoru današnje Slovenije. Na ovom, geografski raznovrsnom prostoru, nalazile su se delovi tri upravne jedinice Rimskog Carstva — Italija i provincije Norik i Panonija.

Karakteristični rimski lokaliteti, određeni kao predmet istraživanja, predstavljaju stepen i poveznicu između značajnih gradskih centara i raštrkanih seoskih naselja koja su, kao svoju okosnicu, imale manju ili veću vilu rustiku.

Tokom proteklih dekada, arheološka istraživanja sprovedena širom Slovenije pružila su značajne podatke o ovom tipu rimskih naselja, ali dobijene informacije nisu bili detaljno razrađene, niti publikovane u zadovoljavajućoj meri. Predstavljena publikacija predstavlja korak koji je bio neophodan za objedinjavanje i adekvatno predočavanje navedene problematiike.

Prezentovani su rezultati četvorogodišnjeg rada i istraživanja, rezultovani u publikovanju podataka o dvadeset lokaliteta, različitih po svom tipu i stepenu istraženosti. Tekstove, predstavljene kao posebna poglavlja sa kompletnim naučnim aparatom, potpisuje 26 autora, radno angažovanih u različitim naučnim ili ustanovama za zaštitu pokretnog i nepokretnog kulturnog nasleđa.

Predstavićemo osnovna saznanja o svakom lokalitetu do kojih su stigli različiti istraživači.

Tina Žerjal i Vesna Tratnik, *FLUVIO FRIGIDO, CASTRA – AJDOVŠČINA* (str. 9—46).

Rimsko naselje na mestu današnje Ajdovščine bilo je smešteno na putu koji je povezivao Emonu i Akvileju. Smatra se da je ustanovljeno tokom I veka pre nove ere. U izvorima iz III veka naziva se *Fluvio Frigido*, dok se tokom IV veka beleži kao *mutatio Castra*. Tokom I i II veka naselje se nalazilo, najvećim delom, na mestu današnjeg centra Ajdovščine. O životu rimskog naselja najbolje svedoče podaci sa nadgrobnih spomenika, koji pružaju podatke o različitim društvenim slojevima stanovništva. Krajem III veka, kod ušća potoka Hubelj i Lokavšček, podignuto je utvrđenje ojačano kulama. Život u utvrđenju trajao je do druge polovine V veka, dok se uočavaju i tragovi postojanja manjih naselja iz VI i VII veka.

Maruška Urek, Ana Kovačič, *FLUVIO FRIGIDO, CASTRA – AJDOVŠČINA Raziskave / Investigations 2017–2019* (str. 47—60).

Drugi rad posvećen lokalitetu *Fluvio Frigido*—-*Castra* predstavlja rezultate arheoloških istraživanja, sprovedenih u periodu od 2017—2021. godine. Iskopavanjima je obuhvaćen, u najvećoj meri, prostor *intra muros*, a delimično i *extra muros* utvrđenja Castra. Istraživan je deo bedema utvrđenja i odbrambeni rov, u blizini kule 12. Rezultati postignuti *intra muros* posvedočili su postojanje kasnoantičkih građevina, kanalizacije i puta. Pokretni nalazi potvrđuju vojni karakter lokaliteta.

Peter Kos, *AD PIRUM – HRUŠICA* (str. 61—76).

Članak je posvećen rimskom „zaseoku“, smeštenom na najvišem prevoju (867 m nadmorske visine), duž puta Aquileia—Emona. Naselje je podignuto tokom I veka nove ere. Sredinom III veka izgrađeno je utvrđenje, kao sastavni deo kasnoantičkog odbrambenog sistema, poznatog pod nazivom *Claustra Alpium Iuliarum*. U antičkim izvorima, utvrđenje je nazivano *Ad Pirum summas Alpes*, a možda i *In Alpe Iulia*. Utvrđenje je, unutrašnjim zidom, bilo podeljeno na gornji (strm i nenastanjen) i donji (nastanjen) deo.

Ahac Šinkovec, *LONGATICUM – LOGATEC* (str. 77—92).

Rimski *Longaticum* je predstavljao putnu stanicu, zabeleženu na kartama i itinerarima, pored puta koje je povezivao Akvileju i Emonu. Reč je o trasi koja je, još u praistoriji, bila deo Ćilibarskog puta. Antičko naselje nalazilo se na mestu današnjeg Logateca. Predstavljalo je deo zaštitnog sistema Claustra Alpium Iuliarum. Putna stanica je, najverovatnije, izgubila funkciju i bila napuštena tokom turbulentnih vremena sa kraja IV i početka V veka.

Jana Horvat, *NAUPORTUS – VRHNIKA* (str. 93—112).

Nauportus (današnja Vrhnika) nalazio se na trasi puta koji je spajao Italiju sa Srednjim Podunavljem, nedaleko od izvora reke Ljubljanice. Autohtono naselje keltskog plemena Tauriska bilo je pod nadzorom novopodignutog rimskog utvrđenja, počev od kraja II ili početka I veka pre nove ere. Najkasnije sredinom I veka pre nove ere, Nauportus ima status vikusa na teritoriji Akvileje. Položaj *magistri vici* bio je rezervisan za pripadnike porodice oslobođenika pri trgovačkoj porodici iz Akvileje. Za vreme Avgustove vladavine podignut je utvrđeni skladišni kompleks sa lukom, radi snabdevanja legija u Srednjem Podunavlju. Nalazio se na lokalitetu Dolge njive, smeštenom na desnoj obali Ljubljanice. Kompleks je napušten nakon Avgustove vladavine, posle čega čitav Nauportus gubi na značaju. Za to vreme, nastavlja da se razvija naselje na lokalitetu Breg, podignuto na suprotnoj obali Ljubljanice. Strateški značaj ovog područja ponovo je prepoznat u kasnoj antici. Tada se podižu utvrđenje na Gradišču i kula na Turnovšču, kao i odbrambeni zid na vrhovima zapadno od Nauportusa. Navedeni graditeljski poduhvati činili su deo sistema Claustra Alpium Iuliarum. Naselje na Bregu napušteno je tokom V veka pre nove ere, poput većine nizijskih lokaliteta na ovom području.

Vesna Tratnik, *VIPAVA* (str. 113—122).

Rimsko naselje u Vipavi smešteno je u oblasti koju su antički geografi smatrali za za deo Julijskih Alpa, na istočnom obodu teritorije Akvileje. Rimski lokalitet nalazio se u podnožju uzvišenja Starog grada i duž ravnice koja se prostire ispod njega. Arheološkim istraživanjima utvrđeno je postojanje građevina iz I—II veka nove ere, kao i istovremene nekropole. Na severnoj periferiji Vipave konstatovani su objekti datovani od I do IV veka. Najmlađi rimski nalazi vremenski se određuju u drugu polovinu IV i početak V veka.

Boštjan Laharnar, Edisa Lozić, Alenka Miškec, *GRADIŠČE NAD KNEŽAKOM* (str. 123—140).

Pronalasci brojnih rimskih rukotvorina, kao i tragova složene arhitekture, inicirali su istraživanje primenom LIDAR tehnologije na visinskom lokalitetu iznad sela Knežak (Gradišče nad Knežakom). Rezultati istraživanja pokazali su tragove intenzivnog urbanog naseljavanja u rimskom periodu. Utvrđen je i kontinuitet naseljavanja, počev od gvozdenog doba. Na Gradišču su pronalaženi manji rimski nalazi iz I i II veka, ali su znatno brojniji kasnoantički predmeti kao pokazatelj da ostaci arhitekture mogu biti datovani u drugu polovinu III i IV vek.

Andrej Gaspari, *ULAKA* (str. 141—172).

Prvi arheološki podaci o Ulaki potiču sa iskopavanja izvedenim od 1936—1940. godine. Nakon više decenija ponovo je posvećena pažnja ovom lokalitetu, sprovođenjem, 2010. godine, laserskih skeniranja iz vazduha. Utvrđeno je da je lokalitet bio nastanjen u kontinuitetu, počev od starijeg gvozdenog doba do V veka nove ere. Postoje slabo očuvani ostaci bedema sa tri konstatovana ulaza. U blizini su pronađeni tragovi dve nekropole, halštatske i latenske. Postojanje rimskog vojnog logora utvrđeno je i na nedalekom uzvišenju Nadleški hrib.

Lucija Grahek, Anja Ragolič, IG (str. 173—186).

Ne postoji mnogo podataka o rimskom naselju na prostoru današnjeg sela Ig. Okolina sela je, sa prekidima, naseljavana počev od neolita. Sistematski je istraživana antička nekropola, datovana u I—II vek. Najznačajnije informacije dobijene su preko natpisa i predstava na nadgrobnim spomenicima. Epigrafski podaci sugerišu da je reč o zajednici peregrina, verovatno organizovanih kao vikus u ataru Emone. Onomastička analiza ličnih imena ukazuje da su meštani govorili autohtonim dijalektom, tzv. „ižanskim“ jezikom.

Milan Sagadin, *MENGEŠ* (str. 187—200).

Praistorijsko utvrđeno naselje registrovano je na uzvišenju Gobavica, iznad Mendeša. Lokalitet se prostire i duž istočnog podnožja uzvišenja. Najstariji tragovi na utvrđenju potiču iz gvozdenog doba. Pronađeni su i retki latenski nalazi. Na zaravni, istočno od Gobavice, utvrđeno je postojanje nekropole sa grobovima spaljenih pokojnika i pojedinačnih grobova sa skeletnim sahranjivanjem. Nalazi sa Gobavice svedoče o postojanju manjeg rimskog vojnog logora iz predavgustovskog i poznoavgustovskog perioda. Krajem I veka nastaje novo rimsko naselje u podnožju Gobavice. Potvrđeno je i postojanje antičke nekropole. Tokom kasne antike dolazi do pomerenja centra naselja u pravcu severa. Poznato je da je šira okolina Mendeša bila gusto naseljena u rimskom periodu.

Milan Sagadin, *CARNIUM – KRANJ* (str. 201—212).

Kranj se nalazi na prirodno zaštićenom planinskom rtu, iznad ušća reke Kokre u Savu. Neolitsko naselje nalazilo se na najjužnijem delu rta. Naselje iz starijeg gvozdenog doba širilo se i preko granica rta, u pravcu Save, dok latenski lokalitet nije zauzimao tako veliki obim. U srednje i poznoavgustovskom periodu na rtu nastaje naselje doseljenika iz Italije. Bilo je zaštićeno kamenim bedemima i kulama, dok su građevine unutar bedema bile najčešće izgrađene od drveta. Neki pokretni nalazi ukazuju na prisustvo rimske vojske. Naselje je prestalo da postoji nakon kraja Avgustove vladavine. Strateški značaj lokaliteta ponovo je iskorišćen u kasnoj antici, iz koje potiče nekoliko solidno zidanih građevina. Naziv *Carnium* se pominje u pisanim izvorima iz V i VI veka. U okviru kamenih bedema otkriveni su ostaci crkve i dve nekropole.

Špela Tomažinčič, Draško Josipovič, ŠMARTNO PRI CERKLJAH (str. 213—230).

Od sredine I veka pre nove ere do ranog perioda Tiberijeve vladavine, na ovom mestu nalazila se mala rimska karaula, podignuta iznad praistorijskog lokaliteta Straža. Kasnije se rimsko naselje prostiralo na prostoru današnjeg sela Šmartno, na čijoj periferiji su pronađeni ostaci ranohrišćanske crkve. Pored naselja prolazio je put, podignut u vreme Tiberija. Otkrivena je i nekropola sa konstatovanih 49 grobova. Većina grobova sadrži ostatke spaljenih pokojnika, dok su sahrane iz poznijeg vremena skeletne. U okruženju nekropole registrovani su građevinski objekti.

Ana Plestenjak, *BLAGOVICA* (str. 231—248).

Članak je posvećen antičkom naselju sa nekropolom, otkrivenom u podnožju zapadne padine Črnog grebena, odnosno istočnom delu današnje Blagovice. Naselje nije zasnovano pre I veka nove ere i bilo je nastanjeno najmanje do sredine IV veka. Najstariji tragovi sahranjivanja na nekropoli, smeštenoj na istočnoj strani lokaliteta, potiču iz II veka. Smatra se da je reč o rimskoj poštanskoj stanici, moguće *Ad publicanos station*, koju navodi Tabula Peutingeriana.

Janja Železnikar, Julijana Visočnik, *ATRANS – TROJANE* (str. 249—294).

Rimsko naselje *Atrans* nalazilo se pored itinerarskog puta, na planinskom prevoju Trojane. Pripadao je ataru Celeje, u provinciji Norik, premda neposredno pored provincijske granice sa Italijom. Reč je o carinskoj stanici o kojoj su sačuvana epigrafska svedočanstva. Autorke su pokušale da rekonstruišu topografiju naselja, sa posebnim osvrtom na veličinu, položaj i funkciju dvanaest otkrivenih rimskih građevina. Pojedinačni nalazi, široko datovani od I do IV veka, mahom ne potiču iz arheološki dokumentovanih celina.

Irena Lazar, ŠEMPETER V SAVINJSKI DOLINI (str. 295—304).

Nije poznato antičko ime, niti precizan položaj naselja koje je, izvesno, postojalo na mestu današnjeg Šempetera. Na njegovo postojanje ukazuju nalazi sa rimske nekropole. Otkriveni su i skromni tragovi arhitekture. Rimski slojevi, u okolini Šempetera, utvrđeni su na više lokaliteta, ali ni jedan od njih nije sistematski istraživan. Sa pomenute nekropole poznati su 96 grobnih celina i ostaci mermernih grobnica. Nekropola se nalazila pored puta Emona—Celeia i uništena je tokom nemirnih vremena III veka. Severno od nje postoje tragovi još jedne antičke nekropole. Pretpostavka da se, na ovom mestu, nalazila rimska stanica *Ad Medias* zaslužuje da bude zabeležena.

Saša Djura Jelenko, *COLATIO – STARI TRG PRI SLOVENJ GRADCU* (str. 305—324).

Antički *Colatio* ležao je na prostoru današnjeg Starog Trga, predgrađa Slovenj Gradeca, pored nekadašnjeg rimskog puta. Prvi put je arheološki istraživan još u periodu od 1909—1912. godine. Reč je o nizijskom naselju, koje je zasnovano u I veku nove ere i trajalo sve do V veka. Otkriveni su ostaci hrama, stambenog dela naselja i nekropole. Utvrđeno je postojanje luksuznih grobnica pripadnika ruralne elite. Nekoliko sačuvanih natpisa ukazuje na prisustvo autohtone keltske populacije, mada se javljaju i latinska imena.

Saša Djura Jelenko, *ZAGRAD* (str. 325—338).

Visinski lokalitet Zagrad nalazi se u blizini rimskog puta, koji je povezivao naselja Colatio i Iuenna. Počev od druge polovine XIX veka, pronađeno je više od pedeset kamenih ostataka rimskih grobnica i arhitektonske dekoracije (verovatno ostaci svetilišta). Mnoštvo fragmenata izrađeno je od istočnoalpskog mermera. U većini grobnica pronađeni su ostaci spaljenih pokojnika. Izuzetak predstavlja brnčurnički sarkofag, koji predstavlja svedočanstvo o skeletnom sahranjivanju na ovom lokalitetu. Reljefi sa Zagrada datuju se od sredine II do sredine III veka. U blizini lokaliteta moguće je postojanje i vile rustike.

Mira Strmčnik Gulič, *SLOVENSKA BISTRICA* (str. 339—348).

Rimsko naselje, na mestu današnje Slovenske Bistrice, nalazilo se pored antičkog puta Celeia—Poetovio. Iskopavanja su utvrdila postojanje drvenih građevina datovanih u I–II vek. Poznijem horizontu pripadaju ostaci velikih zidanih objekata, prevashodno namenjenih za potrebe transporta i skladištenja roba. U okviru naselja pronađeni su i ostaci kovačnice. U blizini lokaliteta registrovana je i nekropola sa ostacima spaljenih pokojnika.

Zvezdana Modrijan, *ANČNIKOVO GRADIŠČE* (str. 349–362).

Ančnikovo gradišče predstavlja kasnoantičko utvrđeno visinsko naselje, smešteno na južnim padinama Pohorja. Uzvišenje je prvobitno nastanjeno još tokom praistorije. Postoje pojedinačni nalazi iz rane antike, ali još nisu utvrđeni tragovi naselja iz tog perioda. Procvat kasnoantičkog naselja dogodio se tokom druge polovine IV i početkom V veka. U ovom periodu naselje je zaštićeno podizanjem kamenog bedema, sa ulazom na zapadnoj strani. Duž zida pružao se red kuća, od kojih je većina bila drvena ili od istog materijala sa temeljima od kamena. Pokretni nalazi ukazuju na trgovačku povezanost naselja sa širim prostorima i prisutnost manje vojne jedinice. Naselje je uništeno pre polovine V veka, najverovatnije u požaru.

Uroš Bavec, *PRAETORIUM LATOBICORUM – TREBNJE* (str. 363–386).

Rimsko naselje *Praetorium Latobicorum* nalazilo se na najaznačajnijem itinerarskom putu, koji je od Emone vodio u pravcu istoka. Danas se na tom mestu nalazi Trebnje. Autohtono stanovništvo činili su pripadnici keltskog plemena Latobici. Epigrafski spomenici kazuju da se ovde nalazila i beneficijarna stanica i svetilište Jupitera Dolihena. Iz perioda Ranog Carstva potiču dve građevine, od kojih je jedna bila livnica. Iz kasne antike postoje ostaci kuća sa radionicama (najverovatnije krojačkim), podignutim duž trase puta. Sa naseljem se može povezati nekropola, od koje je istražen zapadni deo. U bližoj okolini je konstatovano postojanje vile rustike i kamenoloma.

Irena Lazar, *ROMULA – RIBNICA* (str. 387–402).

Rimska stanica *Romula* poznata je iz pisanih izvora i pominje se u dva itinerara (Tabula Peutingeriana i Itinerarium Antonini). Na osnovu otkrivenih ostataka naselja, stanica je locirana na mestu današnjeg sela Ribnica (okolina Jesenica u Dolenjskoj). Podignuta je na strateškom mestu, koje povezuje doline Krke i Save sa Panonskom ravnicom. Arheološka istraživanja pokazala su postojanje velikog naselja sa značajnim odbrambenim građevinama, delove rimskog puta Emona–Siscia i veliki deo zapadne nekropole sa 129 grobova. Posebno se naglašava značaj votivnog spomenika sa posvetom Silvanu Augustusu, čiji je dedikant rob koji je pripadao zakupcu carinske stanice i natpis ROMVLA, urezan na olovnoj ploči. Navedeni nalazi značajni su zbog definisanja statusa naselja i potvrde njegovog imena i lokacije.

Jana Horvat, PRIMERJALNI PREGLED MANJŠIH RIMSKIH NASELIJ / MINOR ROMAN SETTLEMENTS – COMPARATIVE OVERVIEW (str. 403–420).

Zaključno poglavlje publikacije predstavlja sveobuhvatan i uporedan pogled na manja rimska naselja u Sloveniji, primenom jedinstvenog kriterijuma. Na taj način izdvojene su četiri osnovne grupe ovog tipa lokaliteta: urbana naselja, putne stanice, naselja udaljena od glavnih puteva i visinska naselja (zastupljena isključivo na prostoru Notranjske). Većina naselja nastala su u I i II veku nove ere i bivaju napuštena tokom prve polovine V veka. Naselja u okviru prve dve grupe podignuta su u blizini glavnih putnih pravaca i odlikuje ih prisustvo kvalitetno izgrađenih objekata privatne i javne namene. Epigrafski nalazi iz prve dve grupe ukazuju na prisustvo doseljenika iz Italije i pripadnika lokalne elite, od kojih neki potiču iz autohtonog stanovništva. Naselja treće i četvrte grupe bila su udaljena od značajnih puteva i odlikuje ih skromnija arhitektura, dok su njihovi stanovnici imali pretežno autohtoni karakter.

Publikacija pruža značajan doprinos poznavanju antičke prošlosti na teritoriji Slovenije i označava putokaz za pravac buduće sistematizacije antičkih lokaliteta i na drugim geografskim prostorima.

Ljubiša VASILJEVIĆ

Izložba ʻʻBOŽICA I KONJANICI 1 – KULTNI SINKRETIZAM DONJE PANONIJE", Galerija Arheološkog muzeja u Zagrebu, 5-30.VII 2022.

Tokom jula 2022. godine u Galeriji Arheološkog muzeja u Zagrebu, održana je izložba pod nazivom ʻʻ*Božica i konjanici 1 – Kultni sinkretizam Donje Panonije*", autora Ozrena Domitera, kustosa Arheološkog muzeja u Zagrebu. Tema izložbe je tzv. kult podunavskih konjanika, na šta upućuje i sam njen naziv budući da se odnosi na centralni ikonografski prikaz pomenutog, dok izloženi materijal obuhvata gotovo sve olovne pločice koje se njemu pripisuju a čuvaju se u hrvatskim muzejima. Tako je ovom prilikom predstavljeno 87 primeraka, od kojih 83 potiče sa tla rimske provincije Donje Panonije, i to iz muzeja u Splitu, Zagrebu, Đakovu, Osijeku, Požegi, Slavonskom Brodu i Vinkovcima, zajedno sa pratećim uputima na relevantnu stručnu literaturu.

Posebno se može istaći način na koji je izložba koncipirana jer predstavlja jedan sasvim nov interpretativni pristup, gde je autor praktično dao na uvid svoj lični istraživački proces kao podsticaj za uključivanje publike u odgonetanje jedne od glavnih nepoznanica kulta o kome je ovde reč odnosno toga ko su zapravo njegova glavna božanstva. Kroz predložene smernice za istraživanja i metodološke pristupe najvažnijih autora koji se odnose na prostornu i tipološku zastupljenost nalaza olovnih pločica, kao i analizu društvenog konteksta u kome su dominantno mogli biti prisutni, pokreću se i druga važna pitanja vezana za razumevanje ovog kulta poput hronološkog opredeljenja ili toga ko su zapravo bili njegovi poštovaoci te kakva je mogla biti namena ovih ikonica. Stoga ova izložba ne nudi uobičajeno autorsko viđenje problematike i njegovu krajnju interpetaciju iste, već sučeljava autora i publiku, prvenstveno onu stručnu, stavljajući ih pred jednaka sredstva. Tako su pored izloženog arheološkog materijala, publici dati na raspolaganje sto, kompjuter, literatura i beležnica tj. radna atmosfera u kojoj je promišljao sam autor, kao prostor za interakciju i uključivanje. Krajnji koncept postavke podrazumeva da posetioci ponude svoje odgovore i ideje u pisanoj formi kao doprinos proširenoj izložbi pod nazivom *Božica i konjanici 2*, dok je slična zamisao vezana i za katalog izložbe koji je ona sama trebalo da nadogradi. Takođe, stremljenja autora su da se istoimeni nastavak izložbe obogati i novostečenim znanjima i idejama uz nalaze iz srpskog dela provincije Donje Panonije.

Neophodno je naglasiti i da je ova izložba bila izuzetno važna za sve one koji se sa naučnog aspekta prevashodno bave problematikom tzv. kulta podunavskih konjanika, ali i rimskom religijom generalno. Shodno tome da je većina poznatih primeraka olovnih pločica pomenutog kulta anepigrafska, dok je reč o nalazima koji u znatnom obimu nisu otkriveni u procesu sistematskih istraživanja te je evidentan nedostatak arheološkog konteksta, danas se brojni autori slažu da je sagledavanje njihove ikonografije i dalje krucijalno za razumevanje prirode ovog kulta. Stoga je za sve istraživače veoma značajna bila mogućnost da uživo pogledaju reprezentativne primerke velikog broja zastupljenih tipova koji su strukturalno jasno bili odeljeni i na adekvatan način prezentovani prema novijoj tipologiji koja je data u obimnom katalogu nedavno publikovane knjige Vladimira Malbašića, *U potrazi za neimenovanom boginjom: Kult podunavskih konjanika - paradigma ili zabluda* (Sremska Mitrovica 2021). Svemu tome potrebno je dodati i prisutnost ređe zastupljenih tipova, poput onog sa obostranim predstavama koji je poznat u jako malom broju primeraka, što je ovu izložbu činilo jedinstvenom prilikom da se zainteresovani direktno upoznaju sa njihovom likovnom postavkom.

Nažalost, može se reći da ovoj izložbi nije dat regionalni publicitet koji zaslužuje, a posebno u našoj sredini koja, kako je poznato, baštini veoma veliki broj primeraka olovnih pločica tzv. kulta podunavskih konjanika koji potiču sa teritorije rimske provincije Donje Panonije, prvenstveno iz današnjeg Srema. Iz tog razloga smatrali smo da je ovom prilikom bilo neophodno uputiti domaću stručnu publiku na održavanje sada već minule izložbe, kao i na njen katalog čije se publikovanje tek očekuje, a koji će, bez sumnje, činiti dragocen materijal u budućim istraživanjima ovog zagonetnog kulta.

BOJANA PLEMIĆ

UREĐIVAČKA POLITIKA ČASOPISA ARHEOLOGIJA I PRIRODNE NAUKE

Časopis ***Arheologija i prirodne nauke*** posvećen je temama iz naučnih oblasti: arheologije, istorije arhitekture, istorije umetnosti, antropologije, arheozoologije, arheobotanike, geofizike, računarskog inženjerstva i ostalih srodnih disciplina.

Časopis ***Arheologija i prirodne nauke*** je kao samostalno izdanje počeo da izlazi 2005. godine kao glasilo Centra za nove tehnologije Viminacium i Arheološkog instituta iz Beograda.

Časopis ***Arheologija i prirodne nauke*** objavljuje originalne, prethodno neobjavljene radove: originalne naučne radove, pregledne radove, izveštaje sa iskopavanja, kritike i prikaze.

Časopis ***Arheologija i prirodne nauke*** je dostupan u režimu otvorenog pristupa.

Jezici na kojima se mogu predati članci su engleski, nemački ili francuski. Ukoliko je rad napisan na engleskom jeziku, rezime može biti na srpskom (za domaće autore) ili engleskom (za strane autore), dok kod članaka predatih na nemačkom ili francuskom, rezimei moraju biti na engleskom jeziku.

Rukopisi za štampanje u časopisu predaju se sekretaru redakcije, a prema Uputstvu za autore o načinu pripreme članka.

Časopis ***Arheologija i prirodne nauke*** izlazi jedanput godišnje.

OBAVEZE UREDNIKA I REDAKCIJE

Redakcija časopisa ***Arheologija i prirodne nauke*** donosi konačnu odluku o tome koji će se rukopisi objaviti. Prilikom donošenja odluke redakcija se rukovodi uređivačkom politikom vodeći računa o zakonskim propisima koji se odnose na klevetu, kršenja autorskih prava i plagiranje.

Redakcija zadržava diskreciono pravo da primljene rukopise proceni i ne objavi, ukoliko utvrdi da ne odgovaraju propisanim sadržinskim i formalnim kriterijumima. U redovnim okolnostima, redakcija obaveštava autora o tome da li je prihvatila tekst najduže u roku od 120 dana od datuma prijema rukopisa.

Redakcija ne sme imati bilo kakav sukob interesa u vezi sa rukopisima koje razmatra. Ako sukob interesa postoji kod jednog ili više članova redakcije, ti članovi se isključuju iz postupka izbora recenzenata i odlučivanja o sudbini rukopisa. Urednik i članovi redakcije su dužni da blagovremeno prijave postojanje sukoba interesa.

Redakcija je dužana da sud o rukopisu donosi na osnovu njegovog sadržaja, bez rasnih, polnih/rodnih, verskih, etničkih ili političkih predrasuda.

Urednik i članovi redakcije ne smeju da koriste neobjavljen materijal iz predatih rukopisa za svoja istraživanja bez izričite pisane dozvole autora, a informacije i ideje iznesene u predatim rukopisima moraju se čuvati kao poverljive i ne smeju se koristiti za sticanje lične koristi.

U časopisu ***Arheologija i prirodne nauke*** sprovodi se sistem *double-blind* recenziranja radova. Urednik i članovi redakcije dužni su da preduzmu sve razumne mere kako bi identitet recenzenata ostao nepoznat autorima pre, tokom i nakon postupka recenzije i kako bi identitet autora ostao nepoznat recenzentima do okončanja postupka recenzije.

Radove pripremljene za štampu treba predati sekretaru redakcije, od 01. do 30. juna za svesku koja izlazi do kraja tekuće godine. Redakcija se sastaje nakon predaje svih radova i na prvom sastanku redakcije biraju se recenzenti.

OBAVEZE AUTORA

Autori garantuju da rukopis predstavlja njihov originalan doprinos, da nije objavljen ranije i da se ne razmatra za objavljivanje na drugom mestu. Istovremeno predavanje istog rukopisa u više časopisa predstavlja kršenje etičkih standarda. Takav rukopis se momentalno isključuje iz daljeg razmatranja.

Ako autori delimično ili u potpunosti prenose prava na izdavača: Autori takođe garantuju da nakon objavljivanja u časopisu ***Arheologija i prirodne nauke***, rukopis neće biti objavljen u drugoj publikaciji na nekom drugom jeziku bez saglasnosti izdavača.

U slučaju da je poslati rukopis rezultat naučnoistraživačkog projekta ili da je, u prethodnoj verziji, bio izložen na skupu u vidu usmenog saopštenja (pod istim ili sličnim naslovom), detaljniji podaci o projektu, konferenciji i slično, navode se u odeljku ispred prve fusnote rada, koji treba označiti zvezdicom. Rad koji je već objavljen u nekom časopisu ne može biti preštampan u časopisu ***Arheologija i prirodne nauke***.

Autori su dužni da se pridržavaju etičkih standarda koji se odnose na naučnoistraživački rad. Autori garantiju i da rukopis ne sadrži neosnovane ili nezakonite tvrdnje i ne krši prava drugih. Izdavač neće snositi nikakvu odgovornost u slučaju ispostavljanja bilo kakvih zahteva za naknadu štete.

Sadržaj rada

Rad treba da sadrži dovoljno detalja i referenci kako bi se recenzentima, a potom i čitaocima omogućilo da provere tvrdnje koje su u njemu iznesene. Namerno iznošenje netačnih tvrdnji predstavlja kršenje etičkih standarda. Prikazi, kritike i stručni članci moraju biti precizni i objektivni. Ovi radovi se takođe recenziraju i odluku o njihovom prihvatanju donosi redakcija, na osnovu pozitivnih recenzija.

Autori snose svu odgovornost za sadržaj predatih rukopisa i dužni su da, ako je to potrebno, pre njihovog objavljivanja pribave saglasnost svih lica ili institucija koje su neposredno učestvovale u istraživanju koje je u rukopisu predstavljeno.

Autori koji žele da u rad uključe ilustracije, tabele ili druge materijale koji su već negde objavljeni dužni su da za to pribave saglasnost nosilaca autorskih prava. Materijal za koji takvi dokazi nisu dostavljeni smatraće se originalnim delom autora.

Autorstvo

Autori su dužni da kao autore navedu samo ona lica koja su značajno doprinela sadržaju rukopisa, odnosno dužni su da sva lica koja su značajno doprinela sadržaju rukopisa navedu kao autore. Ako su u bitnim aspektima istraživačkog projekta i pripreme rukopisa učestvovala i druga lica koja nisu autori, njihov doprinos treba pomenuti u napomeni ili zahvalnici.

Navođenje izvora

Autori su dužni da ispravno citiraju izvore koji su bitno uticali na sadržaj istraživanja i rukopisa. Informacije koje su dobili u privatnom razgovoru ili korespondenciji sa trećim licima, prilikom recenziranja prijava projekata ili rukopisa i slično, ne smeju se koristiti bez izričite pisane dozvole izvora.

Plagijarizam

Plagiranje, odnosno preuzimanje tuđih ideja, reči ili drugih oblika kreativnog izraza i predstavljnje kao svojih, predstavlja grubo kršenje naučne i izdavačke etike. Plagiranje može da uključuje i kršenje autorskih prava, što je zakonom kažnjivo.

Plagijat obuhvata sledeće:

doslovno ili gotovo doslovno preuzimanje ili smišljeno parafraziranje (u cilju prikrivanja plagijata) delova tekstova drugih autora bez jasnog ukazivanja na izvor ili obeležavanje kopiranih fragmenata (na primer, korišćenjem navodnika);

kopiranje slika ili tabela iz tuđih radova bez pravilnog navođenja izvora i/ili bez dozvole autora ili nosilaca autorskih prava.

Rukopisi kod kojih postoje jasne indicije da se radi o plagijatu biće automatski odbijeni i autorima će biti privremeno zabranjeno da objavljuju u časopisu ***Arheologija i prirodne nauke***.

Ako se ustanovi da je rad koji je objavljen u časopisu plagijat, isti će biti povučen u skladu sa procedurom opisanom pod *Povlačenje već objavljenih radova*, a autorima će biti privremeno zabranjeno da objavljuju u časopisu ***Arheologija i prirodne nauke***.

Sukob interesa

Autori su dužni da u radu ukažu na finansijske ili bilo koje druge sukobe interesa koji bi mogli da utiču na iznesene rezultate i interpretacije.

Greške u objavljenim radovima

U slučaju da autori otkriju važnu grešku u svom radu nakon njegovog objavljivanja, dužni su da momentalno o tome obaveste urednika ili izdavača i da sa njima sarađuju kako bi se rad povukao ili ispravio.

Predavanjem rukopisa redakciji ***Arheologija i prirodne nauke*** autori se obavezuju na poštovanje navedenih obaveza.

OBAVEZE RECENZENATA

Recenzenti su dužni da stručno, argumentovano, nepristrasno i u zadatim rokovima dostave uredniku ocenu naučne vrednosti rukopisa.

Recenzenti evaluiraju radove u odnosu na usklađenost teme rada sa profilom časopisa, relevantnost istraživane oblasti i primenjenih metoda, originalnost i naučnu relevantnost podataka iznesenih u rukopisu, stil naučnog izlaganja i opremljenost teksta naučnim aparatom.

Recenzent koji ima osnovane sumnje ili saznanja o kršenju etičkih standarda od strane autora dužan je da o tome obavesti urednika. Recenzent treba da prepozna važne objavljene radove koje autori nisu citirali. On treba da upozori urednika i na bitne sličnosti i podudarnosti između rukopisa koji se razmatra i bilo kojeg drugog objavljenog rada ili rukopisa koji je u postupku recenzije u nekom drugom časopisu, ako o tome ima lična saznanja. Ako ima saznanja da je isti rukopis razmatra u više časopisa u isto vreme, recenzent je dužan da o tome obavesti urednika.

Recenzent ne sme da bude u sukobu interesa sa autorima ili finansijerom istraživanja. Ukoliko postoji sukob interesa, recenzent je dužan da o tome momentalno obavesti urednika.

Recenzent koji sebe smatra nekompetentnim za temu ili oblast kojom se rukopis bavi dužan je da o tome obavesti urednika.

Recenzija mora biti objektivna. Komentari koji se tiču ličnosti autora smatraju se neprimerenim. Sud recenzenata mora biti jasan i potkrepljen argumentima.

Rukopisi koji su poslati recenzentu smatraju se poverljivim dokumentima. Recenzenti ne smeju da koriste neobjavljen materijal iz predatih rukopisa za svoja istraživanja bez izričite pisane dozvole autora, a informacije i ideje iznesene u predatim rukopisima moraju se čuvati kao poverljive i ne smeju se koristiti za sticanje lične koristi.

POSTUPAK RECENZIJE

Primljeni radovi podležu recenziji. Cilj recenzije je da redakciji pomogne u donošenju odluke o tome da li rad treba prihvatiti ili odbiti i da kroz proces komunikacije sa autorima poboljša kvalitet rukopisa.

Svaki rad predat redakciji časopisa ***Arheologija i prirodne nauke*** dobija po dva recenzenta. Recenzenti su istaknuti istraživači, u naučnom zvanju istom ili višem od autora rukopisa, kompetentni u oblasti kojom se rukopis bavi. Predlog recenzenata daje redakcija, a usvaja glavni i odgovorni urednik.

Rukopisi se recenziraju po sistemu *double-blind*, koji podrazumeva anonimnu recenziju: identitet autora je nepoznat recenzentima i obrnuto.

Recenzent je dužan da recenziju pošalje redakciji najkasnije u roku od 30 dana nakon prijema rukopisa. Recenzenti za svoj rad ne dobijaju honorare.

Ukoliko recenzenti traže izmene u rukopisu, autori su dužni da u roku od 30 dana redakciji vrate izmenjen rukopis, ili ukoliko ne izmene, uz rukopis dostave argumentovano obrazloženje zašto izmena nije učinjena. Isto važi i za radove koji nisu pripremljeni u skladu sa uputstvom za autore.

Odluku o prihvatanju rukopisa za štampu donosi redakcija časopisa ***Arheologija i prirodne nauke*** većinom glasova na predlog recenzenata, a u skladu sa izmenama na rukopisu koje su autori izvršili ili u skladu sa dostavljenim obrazloženjem.

Nakon konačnog formiranja sadržaja broja, rukopisi idu na lekturu, a potom se šalju grafičkom dizajneru koji treba da uradi prelom za štampu. Pre odlaska u štampu rade se još dve korekture u PDF formatu. Konačno odobrenje za štampanje časopisa ***Arheologija i prirodne nauke*** daje glavni i odgovorni urednik. Rukopis celog broja u štampariji treba da bude do 30. novembra.

Predloženi recenzenti od strane redakcije, dobijaju recenzentski obrazac koji sadrži niz pitanja na koja treba odgovoriti, a koja recenzentima ukazuju koji su to aspekti koje treba obuhvatiti kako bi se donela odluka o sudbini jednog rukopisa. U završnom delu obrasca, recenzenti moraju da navedu svoja zapažanja i predloge kako da se podneti rukopis poboljša. Identitet recenzenata ostaje nepoznat autorima pre, tokom i nakon postupka recenzije. Autorima se preporučuje da prilikom pisanja radova izbegavaju formulacije koje bi mogle otkriti njihov identitet. Redakcija garantuje da će pre slanja rukopisa na recenziju iz njega biti uklonjeni lični podaci autora (pre svega, ime i afilijacija) i da će se preduzeti sve razumne mere kako bi identitet autora ostao nepoznat recenzentima do okončanja postupka recenzije.

Izbor recenzenata spada u diskreciona prava redakcije. Recenzenti moraju da raspolažu relevantnim znanjima u vezi sa oblašću kojom se rukopis bavi i poželjno je da to ne budu autori koji su u skorije vreme objavljivali publikacije zajedno (kao koautori) sa bilo kojim od autora podnesenog rada.

Tokom čitavog procesa, recenzenti deluju nezavisno jedni od drugih. Recenzentima nije poznat identitet drugih recenzenata. Ako odluke recenzenata nisu iste (prihvatiti / odbiti), glavni urednik može da traži mišljenje drugih recenzenata.

Tokom postupka recenzije urednik može da zahteva od autora da dostave dodatne informacije, ako su one potrebne za donošenje suda o naučnom doprinosu rukopisa. Urednik i recenzenti moraju da čuvaju takve informacije kao poverljive i ne smeju ih koristiti za sticanje lične koristi.

Redakcija je dužna da obezbedi kontrolu kvaliteta recenzije. U slučaju da autori imaju ozbiljne i osnovane zamerke na račun recenzije, redakcija će proveriti da li je recenzija objektivna i da li zadovoljava akademske standarde. Ako se pojavi sumnja u objektivnost ili kvalitet recenzije, urednik će tražiti mišljenje drugih recenzenata.

RAZREŠAVANjE SPORNIH SITUACIJA

Svaki pojedinac ili institucija mogu u bilo kom trenutku da uredniku i/ili redakciji prijave saznanja o kršenju etičkih standarda i drugim nepravilnostima i da o tome dostave neophodne informacije/dokaze.

Provera iznesenih navoda i dokaza

Urednik će u dogovoru sa redakcijom odlučiti o pokretanju postupka koji ima za cilj proveru iznesenih navoda i dokaza.

Tokom tog postupka svi izneseni dokazi smatraće se poverljivim materijalom i biće predočeni samo onim licima koja su direktno uključena u postupak.

Licima za koja se sumnja da su prekršila etičke standarde biće data mogućnost da odgovore na optužbe iznesene protiv njih.

Ako se ustanovi da je zaista došlo do nepravilnosti, proceniće se da li ih treba okarakterisati ako manji prekršaj ili grubo kršenje etičkih standarda.

Manji prekršaj

Situacije okarakterisane kao manji prekršaj rešavaće se u direktnoj komunickaciji sa licima koja su prekršaj učinila, bez uključivanja trećih lica, npr.:

obaveštavanjem autora/recenzenata da je došlo do manjeg prekršaja koji je proistekao iz nerazumevanja ili pogrešne primene akademskih standarda;

pismo upozorenja autoru/recenzentu koji je učnio manji prekršaj.

Grubo kršenje etičkih standarda

Odluke u vezi sa grubim kršenjem etičkih standarda donosi urednik u saradnji sa redakcijom i, ako je to potrebno, malom grupom stručnjaka. Mere koje će preduzeti mogu biti sledeće (i mogu se primenjivati pojedinačno ili istovremeno):

objavljivanje saopštenja ili uvodnika u kom se opisuje slučaj kršenja etičkih standarda;

slanje službenog obaveštenja rukovodiocima ili poslodavcima autora/recenzenta;

povlačenje objavljenog rada u skladu sa procedurom opisanom pod *Povlačenje već objavljenih radova*;

autorima će biti zabranjeno da tokom određenog perioda šalju radove u časopis;

upoznavanje relevantnih stručnih organizacija ili nadležnih organa sa slučajem kako bi mogli da preduzmu odgovarajuće mere.

Prilikom razrešavanja spornih situacija redakcija časopisa se rukovodi smernicama i preporukama Odbora za etiku u izdavaštvu (Committee on Publication Ethics – COPE): http://publicationethics.org/resources/.

POVLAČENJE VEĆ OBJAVLJENIH RADOVA

U slučaju kršenja prava izdavača, nosilaca autorskih prava ili autora, povrede profesionalnih etičkih kodeksa, tj. u slučaju slanja istog rukopisa u više časopisa u isto vreme, lažne tvrdnje o autorstvu, plagijata, manipulacije podacima u cilju prevare, kao i u svim drugim slučajevima grubog kršenja etikih standarda, objavljeni rad se mora povući. U nekim slučajevima već objavljeni rad se može povući i kako bi se ispravile naknadno uočene greške.

Standardi za razrešavanje situacija kada mora doći do povlačenja rada definisani su od strane biblioteka i naučnih tela, a ista praksa je usvojena i od strane časopisa ***Arheologija i prirodne nauke***: u elektronskoj verziji izvornog članka (onog koji se povlači) uspostavlja se veza (HTML link) sa obaveštenjem o povlačenju. Povučeni članak se čuva u izvornoj formi, ali sa vodenim žigom na PDF dokumentu, na svakoj stranici, koji ukazuje da je članak povučen (RETRACTED).

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Redakcija časopisa ***Arheologija i prirodne nauke*** odlučila je da primenom *Akta o uređivanju naučnih časopisa* Ministarstva za nauku i tehnološki razvoj Republike Srbije, kojim se uređuje opremanje naučnih časopisa u celini, unapredi dosadašnji kvalitet časopisa i na taj način doprinese njegovom potpunijem uključivanju u međunarodni sistem razmene naučnih informacija.

Časopis ***Arheologija i prirodne nauke*** posvećen je temama iz naučnih oblasti arheologije, istorije arhitekture, istorije umetnosti, antropologije, arheozoologije, arheobotanike, geofizike, računarskog inženjerstva i ostalih naučnih disciplina i tehnika.

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1. Naslov treba da bude kratak i jasan, i da što vernije opiše sadržaj članka. U naslovu treba da se koriste reči prikladne za indeksiranje i pretraživanje. Ako takvih reči nema u naslovu, poželjno je da se naslovu pridoda podnaslov. Naslov se piše u petom ili šestom redu ispod gornje margine velikim masnim (bold) slovima veličine 14 (pts).
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Način navođenja u bibliografiji:

Popović, I. 2009

Gilt Fibula with Christogram from Imperial Palace in Sirmium (Резиме: Позлаћена фибула са христограмом из царске палате у Сирмијуму) *Starinar* LVII (2007): 101-112.

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Citat u tekstu/fusnoti: (Поповић 1988: 67)

Način navođenja u bibliografiji:

Поповић, И. 1988

Античко оруђе од гвожђа у Србији, Београд: Народни музеј.

(Popović, I. 1988

Antičko oruđe od gvožđa u Srbiji, Beograd: Narodni muzej).

12. Sastavni delovi bibliografskih jedinica (autorska imena, naslov rada, izvor itd.) navode se u skladu sa usvojenom formom navođenja. Redakcija časopisa ***Arheologija i prirodne nauke*** prihvatila je preporuku Ministarstva za nauku i tehnološki razvoj i odlučila da autori treba dosledno da primenjuju pravila citiranja i navođenja literature prema uzoru na sistem koji navodimo u daljem delu teksta.

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1. Autorizovane knjige

a. jedan autor

u tekstu: (Popović 2006)

u literaturi:

Prezime, Inicijal imena. Godina

***Naslov monografije* (*u kurzivu*), Mesto izdanja: Izdavač.**

Popović, I. 2006

Roma aeterna inter Savum et Danubium, Works of Roman Art from the Petrović-Vasić Collection, Belgrade: Archaeological Institute.

- Potrebno je navesti i naziv serije i broj:

Mirković, M. 1968

Rimski gradovi na Dunavu u Gornjoj Meziji, Dissertationes 6, Beograd: Arheološko društvo Jugoslavije.

Papazoglu, F.1969

Srednjobalkanska plemena u predrimsko doba (Tribali, Autarijati, Dardanci, Skordisci i Mezi), Djela 30, Centar za balkanološka ispitivanja 1, Sarajevo: Akademija nauka i umjetnosti Bosne i Hercegovine.

b. dva ili tri autora

Između imena prvog i drugog autora, ili drugog i trećeg u bibliografskoj jedinici na srpskom jeziku treba da stoji veznik **i (**ćiriličnim pismom, ako je bibliografska jedinica na ćirilici, a latiničnim **i,** ako je na latinici). Ako je rad naveden u literaturi na engleskom ili nekom drugom stranom jeziku, treba da stoji (bez obzira na korišćeni jezik) engleski veznik and.

u tekstu: (Popović i Borić-Brešković 1994: 16-18)

u Literaturi:

Popović, I. i Borić-Brešković B. 1994

Ostava iz Bele Reke, Arheološke monografije 7, Beograd: Narodni muzej.

Ivanišević, V., Kazanski, M. and Mastykova, A. 2006

Les necropoles de Viminacium a l'Epoque des Grandes Migrations, Monographies 22, Paris: Association des Amis du Centre d'Histoire et Civilisation de Byzance.

c. četiri i više autora

Za knjige štampane ćirilicom koje imaju četiri i više autora, u osnovnom tekstu navodi se samo ime prvog autora i dodaje se u nastavku **i dr.** Za knjige štampane latinicom koristi se u nastavku skraćenica ***et al.*** Skraćenica ***etc.*** koristi se u slučajevima kada ima više od tri suizdavača ili mesta izdanja.

2. Autorizovane knjige sa pridodatim imenom urednika

u tekstu: (Jeremić 2009: 40)

u Literaturi:

Jeremić, G. 2009

Saldum, Roman and Early Byzantine Fortification, ed. S. Perić, Cahiers des Portes de Fer, Monographies 6, Belgrade: Institute of Archaeology.

3. Priređene knjige (umesto autora - urednik, priređivač, prevodilac) - (ur.), (ed., eds.), (prev.).

u tekstu: (Поповић 1994)

u Literaturi:

Поповић, И. (ur.) 1994

Античко сребро у Србији, Београд: Народни музеј.

u tekstu: (Morris 2002)

u Literaturi:

Morris, I. (ed.) 2002

Classical Greece-Ancient Histories and Modern Archaeologies, Cambridge: Cambridge University Press.

u tekstu: (Hurst and Owen 2005)

u Literaturi

Hurst, H. and Owen. S.(eds) 2005

Ancient Colonizations-Analogy, Similarity and Difference, London: Duckworth.

u tekstu: (Радојчић 1960)

u Literaturi:

Радојчић, Н. (prev.) 1960

Законик цара Стефана Душана 1349. и 1354, Београд: Српска академија наука и уметности.

4. Knjiga bez naznačenog autora

u tekstu: (Anon. 1985)

u Literaturi:

Anon. 1985

Anonymi Peri strategias, The Anonymous Byzantine Treatise on Strategy, *Three Byzantine Military Treatise* (trans. G.T. Dennis), Washington DC.

5. Istovremeno citiranje i navođenje više knjiga istog autora

a. pisanih različitim pismom

u tekstu: (Поповић 2002: 23-26; Popović 2006: 33)

u Literaturi:

Поповић, И. 2002

Накит са Јухора, остава или сакрални тезаурус, Археолошке монографије 14, Посебна издања 36, Београд: Народни музеј и Археолошки институт.

Popović, I. 2006

Roma Aeterna inter Savum et Danubium, Works of Roman Art from the Petrović-Vasić Collection, Belgrade: Archaeological Institute.

b. pisanih iste godine

u tekstu: (Dawkins 1996a; Dawkins 1996b)

u Literaturi:

Dawkins, R. 1996a

Climbing Mount Improbale, London: Viking.

Dawkins, R. 1996b

River out of Eden, London: Pfoenix.

6. Citiranje i navođenja poglavlja i odeljka u knjizi (zborniku radova)

u tekstu: (Петровић 1997: 87-90)

u Literaturi:

Петровић, Б. 1997

Накит, у: *Античка бронза Сингидунума,* ур. С. Крунић, Београд: Музеј града, 85-117.

u tekstu: (Samson 1970: 44-68)

u Literaturi:

Samson, C. 1970

Problems of information studies in history, in: *Humanities information research*, S. Stone, ed., Sheffield: CRUS, 44-68.

7. Prevedene knjige

u Literaturi:

Bajron, Dž. G. 2005 (1812)

Čajld Harold, predgovor Z. Paunović, prevod i predgovor N. Tučev, Beograd: Zavod za udžbenike i nastavna sredstva.

8. Knjige i članci objavljeni u elektronskom obliku

u tekstu: (Fishman 2005: 11)

u Literaturi:

Fishman, R. 2005

The rise and fall of suburbia, [e-book], Chester: Casle Press. Available through Anglia Ruskin University Library. http://libweb.anglia.ac.uk>[pristupljeno 5 juna 2005].

II RADOVI OBJAVLJENI U ZBORNICIMA, AKTIMA KONGRESA I SLIČNO

Prezime, Inicijal imena. Godina

Naslov rada, *Naslov zbornika (kurziv)*, ur. Inicijal imena. Prezime, Mesto izdanja: Izdavač, broj strane.

Брукнер, О. 1987

Импортована и панонска керамичка продукција са аспекта друштвено-економских промена, у: *Почеци романизације у југоисточном делу провинције Паноније*, ур. М. Стојанов: Нови Сад: Матица српска, 25-44.

Potrebno je navesti i podatke o seriji:

Петровић, П. 1997

Римљани на Тимоку, у: *Археологија источне Србије* (Научни скуп Археологија источне Србије, Београд-Доњи Милановац, децембар 1995), ур. М. Лазић, Центар за археолошка истраживања 18: Београд: Филозофски факултет, 115-131.

III PERIODIKA

Prezime, Inicijal imena. Godina

Naslov rada, *Naziv časopisa (*kurziv) broj časopisa: broj strane.

Бајаловић-Хаџи-Пешић, М. 2001

Налази хабанске и постхабанске керамике у Србији, *Годишњак града Београда* 47-48 (2000-2001): 107–121.

- Za časopise čiji su nazivi slični, iza naziva časopisa u zagradi treba navesti mesto izdanja:

Анђелковић, Б. 1988

Праисторијски налази са локалитета Јелица-Градина, *Зборник радова Народног музеја* (Чачак) 18: 81–85.

Анђелковић, Б. 1994

Први резултати анализе мумије из Народног музеја у Београду, *Зборник Народног музеја* (Београд) 15-1: 153–159.

- *Старинар* se, zavisno od godine izdanja, navodi punim nazivom:

godine 1884-1895 - *Старинар Српског археолошког друштва*

godine 1906-1914 [novog reda] - *Старинар* (н.р.)

godine 1922-1942 [treća serija] - *Старинар* (т.с.)

godine 1950-2010 [nova serija] - *Старинар* (т.с.)

- Ukoliko se godina izlaženja i godina za koju časopis izlazi razlikuju, navesti i drugu godinu u zagradi:

Жеравица, З., и Жеравица, Л. 1979

Средњовековно насеље у Поповици код Неготина, *Старинар* (н.с.) 28-29 (1977-1978): 201–211.

Rad u štampi / u pripremi

- (u štampi), u tekstu na engleskom jeziku (in press)

- (u pripremi), u tekstu na engleskom jeziku (forthcoming).

u tekstu: (Јовановић, u štampi)

u literaturi:

Јовановић, А. (u štampi)

Бор и околина у античком периоду, у: *Бор и околина у праисторији, антици и средњем веку*, ур. М. Лазић, Бор и Београд: Музеј рударства и металургије и Филозофски факултет.

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Umesto mesta izdanja i izdavača navodi se naziv fakulteta/univerziteta gde je teza odbranjena.

u literaturi:

Ilić, O. 2005

Ranohrišćanski pokretni nalazi na području dijeceze Dakije od IV do početka VII veka, Magistarski rad, Filozofski fakultet, Univerzitet u Beogradu.

Patch, D. C. 1991

The Origin and Early Development of Urbanism in Ancient Egypt: A regional Study, Ph.D thesis, University of Pennsylvania.

VI Popularni magazini/časopisi i novinski članci

u tekstu: Кашанин, М. 1929

u literaturi:

Кашанин, М. 1929

Музеј савремене уметности, *Политика, 23. јул, 7-8.*

12. Sve reference citirane u tekstu navode se po azbučnom (abecednom ukoliko je tekst na engleskom ili nekom drugom jeziku) redosledu inicijala u prezimenu autora ili početnog slova u nazivu dela (ako autor ili urednik nisu naznačeni).

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olivera.arh011@gmail.com

Redakcija časopisa
ARHEOLOGIJA I PRIRODNE NAUKE

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In the list of references: **Поповић, И. 1988**
Античко оруђе од гвожђа у Србији, Београд: Народни музеј.
(Popović, I. 1988
Antičko oruđe od gvožđa u Srbiji, Beograd: Narodni muzej).

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The following examples describe the most frequently quoted kinds of references:

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a. single author

within main text: (Popović 2006)

in bibliography:

Surname, name's initial. Year of publishing
***Title of book* (*italic),* Place: Editor.**

Popović, I. 2006
Roma aeterna inter Savum et Danubium, Works of Roman Art from the Petrović-Vasić Collection, Belgrade: Archaeological Institute.

- Series' name and number is also needed:

Mirković, M. 1968
Rimski gradovi na Dunavu u Gornjoj Meziji, Dissertationes 6, Beograd: Arheološko društvo Jugoslavije.

Papazoglu, F.1969
Srednjobalkanska plemena u predrimsko doba (Tribali, Autarijati, Dardanci, Skordisci i Mezi), Djela 30, Centar za balkanološka ispitivanja 1, Sarajevo: Akademija nauka i umjetnosti Bosne i Hercegovine.

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within main text: (Popović i Borić-Brešković 1994)

in bibliography:

Popović, I. i Borić-Brešković B. 1994
Ostava iz Bele Reke, Arheološke monografije 7, Beograd: Narodni muzej.

Ivanišević, V., Kazanski, M. and Mastykova, A. 2006
Les necropoles de Viminacium a l'Epoque des Grandes Migrations, Monographies 22, Paris: Association des Amis du Centre d'Histoire et Civilisation de Byzance.

c. four or more authors

Books written by four or more authors, within the main text and in Serbian cyrillic, only the first name is written and **i dr.** is added. Books printed in Lati alphabet, the abbrevation ***et al.*** is applied. The abbrevation ***etc.*** is used in cases when there are more than three editors or places of editing.

2. Author's books with added name of the editor

within main text: (Jeremić 2009: 40)

in bibliography:

Jeremić, G. 2009
Saldum, Roman and Early Byzantine Fortification, S. Perić (ed.), Cahiers des Portes de Fer, Monographies 6, Belgrade: Institute of Archaeology.

3. Edited books (instead of the author – editor, translator) - (ed., eds.), (trans.).

within main text: (Поповић 1994)

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Поповић, И. (ур.) 1994
Античко сребро у Србији, Београд: Народни музеј.

within main text: (Morris 2002)

in bibliography:

Morris, I. (ed.) 2002
Classical Greece-Ancient Histories and Modern Archaeologies, Cambridge: Cambridge University Press.

within main text: (Hurst and Owen 2005)

in bibliography:

Hurst, H. and Owen. S.(eds) 2005
Ancient Colonizations-Analogy, Similarity and Difference, London: Duckworth.

within main text: (Радојчић 1960)

in bibliography:

Радојчић, Н. (prev.) 1960
Законик цара Стефана Душана 1349. и 1354., Београд: Српска академија наука и уметности.

4.Way of quoting books without author's name

within main text: (Anon. 1985)

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Anon. 1985
Anonymi Peri strategias, The Anonymous Byzantine Treatise on Strategy, *Three Byzantine Military Treatise* (trans. G.T. Dennis), Washington DC.

5. Simultaneous quoting of several books of the same author

a. written in different alphabets

within main text: (Поповић 2002, Popović 2006)

in bibliography:

Поповић, И. 2002

Накит са Јухора, острава или сакрални тезаурус, Археолошке монографије 14, Посебна издања 36, Београд: Народни музеј и Археолошки институт.

Popović, I. 2006

Roma Aeterna inter Savum et Danubium, Works of Roman Art from the Petrović-Vasić Collection, Belgrade: Archaeological Institute.

b. written in the same year

within main text: (Dawkins 1996a, Dawkins 1996b)

in bibliography:

Dawkins, R. 1996a

Climbing Mount Improbale, London: Viking.

Dawkins, R. 1996b

River out of Eden, London: Pfoenix.

6. Quoting chapters in books (acta)

within main text: (Петровић 1997: 87-90)

in bibliography:

Петровић, Б. 1997

Накит, у: *Античка бронза Сингидунума,* С. Крунић (ур.), Београд: Музеј града, 85-117.

within main text: (Samson 1970: 44-68)

in bibliography:

Samson, C. 1970

Problems of information studies in history, in: *Humanities information research*, S. Stone, (ed.), Sheffield: CRUS, 44-68.

7. Translated books

in bibliography:

Bajron, DŽ. G. 2005 (1812)

Čajld Harold, Z. Paunović (predgovor), N. Tučev (prevod), Beograd: Zavod za udžbenike i nastavna sredstva.

8. Books and articles published in electronic form

within main text: (Fishman 2005: 11)

in bibliography:

Fishman, R. 2005

The rise and fall of suburbia, [e-book], Chester: Casle Press. Available through Anglia Ruskin University Library. http://libweb.anglia.ac.uk>[pristupljeno 5 juna 2005].

II PAPERS PUBLISHED IN PERIODICALS, CONGRESS ACTA AND SIMILAR

within main text: (Vasić 2008: 69, fig.3)

in bibliography:

Surname, name's initial. Year

Title, *Title of the acta (italic)*, Name's initial. Surname, (ed.), Place of editing: Editor, page numbers.

Vasić, M. 2006. Stibadium in Romuliana and Mediana. *Felix Romvliana 50 years of archaeological excavations.* M**.** Vasić (ed.). October, 27-29 2003, Zaječar, Serbia. Belgrade: Institut of Arhcaeology, Committee on Archaeology of Serbian Academy of Sciences and Arts, and Zaječar: National Museum, 69-75.

Series' data are also needed:

Петровић, П. 1997

Римљани на Тимоку, у: *Археологија источне Србије* (Научни скуп Археологија источне Србије, Београд-Доњи Милановац, децембар 1995*)*, М. Лазић (ур.), Центар за археолошка истраживања 18, Београд: Филозофски факултет, 115-131.

III PERIODICALS

within main text: (Бајаловић-Хаџи-Пешић, 2001: 108)

Surname, Name's initial. Year

Title, *Name of the periodical (italic*) number of the periodical: page number.

Бајаловић-Хаџи-Пешић, М. 2001

Налази хабанске и постхабанске керамике у Србији, *Годишњак града Београда* 47-48 (2000-2001): 107–121.

- For periodicals with similar titles, behind the name of the periodical, place of publishing should be stated in brackets:

Анђелковић, Б. 1988

Праисторијски налази са локалитета

Јелица-Градина, *Зборник радова Народног музеја* (Чачак) 18: 81–85.

Анђелковић, Б. 1994

Први резултати анализе мумије из Народног музеја у Београду, *Зборник Народног музеја* (Београд) 15-1: 153–159.

- Depending on the year of publishing *Старинар* is named in its full title:

years 1884-1895 - *Старинар Српског археолошког друштва*

years 1906-1914 [novog reda] - *Старинар* (н.р.)

years 1922-1942 [treća serija] - *Старинар* (т.с.)

years 1950-2010 [nova serija] - *Старинар* (н.с.)

- If there is a difference between the year of actual printing and the year of publishing, the second is stated in brackets:

Жеравица, З., и Жеравица, Л. 1979, Средњовековно насеље у Поповици код Неготина, *Старинар* (н.с.) XXVIII-XXIX, (1977-1978): 201–211.

Paper in print / forthcoming

- (in print), within papers written in English (in print)

- (forthcoming), within papers written in English (forthcoming).

within main text: (Јовановић, in print)

in bibliography:

Јовановић, А. (in print)

Бор и околина у античком периоду, у: *Бор и околина у праисторији, антици и средњем веку*, ур. М. Лазић, Бор и Београд: Музеј рударства и металургије и Филозофски факултет.

Papers overtaken from the internet, from electronic periodicals, are quoted in the same way as printed papers, only there is a full web-address written at the end with http://...

V Doctoral and master theses

Instead of place of editing and editor, the full name of faculty/university is given, where the thesis was conducted.

within main text: (Ilić, 2005)

in bibliography:

Ilić, O. 2005

Ranohrišćanski pokretni nalazi na području dijeceze Dakije od IV do početka VII veka, Magistarska teza, Filozofski fakultet, Univerzitet u Beogradu.

within main text: (Patch, 1991)

in bibliography:

Patch, D. C. 1991

The Origin and Early Development of Urbanism in Ancient Egypt: A regional Study, Ph.D thesis, University of Pennsylvania.

VI Articles from newspapers

within main text: (Кашанин, 1929)

in bibliography:

Кашанин, М. 1929, Музеј савремене уметности, *Политика, 23. јул, 7-8.*

Main text

Quoting bibliography in the main text according to the pattern (author's surname and year: page number, footnote, figure, table):

(Papazoglu 1969: 52, sl. 4/1, T. 18-4-6)

(Babović 1984: 68; Moritz 1978: 68, figs. 40-41; Tasić 1997: 84, sl. 21)

- Additional data within brackets can be written after a dash:

(Swoboda-Milanović 1958: 55, Taf. 18/24 – olovne pločice).

- The same work of the same author in the next quotation can be quoted abbrevated *ibidem* (*ibid.*: page number).

- The second work of the same author in the next quoting, if there are no quotations in between, is quoted as (*idem* year: page number): (Faltings 1998a: 367; *idem* 1998b: 31–32).

- In papers written in Serbian language, the transcribed exact pronounciation of a foreign author's name is written within the main text, without brackets, but the original name is written in quotation: ...Vencel (Wenzel 1965: T. HS/4).

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- Abbrevation *cf.* (lat. *confer*) - compare

- Abbrevation *e.g.* (lat. *exempli gratia*) - for example

- Abbrevation *i.e.* (lat. *id est*) - actually.

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