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INFLUENCE OF ANTHROPOGENIC AND ENVIRONMENTAL FACTORS ON SKELETAL PRESERVATION IN SARMATIAN CEMETERIES

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UTICAJ ANTROPOGENIH FAKTORA I FAKTORA SREDINE NA OČUVANOST SKELETNOG MATERIJALA SA SARMATSKIH NEKROPOLA

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ABSTRACT

Influence of anthropogenic and environmental factors on skeletal preservation in Sarmatian cemeteries

Background: It is impossible to comprehend and understand historical burial customs without studying skeletal remains. In an archaeological and forensic research, skeletal remains go through a variety of decomposition processes that are influenced by a number of human factors (such as the manner of burial and the body treatment) as well as environmental factors (such as soil type, water, the influence of flora and fauna, and climate). These factors also affect how long the decomposition process continues and, ultimately, how long skeletal remains remain preserved in necropolises. However, such thorough research is frequently absent from bioanthropological studies, which explains why crucial information about skeletal remains—such as their location, level of preservation, presence of organic remains, and taphonomic elements—remains unobtainable or inadequately studied.

Aims: This study aimed to numerically evaluate the degree of preservation of skeletal material for the available material from the necropolis with the idea of separating the concepts of skeletal completeness and material fragmentation. In addition, the study investigated the impact of grave robbing on skeletal preservation by comparing data from opened and unopened graves. Skeletal material was analysed in order to observe and analyse the visible traces of destruction of bones during the opening of graves in the past, as well as to analyse the taphonomic changes on the surface of the bones resulting from the subsequent action of environmental factors (bioturbation of the soil, change in weather conditions, method of burial, soil composition) on the poor preservation and completeness of the skeletal material from the Sarmatian necropolis.

Material and method 245 graves including skeleton remains from 19 Sarmatian sites in Vojvodina, near modern-day Banat and Bačka, were included in the study, dated between the first and fifth century AD (Svetozar Miletić, Subotica-Verušić, Bačko Petrovo Selo-Čik, Čurug-Detelinara 2, Gospođinci-Banatski Dvor-Melenci-Kentra (Site 15, Site 17, Site 18, Site 20, Site 22, Site 23), Gospođinci-Futog - Site Klisa II, Klisa Highway E-75, Mošorin Šajkaš-Site 10, Orlovat-Vodice, Gospodjinci-Banatski-Dvor- Cerba- Mihajlovo, Aradac-Leje, Velebit, Vojlovica-Rafinerija, Vršac-Neuropsihijatrija. Following established anthropological practices, the skeletal material was examined at the Center for Bone Biology of the Faculty of Medicine, University of Belgrade. Taphonomy, anthropometric measurements, age and sex assessment, dental and paleopathological analysis and the evaluation of the degree of preservation of skeletal material were all included in the bioanthropological investigation.

Information about post mortem activity, or "grave robbing" was gathered from both unpublished and published archeological sources. The archaeothanatological methodology was utilised on this structure to analyse skeleton displacement and manipulation patterns during the act of looting, as well as skeletal decomposition processes that would reveal the exact moment the graves were reopened. According to this the burials were classified into two groups: intacted and reopened graves.

Based on the principles of forensic taphonomy, a macroscopic investigation of taphonomic alterations on skeletal material was conducted. Changes in the surface of each skeleton were observed separately, revealing bleaching, discolouration, gnawing marks, and exfoliation of the bones. There are six main categories that contain subcategories: weather-related changes (such as bleaching and exfoliation), coffin wear patterns (which causes erosive changes on the surface of the bone), animal and insect traces (such as rodents, carnivores, birds, and insects), fungal activities, flora influence, bone staining (from soil or artefact patina), and anthropogenic changes (such as tool mark traces). It was also taken into consideration how the soil's characteristics and the grave's depth affected the preservation of the material's skeleton. To examine the temporal continuity of the skeletal material's exposure to environmental factors and the degree of degradation, taphonomic changes were analysed through six established phases that study the degree of exposure and the postmortem interval.

The established *bone representation index* (BRI), which is calculated as the frequency of each bone in the sample in relation to the expected number of that particular bone according to the minimum number of individuals in the sample, was used to observe the numerical assessment of the state of preservation of the skeleton for the entire sample. The mean value of each person's BRIs was used to compute the BRI for that particular person. Regardless of the completeness of the bone parts, the *index of bone fragmentation* (IBF) was further applied for each bone in the sample to determine the degree of fragmentation (fragmented or non-fragmented bone); the calculation was made by dividing the total number of fragmented bones by the total number of bones present. IBF according to the individual was calculated as the mean value of IBF of all observed bones in that individual.

In order to verify the archaeological relative dating of the Sarmatian sites and to gather more accurate information regarding the chronology of the sites, absolute dating of the Sarmatian sites was conducted. Twenty tooth samples were extracted from nine archaeological sites (Vojlovica-Rafinerija, Vršac-Neuropsihijatrija, Verušić, Aradac-Leje, Velebit, Čurug-Detelinara, Čik, Svetozar Miletić, Mošorin Šajkaš-Site 10) in order to use AMS radiocarbon dating. The analysis at the Oxford Radiocarbon Accelerator Unit was carried out in accordance with conventional laboratory procedures.

In statistical analysis, the normality of the data distribution was ascertained by running the Kolmogorov-Smirnov test. Depending on whether the data distribution is normal, the Student's t test or the Mann-Whitney U test was used to compare differences in per-individual BRI and per-individual IBF between intact and robbed graves. Depending on how the data are distributed, either Pearson's or Spearman's correlation was used to evaluate the association between grave depth and BRI for each individual. The statistical analysis was done using SPSS version 21. A p-value of less than 0.05 indicates statistical significance.

Results and conclusions: By using archeothanatological principles to analyse archaeological documentation, it was possible to determine that, out of the 196/245 graves that were examined, 62% had been opened, 22% had been destroyed by later modern construction projects or did not have sufficient archaeological documentation, and only 16% had remained intact, meaning they had not experienced any postmortem activity. Among graves that have previously been looted, three models of grave reopening were distinguished based on *in situ* bone displacement: reopening the grave and disturbing the upper body with little to significant dislocation; reopening the grave completely and causing extensive movement and destruction of bones *in situ*; and empty graves devoid of skeletal components. These graves were opened some years after the burial, when the body had skeletonized, but the burial structures (coffins) had not yet disintegrated.

Research has indicated that the phenomenon of opening graves in the past has a double effect on bone preservation and fragmentation. According to statistical findings, intact graves have better skeletal preservation (BRI index), whereas opened graves have higher skeletal fragmentation (IBF index). The low proportion of skeletal preservation seen in intact burials, however, points to the possibility of other taphonomic factors contributing to the general poor preservation of skeletal material in Sarmatian cemeteries.

The study's findings demonstrated that the fragmentation of the skeletal material was significantly impacted by the grave reopenings. The presence of broken bones in the top portions of the grave and the evidence of tool marks from the perpetrators usage of tools for digging graves and looking for riches both indicated the physical destruction of the skeleton. Also, during the search for things, the bones at the bottom of the grave were shifted, broken, and a substantial portion of the skeleton was thrown on the surface of the soil, coupled with the earth during the emptying of the contents of the grave. The graves were left partly or entirely uncovered following the plundering, allowing the influence of other taphonomic agents to affect the further degradation of the skeletal material.

The taphonomic analysis of the bones from the reopened graves showed traces on bone surface and deep destruction of the bone structures due to the long exposure of the skeletal material to atmospheric factors (surface abrasion, cracks, porosity, peeling of the cortex). According to the established stages of skeleton degradation in case of exposure to atmospheric conditions, it was observed that the material from Sarmatian graves recorded a high degree of degradation, that is, that the bones were continuously exposed to the point that in some cases they completely disintegrated. On the other hand, bones from intact graves belong to the first phases of this scale, that is, they do not record taphonomic changes. Macroscopic changes on the bones, in addition to extremely pronounced taphonomic changes, indicate that the bones in the reopened graves were also exposed to different temperature cycles or different seasons. This is indicated by superficial and deep bone cracks and fractures, as well as surface abrasion, suggesting repeated bone freezing-thawing processes that eventually led to bone disintegration.

However, the poor skeletal preservation of skeletal material in intact graves indicated additional factors that influenced skeletal preservation. Among them is the influence of burials in coffins made of tree trunks which, creating a chemical reaction during the decomposition of the wood, corroded the bones and thus the skeletal remains disintegrated in context regardless of postmortem activities. Also, there is a possibility that the bones were additionally destroyed during the violent opening of the lids during the robbery due to the pressure of the falling sediment and the lid of the coffin.

Using archaeothanatological knowledge for the reconstruction of grave opening time frames, it was shown that earlier interpretations about the responsibility of the Hun and Avar populations for the systematic opening of Sarmatian graves are partially correct, and only for the later cemeteries in this sample. Furthermore, the results of the AMS dating of the skeletal material, compared with archaeothanatological principles (time of grave opening) indicate that most Sarmatian graves were opened between 10 and 35 years after death, which in archaeological terms suggests the existence of some other population responsible for the opening and destruction graves. Precise knowledge of the position of the grave, the position of the body in the grave, as well as the grave contents indicate that this activity could have been carried out by a population contemporaneous with the Sarmatians, even possibly by some other Sarmatian tribes, especially if turbulent times and historical sources are taken into account which record the mutual struggles of the Sarmatian tribes during periods of war.

Keywords: Sarmatians, Late Antique period, bone weathering, funerary taphonomy, skeletal preservation, environmental factors, archaeothanatology, coffin wear changes

Research field: Medicine

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REZIME

Uticaj antropogenih faktora i faktora sredine na očuvanost skeletnog materijala sa sarmatskih nekropola

Uvod: Razumevanje i tumačenje pogrebne prakse u prošlosti nemoguće je bez istraživanja skeletnih ostataka. Skeletni ostaci u arheološkom i forenzičkom kontekstu prolaze različite procese dekompozicije, koji su uslovljeni brojnim antropogenim faktorima (načinom sahranjivanja, tretmanom tela pre sahrane) i faktorima životne sredine (tip zemljišta, voda, uticaj biljnog i životinjskog sveta, klima) koji utiču na dalji proces dekompozicije i samim tim i očuvanosti skeletnih ostataka na nekropolama. Ovakva istraživanja sveobuhvatna, ipak, vrlo često nedostaju u bioantropološkim studijama zbog čega važni podaci o skeletnim ostacima (pozicija skeleta, stepen očuvanosti, prisustvo organskih ostataka, tafonomski elementi) ostaju nedostupni ili nedovoljno istraženi.

Ilustrativan primer nedostatka tafonomskih istraživanja prisutan je u arheološkim istraživanjima sarmatskih nekropola u Panonskoj niziji, gde su samo načelno konstatovani podaci o slaboj očuvanosti skeleta. Teritorija Panonske nizije bila je gusto naseljena između 1. i 5. veka nove ere i predstavljala je područje gde su se aktivno događale migracije različitih nomadskih populacija (Sarmati, Huni, Germani, Avari itd.). Međutim, od svih populacija samo su skeletni ostaci Sarmata u slabom stanju očuvanosti.

Jedini do sada pominjan razlog loše očuvanosti sarmatskih skeleta od strane arheologa jeste sistematsko plačkanje grobova u antičko doba. U arheološkim izveštajima ovaj fenomen je evidentiran kroz prisustvo sekundarnih jama, fragmentovanih skeletnih ostataka u gornjim delovima rake, poremećenim skeletnim ostacima na dnu groba i oštećenim ili nestalim predmetima. Međutim, čak i istraživači koji su proučavali sarmatske grobove u Panonskoj niziji fokusirali su se isključivo na analizu arheoloških nalaza i rituala, bez detaljnog analiziranja fenomena pljačkanja grobova, sa stanovišta bioantropološke i arheotanatološke analize. Štaviše, arheološka istraživanja potpuno su zanemarila temu očuvanosti i kompletnosti skeleta tako da čak ni netaknuti grobovi sa fragmentovanim skeletnim ostacima nisu skrenuli pažnju za potrebu daljeg ispitivanja dodatnih procesa odgovornih za očuvanost skeletnog materijala. Takođe nema podataka o tome šta se dešavalo sa razbacanim skeletnim ostacima u grobu i van njega nakon pljačke, niti odgovarajućih antropoloških ili tafonomskih analiza koje bi pružile dodatne podatke o tome kako je i u kojoj meri fenomen pljačkanja sarmatskih grobova uticao na očuvanost skeletnog materijala. Iako su novije studije o fenomenu pljačkanja grobova u Evropi malo više fokusirane na skeletne ostatke, čak i tim studijama generalno nedostaju tafonomske analize skeletnog materijala i očuvanosti prisutnih kostiju.

Ciljevi: Ova studija imala je za cilj da numerički proceni stepen očuvanosti skeletnog materijala za dostupan materijal sa nekropola sa idejom razdvajanja pojmova skeletne kompletnosti i fragmentovanosti materijala. Pored toga, studija se bavila ispitivanjem uticaja pljačkanja grobova na skeletnu očuvanost poredeći podatke iz otvaranih i neotvaranih grobova. Skeletni materijal je analiziran kako bi se uočili i analizirali vidljivi tragovi uništavanja kostiju prilikom otvaranja grobova u prošlosti, kao i da bi se analizirale tafonomske promene na površini kostiju nastale kao posledica naknadnog delovanja faktora

sredine (bioturbacija zemljišta, promena vremenskih uslova, način sahrane, sastav zemljišta) na lošu očuvanost i kompletnost skeletnog materijala sa sarmatskih nekropola.

Materijal i metod: Studija je obuhvatila 245 grobova sa skeletnim ostacima sa 19 sarmatskih lokaliteta, koji se nalaze u Vojvodini, u oblasti današnjeg Banata i Bačke. Nekropole datiraju od 1. do 5. veka nove ere. Lokaliteti uključeni u studiju su: Svetozar Miletić, Subotica-Verušić, Bačko Petrovo Selo-Čik, Čurug-Detelinara 2, Gospodinci-Banatski Dvor- Melenci-Kentra (Lokalitet 15, Lokalitet 17, Lokalitet 18, Lokalitet 20, Lokalitet 22, Lokalitet 23), Gospođinci-Futog – Lokalitet Klisa II, Klisa Autoput E-75, Mošorin Šajkaš- Lokalitet 10, Orlovat-Vodice, Gospođinci-Banatski, Dvor-Cerba-Mihajlovo, Aradac-Leje, Velebit, Vojlovica-Rafinerija, Vršac-Neuropsihijatrija. Skeletni materijal analiziran je u Centru za biologiju kosti Medicinskog fakulteta, Univerziteta u Beogradu prema standardnim antropološkim procedurama. Bioantropološka analiza obuhvatala je procenu stepena očuvansoti skeletnog materijala, tafonomiju, antropometrijska merenja, procenu starosti i pola individua, kao i dentalnu i paleopatološku analizu.

Podaci o postmortem aktivnostima (pljačkanju grobova) dobijeni su iz publikovane arheološke literature i nepublikovanih arheoloških izveštaja. Na ovoj građi primenjena je arheotanatološka metodologija kako bi se uočili obrasci pomeranja i manipulisanja skeleta tokom pljačke, kao i procesi skeletne dekompozicije koja bi mogla ukazati na vreme otvaranja grobova. Prema ovim podacima, grobovi su najpre podeljeni u dve kategorije - netaknuti i pljačkani grobovi.

Makroskopska analiza tafonomskih promena na skeletnom materijalu rađena je na osnovu metodologije iz forenzičke tafonomije. Na svakom skeletu pojedinčno praćene su promene na površini kosti koji ukazuju na eksfolijaciju, delaminaciju, tragove glodanja, izbeljenost i obojenost kostiju. Ove promene podeljene su u šest kategorija sa potkategorijima: promene nastale usled vremenskih uslova (eksfolijacija, beljenje), dejstvo kovčega (erozivne promene na površini kosti), tragovi aktivnosti životinja i insekata (glodari, mesožderi, ptice, insekti), uticaj flore, gljivične aktivnosti, bojenje kostiju (iz zemlje, patina of artefakta), antropogene promene (tragovi alatki). Takođe se razmatrao i uticaj dubine groba i svojstva zemljišta na skeletnu očuvanost materijala. Kako bi se analizirao vremenski kontinuitet izloženosti skeletnog materijala sredinskim faktorima i stepen degradacije, tafonomske promene su analizirane kroz šest ustanovljenih faza koje proučavaju stepen izloženosti i postmortem interval.

Numerička procena stanja očuvanosti skeleta za ceo uzorak posmatrala se kroz utvrđeni indeks zastupljenosti kostiju (BRI), koji se izračunava kao učestalost svake kosti u uzorku u odnosu na očekivani broj te određene kosti prema minimalnom broju individua u uzorku. BRI po individui izračunavan je kao srednja vrednost svih BRI kod te individue. Za svaku prisutnu kost u uzorku, dalje je primenjivan indeks fragmentacije kosti (IBF) kako bi se procenio stepen fragmentovanosti (fragmentovana ili nefragmentovana kost) bez obzira na kompletnost delova kosti; izračunavanje je izvršeno tako što će je ukupan broj fragmentovanih kostiju podeljen sa ukupnim brojem prisutnih kostiju. IBF po individui izračunavan je kao srednja vrednost IBF svih posmatranih kostiju kod te individue.

Apsolutno datovanje sarmatskih lokaliteta sprovelo se kako bi se potvrdilo arheološko relativno datovanje sarmatskih lokaliteta i dobili precizniji podaci o hronologiji lokaliteta. Za potrebe AMS radiokarbonskog datovanja uzeto je 20 uzoraka zuba sa 9 arheoloških lokaliteta (Vojlovica-Rafinerija, Vršac-Neuropsihijatrija, Verušić, Aradac-Leje, Velebit, Čurug-Detelinara, Čik, Svetozar Miletić, Mošorin Šajkaš-Lokalitet 10). Analiziranje je obavljeno prema standardnim laboratorijskim protokolima u Oksford Radiocarbon Accelerator Unit.

Statistička analiza podrazumevala je primenu Kolmogorov-Smirnov testa za određivanje normalnosti distribucije podataka. Razlike u BRI po individui i IBF po individui između netaknutih i pljačkanih grobova određivaće se korišćenjem Studentovog t testa ili Man-Vitni *U* testa, u zavisnosti od normalnosti distribucije podataka. Odnos između dubine groba i BRI po individui procenjivaće se korišćenjem Pirsonove ili Spirmanove korelacije u zavisnosti od distribucije podataka. Statistička analiza sprovodiće se u SPSS softveru 21. $P<0{,}05$ će se smatrati statistički značajnim.

Rezultati i zaključci: Analiziranjem arheološke dokumentacije i primenom arheotanatoloških principa pokazalo se da je od ukupnog analiziranog broja grobova (196/245) 62% grobova bilo otvarano, 22% su uništeni naknadnim savremenim radovima ili nije postajala adekvatna arheološka dokumentacija za njih, dok je samo 16% grobova bilo netaknuto, odnosno bez postmortem aktivnosti. Među grobovima koji su pljačkani u prošlosti izdvajaju se tri modela poremećaja kostiju *in situ*: otvaranje grobova i remećenje gornjeg dela tela sa minimalnom ili većom dislokacijom; kompletno otvaranje groba i intezivno pomeranje i destrukcija kostiju *in situ*; prazni grobovi bez skeletnih elemenata. Arheotanatološka analiza ovih grobova pokazala je da su oni otvarani nakon što su se tela skeletonizovala, nekoliko godina nakon sahrane, ali se grobne konstrukcije (kovčezi) još uvek nisu raspale.

Istraživanje je pokazalo da je fenomen otvaranja grobova u prošlosti dvojako uticao na skeletnu očuvanost i fragmentaciju. Statistički rezultati ukazuju na to da je skeletna očuvanost (BRI indeks) veća u slučaju intaktnih grobova, kao i da je skeletna fragmentovanost (IBF index) veća kod grobova koji su otvarani. Međutim, stepen skeletne očuvanosti kod grobova koji su intaktni nije pokazao visoku procentualnost očuvanosti, što sugeriše na dodatne tafonomske uzroke koji su uticali na sveukupnu lošu očuvanost skeletnog materijala na sarmatskim nekropolama.

Rezultati istraživanja pokazali su da je otvaranje grobova u velikoj meri direktno uticalo na fragmentovanost skeletnog materijala. Fizička destrukcija skeleta uočena je kroz postojanje fragmentovanih kostiju u gornjim delovima rake, kao i evidentiranjem tragova
ureza od alatki koji su počinioci koristili prilikom otvaranja grobova i pretrage za dragocenostima. Takođe, prilikom traženja predmeta, kosti na dnu groba su pomerane, fragmentovane, a veliki deo skeleta je i bacan na površinu zemlje, zajedno sa zemljom tokom pražnjenja sadržaja groba. Nakon pljačke, grobovi su ostajali kompletno otvarani ili delimično otvarani što je omogućilo uticaj drugih tafonomskih agenata da utiču na dalju degradaciju skeletnog materijala.

Tafonomska analiza kostiju iz grobova koji su otvarani pokazala je da se na kostima nalaze tragovi površinske i dubinske destrukcije zbog duge izloženosti skeletnog materijala

atmosferskim faktorima (abradiranost površine, pukotine, poroznost, ljuštenje korteksa). Prema ustanovljenjim fazama degradacije skeleta u slučaju izloženosti atmosferskim uslovima, uočeno je da materijal iz sarmatskih grobova beleži visok stepen degradacije, odnosno da su kosti kontinuirano bile izložene da su se u nekim slučajevima u potpunosti dezintegrisale. S druge strane, kosti iz intaktnih grobova pripadaju nultim fazama ove skale, odnosno ne beleže tafonomske promene. Makroskopske promene na kostima, pored izuzetno izraženih tafonomskih promena ukazuju i na to da su kosti u otvaranim grobovima ostajale izložene i različitim vreenskim ciklusima, odnosno različitim godišnjim dobima. Na to ukazuju površinske i dubinske pukotine i frakture kostiju, kao i abradiranost površine, sugerišući ponovljene procese smrzavanja-odmrzavanja kostiju što je na kraju dovelo do dezintegracije kostiju.

Međutim, loša skeletna očuvanost skeletnog materijala u netaknutim grobovima ukazala je na dodatne faktori koji su uticali na skeletnu očuvanost. Među njima je uticaj sahrana u kovčezima napravljenih od debla drveta koji su, stvarajući hemijsku reakciju prilikom raspadanja drveta, nagrizali kosti i na taj način su se skeletni ostaci dezintegrisali u kontekstu bez obzira na postmortem aktivnosti. Takođe, postoji mogućnost da su se kosti dodatno uništile prilikom nasilnog otvaranja poklopaca tokom pljačke usled pritiska padajućeg sedimenta i poklopca kovčega.

Koristeći arheotanatološka saznanja za rekonstrukciju intervala otvaranja grobova pokazalo se da ranija tumačenja o odgovornosti populacija Huna i Avara za sistematsko otvaranje grobova Sarmata delimično tačna i to za samo kasnije nekropole u ovom uzorku. Štavište, AMS rezultati datovanja skeletnog materijala, upoređeni sa arheotanatološkim principima (vreme otvaranja groba) ukazuju na to da su grobovi Sarmata većinom otvarani između 10 i 35 godina nakon smrti, što u arheološkom smislu sugeriše postojanje neke druge populacije koja je odgovorna za otvaranje i uništavanje grobova. Precizno poznavanje pozicije groba, položaja tela u grobu, kao i grobnog sadržaja ukazuje na to da je ovu aktivnost mogla da sprovede i neka populacija istovremena sa Sarmatima, čak mogućno i neka druga plemena Sarmata, posebno ako se uzmu u obzir turbulentna vremena i istorijski izvori koji beleže međusobne borbe plemena Sarmata tokom ratnih perioda.

Ključne reči: Sarmati, kasna antika, funerarna tafonomija, skeletna očuvanost, faktori sredine, arheotanatologija, kovčeg

Naučna oblast: Medicina

Uža naučna oblast: Biologija skeleta

UDK broj:

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1. INTRODUCTION

The taphonomic study of skeletal remains from Sarmatian necropolises in Vojvodina, which derive from previously opened postmortem burials, will be the focus of this thesis. These skeletal remains were not the subject of earlier studies since it was the widely accepted scientific view up until this point that they were exceptionally poorly preserved as a result of grave robbery. The thesis will address if there are any additional anthropogenic or environmental elements that contribute to the poor preservation of skeletal material, as well as how postmortem activities affect the preservation of skeletal remains.

1.1 Bone taphonomy

The reconstruction of burial practices and past human activities requires the study of skeletal remains. From the moment of placing in the ground, the body goes through various processes of decay, conditioned by various external factors that can slow down or accelerate this process. After the body becomes skeletonised, the process of bone modification at archaeological sites continues. The bone surface can change due to various environmental or anthropogenic factors [1]. The burial ritual itself has a direct influence on the process of decomposition and bone breakdown, that is, the sociocultural aspect of burial depends on the cultural practices of a community. The way the body was treated and prepared for burial (coating and cleaning of the body, clothing), the burial ritual itself (inhumation or cremation), the conditions in which the body is laid in the ground (type of containers, organic coverings, depth of burial), and the position of the body have immense impact on the process of body decomposition, and consequently on bone breakdown.

The action of non-anthropogenic environmental factors commences after the body is lowered into the ground and is controlled by natural factors that can alter the bone surface. They include the type of soil (acidic or alkaline soil), the presence of groundwater, climatic conditions (humid or dry environment, changeable climate conditions), as well as the activities of insects and large and small animals (rodents, mammals) in the funerary space.[2-4] However, this local environment can be further infringed by humans if there is a process of violent disturbance of the burial context, caused by secondary perturbations of the archaeological site. This can be caused by secondary opening of the grave due to rituals (secondary burial), use of the place for subsequent burials, or by grave reopening due to robbing. Even modern archaeological excavations of necropolises can be considered a direct factor for bone damage and scattering.
Bone deposits in archaeological sites are distinguished as a primary or secondary burial, where primary burials correspond to the original placement of the body, which in archaeological context is read as an anatomical connection *in situ*. In contrast, secondary deposition refers to an additional movement in the primary grave context, caused by human intervention in the past[5], which is archaeologically recognized as commingled skeletal remains.

Despite the importance of bone taphonomy research in archaeology, it is often neglected in the field of osteoarchaeology. Thus, bone preservation, formation process and aspects of ancient burial (type of deposition, burial depth, body position, grave structure, funerary containers, organic elements, etc.) remain overlooked since archaeothanatological and taphonomic observations are usually uncommon during excavations.[5-6] On the other hand, zooarchaeological studies[7,-9] traditionally investigate bone taphonomic agents, while forensic anthropology experts [4,10,11] develop methodology and diagnostic criteria for recording and distinguishing all types of bone surface modification and bone taphonomy in order to comprehend the process of body decay in different environments. Those taphonomic processes depend on several factors in the burial environment, including animal activity, fluvial or human transport, different cultural modifications of body or skeleton, subaerial weathering, water, fire, microorganisms, and the process of recovery of the remains.[4,10,11]

The term taphonomy has been widely used in palaeontology, geology, bioarchaeology, and forensic anthropology. Osteoarchaeologists use the term taphonomy to describe postmortem modifications on bones (human, nonhuman), models of bone preservation and formation process at archaeological sites.[5] In bioarchaeology, data on bone taphonomy should be usually collected in the field - archaeological sites (deposition of skeletal remains, articulation, their relation to funerary space) and in the lab afterwards, analysing the bone structures (internal and external bone component). However, bone research analysis is often missing from funerary archaeology publications (and practice), while the focus of those studies is usually on stratigraphy, grave architecture, finds and the other elements of burial.[5-6] Nevertheless, a relatively new discipline arises - archaeothanatology - providing the focused research on skeletal remains and body decomposition process, aiming to study the biological and social component of the death.[6]

1.2 Sarmatian funerary complex

During Antiquity and the early Middle Ages (1st–8th century AD), the Carpathian Basin (present-day Hungary, Romania, and Serbia) was an area of many important migration and population changes. The Sarmatian population, known from the written sources as a people of south Iranian ancestry, inhabited this territory from the end of the 1st century AD until the beginning of the 5th century AD.[12-14] Sarmatians are described as a population whose culture contains autochthonous elements originating from Asia, as well as Celtic-Dacian and Roman elements that arose as a result of the influence of local populations on the life of the Sarmatians in these areas.[12] Literature on Sarmatians recognizes the two migration waves of different Sarmatian tribes into the Carpathian basin. The first migration occurred in the middle of the 1st century, with the arrival of the Sarmatian tribe of Jazygen and again at the end of the 2nd and the beginning of the 3rd century, with new Iranian/Sarmatian groups arriving from the Tisza River basin (Roxolani, Alans).[12]

Their presence was recognized by the archaeologists throughout both their settlements and cemeteries within the mentioned territory. To date, more than a thousand graves with funerary rites which changed over time with migration waves, were recognized as Sarmatian burials. The funerary archaeology of Sarmatians was evidenced in necropolises with a variety of burial structures including flat graves, barrow graves and graves marked by ditches. Graves are typically positioned in rows, occasionally clustered around a single central grave. During the first period (1st-3rd century AD) the graves were primarily oriented south-north with the head on the south; from the end of the 2nd until the 3rd century AD, they were oriented north-south. The disposal of the dead was exclusively by inhumation, in single burials, with bodies placed in supine position, within or without wooden coffin structures.[12,14]

Grave furnishing constituted very rich and diverse customs, where the deceased were buried with their personal belongings (jewellery, weapons, toiletry utensils, tools), clothing (thousands of semi-precious beads, brooches, buckles) and grave offerings in form of coins, food and drink (vessels, animal bones).[12] Sarmatians costumes changed over time. The graves of first Sarmatians are known as a "golden horizon", while their burials contained golden dress ornaments (pendants, beads, buckles) and jewellery.[12-14] Those golden objects were replaced with silver or bronze in the later Sarmatian period.[14]

In the early phase, female costumes consisted of carnelian beads worn around the neck or arms, together with gold jewellery. Later, roman brooches were worn with overgarments which had thousands of colourful beads embroidered around the neck, sleeves, and hemline, as well on the shift or trousers. The dress had a belt, richly decorated with beads, pendants, bells and with the knife fastened to the belt. By the end of the 4th century, female costume once more changed, being more furnished with golden jewellery and several bracelets and brooches. Males had modest costumes, which consisted of an upper garment attached with a Roman brooch, belt with a buckle and a leather pouch suspended to it, which contained tools. Knives were usually worn suspended on the belt. Later, coins were placed in leather bags, along with straps, while at the end of the 4th century male graves contained more weapons, buckles and strap ends.[13] The grave furnishings reflected their origins and trading connections, while grave goods (costumes, personal items, pottery) show Roman, north Pontic, and Germanic origin.

The territory of the Great Hungarian Plain was characterised by turbulent and unstable times, with dynamic migrations of several populations beside the Sarmatians (Germanic tribes, Avars, Slavs, etc.) and repeated warts (Daco-Roman wars, Marcomannic wars, Hunnic invasions, etc.). During such times, all the groups waged wars and organised raids which, according to researchers (Istvánovits E. and Kulcsár V.), led to the systematic reopening of enemies' graves or graves in surrounding cemeteries.[13]

1.3 Grave disturbance and skeletal preservation among Sarmatians sites

The Sarmatian funerary complex was thoroughly studied in terms of the basic archaeological information on funerary construction, body treatment, and burial practices. Contrarily, neither anthropological nor archaeological research has ever focused on the human skeletal material from such burials until quite recently. All previous research focused on rituals and beliefs, grave goods, the subject of trading and connections, and ethnicity.[15] Skeletal remains were either not examined at all or merely occasionally referenced in archaeological literature.[15]

The poor preservation of skeletons from Sarmatian necropolises is documented in sporadic archaeological reports. These reports highlight the fact that, within the same geographic area, only Sarmatian skeletons are poorly preserved, while the skeletal remains of other populations are in good condition.[16] However, this has never been further discussed or researched by anthropologists. The purported cause for such skeletal preservation was the systematic grave reopening and robbing in the past.[15] According to the generally accepted interpretation among researchers, those graves were opened on several occasions during turbulent times in the Great Hungarian Plain. While some academics consider that graves were plundered shortly after initial burial[13], others believe that many burials were disturbed initially by the Huns and afterwards by the Avars.[14]

According to data, up to 80% of Sarmatian cemeteries in Hungary were robbed.[17-19] However, there is no information available for Romania or Serbia. Aspects of grave disturbance are explained mainly in Hungarian and Romanian literature[13,14,17,20] with clear evidence of intrusive pits, extra bones in the upper layers of the grave, displacement, and fragmentation of skeletal material *in situ*, and removal of the grave goods. Such data information is typically unpublished for Serbia and can only be seen through old archaeological documentation (notes, sketches, and photographs). During the excavation, disturbance was noticed and simply noted. However, until recently, there has been no information on the skeletal material, no descriptions of the grave disturbance and bone displacement patterns, and no anthropological or taphonomic analysis of the bones.[15] As a result, the issue of grave reopening in Sarmatian sites as an anthropogenic factor in the past, its impact on the burial environment, and its potential for additional damage to the bones (bone preservation) have never been addressed.

1.4 Grave disturbance phenomena in European studies

The phenomenon of grave disturbance was widely researched in European archaeological studies.[21-32] However, even those studies lacked analyses of human remains.[23,27,31] The definition of disturbed grave implies archaeological evidence of extra intrusion pits, additional bones in the upper layers, damaged containers (broken lids), displaced or broken human bones, and commingled grave goods.[23] Grave interference in the past could have occurred soon after burial, meaning that perpetrators opened the grave when body was still decomposing, or it could have occurred years later, when the body was skeletonized. Research of postmortem practice has become popular only recently[23], even though the phenomenon of grave disturbance has already been acknowledged among archaeologists.

Intact graves provide abundant information for cemetery analysis, while disturbed contexts limit interpretations about funerary customs. However, such graves could provide important information on body manipulation and the sociocultural reasons for grave reopening (robbery, rituals, and beliefs), which are important for understanding postmortem occasions. Newer studies have shown that this type of information is equally valuable for reconstructing past practices and demand modern approaches.[23]

In those studies, dealing with the phenomenon of opening graves, new terminology was introduced, neglecting the term “grave robbery” as an interpretative term, and introducing the term “grave reopening” as a more neutral one, thereby avoiding the implying interpretation for graves reopening in the past. However, even those studies have focused more on the archaeological context itself, on the grave taphonomy (inverted layers, outlines of the intrusion pits), position of the items, and presence of the containers [23,27,30,32], while the condition of skeletal remains and the body position remain under-investigated. Recent archaeothanatological studies have provided new insights into understanding skeletal taphonomy in reopened graves.[23,28,33-35]

Results of those studies are important for understanding the initial position of the body and primary grave environment, the process of body decomposition during the reopening, and the way of corpses or skeletal remains manipulation (articulation of the remains). These studies reconstruct the primary position of the body, the state of bone damage and bone loss. In the end, such analyses could provide information if the body or skeletal displacement is a consequence of natural (geological processes, animal activity, collapse of the containers) or anthropogenic (secondary deposition, grave robbery) factors. Such questions have the potential to improve interpretation of funeral practice in the past and are thus valuable for both archaeologists and anthropologists.

2. RESEARCH GOALS

To investigate how the grave reopening phenomenon among Sarmatian cemeteries affected bone preservation, the objectives of this thesis were as follows:

- To numerically determine preservation of Sarmatian skeletal material in the sample according to two separate characteristics, namely skeletal completeness and bone fragmentation;
- To examine the impact of the grave reopening phenomenon on skeletal preservation, comparing the data from reopened and intact graves in the sample from the archaeological records;
- To analyse skeletal displacement patterns following the archaeothanatological principles based on the archaeological records from the excavation and to note whether there is skeletal evidence of bone scattering (marks made by tools) during the act of grave reopening in the past;
- To examine the skeletal material to determine whether there are some visible taphonomic changes on bone surfaces resulting from environmental factors (bioturbation, subaerial weathering changes, soil composition), which could be responsible for the poor skeletal preservation and completeness of Sarmatian skeletal material;
- To examine taphonomic alterations in the skeletal material, evidenced as coffin wear, in order to determine whether the manner of burial itself or any other cause contributes to the poor preservation of the skeletal material.

3. MATERIAL AND METHODS

3.1. Study material

A total of 245 graves from 19 archaeological sites covering the 1st to the 5th centuries AD (Table 1) were analysed. The sites (Map 1) are located in the Bačka and Banat region of the Great Hungarian Plain, in the present-day northern Serbian province of Vojvodina.

Map 1. Distribution of archaeological sites included in the study

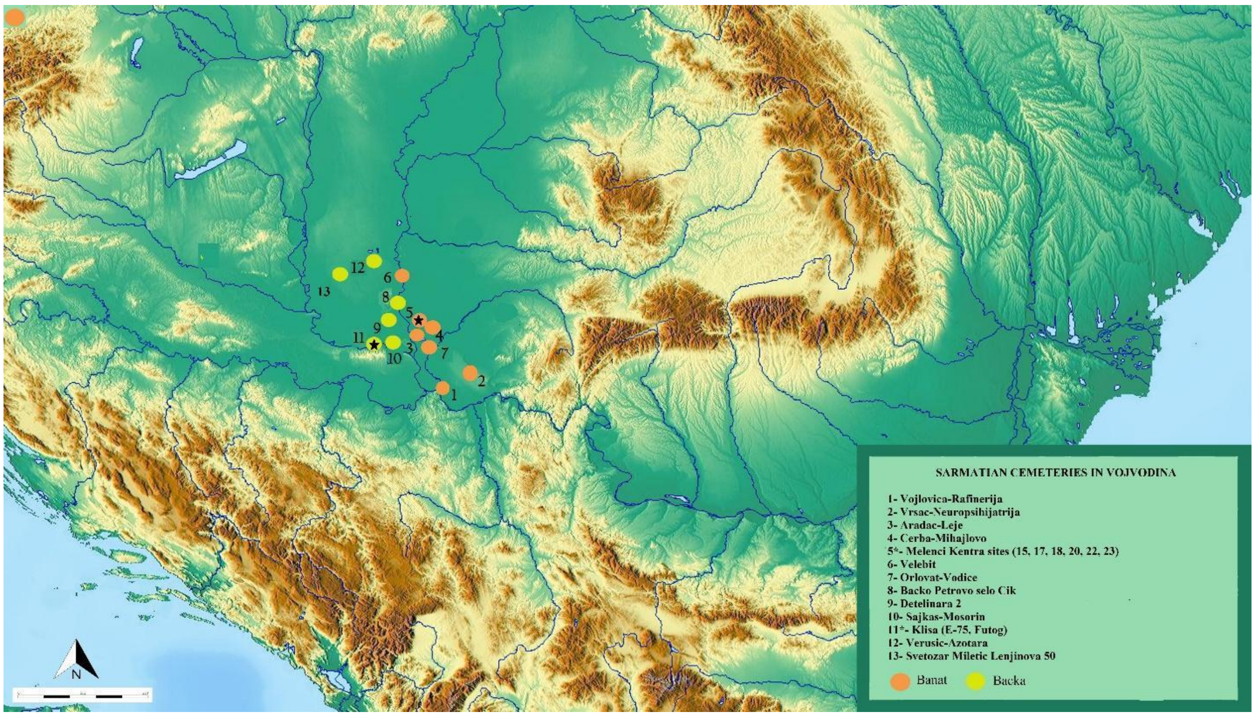


Table 1. Sarmatian sites included in the study

SARMATIAN SITES	DATING Relative chronology *	NUMBER OF GRAVES DISCOVERED	NUMBER OF GRAVES INCLUDED	INSTITUTIONS IN CHARGE OF THE MATERIAL
Svetozar Miletić, Lenjinova 50	2^{nd}-4^{th} century AD	11	5	Sombor city Museum
Azotara-Verušić	4^{th}-5^{th} century AD	63	49	Subotica city Museum
Bačko Petrovo Selo – Čik	2^{nd}-3^{rd} century AD	15	8	Bečej city Museum
Čurug – Detelinara 2	2^{nd} century AD	15	12	Museum of Vojvodina
Aradac - Leje	2^{nd}-4^{th} century AD	9	5	National museum of Zrenjanin
Velebit	1^{st}-3^{rd} century AD	6	5	Senta city Museum
Melenci-Kentra-Lokalitet 15	3^{rd}-4^{th} century AD	1	1	Provincial institute for the Protection of Cultural Monuments
Melenci-Kentra-Lokalitet 17	3^{rd}-4^{th} century AD	3	2	Provincial institute for the Protection of Cultural Monuments
Melenci-Kentra-Lokalitet 18	3^{rd}-4^{th} century AD	3	3	Provincial institute for the Protection of Cultural Monuments
Melenci-Kentra-Lokalitet 20	3^{rd}-4^{th} century AD	1	1	Provincial institute for the Protection of Cultural Monuments
Melenci-Kentra-Lokalitet 22	3^{rd}-4^{th} century AD	1	1	Provincial institute for the Protection of Cultural Monuments

Melenci-Kentra-Lokalitet 23	3rd-4th century AD	1	1	Provincial institute for the Protection of Cultural Monuments
Gospođinci-Futog, Lokalitet Klisa	4th-5th century AD	6	6	Provincial institute for the Protection of cultural monuments
Klisa E-75	4th century AD	5	5	Provincial institute for the Protection of Cultural Monuments
Vinogradi Gasovod Šajkaš-Mošorin, Lokalitet 10	4th century AD	12	12	Provincial institute for the Protection of Cultural Monuments
Orlovat-Vodica	4th century AD	4	4	Provincial institute for the Protection of Cultural Monuments
Gospođinci-Cerba-Mihajlovo	4th century AD	6	6	Provincial institute for the Protection of Cultural monuments
Vojlovica-Rafinerija	3rd-4th century AD	56	47	National Museum of Pančevo
Vršac-Park Neuropsihijatrije	4th century AD	27	23	Vršac city Museum

*Relative chronology - established method for dating archaeological context that compares archaeological artefacts to one another without establishing an exact, absolute age

None of the cemeteries were fully excavated, only four were excavated systematically: Vojlovica-Pančevo, Vršac-Neuropsihijatrija, Bačko Petrovo selo – Čik, Verušić-Azotara, while others were part of the rescue excavations, excavated only partially or with only a few isolated graves discovered. Most of the sites were investigated in previous decades, which is why for some of them there is no available archaeological documentation, and, in some cases, even osteological material is missing. Archaeological reports of only four sites were published (Vojlovica-Pančevo, Bačko Petrovo selo – Čik, Verušić-Azotara, Svetozar Miletić-Lenjinova 50)[36-40] while for others archaeological documentation – photos, sketches, reports, situation plans) was used.

Cemeteries like Velebit, Aradac-Leje, Bačko Petrovo selo – Čik, Azotara Verušić, Gospođinci Klisa Futog are multilayered sites.

Graves represent single inhumation within cemeteries, with skeletons in a supine position, oriented N-S or S-N, depending on the chronological period.

After excavations, the skeletal material was stored in museum depots, without previously conducted anthropological analysis, which in some cases resulted in the mixing or loss of skeletal material. This was the initial motive for performing the anthropological project "Museological protection and bioanthropological analysis of human osteological material from the Late Antique sites from Banat and Bačka region" led by the Center of Bone Biology, in the period of 2018-2019 funded by the Ministry of Culture and Information of the Republic of Serbia. The aim of the project was to collect and analyse all the available skeletal remains from the Sarmatians sites —1st to 5th century AD— that have never been analysed before. The first step was to list all the available material, to systematise archaeological documentation and to clean, label and systematically process all the skeletal material. After the project, the skeletal material was protected, labelled, packed and stored back in the museum depots.

The amount of skeletal material currently housed in the museums is far less than what is expected to be reported in the archaeological literature, despite the fact that the literature lists hundreds of skeletal remains and various sites that were explored in Vojvodina in the 20th century.[29, 36–45] Official documentation or direct testimony from museum curators indicate that human skeletal remains have occasionally not been taken from the site (personal information Stanko Trifunović, MA Aleksandar Šalomon). For example, site Dvorište Eparhije Banatske in Vršac (with 16 graves) was excavated and published but completely missing from the Vršac city museum[43], while for two graves at Vršac-Neuropsihijatrija[40], the graves were excavated during 60's, but skeletal material was not recovered.

In general, the archaeology of the Sarmatians in Vojvodina is insufficiently researched and therefore not published, as indicated by researchers from the region.[12-14] Data about Sarmatian cemeteries appear in several publications[36-47], while reports on only four sites were published: Verušić-Azotara Rafinerija.[39] The last overview of the state of research on Sarmatian cemeteries in Vojvodina was done in the 1980s[41], when it was pointed out that numerous cemeteries and isolated graves have been located in Vojvodina, but none of them have been systematically investigated.[41]

3.2 Grave disturbance patterns

Data on postmortem grave disturbances in the sample were evaluated based on information gained from published archaeological literature[36-40] or field documentation (photographs, sketches, descriptions, and notes) (unpublished documentation from Museum of Vojvodina, The Provincial Institute for the Protection of Cultural Monuments, Senta city Museum, National Museum of Zrenjanin). Archaeologists label grave disturbance in Sarmatian graves according to the presence of intrusion pits (different colour of sediment in grave layers), disturbed and fragmented bones in situ, discarded bones in upper layers, and displaced or missing grave furnishing.

Archaeothanatological methodology and dispositional taphonomy[6,33,35,48] was applied on the mentioned field documentation (photos, sketches, reports) and published papers to distinguish patterns of grave disturbance and to reconstruct the body decay process. The first step was to distinguish the categories of intact and reopened graves in the sample. Graves destroyed during contemporary building operations were eliminated from further studies, along with burials without comprehensive or unclear archaeological evidence on grave disturbance (Figure 1). This type of document (photos, sketches) was crucial for creating the grave disturbance database and the categorization of graves.

Figure 1. (a) Intact grave, grave no. 3, Šajkaš-Mošorin (young adult, indeterminate sex); (b) Reopened grave, grave no. 9, Šajkaš-Mošorin (female adult)

In archaeological documentation and reports intact categories were considered graves with complete skeletons *in situ* and intact grave inventory. These presented the starting point for analysing the patterns of grave disturbances, as an example of primary deposits or undisturbed context. Reopened graves are a category of graves for which archaeological documentation suggests reopening based on comingled or damaged bones, bone absence, damaged or missing grave inventory, occurrence of skeletal parts in upper grave layers and evidence of intrusion pits.

Grave disturbance patterns in reopened graves were observed based on the analysis of the spatial distribution of skeletal elements *in situ*, the persistence or lack of their anatomical connections, and relation to the primary body volume (Figure 2). Furthermore, effects of burial architecture (coffins, wooden covers, empty space) on body decay were also considered to distinguish natural bone movements (containers, activity, groundwater) in the burial environment from violent postmortem activities in funerary space.

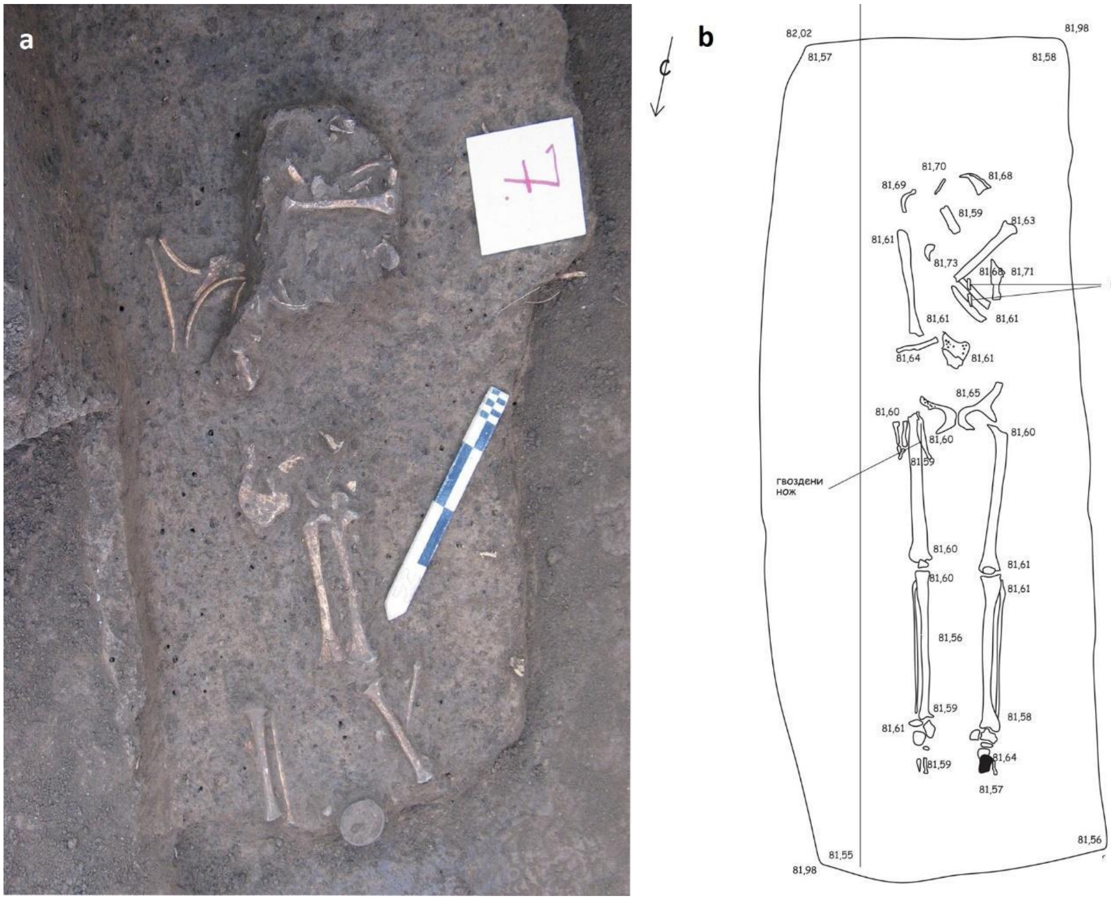


Figure 2. Patterns of reopened graves with skeletal displacement evidence: (a) Reopened grave, grave no. 7, Vršac-Park Neuropsihijatrija (Infans I); (b) Sketch illustration of reopened grave, grave no. 7, Čurug-Detelinara 2 (Female, senile)

The term *reopened* was used to generally describe graves with disturbed grave contexts; *grave disturbance* referred to physical evidence of displaced grave contexts (upturned layers, bones, and grave furnishing) previously established by archaeologists during excavations; *grave robbery* was used in the final interpretation stage for those cases where robbery was the most likely explanation for the pattern of disturbance.

3.3. Bioanthropological analyses

The skeletal material was anthropologically analysed at the Center of Bone Biology, Faculty of Medicine, University of Belgrade. The material was previously deposited in the local institutions of cultural heritage: Subotica city Museum, Senta city Museum, Bečej city Museum, National Museum of Zrenjanin, Vršac city Museum, National Museum of Pančevo, Museum of Vojvodina, Provincial institute for the Protection of Cultural Monuments.

The standard anthropological analysis included sex and age assessment, palaeopathological and dental analysis, as well as assessment of skeletal preservation degree, all according to the anthropological standards.[49]

Sex assessment was performed according to the morphological dimorphic features of the *os coxae* of the skeleton. Cranial morphology was used as an additional criterion for sex estimation.[49-50]

The skeletal age in the sample was determined based on the morphological appearance of the pubic symphysis, following the criteria of Suchey and Brooks[51], the appearance of the sternal end of the ribs, cranial sutures closure, and dental wear.[51-55] In subadults, skeletal age was determined based on the epiphyseal union, diaphysical length measurement, dental development, and tooth eruption, following anthropological standards.[56-58]

After the analysis, the individuals were grouped in age categories as follows: Infans I (0-7 years), Infans II (8-14 years), Juveniles (15-22 years), Adultus (23-39 years), Maturus (40-59 years), Senilis I (60-70 years), Senilis II (above 71 years).

Palaeopathological observations were made for all individuals in the sample, using the standard anthropological procedures, using the macroscopic examination and digital radiography.

3.4 Taphonomic analysis

Macroscopic taphonomic analysis of bone specimens in the sample was performed following the methodology and criteria of anthropological, zooarchaeological and forensic taphonomy literature.[2,4,5,7,8,10,11,59] Analyses covered all the human or nonhuman processes responsible for bone alteration.

Bone weathering, a physical and chemical process affecting bone, was included in the study analysis. The weathering effect was implied by bone cracking (splits penetrate inward) and delamination (splits occur circumferentially with peeled bone layers). Bone cracking due to weathering normally runs parallel to the orientation of the osteons, following the split-line orientation of a bone.[59-61] Changes such as cracking, flaking, splitting, and exfoliation were observed in the sample. Furthermore, rounding and wear of the bone surface were also included, as a subsequent taphonomic process occurring after the initial bone breakdown as soon as the bone encounters abrasive fluvial environment.[59,60,62]

Taphonomic analyses also included observations of any macroscopic alterations on bone surface in terms of colour changes (bleaching, staining), physical damage of bone cylinder (shallows, cracks, striations, erosion, abrasion, fracture lines), bone loss, or cut marks. Morphology of these changes was observed, along with the position on the bone and their frequency. Additionally, the stage of bone weathering was observed according to established six phases[8,49,60,61] aimed to reconstruct the postmortem interval of bone exposure to environmental conditions (Figure 3):

- 0- unweathered bone with bone surface being intact
- 1- mildly weathered bone with thin, mosaic cracks
- 2- bone surface starting to flake and spalling, internal cortical bone is still undamaged
- 3- slow bone breakdown, weathered bone with rough fibrous surface
- 4- advanced bone breakdown, highly weathered bone surface with fibrous and rough small splinters, and deep cracks penetrated to the marrow cavity
- 5- bones with large splinters falling apart into fragments

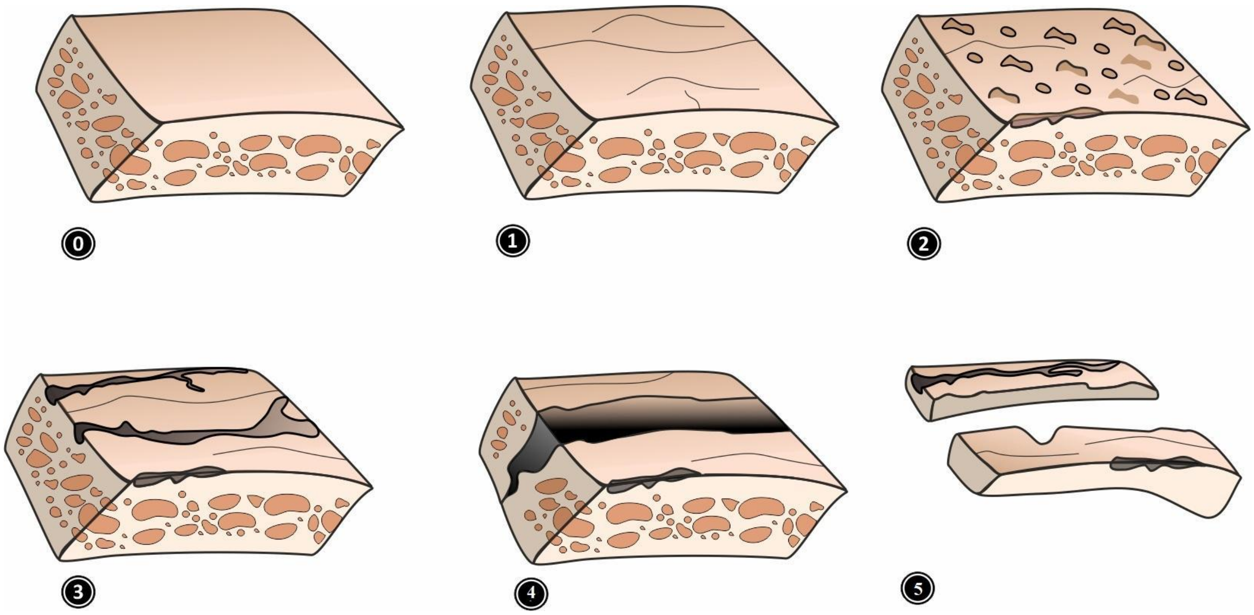


Figure 3. An illustration of the bone weathering stages (made by J. Jadzic)

To examine the effects of graves reopening on bone preservation, as a cultural alteration, a database was created to cross-check the data on grave disturbance patterns, taphonomic changes and anthropological data. The database contains information about each grave individually: sex and age; intact or reopened grave; model of grave reopening (reopened in the upper part, completely reopened with disturbed bones, emptied graves without skeletal remains); subaerial weathering changes (exfoliation, abrasion, grooves, cortical bone loss, etc.); effects of coffin burials (coffin wear changes); plant activity; animal gnawing marks (rodent, carnivore); bird and insect damage; fungi/algae/lichens invasion; cultural alteration (tool cut marks); colour variation (staining, burning, patina, bleaching). These bone modifications were noted as present or absent for each individual in the sample, with recording on which bones the changes occur.

3.5 Grave depth

Due to its significant effect on skeletal preservation, the burial depth was also taken into consideration to establish any potential relationships between the depth and low skeletal preservation.[59,60] The data on the depth of the graves were taken from the archaeological documentation that contained this type of data, whenever it was available in the original rchaeological documentation of the sites of Vojlovica-Rafinerija, Vršac-Park Neuropsihijatrije, Orlovat-Vodica, Melenci-Kentra,Cerba-Mihajlovo, Azotara-Verušić.

3.6 Soil properties in Vojvodina Province

The published geological literature[63-64] was used to obtain information on the soil composition of the Vojvodina Province, where the sites are placed. The organic soil content in this area is comparatively uniform. Smaller sections of Vojvodina are covered by marsh black soil (16%) and alluvial soil (9%), while most of the region is covered by chernozem with a pH value that is a bit alkaline.[63-64]

3.7 Skeletal completeness and skeletal preservation

The numerical assessment of the state of skeletal preservation for the whole sample was conducted for two groups of graves, namely reopened and intact. Intact graves were used as a control group, given the fact that those graves represent the primary deposit in which skeletal preservation could not be related to grave reopening, but rather to other factors.

Numerical assessment was provided through the established *Bone representation index* (BRI), which calculates the frequency of each bone in the sample relative to the expected number of that particular bone, considering the minimum number of individuals[3], yet with adaptation to use only two categories: absent or present bone. BRI per individual was calculated as the mean value of all BRIs for that individual.

For each bone recorded as present, the *Index of bone fragmentation* (IBF) was developed to assess the state of fragmentation (fragmented or non-fragmented bone) regardless of the completeness of the bone parts, the index was calculated by dividing the total number of fragmented bones with the total number of present bones. IBF per individual was calculated as the mean value of all IBFs in that individual.

The bones for which both indexes (BRI and IBF indexes) were determined were the following bones or groups of bones: cranium, mandible, clavicle, sternum/manubrium, scapulae, humerus, ulna, radius, skeleton of the hand, ribs, vertebrae (cervical, thoracic, lumbar), pelvis with sacrum, femur, tibia, fibula, skeleton of the foot.

3.8 AMS radiocarbon dating

Absolute radiocarbon dating (AMS) of the Sarmatian sites was performed to confirm archaeological relative chronology for Sarmatian sites and to get more precise data on the site chronology. Twenty skeletons from nine archaeological sites (Vojlovica-Rafinerija, Vršac-Neuropsihijatrija, Verušić-Azotara, Aradac-Leje, Velebit, Čurug-Detelinara 2, Čik Bačko Petrovo selo, Svetozar Miletić Lenjinova 50, Mošorin Šajkaš- Lokalitet 10) were selected for AMS radiocarbon dating. We sampled 20 permanent human adult teeth following standard laboratory protocols and sent them to the Oxford Radiocarbon Accelerator Unit for further analyses. The samples were chemically prepared and measured following the standard procedure for sample preparation and measurements.[66-67] The dates are uncalibrated in radiocarbon years BP (Before Present - AD 1950) using the half-life of 5568 years. Isotopic fractionation was corrected for using the measured $\delta 13C$ values measured on the AMS. The quoted $\delta 13C$ values were measured independently on a stable isotope mass spectrometer (to ±0:3 per mil relative to VPDB). Samples calibration plots showing the calendar age ranges were generated using the Oxcal computer program (v4.3) of C. Bronk Ramsey[66-67], using the 'IntCal13' dataset.

3.9 Statistical analysis

Categorical variables were presented as counts (percentages), while continuous variables were presented as a mean value ± standard deviation. The Kolmogorov–Smirnov test was used to determine the normality of data distribution.
The differences in *Bone representation index* (BRI) per individual between intact and reopened graves were determined using Student's *t* test. Student's *t* test was also used to compare the *Index of bone fragmentation* (IBF) per individual between intact and reopened graves.
The relationship between the grave depth and the BRI per individual in the intact graves was assessed using Pearson correlation, while for the reopened graves Spearman correlation was used, in line with the data distribution.
In order to analyse possible association between grave depth and BRI index, based on the normal distribution of the data. Pearson's correlation was used to evaluate the association between the depth of the burial and the BRI for each individual in intact graves, whereas Spearman's correlation was used to assess the association between the grave depth and the BRI for each individual for reopened graves.
The statistical analysis was conducted in SPSS software 21. $P<0.05$ was considered statistically significant.

4. RESULTS

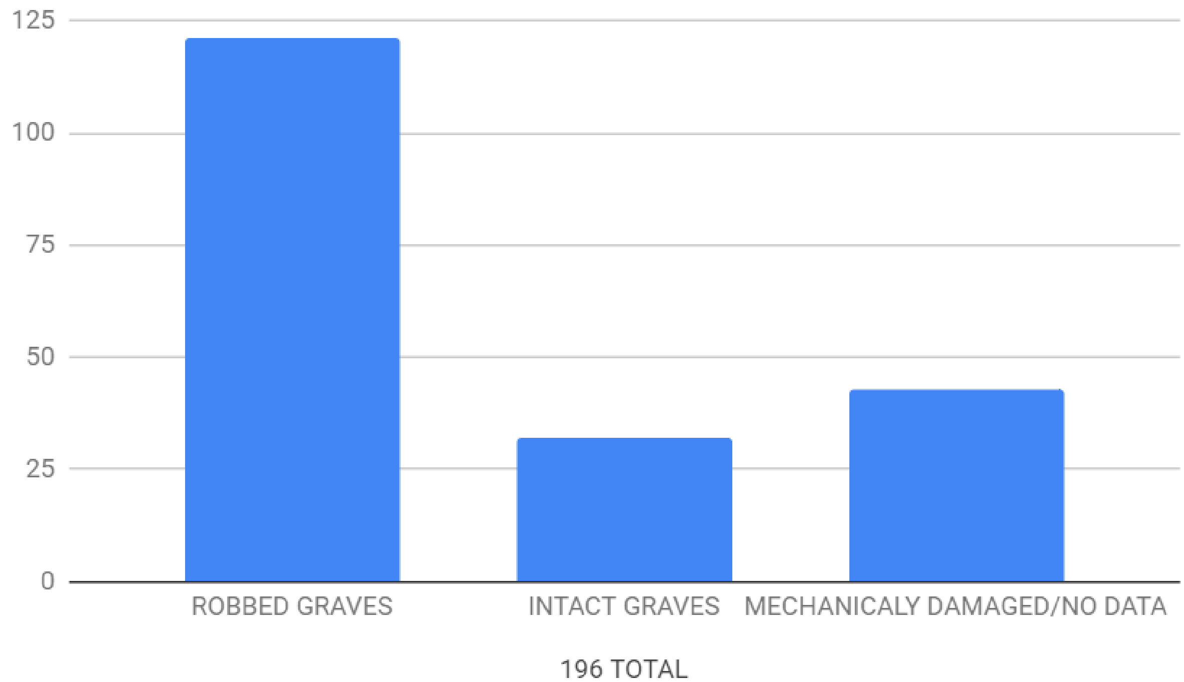
4.1 The grave reopening and patterns of grave disturbance in the study sample

A total of 245 discovered graves were processed using archaeological data from Sarmatian sites in Vojvodina (Banat and Bačka). Of these, 196 graves had preserved skeletal remains;the skeletal remains were missing from the museum depots for 49 graves. In some cases, there was information about grave disturbance for these graves, including sketches or photographs, but without skeletal remains it was not possible to do further bioanthropological and archaeothanatological analyses.

Anthropological analyses were performed of a total of 196 graves of which 32 were intact, 121 were reopened, and 43 were mechanically damaged or without detailed data (Chart 1) (Table 2). In further analysis, the last group of graves (43 graves) was excluded because some graves were mechanically destroyed due to modern devastation (Figure 4), while others did not have adequate data on grave disturbance (photographs, sketches, notes) and it was also not possible to preclude an archaeothantalogical analysis. In the case of mechanically devastated graves, there was archaeological data on grave disturbance; however, archaeothanatological analysis was not possible in those cases because it was not possible to distinguish what caused the bone movement in context, whether mechanical damage or reopening in the past. The final analysis included 153 graves, i.e., 153 individuals.

Figure 4. (a) Grave no. 11 from Mošorin-Šajkaš, mechanically destroyed due to installation of a fibre optic cable (trench cutting through it) (Female, adult); (b) Contemporary trench that passed through the burial grave no. 6 from Klisa E-75 (Male, young adult)

Chart 1. The prevalence of postmortem activities among Sarmatian sites (n=196)



In the cases of larger sites that have mostly been investigated an extremely large degree of grave reopening was present. For example, in the Verušić site, almost 52% of graves (33/63) were opened postmortem, in Vršac 67% (18/27), and in Vojlovica even 69% (38/56) (Table 2).

Table 2. Data on postmortem activities per site

SITE	NUMBER OF GRAVES	POSTMORTEM ACTIVITIES		
		reopened	intact	no data/damaged
Svetozar Miletić, Lenjinova 50	**11**	/	3	8
Azotara-Verušić	**63**	33	11	19
Bačko Petrovo Selo – Čik	**15**	2	1	12
Čurug – Detelinara 2	**12**	9	1	2
Aradac - Leje	**9**	/	/	9
Velebit	**6**	1	/	5
Banatski Dvor Gospođinci Melenci-Kentra- Lokalitet 15	**1**	/	1	/
Banatski Dvor Gospođinci Melenci-Kentra- Lokalitet 17	**3**	/	1	2
Banatski Dvor Gospođinci Melenci-Kentra- Lokalitet 18	**3**	1	1	1
Banatski Dvor Gospođinci Melenci-Kentra- Lokalitet 20	**1**	1	/	/
Banatski Dvor Gospođinci Melenci-Kentra- Lokalitet 22	**1**	1	/	/
Banatski Dvor Gospođinci Melenci-Kentra- Lokalitet 23	**1**	/	/	1
Gospođinci-Futog, Lokalitet Klisa	**6**	4	2	/
Autoput E-75 Klisa	**5**	2	1	2
Šajkaš-Mošorin, Lokalitet 10	**12**	5	4	3
Orlovat-Vodica	**4**	3	/	1
Banatski Dvor Gospođinci-Mihajlovo Cerba-Lokalitet 14	**6**	3	/	3
Vojlovica-Rafinerija	**56**	38	2	16
Vršac-Neuropsihijatrija	**27**	18	4	5
TOTAL		**121**	**32**	**89**

4.1.1 Intact graves

Only 32 intact graves were found at 12 locations, according to archaeological documentation (Čik, Svetozar Miletić, Mošorin Šajkaš, Klisa E75, Klisa Futog, Vojlovica, Vršac; Melenci Kentra sites no. 15, 17, and 18) (Figure 5).

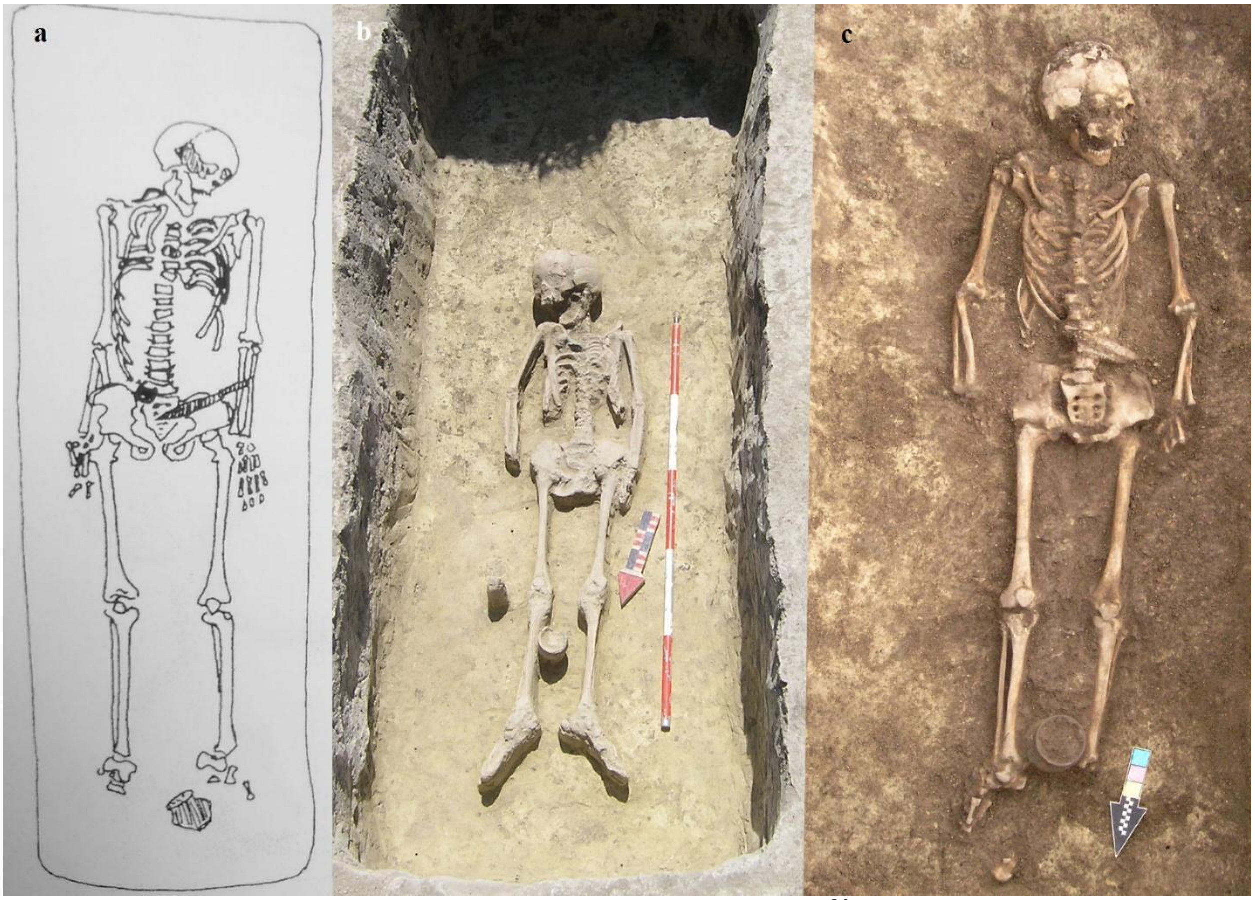


Figure 5. Intact graves *in situ*: (a) grave no. 72, Azotara-Verušić[39] (Male, adult); (b) grave no. 10, Šajkaš Mošorin (Infans II); (c) grave no. 5, Klisa E-75 (Male, young adult)

The anthropological analysis revealed low skeletal completeness (the mean value of 0.61; 61% of skeletal completeness), despite the burials being intact. Six out of 32 individuals (Vršac g. 10, 12, Verušić g. 120, Svetozar Miletić g. 2, Futog Klisa g. 2, and Melenci-Kentra Lok. 15, g.1) were subadults, while the other 26 individuals were adults. Skeletal preservation *in situ* was complete for nine adult skeletons (Čik g. 86; Verušić g. 32, 72, 46, 84, 96, 100, 112; Vršac-Park Neuropsihijatrije g. 24); however, exhumation left them fragmentary (Figure 6).

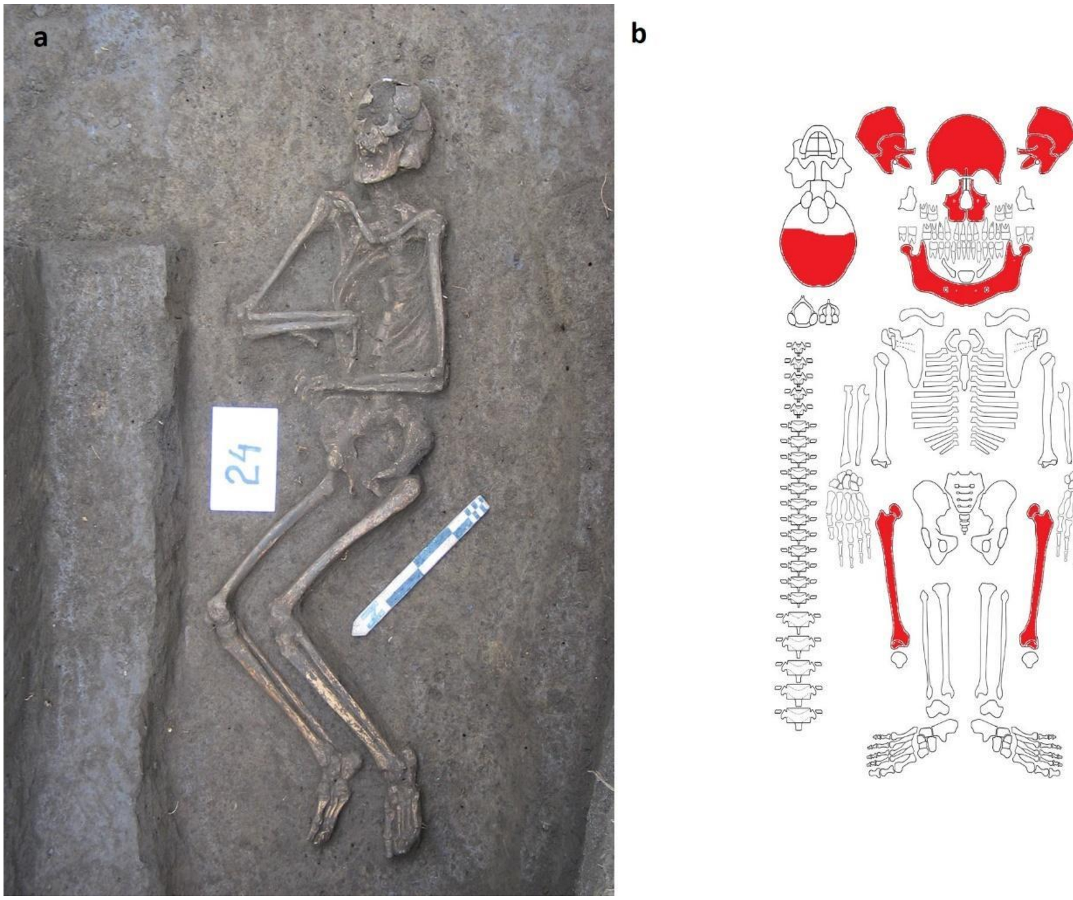


Figure 6. (a) Intact grave with adult skeleton being complete *in situ* (grave no. 24, Vršac-Park Neurospihijatrije)*;* (b) Schematic representation of the preserved parts of the same skeleton (Vršac, g. 24) after excavation and during anthropological analysis (Visual Form for Recording the Presence of Human Skeletal Elements following Roksandić 2003)

4.1.2 Reopened graves

Archeothanatological analysis of reopened graves showed three different patterns of grave opening: (1) upper body - opening of the grave in the upper part of the body where the lower part remains intact (36%); (2) entirely disturbed - opening the entire surface of the grave and commingling of the bones (60%); (3) emptied graves - opening of the entire grave and complete emptying the grave content (4%) (Figure 7). In the studied sample, there were no cases of opening only the lower part of the body (Table 3).

Figure 7. (a) Reopening of the upper part of the body, grave no. 1, Melenci-Kentra Lokalitet 18 (Adolescent); (b) Completely disturbed grave, grave no. 15, Vršac-Park Neuropsihijatrije (Female, young adult); (c) Emptied grave, grave no. 16, Vršac-Park Neuropsihijatrije

Two exceptional examples of grave reopening where all the bones are present were recorded at the Verušić site, in graves 45 and 97 (Figure 8). The archaeological record for both graves records looting, and the unusual positions of the bodies are explained by the rotation of the body during attempted looting.[39] According archaeologists the skeleton in grave no. 97 was in a sitting position.[39] From a bioanthropological perspective, the body position in grave no. 97 suggests only an unusual position (dorsal rotation with flexed legs on the torso) rather than a sitting position. However, there are no additional descriptions of the body position for skeleton no. 97, nor are there any photos of this case.

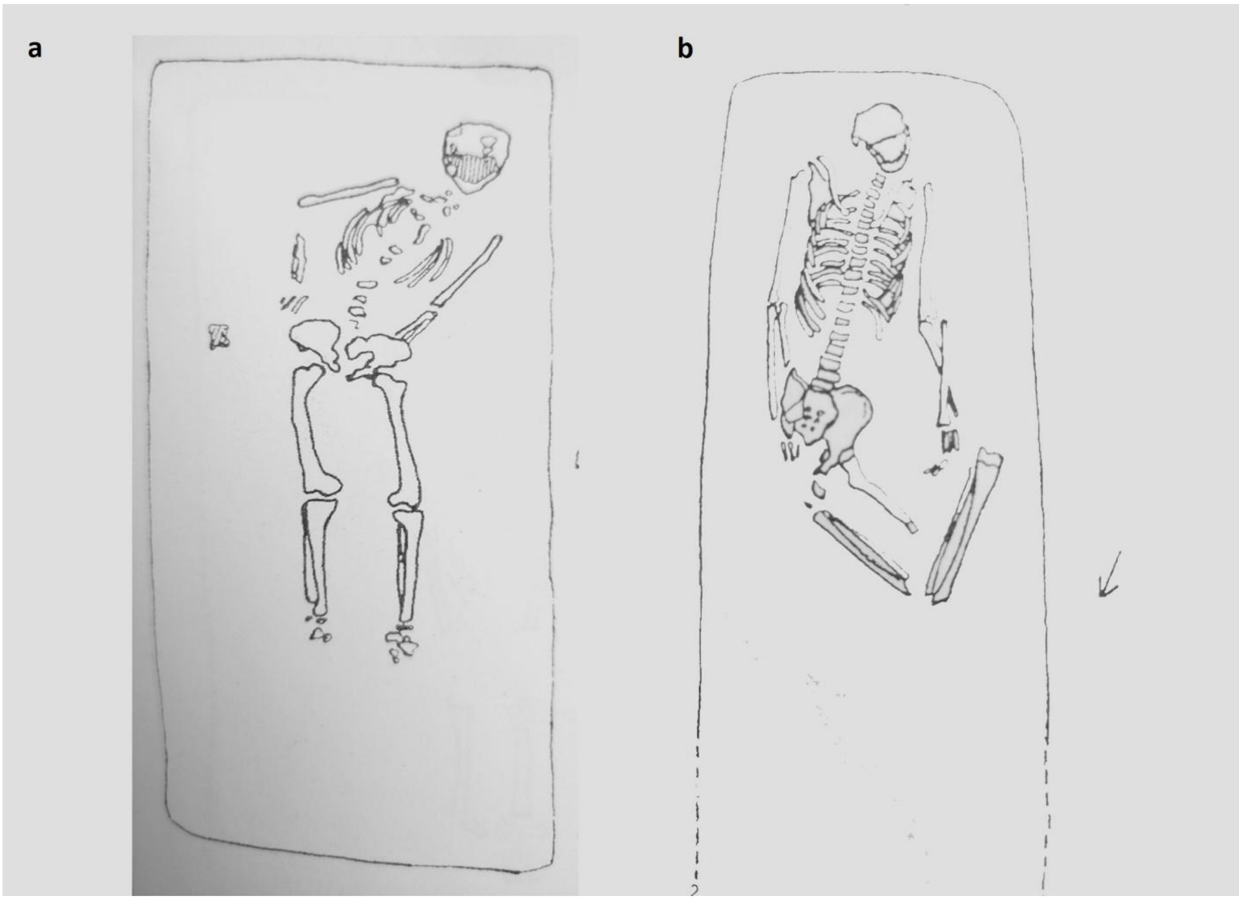


Figure 8. Adult skeletons in unusual position, Verušić-Azotara site[39]: (a) grave no. 45 (Male, adult); (b) grave no. 97 (Male adult)

Table 3. Patterns of grave disturbance per site

SITE	NUMBER OF REOPENED GRAVES	UPPER BODY DISTURBANCE	LOWER BODY DISTURBANCE	ENTIRELY DISTURBED	EMPTIED GRAVES
Azotara-Verušić	**33**	6	0	27	0
Bačko Petrovo Selo – Čik	**2**	2	0	0	0
Čurug – Detelinara 2	**9**	2	0	7	0
Velebit	**1**	0	0	1	0
Melenci-Kentra-Lokalitet 18	**1**	1	0	0	0
Melenci-Kentra-Lokalitet 20	**1**	0	0	1	0
Melenci-Kentra-Lokalitet 22	**1**	0	0	1	0
Gospođinci-Futog, Lokalitet Klisa	**4**	2	0	2	0
Klisa E-75	**2**	1	0	1	0
Šajkaš-Mošorin, Lokalitet 10	**5**	2	0	3	0
Orlovat-Vodica	**3**	3	0	0	0
Gospođinci-Cerba-Mihajlovo	**3**	1	0	2	0
Vojlovica-Rafinerija	**38**	19	0	16	3
Vršac-Park Neuropsihijatrije	**18**	5	0	11	2
TOTAL 121 (79%)		44 (36%)	0 (0%)	72 (60%)	5 (4%)

Disturbances in the upper body parts were recorded at every site in the sample with an exception for sites Melenci Kentra Lokalitet 20 and Lokalitet 22. Two groups were found: a group with slight bone disturbance (a small dislocation of the upper skeleton with a lot of bones still present) and a group with a heavy bone disturbance (commingled bones, mostly broken or missing body parts) The slightest disturbance was detected only in three cases (Cerba g. 2, Vršac g. 3, Vršac g. 18) (Figure 9).

Figure 9. Reopening of the upper body part: (a) slight bone disturbance of the upper body part, grave no. 3, Orlovat-Vodica (Adult, indeterminate sex); (b) intense bone disturbance, grave no. 1, Vojlovica-Rafinerija (Adult, indeterminate sex); (c) intense bone disturbance, grave no. 8, Klisa E-75 (Infans II)

The most common type of grave reopening was entire grave disturbance, recognized at every site, except for Svetozar Miletić and Melenci Kentra lok 15. Two subgroups of completely disturbed graves could be distinguished: disturbances with more bones present in situ (58/72) and disturbances with few bones visible over the grave pit's bottom (14/72) (Figure 10).

Figure 10. Complete disturbance of the grave content: (a) greater number of bones present *in situ* after reopening, grave no. 3, Mihajlovo-Cerba (Male, adult); (b) intense grave reopening with only a few bones present *in situ*, grave no. 17, Vršac-Neuropsihijatrija (Male, young adult); (c) complete emptying of the grave content with sporadic bone *in situ*, grave no. 6, Šajkaš-Mošorin (Adult, indeterminate sex)

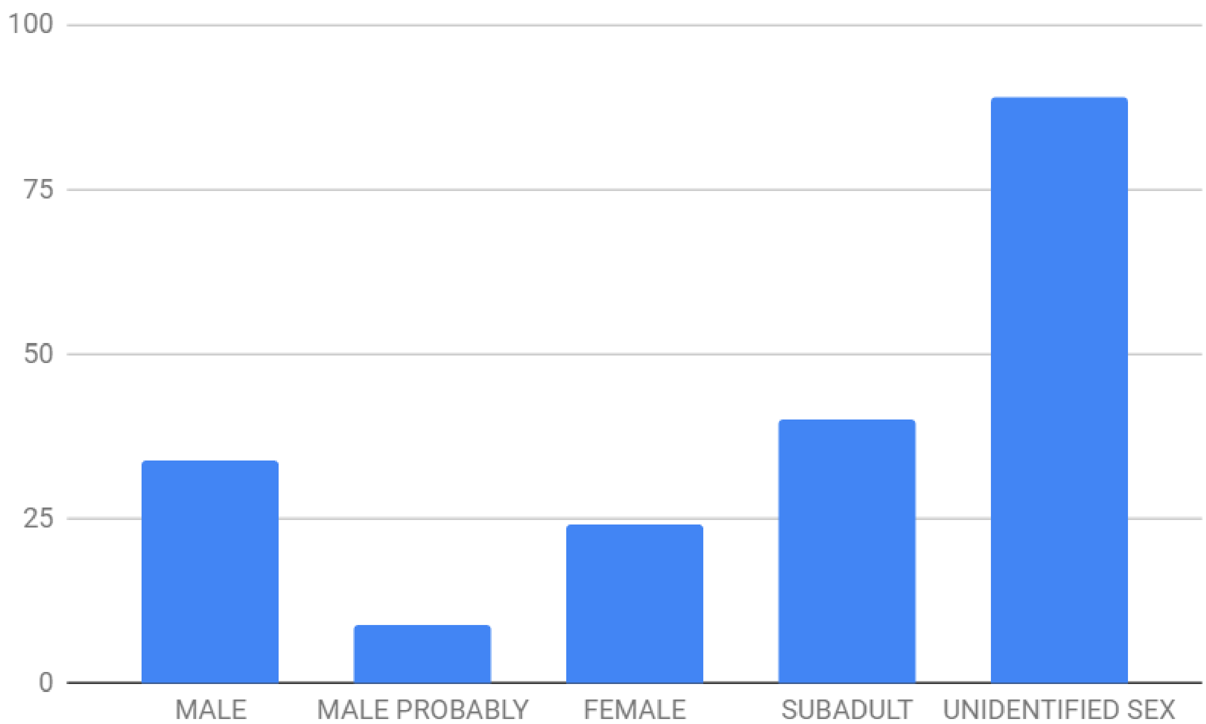
In the sample, five empty graves were identified (Vojlovica g. 22, 28, 29, and Vršac g. 3, 16). Only one grave (Vršac g. 3) contained grave items (offerings, mobiliary) and small amount of fragmented human remains at the bottom of the pit (Figure 11). Because of the missing skeleton, anthropological analysis could not be performed. However, adult graves are indicated in two cases (Vojlovica g. 22, Vršac g. 16) and non-adult graves in one case (Vršac 3) by comparing their lengths to other graves from the same sites. There is information available on the length of the grave pit for the remaining two graves.

Figure 11. Emptied graves: (a) complete emptied grave content, grave no. 3, Vršac-Neuropsihijatrija; (b) completely emptied grave content, grave no. 16, Vršac-Neuropsihijatrija; (c) emptied grave with only right femur being present *in situ,* grave no. 23, Vršac-Neuropsihijatrija (Adult, indeterminate sex)

4.2 Bioanthropological results: sex and age distribution

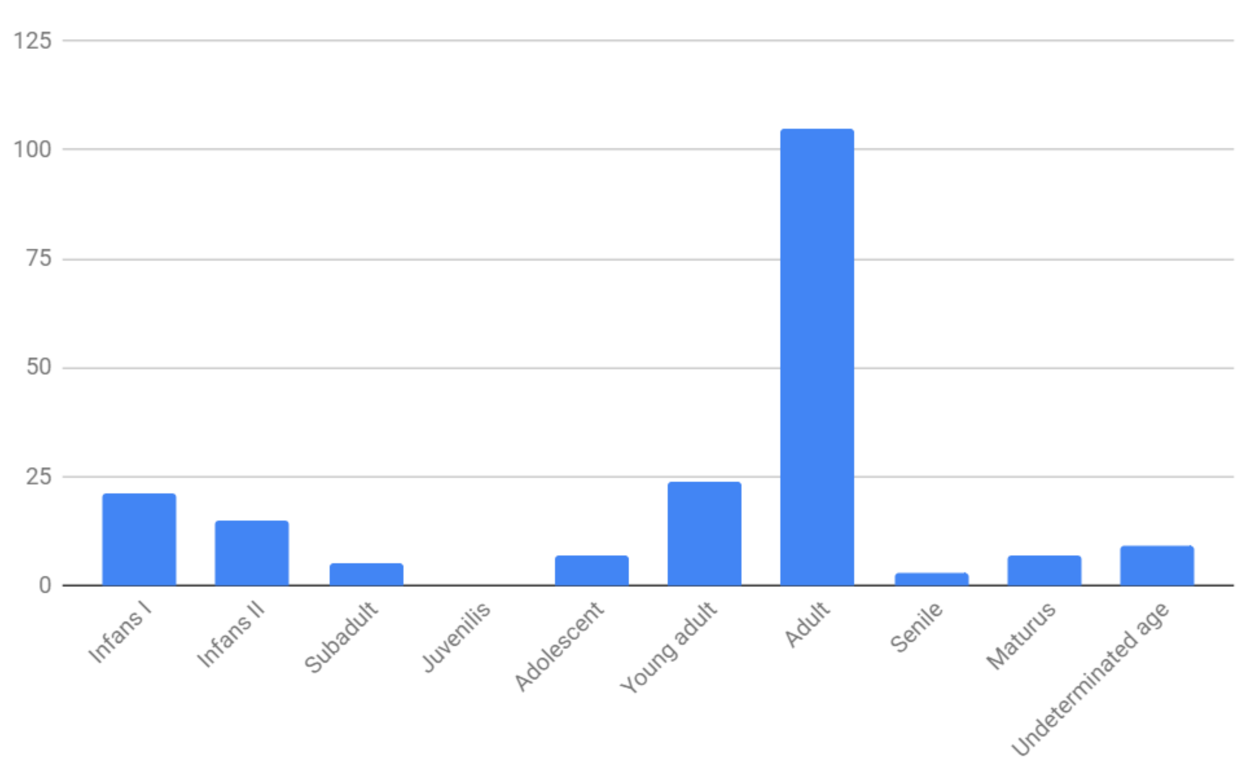
Due to poor skeletal preservation, sex determination was not possible in 89 (45.4%) individuals. There were 40 non-adults (20.4%) whose sex was not determined due to undeveloped secondary sexual dimorphism. Of the remaining 49 individuals. For the rest of the sample 34 were consistent with males (17.3%), another nine individuals were most likely male, but this was not possible to determine with precision due to the fragmentation of their pelvic bones. A total of 24 individuals were consistent with female sex, who were less represented in the sample (12.2%) than males (Chart 2).

Chart 2. Sex distribution in the sample (n=196)



Given the significant fragmentation of these individuals, it was not possible to estimate the age for nine individuals (4.6%). Adults (53.6%) represent the largest category in the sample; nevertheless, for them as well as for five subadults (2.6%), it was not possible to determine the precise age category. A total of 21 individuals belong to the Infans I category (10.7%), 15 individuals are in the Infans II category (7.7%), and there are 7 adolescents (3.6%). Three are elderly (1.5%), seven are mature (3.6%), and 24 people are young adults (12.2%) (Chart 3).

Chart 3. Age distribution in the sample (n=196)



4.3 Results of taphonomic analysis

4.3.1 Subaerial weathering changes

Bone breakage patterns associated with subaerial weathering (exfoliation, effects of heating/cooling, freezing/thawing, sun bleaching) were the most frequently observed change in skeletal assemblages from the reopened graves.[59-61] In 56/152 (37%) individuals, four types of modifications were observed.

The first type was longitudinal or dispersed cracking, both shallow and deep, that can be seen on the diaphyses of long bones, most commonly the humerus, femur, and tibia (Figure 12). While small cracks occurred on the surface, deep cracking appeared in the form of a long fracture in the middle of the shaft and usually penetrated the medullary cavity.

Figure 12. Longitudinal and dispersed crackings on bones from reopened graves, macroscopic details: (a) Longitudinal cracking on the anterior side of the left femur followed by intensive weathering and cortical loss, grave no. 2, Mihajlovo-Cerba (Male, adult); (b) Deep longitudinal crack on the anterior side of the right tibia followed with intense delamination, grave no.1, Orlovat-Vodica (Adult, indeterminate sex); (c) Deep longitudinal cracking on the anterior side of the right femur followed by intense delamination, grave no. 30, Vojlovica-Rafinerija (Male, adult); (d) Shallow longitudinal crack on the anterior side of the left femur with light delamination of the surrounding bone, grave no. 7, Vojlovica-Rafinerija (Female, young adult); Deep longitudinal crack on the anterior side of the left femur followed by dispersed cracking of the surrounding bone, grave no. 42, Azotara-Verušić (Indeterminate sex, adult); (f) Dispersed crackings on the anterior side of the left tibia, grave no. 112, Azotara-Verušić (Indeterminate sex, adult).

Another prevalent finding was the erosion of the cortical surfaces as a delamination change, observed on the long bones of the arms and legs. This erosion was usually present as a small flaking and progressive rough fibrous texture (Figure 13).

Figure 13. Delamination process on bones from reopened graves, macroscopic view: (a) Highly weathered right femur, grave no. 2, Cerba-Mihajlovo (Male, adult); (b) Peeled cortical bone of right humerus, grave no. 1, Banatski-Dvor Lokalitet 18 (Adolescent); (c) Highly weathered right tibia with rough fibrous surface, grave no. 2, Orlovat-Vodica (Adult, indeterminate sex); (d) Initial stage of the delamination of the right femur followed by dispersed crackings, grave no. 3, Orlovat-Vodica (Adult, indeterminate sex); (e) Peeled cortical bone of the left femur followed by small cracking, grave no. 21, Vojlovica-Rafinerija (Adolescent); (f) Peeled cortex of the right femur followed by dispersed crackings, grave no. 12, Vojlovica-Rafinerija (Adult, indeterminate sex)

Another type of cortical bone erosion, manifested as erosion with entirely rounded and smooth edges, frequently occurred in graves that had been entirely reopened. The long bones of the arms and legs were the most affected (Figure 14).

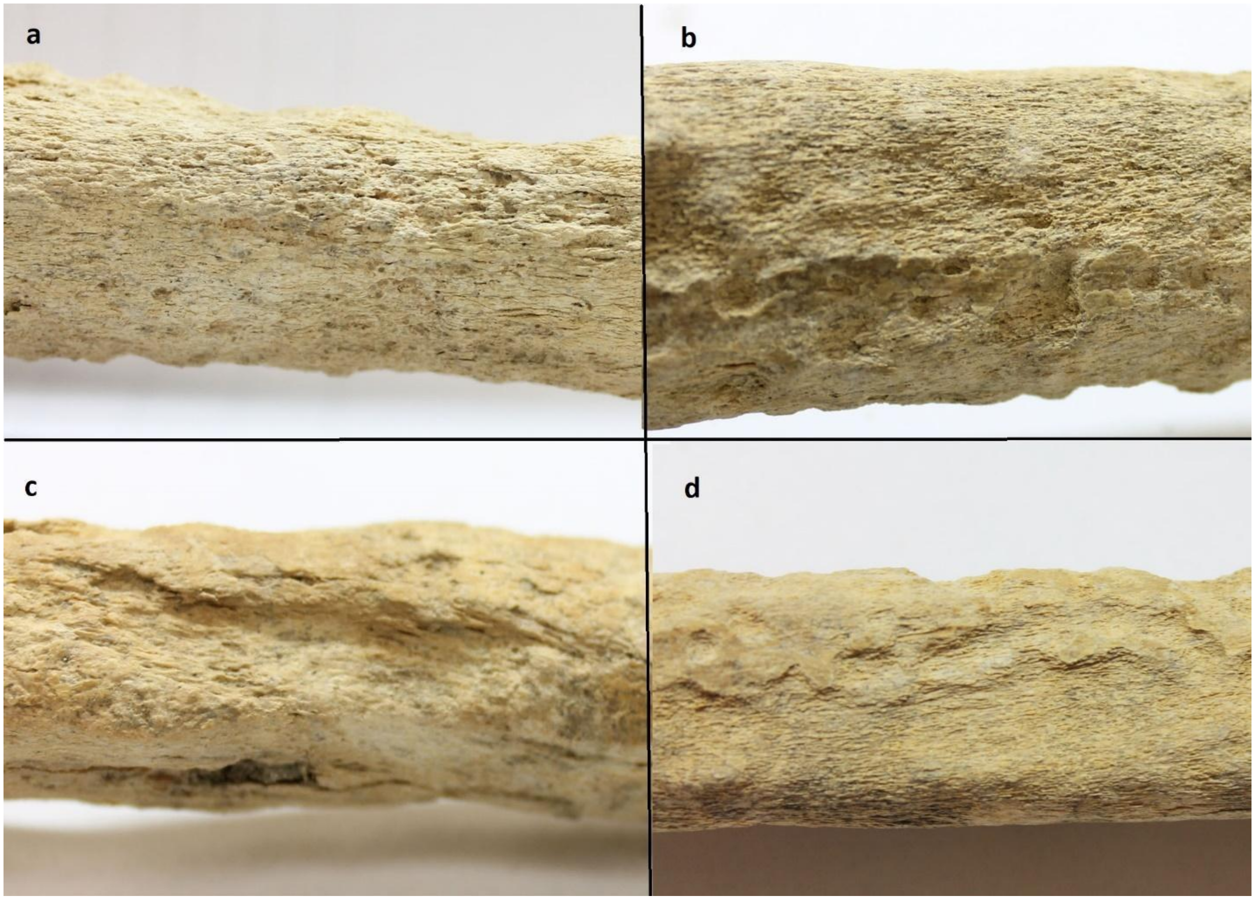


Figure 14. Abrasion of the cortical bone from reopened graves: (a) Highly abraded bone surface of the right femur followed by delamination, grave no. 5, Vojlovica-Rafinerija (Male, adult) (b) Highly abraded bone surface of the left femur followed by dispersed crackings, grave no. 3, Čurug-Detelinara (Probably male, adult); (c) Highly abraded bone surface of the left humerus followed by delamination, grave no. 32, Vojlovica-Rafinerija (Adult, indeterminate sex); Highly abraded bone surface of the right femur followed by delamination, grave no. 16, Vojlovica-Rafinerija (Maturus, indeterminate sex)

Along with those modifications, sun bleached bones were another common weathering change.[61] A total of 19/152 individuals from reopened graves (Vojlovica, Verušić, Detelinara 2, Klisa Futog, Melenci-Kentra 17, Melenci Kentra 18, Cerba-Mihajlovo) had bone bleaching (Figure 15). Skeletal material from intact graves did not show bleaching, and the bones had the usual ivory colour.

Figure 15. Bone bleaching on bones from reopened graves: (a) completely bleached right radius, grave no. 3, Vojlovica-Rafinerija (Probably male, adult); (b) completely bleached left tibia, grave no. 72, Azotara-Verušić (Male, adult); (c) completely bleached right femur, grave no. 30, Vojlovica-Rafinerija (Male, adult); (d) completely bleached femur, grave no. 32, Azotara-Verušić (Male, senile)

Multiple stages of bone weathering were evident in the samples because of long exposure to the surface. Stage 0, without bone weathering, was identified in skeletal material from intact burials, while the most weathered bones were typically found in reopened graves. Bones from intact graves had a regular external cortex and internal structure. Bones from reopened graves displayed all weathering stages, from mild to advanced bone breakdown with bone flaking, fibrous surface, and deep penetration into medullary. The final stage of bone weathering, implying complete disintegration of bones into small fragments, was mostly present in the subcategory of entirely reopened graves, where only a few bones were identified in the grave. Even archaeologists mentioned in their reports that in some cases bones began to disintegrate during excavation, which corresponds to the final stage of the weathering phase (Figure 16).

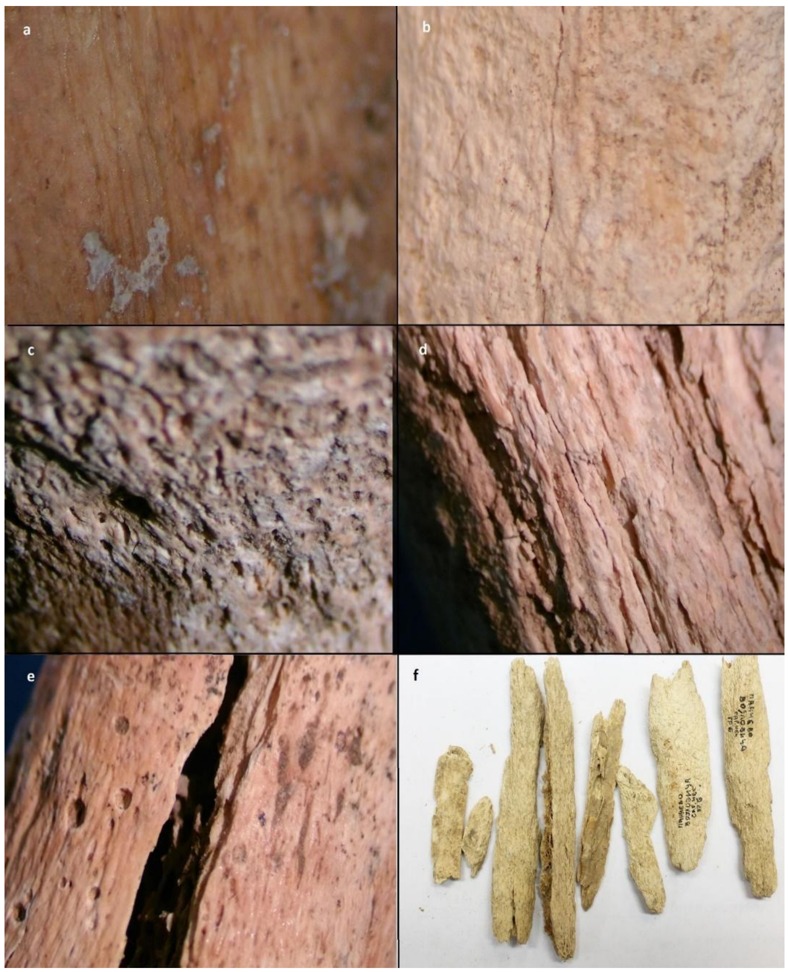


Figure 16. Established stages of bone weathering[8,49,60,61] applied on the sample, microscopic details: (a) Phase 0 - bone surface of the bone from intact grave (grave no. 86, Čik- Bačko Petrovo Selo); (b) Phase 1 - mildly weathered bone with longitudinal and thin crack, followed by mosaic cracks from reopened grave (grave no. 10. Azotara-Verušić); Phase 2 - Starting process of bone flaking with unchanged internal structure (grave no. 25, Vršac- Park Neurospihijatrije); Phase 3 - Weathered bone with rough fibrous surface (grave no. 9, Vršac- Park Neurospihijatrije); Phase 4 - Highly weathered bone with rough structure and deep cracks penetrated to the internal structure (grave no. 10, Vršac- Park Neurospihijatrije); Phase 5 - Completely disintegrated skeleton with only a few bone fragments preserved (grave no. 6, Vojlovica-Rafinerija).

4.3.2 Evidence of animal (rodents, scavengers, birds), and plant activity

Animal- and bird-related bone alterations were not found in the collection, but plant activity was recognized in just one case as a root invasion on the distal part of the femur (Čurug-Detelinara g.11)[61] (Figure 17).

Figure 17. Example of root invasion on the posterior distal part of the right femur, grave no. 11, Čurug-Detelinara 2

4.3.3 Insects activity

Insect activity was detected on the postcranial skeleton of an adult female (Vršac-Neuropsihijatrija g. 26). Changes were found on the entire skeleton in the form of small oval pits (R=2 mm approximately) and tunnels along the bone shaft, densely organised along the diaphysis (Figure 18). According to authors (Huchet et. al)[68] these patterns are indicative of termite activity. Namely, termites destroy bone secondarily; the primary focus of termites colonies is the coffin because of cellulose substances in the coffin, representing a source of food.[68] The grave had no archaeological evidence of a coffin, but skeletal remains showed signs of coffin wear on the posterior side of the femur and calcaneus.

Figure 18. Example of insect (termites) activity on the skeleton from intact grave no. 26, Vršac-Park Neurospihijatrije (Female, young adult): (a) left humerus; (b) right ulna; (c) left ulna; (d) right radius

4.3.4 Fungi, algae and lichens growth

There were no indications of fungi, algae, or lichen growth on bones in the sample.

4.3.5 Postmortem cut-marks

Sharp cut edges were observed in 8/152 cases of reopened graves, which are indicative of modifications caused by sharp tool marks.[5] In four entirely reopened graves, sharp parallel cuts were identified on the anterior surfaces of the femora, tibiae, and humeri (Verušić g. 88; Vojlovica g. 21 and 32; Gospođinci-Cerba g. 1) (Figure 19). As for the graves reopened in the upper part, cuts in the humerus were found in three cases (Vojlovica g. 3 and 35; Orlovat g. 3).

Figure 19. Cut marks changes on bones from reopened graves: (a) Four parallel sharp cuts on the middle bone shaft, anterior side of right femur (grave no. 21 Vojlovica-Rafinerija, Adolescent); (b) Four parallel sharp cuts on the anterior side on the proximal part of the left femur (grave no. 36, Vojlovica-Rafinerija, Adult, indeterminate sex); (c) Two sharp cuts in form of V section on the anterior side of the middle shaft of the right femur (grave no. 1, Melenci Kentra lok. 18, Adolescent); (d) An irregularly shaped cut that damaged part of the cortical bone from the anterior side of the right femur (grave no. 1, Melenci Kentra lok. 17, Adult, indeterminate sex)

4.3.6 Colour staining

A total of 46/152 skeletons (30%) had bone staining, which included red staining (6/152), dark staining in 4/152 long bones, and cupric staining in 35/152 cases (Figure). Red staining in five cases was the result of burial in coffins, while in one case an iron object in the grave stained a part of the bone (Vojlovica g. 34). Dark and cupric staining were caused by contact with grave goods. [69-70] Dark staining was represented as gray (Detelinara g.7, Klisa E-75 7, Klisa-Futog g.2) and black staining (Verušić g.46 and 112) (Figure 20).

Figure 20. Bone staining: (a) Red pigmentation of the femur, grave no. 5 Mošorin-Šajkaš (reopened grave, Adult, indeterminate sex); (b) Red pigmentation of the femur, grave no. 2 Mošorin-Šajkaš (intact grave, Infans I); (c) Dark pigmentation of the femur, grave no. 46, Verušić-Azotara (intact grave, male, adult); (d) Gray pigmentation of the femur, grave no. 1, Melenci Kentra lok. 17 (Adult, indeterminate sex); (e) Patina staining of the pelvis, grave no. 3, Čurug-Detelinara 2 (reopened grave, probably male, adult); (f) Patina staining of the temporal bone, grave no. 43, Vojlovica-Rafinerija (intact grave, adolescent)

4.4 Coffin wear changes and the ritual of burial in coffins

4.4.1. Coffin wear changes on bones

Coffin wear changes characterised by cortical bone breakdown manifested as flattening of the posterolateral bone features.are present in 38/152 (25%) individuals.[59-60] Changes were present on the pelvis, at the proximal and distal ends of the long bones (humerus, radius, ulna, femur, tibia, and fibula) (Figure 21). The anterior skeletal parts of the feet, which were in contact with the coffin lid or walls, also showed changes.[59-60] Detailed macroscopical examination revealed a defined boundary separating the normal bone surface from the flattened damage area of the bone (with visible cancellous bone) (Figure 20 f-g).

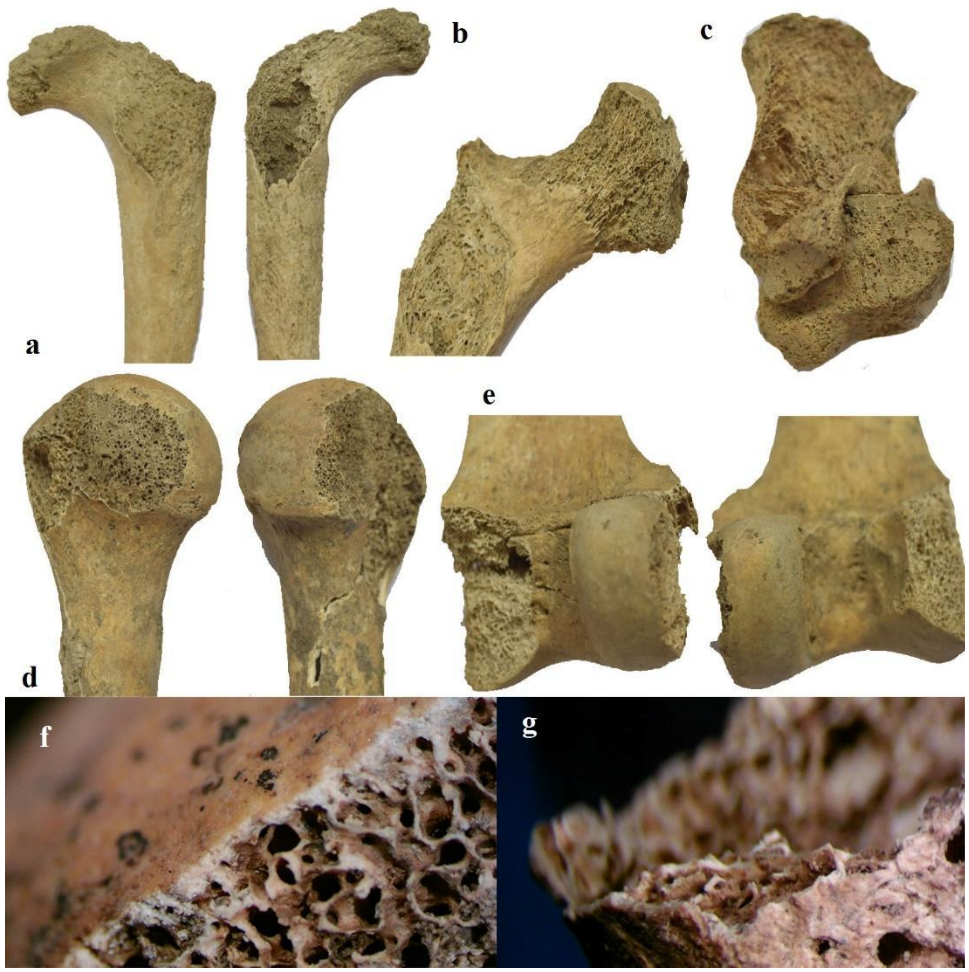


Figure 21. Examples of coffin wear changes with cortical bone loss on the posterior side: (a) proximal parts of both femurs in the area (b) proximal end, grave no. 43, Vojlovica-Rafinerija (c) entire surface, grave no. 3, Vojlovica-Rafinerija (d) proximal ends of both humeri (e) postero-lateral side of distal ends of both femurs, grave no. 7, Klisa Futog; (f-g) microscopic detail of cortical bone loss of femur and humerus with the view on boundary line between the regular bone surface and coffin wear changes

The level of skeletal preservation for those skeletal materials was extremely low. Only a few bone fragments were found in some of the cemeteries during the excavations (Verušić g. 13, 101, 102, 103, 114).[39] Only six cemeteries (Veršić g. 83 and 88; Klisa-Futog g. 5; Velebit 66; Vojlovica g. 5 and 18) had skeleton preservation that was generally complete, with a mean BRI index value of more than 0,5 (50%). The remaining graves all displayed low skeletal preservation. Thirteen of the 38 skeletons with identifiable modifications were from the graves that were still intact (Vršac-Neuropshijiatrije g. 26, Vojlovica-Rafinerija g. 43, Klisa-Futog II g. 2 and g. 5, Klisa E-75 g. 5, Šajkaš-Mošorin g. 3, Verušić-Rafinerija g. 32, 46, 72, 96, and 112; Čurug-Detelinara g. 11; Čik g. 86) (Figure 22).

Figure 22. Coffin wear changes on bones from intact graves: (a) Coffin wear changes on postero-lateral part of the distal end of tibia, grave no. 86, Čik-Bačko Petrovo selo (Female, young adult); (b) Coffin wear changes on anterior surface of the calcaneus, grave no. 86, Čik-Bačko Petrovo selo; (c) Coffin wear changes on the posterior part of the proximal femur, grave no. 2, Klisa-Futog (Infans II); Coffin wear changes on posterior side of the distal end of the femur, grave no. 26, Vršac-Park Neuropsihijatrije (Female, young adult)

4.4.2. Coffins in Sarmatian funerary complex

Direct archaeological evidence of coffin presence (traces of wood and „S“ or „C“ iron cramps) was distinguished in 16 cases (14 in disturbed graves, 2 in intact graves) from different locations (Vojlovica, Vršac, Verušić, Klisa-Futog, and Velebit)[36,39] (Archaeological documentation Provincial Institute for the Protection of Cultural Monuments and Senta city Museum). The characteristic indicators of coffin wear pattern, including erosions on the posterolateral positions of bone surface, were also observed on skeletons from those graves (Figure 23).

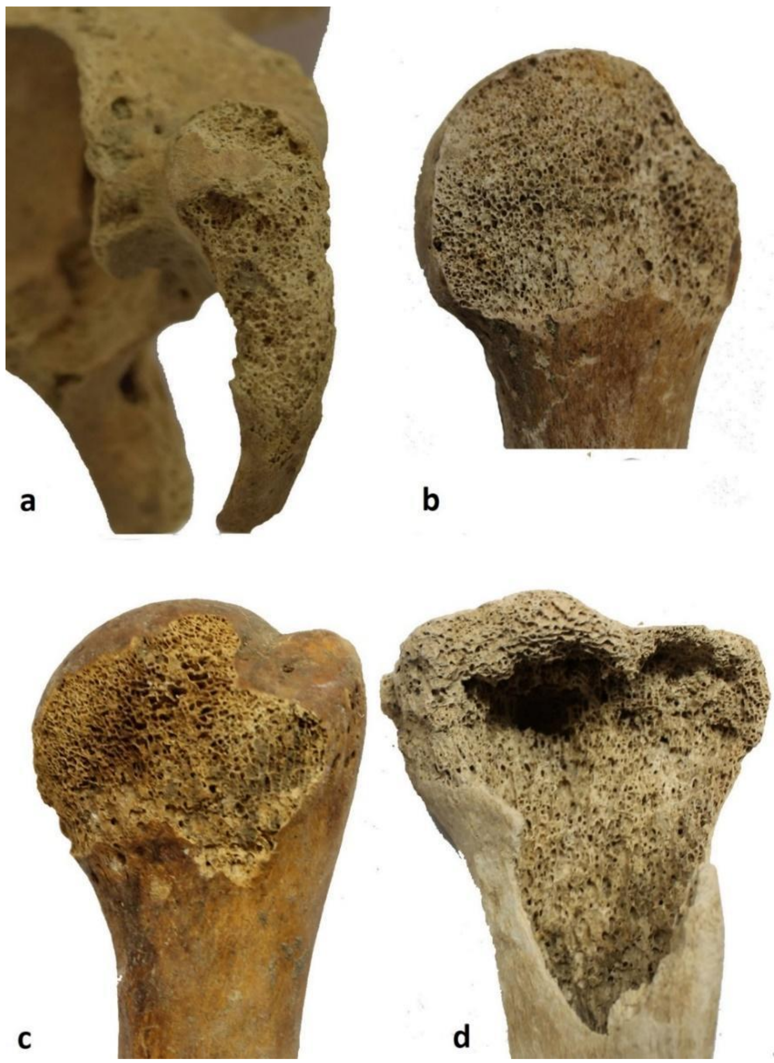


Figure 23. Coffin wear changes on skeletal material from intact graves with identified coffin structures: (a) posterior aspect of the pelvic bone, grave no. 5, Vojlovica-Rafinerija (Male, adult); (b) posterior aspect of the right humerus, grave no 5, Klisa Futog (Adult, indeterminate sex); (c) posterior aspect of the right humerus, grave no. 18, Vršac-Neuropsihijatrija (Probably male, adult); (d) anterior side of the left tibia, grave no. 88, Azotara-Verušić (Female, young adult)

Knowledge on funerary architecture was based mainly on recent archaeological investigations in Romania and Hungary. Coffins are found in one third of Sarmatians graves in the Carpathian Basin (about 23%), noticed by the presence of wood and "S" or C" shaped iron clamps.[12,65,71] Two types of coffins are known: simple funerary bead/bier (probably completed with textile or leather sheets) and chambers (box type) with solid coffins with heavy and compact lid (tree-trunks) (Figure 24). Besides coffins, the grave structures consisted also of vegetal pillows placed under the head and vegetal materials (grass, reed, tree bark, brushwood) covering the bottoms of the grave.[12,65,71] Dimension of graves with coffins were significantly larger than others in Sarmatians cemeteries, especially barrow graves where the dimensions are even larger (more than 3-4 m). All skeletons with observed changes belong to graves whose pits dimensions range from 2.10 m up to 2.90 m in length.

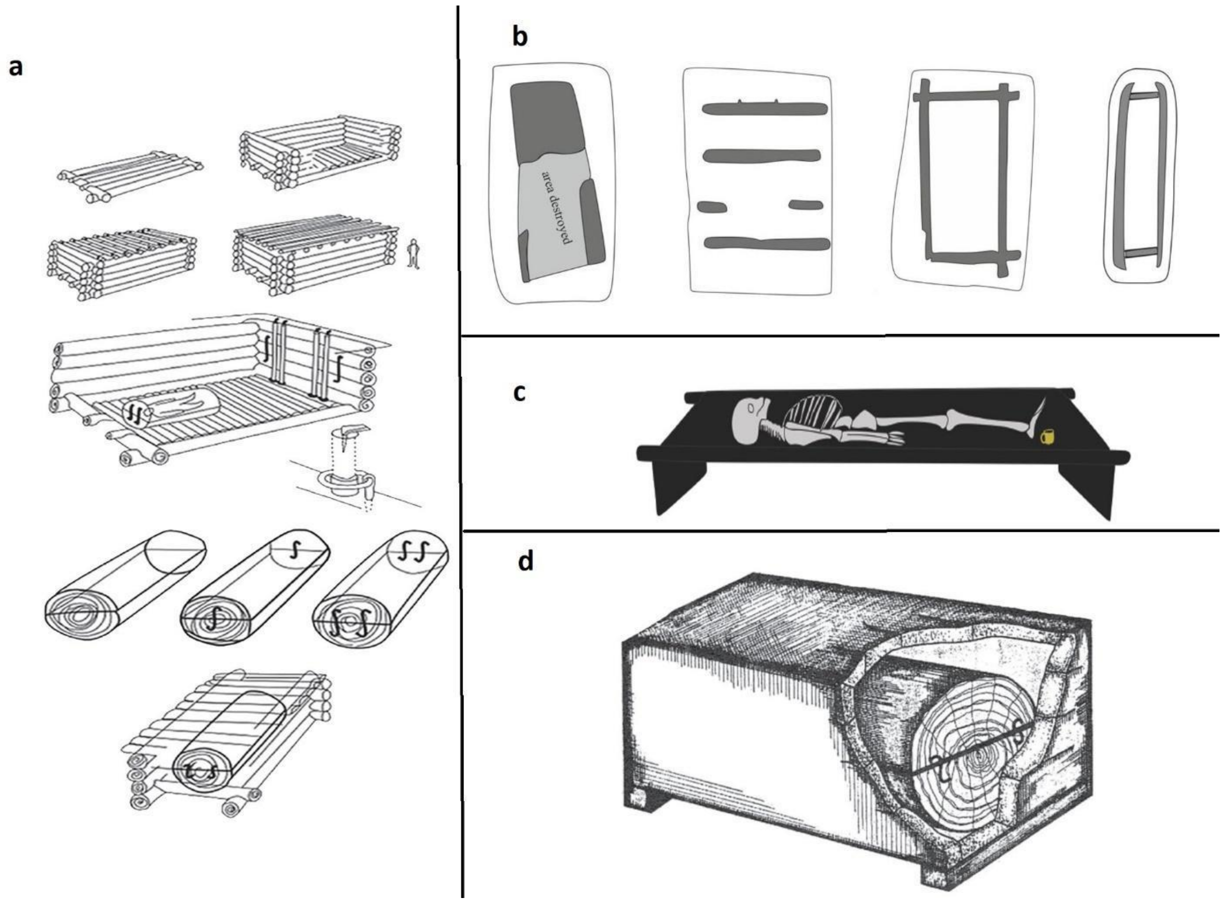


Figure 24. Types of coffins in Sarmatian cemeteries (following authors Grumeza[12], Vörös[17], Grumeza and Ursuțiu[84],Barcă and Grumeza[88], Gallina[89]): (a) Solid coffins and chambers discovered at Sarmatian sites in the Great Hungarian Plain (attached with S or C clamps)[17,88]; (b) Rectangular coffins from Timișoara-Nădlac (Romania): box type coffins made of planks or wooden beams and biers or beds for carrying the dead, with or without attached coffin[84]; (c) funerary bier among Sarmatians, Giarmata site (Romania)[12,88]; (d) Reconstruction of solid coffin, made of tree trunk with lid from Hungary.[89]

4.5. Bone scattering

Evidence for skeletal disturbance and scattering has been recorded at several sites, where archaeological reports provide detailed descriptions of the discovery of bone fragments in grave unit fills, i.e., the upper layers of the grave unit. At the sites of Vojlovica-Rafinerija (g. 3,5, 6, 7, 12), Vršac-Neuropsihijatrija (g. 4,5, 9, 13, 18) and Orlovat-Vodica (graves 1,2), Melenci Kentra Lokalitet 18 (g.1), archaeologists recorded and described in detail the bone fragments they found in the upper layers of the grave. The found bone fragments match the missing bones in the grave. In all cases, the type of bones found in the upper layers followed the pattern of the grave reopening. Thus, in graves that were opened in the upper parts (Melenci Kentra Lok. 18, g. 1; Vršac g. 4, 13, 18; Orlovat g. 1, 2; Vojlovica g. 3,5), fragments of skulls, vertebrae, and hands were found in the upper layers, while in the case of completely disturbed graves (Vršac g. 5, 9; Vojlovica g. 6, 7, 12), both upper and lower extremities were found.

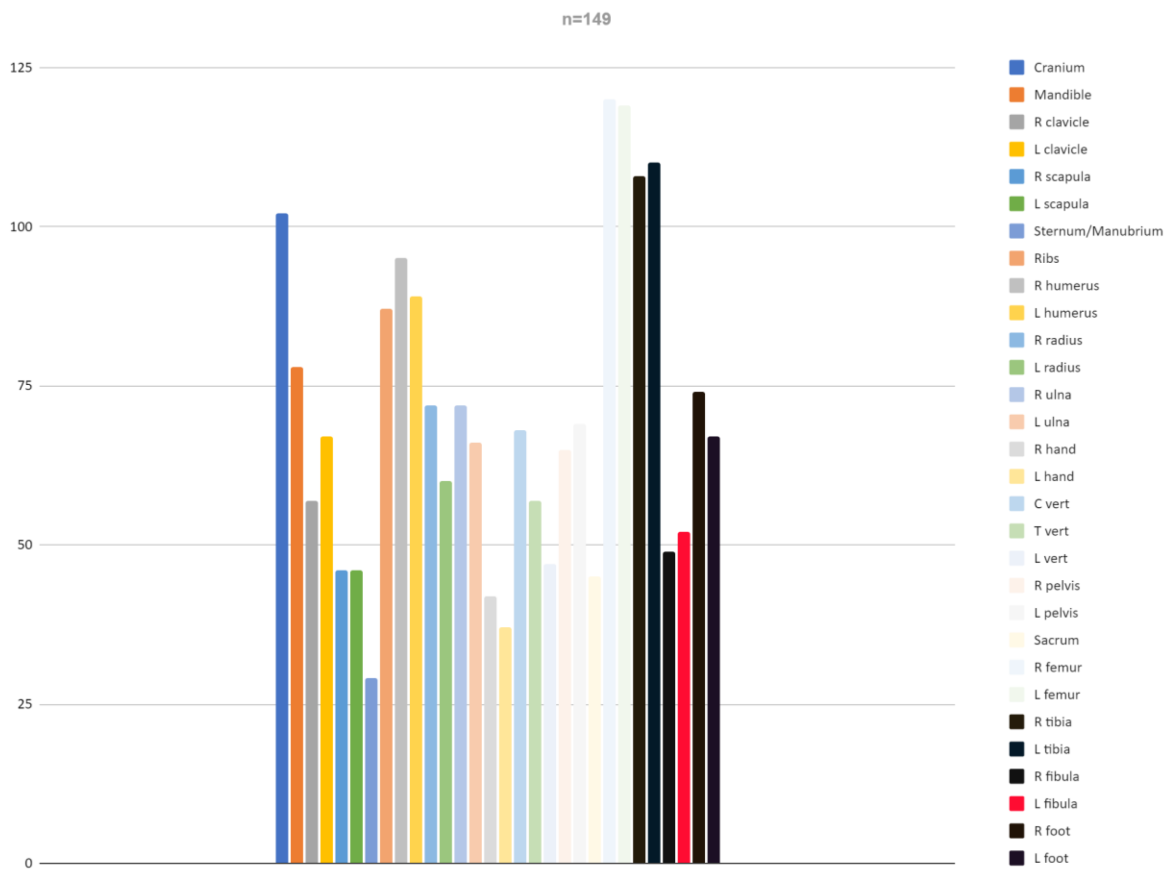
During anthropological analysis, extra bones were found in seven adult graves from the Vojlovica-Rafinerija site (g. 9, 16, 25, 32, 36, 47, and 52). In labelled boxes, apart from single individuals, there were additional fragments of long bones (femur, humerus, and tibia) and skulls, which did not anatomically correspond to the majority of the skeleton, making the minimal number of individuals more than one. However, according to archaeological reports, the burials were single inhumations. Those graves were robbed and during the process of shovelling of the grave contents, skeletal parts could have fallen into the opened pits of surrounding graves, which could have produced mixing of the skeletal material and extra bones in the graves. An anthropological comparison was conducted to determine whether the extra bones might match individuals from surrounding graves; however, none of the extra bones could be matched with the nearby graves. Therefore, it can be concluded that the extra bones in the graves were a consequence of further mixing of skeletal material after excavation (cleaning or packing) rather than postmortem action during grave reopening (commingling bones with nearby graves).

4.6 Skeletal completeness (BRI) and fragmentation (IBF) in reopened and intact graves

Even though the total sample number comprised 152 graves, with 121 of them being reopened and 32 remaining intact, the numerical evaluation of the skeletal preservation was conducted on 149 graves, as three of the reopened graves were completely empty, that is, without any skeletal remains available for further skeletal completeness and fragmentation analysis.

The femur was the most frequent bone in the sample (left 79%; right 80%), followed by the tibia (right 72%; left tibia 73%), and the cranium bones (68%). The most often missing part of the skeleton was the sternum or manubrium (19%), followed by the bones of the hands, but the latter could be explained as a methodological lapse during the excavations (Chart 4).

Chart 4. Frequency of the particular bones in the sample (149 individuals)



Archaeological evidence did not suggest postmortem grave reopening for 32 burials (intact graves), indicating that neither secondary disturbance of the funerary environment nor bone damage had occurred.

The differences in BRI per individual between intact (0.612±0.278) and reopened graves (0.429±0.258) was determined using Student's *t* test for two independent samples, and the results showed significant decrease in skeletal completeness index in reopened graves (p=0.001).

The differences in IBF were determined using Student's *t* test, and the results showed statistically significant difference in fragmentation degree between intact (0.783±0.443) and reopened graves (0.468±0.309; p=0.001). Skeletal remains from reopened graves had a lower value of IBF index, which means that skeletal remains in those graves were more fragmented.

4.7 Influence of soil type and grave depth on skeletal preservation

The influence of the soil on the preservation of the skeletal material was excluded as a factor of the poor preservation because the geological data indicate the homogeneity and alkalinity of the soil in Vojvodina. Moreover, some authors point out that only Sarmatian skeletons are poorly preserved, although they were buried in the same soil as other populations.[16]

Archaeological data on grave depth were available for only 68/156 graves (Table 4). Analysis of the correlation between the BRI index for intact graves and grave depth showed that there was no correlation (p=0.734) between the skeletal completeness and grave depth in intact graves. Results of Spearman correlation analysis between the BRI index for reopened graves and grave depth showed positive correlation (p=0.18, R^2=0.333).

Table 4. Data on the grave depth from archaeological reports

SITE	GRAVE NO.	GRAVE DEPTH (m)	BRI INDEX
Vojlovica-Rafinerija	**15**	0.6	0,5333333333
Vršac-Neuropsihijatrija	**7**	1.62	0.9333333333
Vršac-Neuropsihijatrija	**8**	1.30	0.6
Vršac-Neuropsihijatrija	**9**	2.95	0.3666666667
Vršac-Neuropsihijatrija	**10**	1.43	0.4
Vršac-Neuropsihijatrija	**11**	1.72	0.3666666667
Vršac-Neuropsihijatrija	**12**	2.90	0,1666666667
Vršac-Neuropsihijatrija	**13**	2.05	0.5666666667
Vršac-Neuropsihijatrija	**14**	1.62	0.3666666667
Vršac-Neuropsihijatrija	**15**	2.45	0.6333333333
Vršac-Neuropsihijatrija	**17**	1.70	0.6666666667
Vršac-Neuropsihijatrija	**18**	2.58	0,4666666667
Vršac-Neuropsihijatrija	**19**	2.58	0.3666666667
Vršac-Neuropsihijatrija	**20**	2.20	0.9

Vršac-Neuropsihijatrija	**21**	2.10	0.9
Vršac-Neuropsihijatrija	**23**	2.22	0.5666666667
Vršac-Neuropsihijatrija	**24**	1.60	0.1333333333
Vršac-Neuropsihijatrija	**25**	2.45	0.4482758621
Vršac-Neuropsihijatrija	**26**	2.38	0.6666666667
Vršac-Neuropsihijatrija	**27**	2.65	0.8666666667
Orlovat-Vodica	**2**	1.40	0.7666666667
Orlovat-Vodica	**3**	2	0.7
Melenci Kentra Lokalitet 17	**1**	0.6	1
Melenci Kentra Lokalitet 17	**2**	1.3	1
Melenci Kentra Lokalitet 18	**1**	1	0.7
Melenci Kentra Lokalitet 18	**2**	1	0.8666666667
Gospođinci-Cerba Mihajlovo	**1**	1.30	0.5666666667
Gospođinci-Cerba Mihajlovo	**2**	0.90	0.6666666667
Gospođinci-Cerba Mihajlovo	**3**	0.85	0.8666666667
Melenci Kentra Lokalitet 20	**1**	1	0.06666666667
Melenci-Kentra Lokalitet 22	**1**	0.9	0.1333333333
Verušić-Azotara	**7**	0.45	0.4
Verušić-Azotara	**8**	0.66	0.2666666667
Verušić-Azotara	**10**	0.51	0.5333333333
Verušić-Azotara	**11**	0.66	0.3333333333
Verušić-Azotara	**14**	0.6	0.6333333333
Verušić-Azotara	**15**	0.73	0.2

Verušić-Azotara	**16**	0.78	0.4666666667
Verušić-Azotara	**46**	0.46	0.566
Verušić-Azotara	**49**	0.94	0.933
Verušić-Azotara	**57**	0.64	0.3
Verušić-Azotara	**67**	0.65	0.03333333333
Verušić-Azotara	**69**	0.63	0.3
Verušić-Azotara	**72**	0.64	0.633
Verušić-Azotara	**73**	0.9	0.4
Verušić-Azotara	**75**	0.59	0.2
Verušić-Azotara	**76**	0.54	0.1
Verušić-Azotara	**77**	0.71	0.3
Verušić-Azotara	**79**	0.47	0.3
Verušić-Azotara	**81**	0.67	0.1
Verušić-Azotara	**83**	0.44	0.8666666667
Verušić-Azotara	**85**	0.57	0.366
Verušić-Azotara	**87**	0.56	0.4
Verušić-Azotara	**88**	0.93	0.9333333333
Verušić-Azotara	**89**	0.76	0.5
Verušić-Azotara	**95**	0.74	0.5333333333
Verušić-Azotara	**96**	0.92	0,533
Verušić-Azotara	**97**	0.99	0.6666666667
Verušić-Azotara	**98**	0.91	0.1333333333

Verušić-Azotara	**99**	1.27	0.2333333333
Verušić-Azotara	**100**	1.3	0.1
Verušić-Azotara	**112**	0.49	0.366
Verušić-Azotara	**113**	0.46	0.3666666667
Verušić-Azotara	**115**	0.68	0.1666666667
Verušić-Azotara	**116**	0.53	0.5333333333
Verušić-Azotara	**120**	0.17	0.2
Verušić-Azotara	**123**	0.74	0.06666666667
Verušić-Azotara	**124**	0.7	0.7333333333

4.8 Results of AMS radiocarbon dating

Absolute chronology for Sarmatian localities has never been done in Serbia, not even in the region. The dating of these necropolises was based solely on relative chronology based on the dating of archaeological objects from the graves.

Based on the analysis of 20 permanent teeth, the results of AMS radiocarbon dating were obtained for 20 graves from nine localities included in the study (Table 5).

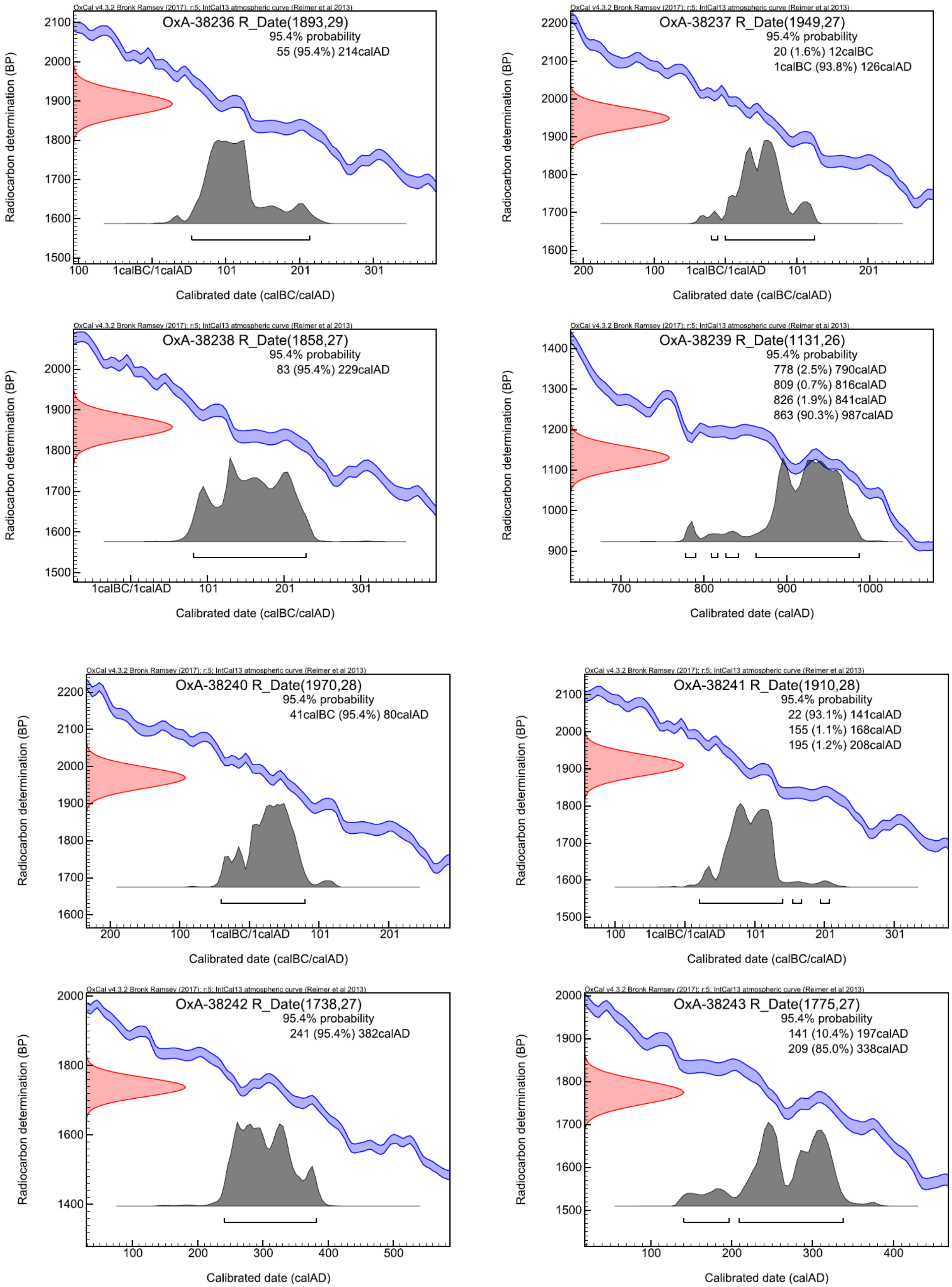
Table 5. AMS radiocarbon results

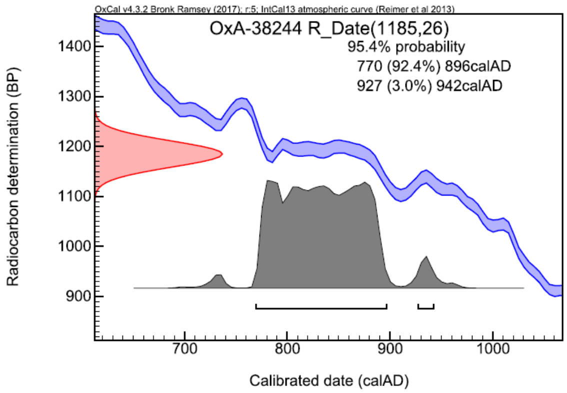
SITE	GRAVE NO.	REFERENCE NUMBER	ANTHROPOLOGICAL DATA	RELATIVE CHRONOLOGY DATING	AMS DATES (calibrated CE)	δ13C
Bačko Petrovo selo Čik	86	OxA-38236	Female, young adult	2nd century AD (Bugarski 2009)	214 (95.4%)	-11.72
Bačko Petrovo selo Čik	133	OxA-38237	Female, maturus	2nd century AD (Bugarski 2009)	126 (93.8%)	-13.37
Velebit	67	OxA-38238	Male, adult	1st-4th century AD (Senta city museum)	229 (95.4%)	-14.57
Velebit	24	OxA-38239	Male, adult	1st-4th century AD (Senta city museum)	987 (90.3%)	-13.00

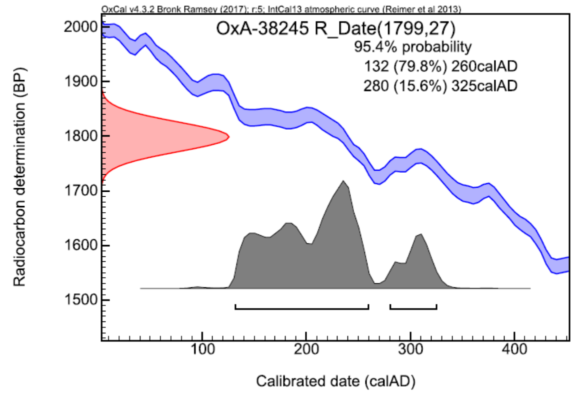
Svetozar Miletić Lenjinova 50	1	OxA-38240	Male, adult	1^{st}-2^{nd} century AD (Putica 2012/2013)	80 (95.4%)	-14.77
Svetozar Miletić Lenjinova 50	5	OxA-38241	Child, Infans I	1^{st}-2^{nd} century AD (Putica 2012/2013)	141 (93.1%)	-12.54
Aradac-Leje	2	OxA-38242	Female, adult	2^{nd}-4^{th} century AD (Zrenjanin)	382 (95.4%)	-14.83
Aradac-Leje	6	OxA-38243	Indeterminate sex*, maturus	2^{nd}-4^{th} century AD (Zrenjanin)	338 (85.0%)	-15.83
Verušić-Azotara	77	OxA-38244	Female, adult	4^{th}-5^{th} century AD (Sekereš)	896 (92.4%)	-19.34
Verušić-Azotara	84	OxA-38245	Male, adult	4^{th}-5^{th} century AD (Sekereš)	260 (79.8%)	-18.41
Verušić-Azotara	96	OxA-38301	Male, maturus	4^{th}-5^{th} century AD (Sekereš)	381 (95.4%)	-15.29
Vojlovica Rafinerija	32	OxA-38302	Female (P*), adult	3^{rd}-4^{th} century AD (Batistic)	334 (95.4%)	-14.86
Vojlovica Rafinerija	5	OxA-38303	Male, adult	3^{rd}-4^{th} century AD (Batistic)	230 (95.4%) 235 (95.4%)	-15.19 -15.85
Vojlovica Rafinerija	13	OxA-38304	Male, adult	3^{rd}-4^{th} century AD (Batistic)	420 (88.7%)	-15.88
Vršac-Neuropsihi jatrija	9	OxA-38306	Indeterminate sex*, juvenilis	4^{th} century AD (aralica)	411 (78.5%)	-14.97
Vršac-Neuropsihi jatrija	24	OxA-38307	Indeterminate sex*, maturus	4^{th} century AD (aralica)	383 (95.4%)	-15.89
Vršac-Neuropsihi jatrija	4	OxA-38308	Male, adult	4^{th} century AD (aralica)	409 (76.9%)	-15.42
Šajkaš Mošorin Lok. 10	3	OxA-38309	Female (P*), young adult	2^{nd}-4^{th} century AD (Pokrajinski)	179 (89.9%)	-13.52
Šajkaš Mošorin Lok. 10	9	OxA-38310	Female (P*), adult	2^{nd}-4^{th} century (Pokrajinski)	418 (85.4%)	-17.40
Čurug Detelinara 2	11	OxA-38311	Male (P*), adult	1^{st} century AD (Muzej Vojvodina)	253 (92.9%)	-11.92

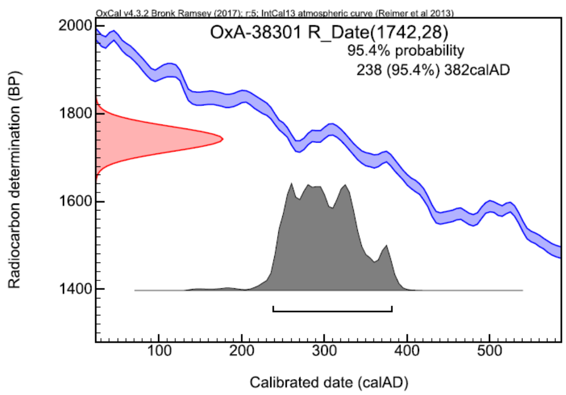
*Indeterminate sex - it was not possible to determine the sex due to the lack of appropriate skeletal parts; P- probably female/male due to fragmented appropriate skeletal parts

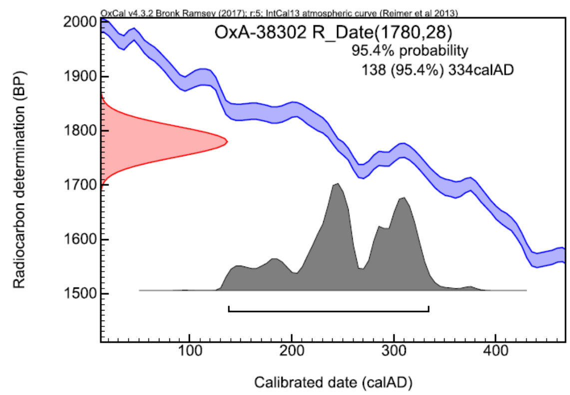
Chart 5. AMS radiocarbon results – calibration curve

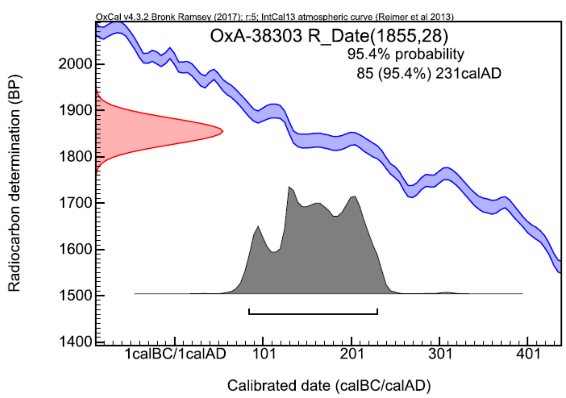


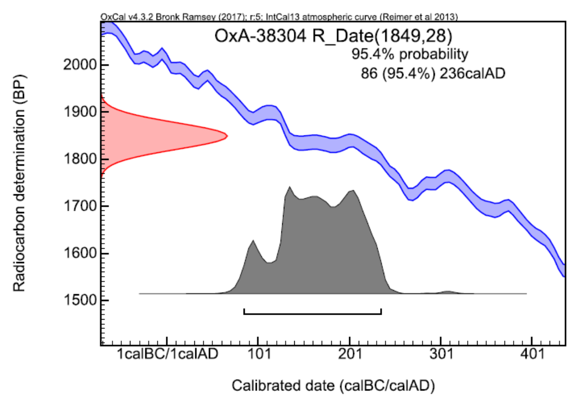

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38244 R_Date(1185,26)
95.4% probability
770 (92.4%) 896calAD
927 (3.0%) 942calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

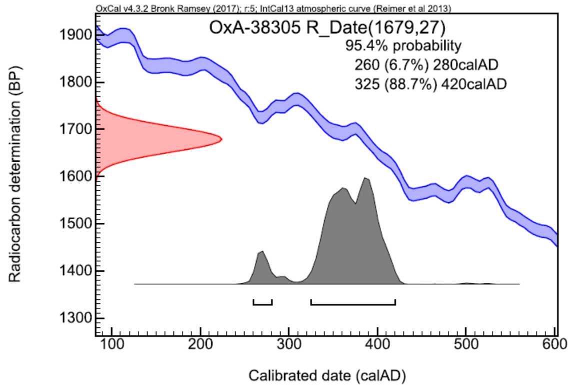

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38245 R_Date(1799,27)
95.4% probability
132 (79.8%) 260calAD
280 (15.6%) 325calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

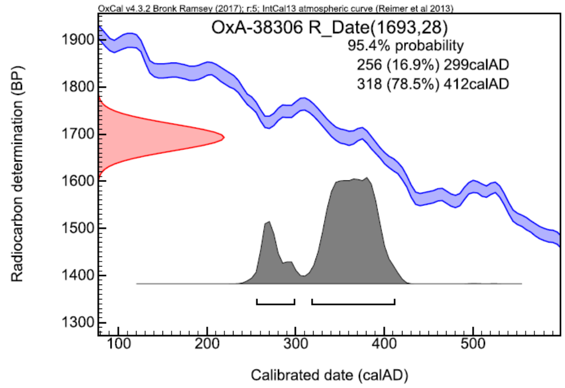

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38301 R_Date(1742,28)
95.4% probability
238 (95.4%) 382calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

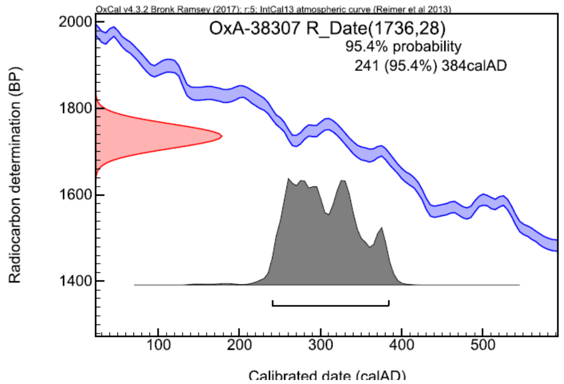

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38302 R_Date(1780,28)
95.4% probability
138 (95.4%) 334calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

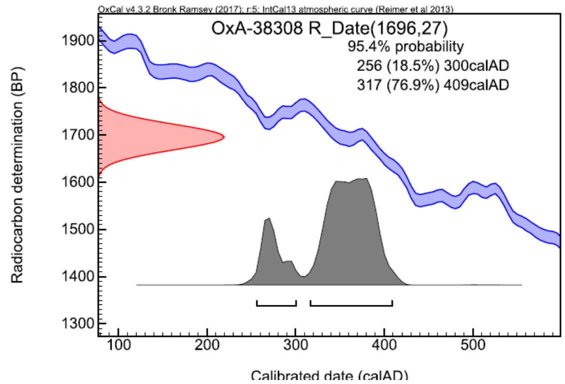

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38303 R_Date(1855,28)
95.4% probability
85 (95.4%) 231calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

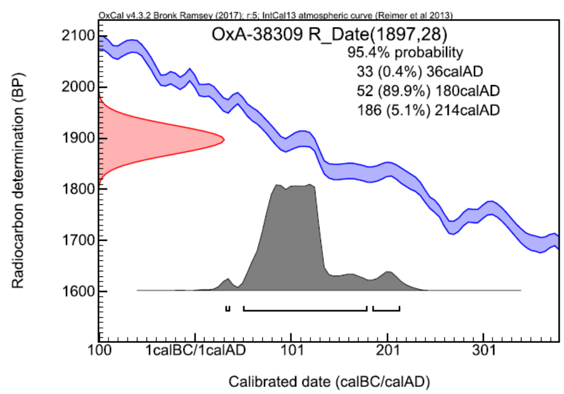

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38304 R_Date(1849,28)
95.4% probability
86 (95.4%) 236calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

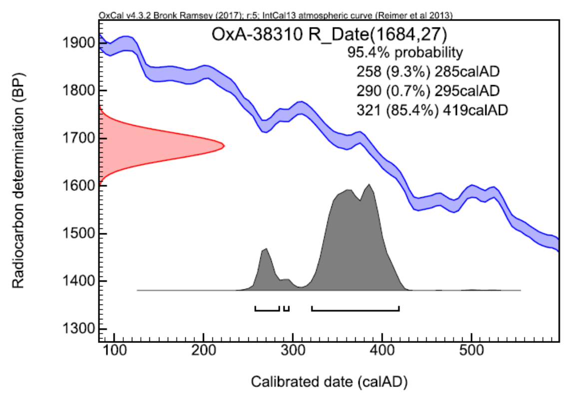

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38305 R_Date(1679,27)
95.4% probability
260 (6.7%) 280calAD
325 (88.7%) 420calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

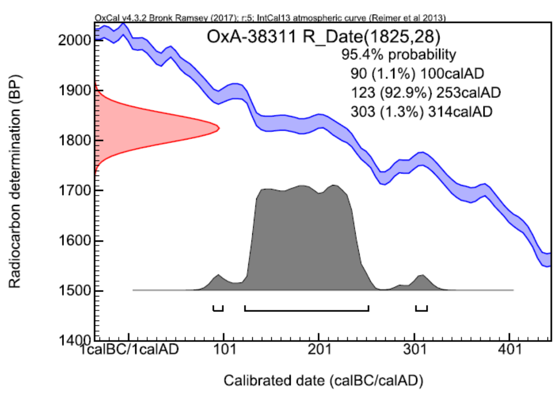

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38306 R_Date(1693,28)
95.4% probability
256 (16.9%) 299calAD
318 (78.5%) 412calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38307 R_Date(1736,28)
95.4% probability
241 (95.4%) 384calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38308 R_Date(1696,27)
95.4% probability
256 (18.5%) 300calAD
317 (76.9%) 409calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38309 R_Date(1897,28)
95.4% probability
33 (0.4%) 36calAD
52 (89.9%) 180calAD
186 (5.1%) 214calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38310 R_Date(1684,27)
95.4% probability
258 (9.3%) 285calAD
290 (0.7%) 295calAD
321 (85.4%) 419calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
OxA-38311 R_Date(1825,28)
95.4% probability
90 (1.1%) 100calAD
123 (92.9%) 253calAD
303 (1.3%) 314calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

A discrepancy between relative and absolute chronology was revealed in some cases. The analysis in the case of the sites of Vojlovica (g. 13), Vršac (g. 9), Šajkaš (g. 9), and Verušić (g. 84) showed deviations of a century, while in the case of Detelinara 2 (g. 11), the AMS dates showed the difference of two centuries. The biggest discrepancy was found between two individuals from the sites of Verušić (g.77) and Velebit (gr. 24) which, according to AMS dates, are dated to the early Middle Ages, which deviates significantly from the previous chronology that dated them to late antiquity. These two graves could be the result of the subsequent mixing of skeletal material after archaeological excavations, considering that both sites are multilayered. Such results certainly point to the need for systematic dating of Sarmatian sites and revision of skeletal material.

5. DISCUSSION

The first part of the research was related to the discussion of how grave reopenings affected bone preservation and altered the burial environment.

Different taphonomic processes naturally influence skeletal preservation in the grave environment, while additional post-burial disturbance also influences skeletal decomposition and disrupts the ongoing process. Beside physical damage of bones or body, post-grave disturbance changes the burial microenvironment, by inversion of soil layers during plundering, allowing an additional influx of oxygen and exposing the body or skeleton to subaerial weathering if the grave pit is left open.

In Sarmatian cemeteries in Vojvodina archaeologists discovered secondary pits, extra bones, bone fragments in the upper layers of the grave pit, scattered skeletons *in situ* and unusual skeletal positions in some cases. These findings all pointed to the possibility of grave reopenings. [15,36-40] Distinct patterns of grave reopenings (partial or complete) were identified among these sites, which comprised various models of skeletal fragmentation and incompleteness.[15]

Several sites in the sample (Vojlovica, Vršac, Orlovat-Vodica, and Melenci-Kentra Lok. 18) showed indications of bone scattering during the post-burial reopening process. Matching the bone fragments found i*n situ* with those scattered in the upper layers of the grave pit suggests that skeletal parts were thrown from the grave and consequently, unintentionally deposited on the ground surface during robbery.[15] This assumption is supported by the incomplete skeletons in the grave and missing bones found in the upper layers. Such a scenario could happen only if a body was totally skeletonized at the time of robbery and the grave pit was not entirely filled after robbery. In this manner, when the natural process of soil sliding from the surrounding ground surface and filling the grave pit started, bone fragments combined with soil would eventually slip into the burial pit.[21]

Another direct act of plundering and the evidence of how graves reopening affected skeletal material could be seen in the form of postmortem cut marks on the bones from reopened graves. It is evident that diggers used sharp tools for digging during the process of plundering (to dig graves and look for items), which consequently damaged bones. Literature mentions possible equipment for grave digging, which includes ladders, stick-like probes, wooden spades, iron rods, or poles with a hook.[22,24,32] The position of the cuts on the bones matches the model of reopening (for example, cut marks on humerus are found on skeletons from graves reopened in the upper section). These marks, which are commonly found on the surfaces of bones from reopened graves, are recognized from the literature on grave disturbance.[28,31] The appearance of these incisions suggests that the graves were opened after the bodies had been skeletonized, and not protected by soft tissue. What distinguishes them from the possibility that they could have been created during modern excavations is the fact that the fractured lines are not fresh.

Direct physical manipulation of the skeletal material (scattering and throwing bones) due to grave shovelling could explain the low skeletal completeness. Namely, a certain percentage of the bones remained on the ground surface permanently, while the remaining part of the skeleton on the grave bottom was exposed to open air conditions, thus weathering. Grave diggers contributed to further bone breakdown, allowing various additional extrinsic, non-anthropogenic factors to influence bone preservation. It is well-known that bones deposited in a closed grave setting (covered by plants, soil, grave containers, etc.) weather more slowly because they remain moist for longer and are protected from the repeated effects of freeze-thaw cycles, which eventually cause bone crackings.[59] This indicates that the violent uncovering of the graves would undoubtedly disrupt the natural process of body decomposition and bone alterations.

According to this study, 37% of individuals from reopened graves had signs of exfoliation due to subaerial weathering that could be clearly confirmed macroscopically. Known patterns of weathering (cracks, fractures, flakes, grooves, rough structure, or sun bleaching)[72] were observed on these bones. Moreover, not only taphonomic changes were observed in the sample but also different degrees of bone weathering, which indicate the time continuity of exposure of the skeletal material to external influences, which gradually led to the increasing disintegration of the bones in the Sarmatian graves.

Highly weathered bone, beside surface changes, also displayed an extensive crack penetration into the bone's microstructure, together with the emergence of additional nearby micro-cracks. We can assume extensive and long-term bone exposure to environmental conditions given that deeper flaking characterises the advanced stage of bone exfoliation and may be related to the process of freezing and thawing due to changes in temperature.[59,73] The last phase of bone weathering, when the bones fall into fragments, which was observed in a couple of cases in the sample, can be an indication of an extremely long exposure of the skeletal material to the surface and that the grave remained open for a long time after the robbery. Moreover, this situation could explain the archaeological comments about the presence of complete skeletons during the excavation and the subsequent lack of skeletons for analysis because the bones completely disintegrated during lifting. In addition, the emptied graves would further confirm this theory, thereby unequivocally ruling out the theory of symbolic burials and once again pointing to the influence of grave reopening on skeletal preservation.

The bones from some reopened graves, particularly those from the Vojlovica and Verušić assemblages, had an extraordinary bleaching along with exfoliation patterns on cortical bone. In contrast, the bones in intact graves had a typical ivory-like colour (Figure 25).

Figure 25. Colour staining between reopened and intact graves: (a) bleached bone from reopened grave, grave no. 3, Vojlovica-Rafinerija; (b) usual bone colouration in intact grave, grave no. 5, Vojlovica-Rafinerija

The sun bleaching process, which is thought to be the main cause of post-mortem bone alteration, may be responsible for the discolouring of these bones.[73] Forensic literature states that if the bones are affected by sunshine UV radiation, this will alter the normal bone colour and bones become bleached.[73] The amount of time the bone was exposed to the light influences this discolouration. This type of alteration is usually followed by additional external conditions (cold, heat, moisture, wind) and thus exfoliation patterns.[69] Since some of the bones from the reopened Sarmatian graves entirely lost pigment and underwent additional exfoliation changes, it could be assumed those bones underwent long-lasting bone exposure to solar radiation and additional weathering changes.

All of these discoveries suggest that the reopened graves were left open for a considerable amount of time after the first reopening, exposing the skeletal remains to environmental factors that contribute to weathering, such as sun radiation, precipitation, and temperature inversions. Particularly, advanced and intense bone taphonomic alterations (exfoliation with deep, elongated cracks and fractures on the cortical bone and in the medullary cavity) highlight that evidence. According to forensic literature, advanced bone weathering-when bones have completely lost their organic components-leads one to believe that scavengers were not interested in such bones.[60,74] This fact could be the explanation for the total lack of animal activity (gnawing) on the Sarmatian assemblage.

It is important to take into account the season, time of the year, when the graves were reopened because it has been discovered that extreme temperature changes throughout seasons like fall and spring promote much more severe bone degradation.[73] Sarmatian sites show a high degree of looting, with over 50% of graves having been opened. In this context, the systematic and multi-century plundering of graves had to take place in different weather conditions.

The first disturbance of the burial environment was directly induced by grave reopening, and this greatly contributed to bone exposure, which further promoted the impacts of other taphonomic factors and resulted in extensive bone destruction. Emptied graves may serve as a most representative indicator of such occasions, meaning that during intense grave robbery content of the grave was completely emptied, and if any bones survived the robbery act, they were well-suited for the weathering processes that ultimately resulted in the total disintegration of the bones. All these findings also point to a particular socio-cultural component of the grave robbing phenomenon, namely the negligent actions of the perpetrators, while also raising concerns about the existence of a local community that could provide care for dispersed skeletal remains following systematic grave disturbance.

Research on **burial disturbance** in Vojvodina revealed systematic reopening in 62% of graves, with no site-to-site variations. The grave reopening revealed three distinct patterns of skeletal disturbance. Complete disturbance, where the majority of bones were missing, was the most prevalent (60%). Complete disturbance was followed by upper body disturbance (36%), with more or fewer bones missing, and a few empty graves (4%).

Reopening of the upper body section implies disturbance of the upper body (head, arms, forearms, shoulders, chest and hands), while lower body (from pelvis to feets) stays intact. This type of disturbance was discovered in more than 30% of the graves investigated, with two patterns of disturbance that could be distinguished, namely slight and heavy disturbance.

It is not unexpected that reopening a grave in the upper body region is a prevalent model in Sarmatian sites, as chest robbery is a common occurrence. The most important objects are supposed to have been hidden in this area, which is why the upper body is disturbed while the lower limbs stay in place.[30] This type of disturbance could be possible only if bodies were totally skeletonized by the time of the intrusion, giving the potential for diggers to dislocate and toss away the upper half of skeleton while the lower body remains in situ. The possibility that the lower parts of the body remained intact could have happened if the robbers opened only the upper half of the grave, if the soft tissues (ligaments, tendons) were still holding the body parts, or if burial structures or clothing were still in place at the time of the robbery and may have shielded lower body parts from additional disruption.[21] If clothing was already dissolved, items could have been removed without much disturbance behind. On the contrary, if items were still attached to the clothing or have fallen into the rib cage, disturbance of the upper part would be intense due to the plucking.[29] For example, grave no. 4 from Vršac-Neuropsihijatrija had a few fragments of a leather cloak and only minor bone dislocation of the upper body. In this case the cranium was not present, while the dislocation encompassed just the right arm, chest, and head area (Figure 26). While the cloak could keep the rest of the body intact, such slight disturbance was only conceivable if the upper body part was partially or entirely skeletonized. The existence of tissue during the opening of the graves could be ruled out as a possibility, given that discarded bone fragments during looting were found in the upper strata of the majority of these graves. This undoubtedly suggests that the bodies must have been skeletonized at the time of opening.

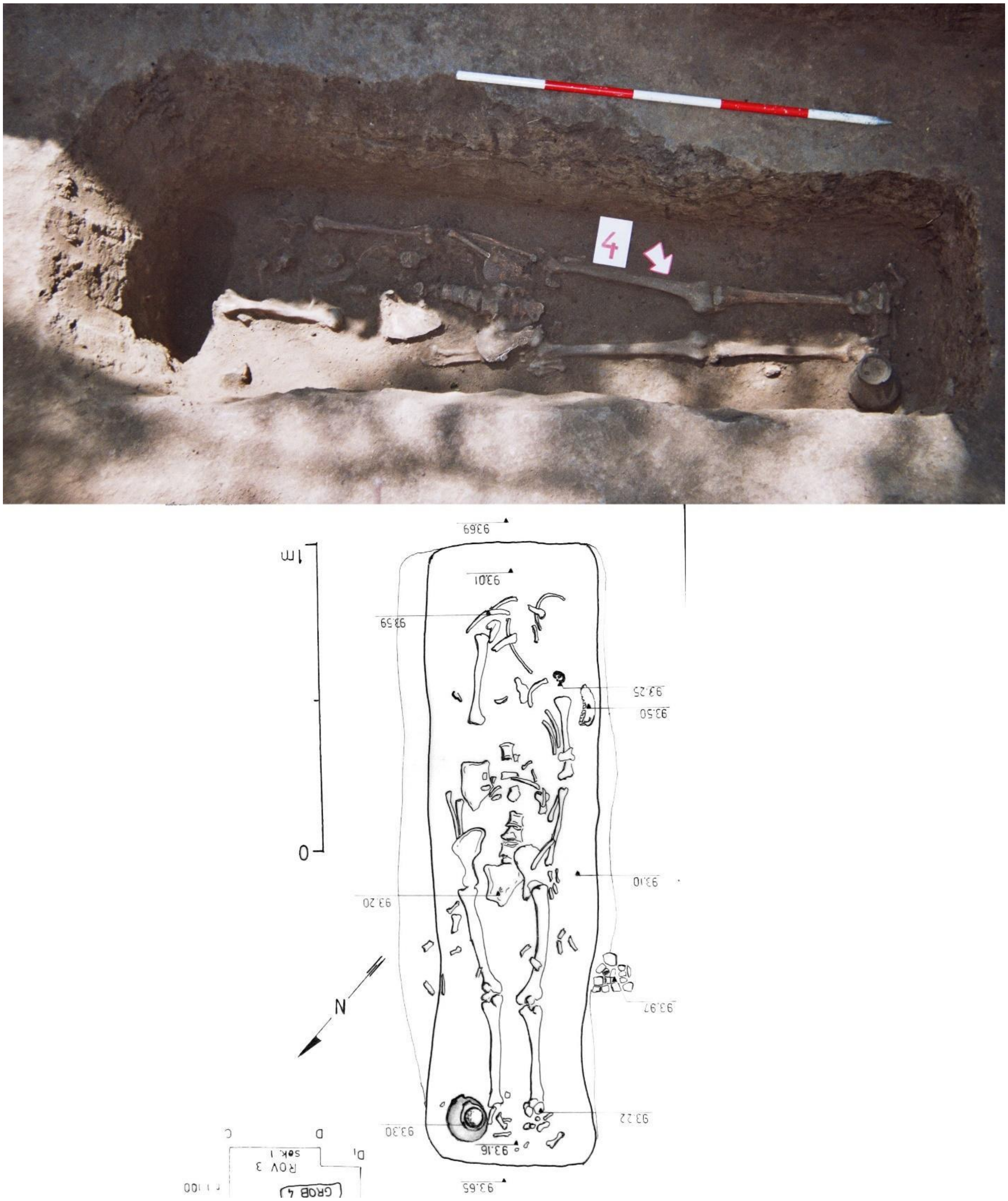


Figure 26. Example of slight bone dislocation in the grave reopened in the upper body part, grave no. 4, Vršac-Park Neuropsihijatrije (Probably Male, adult): The skull is missing, the left arm is i*n situ*, with a slightly dislocated forearm, while the right side of the upper extremities is completely dislocated downwards, so that the humerus is turned upside down, and the right scapula is positioned in the area of the right chest, at the level of the proximal edge of the right ulna and radius. The lower parts of the spine are connected to the sacrum (lumbar vertebrae intact), the pelvic bones are intact and anatomically connected to the lower extremities

However, minor bone dislocation in grave apart grave reopening may also result from the body decomposition process (body treatment) and crushing of burial structures such as coffins, chambers, and frameworks, which can cause bone movements inside the grave.[6,33] One of the interpretations is that if the body is placed in a filled-in space during the burial, after the decomposition of the tissue, the sediment will immediately fill that space, and thus no bone movement will occur and the connections between the bones will remain.[33] On the other hand, if there is some funerary architecture (coffin, sarcophagus, cofferings), after the disintegration of the container, there may be a significant bone disturbance, and the anatomical connection between the bones will disappear.[33] Grave no. 3 from Orlovat site, classified as upper robbed, may provide an illustration of this circumstance, given that the upper body parts and head were present but fully commingled, while the lower body portion was articulated and in anatomical position (Figure 27).

Figure 27. Minimal bone dislocation in grave reopened in the upper body part (Adult, indeterminate sex) with detailed illustration of the bone dislocation – lower extremities are still connected, while skull is disconnected and slipped on the left side, left arm is positioned on the right side of the body and anatomical connection is lost

It appears that bone displacements were restricted to the body boundaries. Grave finds were also found in the grave (coin, buckle, vessel). Archaeologists observed the presence of organic material and the reddish-coloured soil and bones, which may suggest the presence of prior coffin structures even in the absence of clear archeological evidence of a coffin structure (traces of wood or clamps). Such a case could indicate that archaeologists in some cases misinterpreted grave robbery, based only on the dislocation of the remains, disregarding archaeothanatological knowledge. In that case, grave no. 3 Orlovat-Vodica could be classified as an intact grave rather than reopened. For other graves with mild bone dislocation (Cerba g. 2, Vršac-Neurospihijatrija g. 18), we could rule out this hypothesis since the graves often had a considerable number of missing bones in addition to damaged upper body parts (Figure 28). Additionally, in those graves, small fragments of bones were found in upper layers, which could evidence the throwing of bones during the grave intrusion. In grave no. 18 from Vršac, leather traces were found around the trunk and legs, which led archaeologists to assume the presence of a cloak. The presence of leather cloth could hold the lower body parts *in situ*, while the upper body parts (most likely skeletonised) were thrown out of the grave.

Figure 28. Bone displacement in graves reopened in the upper body part: (a) grave no. 2, Mihajlovo-Cerba (Male, adult); (b) grave no. 18, Vršac-Park Neuropsihijatrije (Probably male, adult)

Heavy disturbance of upper limbs was a more common method of plundering, evidenced at several sites. Traces of wood were found in only one grave with upper body disturbance (Vojlovica g. 5), for which we can assume the presence of the burial structure and completed skeletonisation at the time of the robbery.

In this category, quite often the disturbed skeletal parts remained anatomically connected in situ. So, in the case of grave no. 13 from Vršac, the left ulna was missing, but the left radius was still anatomically connected to the bones of the left hand (Figure 29a). Likewise, in the case of grave no. 9 from Vojlovica, a large part of the bones of the trunk was missing, the right side of the skeleton was disturbed, while the left upper arm and forearm were joined (Figure 29b). These instances demonstrate once more that even though the bodies were skeletonised, the skeletal remains of these people were probably encased in a container or clothing, which stopped the bones from dislocating further. Undoubtedly, the possibility still exists that tissues in certain body parts (such as the legs and pelvis) could have retained the ability to hold bones in place.

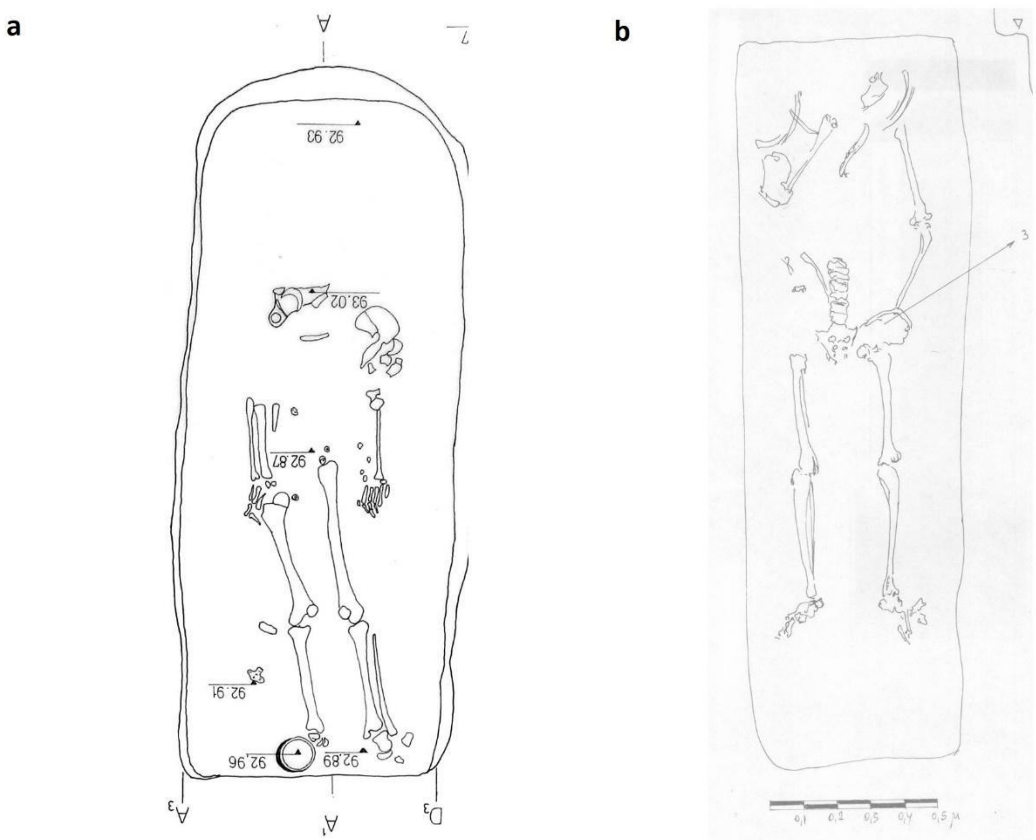


Figure 29. Anatomical connection in graves reopened in the upper body part: (a) grave no. 13, Vršac-Park Neuropsihijatrija (Male, adult); (b) grave no. 9, Vojlovica-Rafinerija (Female, young adult): The upper parts of the body are missing or disrupted, while the lower extremities (from the pelvis down) are anatomically connected

Phenomenon of precise upper body reopening in Sarmatian sites could mean that the perpetrators had special knowledge about the orientation and position of the body in the grave and were planning to access the goods surrounding the head and trunk. However, such information could be feasible only if the graves had overground markers or the diggers were acquainted with the burial customs. It is not ruled out that after drilling the first hole in the cemetery, they would gain experience with body orientation especially given the fact that typical Sarmatian orientation for all periods was south-north, with heads facing south with a few minor exceptions.[12] Thus, reopening operations might be facilitated by such a standardised orientation, particularly for foreigners.

At the Sarmatian sites that were studied, the most common act of grave reopening was the **complete disturbance of skeletal remains**. Bones were discovered commingled along the pit's bottom, with most bones missing from the grave. This model might be typical in situations where the corpse was already completely skeletonised at the time of the intrusion. Most likely, the coffin was undamaged at the time of the robbery, so items could have been searched using a tool through a hole cut into the coffin lid.[75] In the case of a coffin cavity presence, moving bones and other grave furnishings would not seriously harm the grave's contents. This kind of situation could be recognized in several examples at Sarmatian sites (Verušić g. 83; Vršac-Neuropsihijatrija g. 5, 7, 21; Vojlovica-Rafinerija g. 4, 15; Mihajlovo-Cerba g. 1; Futog-Klisa g. 3; Verušić-Azotara g. 83), where bones were pushed aside in the corner or at the grave's boundary (Figure 30). This implies that at the moment of the intrusion, there was a coffin cavity present, which suggests that the coffin must have been intact or partially intact.[76,77] Even though direct evidence of coffin presence has been confirmed only for the grave no. 83 Verušić-Azotara (coffin clamps), the position of bone displacements in other cases suggests the presence of a coffin cavity.

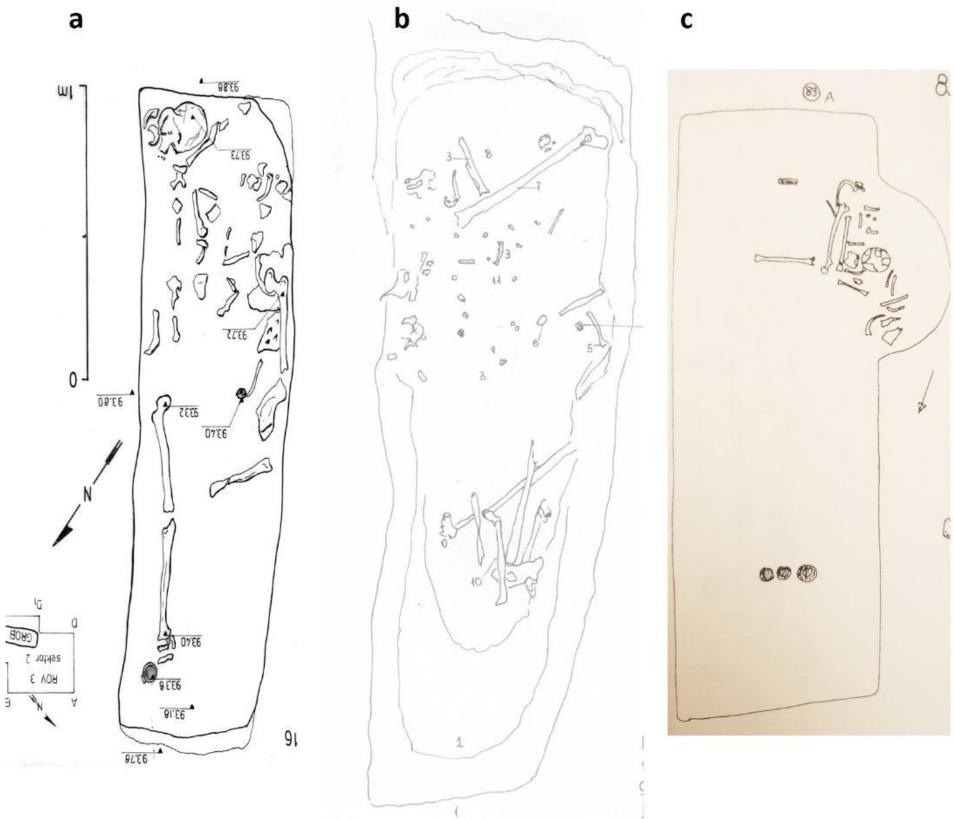


Figure 30. Bone displacements in graves with completely commingled bones and possible coffin presence during the robbery: (a) complete bone dislocation with only the left leg being anatomically connected and *in situ*, grave no. 5, Vršac-Park Neuropsihijatrija; (b) completely disturbed bones with no anatomical connection *in situ*, grave no. 4, Vojlovica-Rafinerija (Probably male, adult); (c) a small amount of fragmented bones pushed into a pile, grave no. 83, Verušić-Azotara (Male, adult); (d) complete absence of the bones of the chest and pelvis, while the skull and extremities have minimal dislocation, grave no. 3, Klisa-Futog (Infans II)

Intense disturbance with only few long bones or single bone was identified in few cases (Vojlovica g. 3, 25, 30, 49; Vršac g. 5, 9). In two of these graves (Vojlovica g. 25; Vršac g. 9), archaeologists detected fragments of bones in the upper layers during excavation. Anthropological analysis showed that those bones match missing bones in those graves, once more confirming that during plundering the skeletal parts were thrown outside of the grave, causing the presence of only a few bones in the grave during excavations.

Another possibility for entirely disturbed graves is that the diggers did not know where to look for inventory, so they thoroughly damaged the grave and made several uneven trenches in it. It is also possible that the significant disturbance was caused by several activities (multiple robberies), resulting in significant bone damage; however, this would be difficult to differentiate from exhaustive single reopening. Nevertheless, archaeologists consider that graves in the Great Hungarian Plain were looted twice: once soon after the funeral, when the bones were not disturbed, and again when bodies were decomposed, causing damage to the entire contents.[78]

In this reopening model, the existence of anatomical connections between the displaced bones was not observed. The bones in those graves were mixed; for example, the pelvic bones were placed at one end of the grave, and the proximal part of the femur was at the other end (grave 15, from Vršac), or the femur bones were mixed with the chest bones, while the feet were at the other end of the grave (grave no. 27 from Vršac) (Figure 30). This indicates that the individuals were fully skeletonised when the burial was opened, meaning that there was no anatomical connection between the skeletal components.

Figure 30. Examples of reopened graves with bones completely commingled without anatomical connections *in situ*: (a) grave no. 15, Vršac-Park Neuropsihijatrije (Female, young adult); (b) grave no. 27, Vršac-Park Neuropsihijatrije (Female, young adult)

Emptied graves in the sample demonstrate the lack of skeletal remains and other artefacts from the grave. They are typically recognised as signs of a grave being reopened soon after burial, when thieves might have completely removed the corpse that has not decayed.[21,79] Some researchers regarded them as the outcome of a more focused and intensified grave heist.[24]

The first argument could be illustrated by two cases from this study where skeletons were found in unusual position *in situ* with rotated body (Verušić-Azotara g. 45) and in sitting position (Verušić-Azotara g. 97). Both graves were classified as robbed by archaeologists, based on the skeleton position. Such unusual positions are not an uncommon finding in Sarmatian sites, because archaeologists recognized such cases in Hungary where skeletons were discovered in both sitting and standing postures, suggesting a robbery that occurred soon after burial.[50,77] It is believed that this performance demonstrates an action in which robbers could attempt to pull the body to the surface, leaving the grave empty at the end. Such evidence could suggest that at least some Sarmatian cemeteries were reopened immediately after burial. Except for these two cases in the sample, there are two additional from Banat (Banatski Despotovac – Kollinger kertek, Izbište), known from the literature.[80] However, those graves were excluded from this study because skeletal remains, although reported in archaeological reports, do not exist in the museum depots. Though the presence of such cases in Sarmatian necropolises may point to a particular practice of manipulating the body when reopening graves, it is important to remember that other social practices (deviant burials, rituals, clumsy act of funeral, etc.) may have contributed to these aberrant burials, which are not always linked to robbery.

The discovery of single bones on the grave bottom in two cases supported the scenario of intensive robbery, indicating that the reopening took place a long time after the skeletonisation. With only a few bones remaining in the grave pit, those empty graves were similar to the group of entirely disturbed graves, which were previously discussed. According to the literature, the intensive shovelling of the contents of the grave during plundering will yield similar results as empty graves.[30] This suggests that the both groups of graves—empty and fully disturbed—may have suffered an intensive or multi-robbery action. Although the archaeological data for the territory of Serbia do not show a detailed analysis of pits in the upper layers of the graves, finds in Romania from Sarmatian sites testify to such scenarios. Namely, at the Giarmata site (Tamis county), archaeologists recorded several irregular ditches in the stratigraphy of the grave, which indicate that robbers tried to find objects by opening several pits.[12]

The dislocation and mixing of the lower limbs only happened in situations where there was a total disturbance, maybe as a result of severe robbery. These discoveries may also suggest that the offenders were acquainted with the Sarmatians rituals as they could have known with accuracy the orientation of the body within the grave. However, it is also possible that the lower sections were uncovered initially accidentally at which point the robbers realised the body orientation and widened the pit, causing entirely grave disturbance.

Due to a lack of anthropological data, it appears that a comprehensive investigation of potential changes in the proportion of reopened adult female or male burials for the Sarmatian cemeteries is not conceivable. Nevertheless, no sex-specific variations of the model of grave disturbance were found for the cases where anthropological data was available. Children's graves were also not spared from reopening. Finally, the proportion of reopened graves in Vojvodina suggests systematic plundering rather than selectivity in the choice of grave opening.

In the following text, we will discuss the archaeothanatological evidence that helps in the reconstruction of the time-frames for interpretation of post-burial activities on Sarmatian sites.

Based on the position and anatomical connection of the skeletal parts in the reopened graves, researchers have established several chronological frameworks that could more closely determine the time when the graves were opened. Such observations are based mainly on forensic and archaeothanatological knowledge, which follow the context, analysing the degree of decomposition of the body and the presence of the grave structure. Four phases of the grave reopening were distinguished according to authors.[32,35]

The first phase refers to the grave reopening relatively soon after the burial (one year later) while the body is still in the ongoing process of decomposition. At this stage, the body, and thus the skeletal remains, would have remained intact, and the finds would have been stolen without any dislocation of the body.[32,35] This situation can be also applied to the findings of skeletons in the unusual positions, which was identified in two mentioned graves from the Verušić site, found in a sitting and rotated position. This would mean that the perpetrators, when opening the grave, found bodies that they could manipulate by pulling, which would ultimately result in the presence of complete skeletons *in situ*, but in an unusual position. However, one should be careful with the interpretation here because there are other sociological phenomena that could have led to such positions of the skeleton, without being related to looting, especially because bioanthropologists were not present at the time of discovery, meaning the absence of detail archaeothanatological investigation on the site.

The second stage of reopening would refer to a period of approximately 10 years after the burial, when the body should be skeletonised but still partially articulated. The joints of the pelvis, lumbar vertebrae and knees remain for several years after burial[32,35], and even if the other soft tissues completely disappear, parts of the skeleton may still be attached by sinews, tendons or clothing. However, the skeletonisation process should be completed within 10 years in some conditions. This situation in the grave would be legible through the absence of dislocations or through the findings of minimal dislocations because the skeletons are still connected by tendons or clothes. It is considered that if there are findings of disturbance of skeletal parts in relation to the rest of the body, and that these disturbed skeletal parts are still articulated, this means that they could be an indicator of the opening of the graves while the body was partially skeletonised. This time frame could be recognized in our sample, in the subgroup of slight bone disturbance in graves reopened in the upper body parts.

The third time frame would represent the period up to approximately 35 years after the burial, when the coffin structure is still intact, considering that this is the average number of years it takes for the wooden container to decay (from 10 to 35 years). [32,35] Process of coffin decay could be influenced by both violent (destruction during the reopening) or natural causes. Therefore, skeletal appearance must be taken into account to make differentiation in those two occasions. If the coffin had disintegrated before the reopening, then the objects would have had to be mixed with the soil and detected in the upper layers. If bones and objects were found on the floor of the grave, it can be assumed that there was an open space inside the container when the grave was opened. The first case, when objects were mixed with soil, is extremely rarely recorded on Sarmatian sites. On the other hand, mixing of finds and bones in the grave *in situ* was recorded in all cases, which suggests the existence of a coffin. Moreover, in some examples, the existence of an open space of coffins can be assumed in the archaeological documentation (photographs), mainly in the category of graves that were robbed in the upper part of the body (Orlovat g. 3, Vršac g. 4, 18, Mošorin g. 4, Klisa g. 7) (Figure 32a,b). Based on the position of the skeletal parts in these graves, it is clear that there was a physical limitation in the manipulation of the bones during the robbery, because the bones that were moved were placed aside in a narrow space, which must have been conditioned by the existence of the coffin. Moreover, the findings of graves with bones gathered into the corner of the grave (Cerba g. 1, Vršac g. 21) (Figure 32c) from the category of graves that are completely disturbed also testify to the existence of coffins. The authors state that this kind of dislocation is possible only if there is a hollow space from the coffin, because otherwise the bones would not be able to mix and be manipulated by robbers in this way.

Figure 32. Grave disturbance and bone displacements in graves with possible coffin structure being present at the time of the robbery: (a) grave no. 4, Mošorin-Šajkaš (female, adult); (b) grave no. 7, Klisa E-75 (Infans I); (c) grave no. 1, Mihajlovo-Cerba (Adult, indeterminate sex)

The last stage refers to the opening of the grave 35 years after the burial, when the body should be completely skeletonised without the presence of organic material or grave containers, and the pit is filled with soil.[32,35] However, this time frame is difficult to distinguish from the situation in which the grave was opened many centuries later. Individual bones can be moved anywhere within the grave. [30,32,35]

The discovery of patina staining on bones from reopened graves may potentially provide some additional insight into the time when the graves were opened. Specifically, bone staining is possible when remains were skeletonised and bones came into contact with corroded copper artefacts (weapons, coins, jewellery). The precise assessment is not possible because the time required for the bones to stain depends on the object itself (hardness, chemical composition), but also on environmental factors (pH soil, moisture, grave depth).[24] However, it is estimated that the upper limit would have to be 35 years after death, and the lower limit would have to be at least one year after death, after the skeletonisation process had advanced.[24] Remains of patina on the bones from the Sarmatian assemblage were present to a large extent (23%), which certainly once again confirms that the graves were opened after the skeletonisation process was completed.

The next section will deal with the analysis of skeletal preservation in intact graves, which undoubtedly testify to existence of additional causes responsible for low skeletal completeness in Sarmatian sites.

Detailed investigation of the skeletal remains in both reopened and intact graves was conducted to quantify the degree of skeletal completeness and fragmentation. In comparison to the contents of intact graves, the results indicated significantly lower indexes of skeletal completeness (BRI) and skeletal fragmentation (IBF) in reopened graves. Given the proportion of reopened graves, such results were expected; however, it was surprising that there were lower values of skeletal preservation and fragmentation even in intact graves. Namely, a direct correlation should be expected between skeletal completeness and the reopened graves; nevertheless, intact graves with relatively poor preservation (average BRI index score of 0.61) suggest that there may be other factors contributing to the incompleteness and fragmentation of the Sarmatian skeletal remains. It was anticipated that the skeletons in some of the intact graves represented subadults, for which poor preservation is not unexpected given the recognized weak morphology and susceptibility to decay.[3,50] However, in addition to other intact graves, eight adults were found, all perfectly preserved *in situ* but fragmented during the exhumation procedure.

Extrinsic factors such as soil composition should be excluded as it has been shown that bone preservation in Sarmatian graves was not significantly affected by these factors-[63,64] Our results also indicated that there was no correlation between the grave depth and skeletal completeness, meaning that this factor should also be excluded. However, taphonomical observation revealed that all these skeletons from intact graves had bone modifications on the anterolateral and posterolateral bone aspects, which may be related to the coffin burial structure—the impacts of which will be discussed later. Therefore, it appears that Sarmatian funerary practices contribute to the anthropogenic effects that cause bone alteration in the burial context and impact skeletal preservation. For example, the skeletons from grave no. 5 from the Klisa-Futog and grave no. 19 from the Vršac site undoubtedly showed poor preservation *in situ*, as well as the presence of a coffin (linear delamination, red colouring of the soil), which was confirmed by the taphonomic analysis of the skeletal remains (red pigment on the bones, coffin wear changes) (Figure 33).

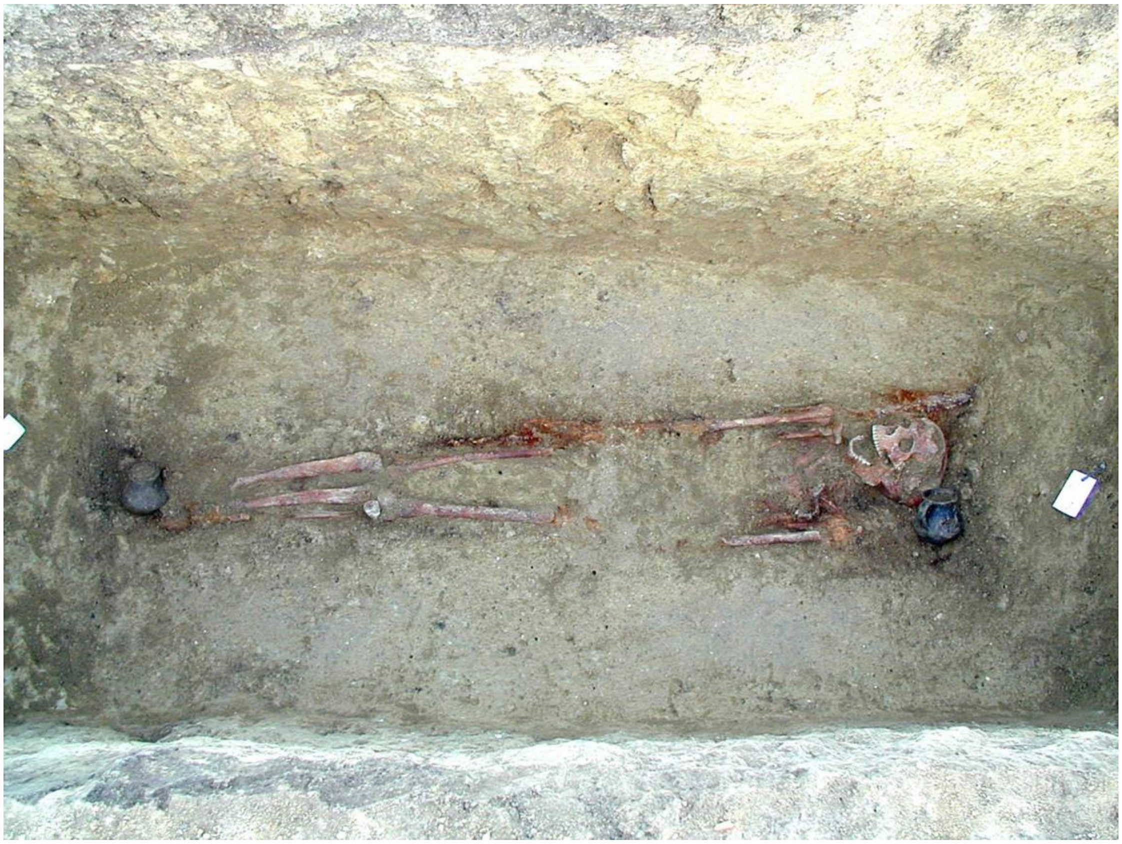


Figure 33. Skeleton preservation of adult individuals *in situ* with signs of coffin presence (intact grave), grave no. 5, Klisa-Futog E-75

The significance of the coffin in relation to inadequate bone preservation will be examined in the following section of the discussion.

The effect of coffin-related decay on skeletal remains is an uncommon topic in anthropological studies, with almost no research addressing these issues. The only research focusing on this topic is represented in the field of forensic anthropology, through discussion as to how the bones are impacted by the chemical degradation of the coffin (by creating coffin wear changes) in forensic context.[59,60] In addition, archaeothanatological research sheds light on how skeletal remains might shift in a burial context and break under the weight of a coffin. In this regard, there are no extensive studies on how and to what extent different types of coffins can affect skeletal remains.

The findings of coffin wear changes on the bones from the Sarmatian context are a significant discovery for understanding the phenomenon of poor preservation of this skeletal material, which until now has not been recognised and was explained exclusively as a consequence of grave robbing. This represents a complete novelty for the understanding of taphonomic characteristics and the way in which anthropogenic factors (Sarmatians ritual burials in coffins) indirectly influenced the poor preservation. The findings of coffin wear changes are typically found as erosions on the posterolateral aspects of the bone surface. This indicates that bone is dissolved by direct contact between wooden structures and skeletal remains because of accumulation of acidic groundwater in the coffin.[59,60] In each grave with archaeologically confirmed presence of coffin structure (nails, clamps, wood), coffin wear patterns were observed on long bones. However, in some intact graves without archeological evidence of a coffin structure, those changes were also found, suggesting that coffins may have also been present in those graves and contributed to the poor skeletal preservation.

Conversely it should be mentioned that the skeletal fragmentation may also be impacted by the collapse of the wooden construction. Furthemore, in relation to the systematic opening of graves and violent destruction of a coffin lid, the normal process of coffin decay is changed with more bioturbation to grave settings and the surrounding environment. This must have caused sudden fall of the soil sediment, which could have caused the bones shifting and finally bone crushing[6]. Cases belonging to the category of graves opened in the upper parts of the body, where the existence of the coffin at the time of the grave opening is assumed, could undoubtedly depict this situation. This may further explain the low skeletal completeness of the sample, assuming that bones already compromised by chemical degradation of the coffin were further damaged by the physical destruction of the coffin during the robbing. Furthermore, it should be borne in mind that the poor skeletal preservation of Sarmatian assemblages could even be a result of the natural decay of grave containers, especially because of the compactness and weight of solid coffins made of heavy trunks. For example, the skeleton from grave no. 4 from Vršac displayed a fracture line along its entire length on the posterior side of the tibia, related to crushing of the cylinder[4], which may be related to the pressure of the coffin's disintegration. The same pattern could be recognized with the skeletal remains from grave no. 1 from Orlovat, where an identical fracture line was observed on the tibiae, while the other bones showed coffin wear changes on the posterior parts (Figure 34).

a

b

Figure 34. Signs of the impact of coffin decay on skeletons in Sarmatian graves: (a) crushed bone cylinder in form of longitudinal cracking on the tibia shaft, grave no. 4, Vršac-Park Neuropsihijatrija (Probably male, adult); coffin wear changes on calcaneus, grave no. 1, Orlovat-Vodica (Adult, indeterminate sex)

However, it should be noted that during the archaeological excavations, especially in the old campaigns, bioanthropologists were not present; therefore, the archaeothanatological analyses were absent in the final interpretations. The problem arises when archaeologists interpret post-burial activity (secondary opening of the grave due to robbery or other ritual) in the context of *in situ*, only based on bone movement without knowledge of the existence of the effect of linear delamination. Linear delamination effect is a term used in archaeothanatology to describe the condition in which disturbed bones *in situ* are moved outside the initial body volume, towards the edge of the grave due to the existence of a physical barrier - containers. Such evidence very often helps the reconstruction of funerary architecture inside the grave, because based on bone movements, it indicates the existence of some kind of burial structure, which may not have clear archaeological evidence (fragments of wood, nails or clamps), which is why archaeologists often misinterpret the context and assume post-burial activity.[6,33]

One such case could be the skeleton from grave no. 3 from the site of Orlovat, where archaeologists assumed the opening of the grave based on the disturbance of the upper part of the skeleton, while the lower part remained intact. The existence of a secondary pit or bioturbation of the sediment, as well as bone fragments in the pit fill, were not recorded, and the objects in the grave were found *in situ* (a coin and two clasps in the pelvis area, a vessel in the leg area). According to archaeological evidence, organic matter was found in the grave, following the skeletal axis, but the existence of the coffin was not discussed. The length of the grave was 2.5 m, and an adult individual was buried in the grave. The skeleton was in an evidently poor state of preservation during the excavation. Spatial distribution of skeletal elements of the upper part of the body, as well as red staining, may indicate the presence of a coffin, which could have caused bone movements during the decomposition process. All the bones of the upper part were present except for the right hand, and the bone disturbance was visibly limited by the existence of the structure (container), which is why all the displaced bones followed the original body void space. Taphonomic analysis showed red staining on the bones. All these parameters indicate that the dislocation of the bones could have occurred due to the disintegration and crushing of the coffin lid. Therefore, this case could be an indicator of a misinterpretation of the existence of post-burial practice - the grave reopening according to the model of opening the upper part of the skeleton and minimal dislocation. Apart from this case, no other such debatable cases were found among the looted graves.

Despite the fact that only a small percentage of graves had direct archeological evidence of coffins, their presence can be inferred from the graves' dimensions because it is generally known that coffin-containing graves are noticeably larger than those without.[12] Additionally, considering the recent excavations of Sarmatian sites from the same period in Romania and Hungary, one could predict a higher presence of coffins and wooden or vegetative structures within the sample.[12,81]

The study sample's skeletons with altered coffin wear all come from the graves that ranged in length from 2.10 m to 3.53 m, with other graves measuring less than 2 m. Furthermore, the coffin staining may be related to the dark staining on the bones. Specifically, coffin-derived skeletal material exhibited dark staining due to tannins found in the wood of the coffin, with the staining primarily affecting the skeletal parts that came into close contact with the coffins.[82]

Archaeologically, two types of coffins can be recognized in the Sarmatian burials: the simple funerary bead/bier, which is likely finished with textile or leather sheets, and the substantial box-type wooden coffins with heavy lids, made from tree trunks.[12] Given that the skeletal remains in simple coffins suffered great damage, one may wonder to what extent tree-trunks could then destroy the skeletal material due to the solid structure of that coffin type, which could destroy bones on all sides, not only on the posterior side. This means that the space between the coffin walls and skeletal remains was narrow, creating more direct contact between the coffin walls and bones. Furthermore, skeletal remains may be more severely damaged by the collapse of a lid from a solid coffin than by the hollow, basic design of a burial coffin.

The last part of this thesis is focused on the synthesis of all previous evidence that explains the phenomenon of the opening of Sarmatian graves from the point of view of archaeology, bioanthropology and archaeothanatology.

When graves are reopened, archaeologists typically discover a modest **grave inventory** consisting of pottery, beads, and artefacts made of bronze, iron, and glass; nevertheless, valuable objects such as silver, gold, and semiprecious material are typically absent. The study sample supports this finding because gold jewellery was missing on studied cemeteries. It is believed that the early graves (1^{st}–2^{nd} century AD) in the Great Hungarian Plain have not been looted as much as graves from later times.[83] Moreover, silver or golden grave goods were found in few reopened graves (Vojlovica, Verušić).[36,39]

Due to the high percentage of post-burial reopening, funerary reconstruction for Sarmatian graves is fragmented, hindering our ability to fully understand funerary complexes and rituals. The materialistic value of items stolen and left in graves cannot be discussed with confidence, but we can notice a trend in the types of grave items that were left behind. Based on this, not only objects made of valuable materials were important, but also weapons in men's graves. On the other hand, it is known that the Sarmatian cemeteries contained golden objects, which may have contributed to their frequent and intensive robberies.[83] These assumptions were made based on the discovery of hundreds gold objects from Sarmatian burials from the Great Hungarian Plain.[83] Additionally, researchers found distinctions between the early Sarmatian period, in which many golden things were found in graves, and the later period, in which silver and bronze goods took the place of the gold items.

There are various hypotheses and opinions regarding the reasons why particular artefacts, whether purposeful or accidental, remained in the graves when it comes to interpretation concerning the findings left there. Numerous explanations, including insufficient time for reopening pits, abrupt robberies, or falling in reopening model, could be offered for why some occasionally valuable objects were left behind.[21] Additionally, it should be claimed that insufficient equipment could be responsible for the unintentional leaving behind of certain objects.[21] It is possible that some objects were missed because the robbers removed the grave goods using equipment like wooden spades, iron rods, or poles with hooks. Some researchers even assumed that a ladder was used.[24] Additionally, some items are said to have survived because thieves occasionally found it difficult to separate their prey due to clothing and soft body tissue[24] or were difficult to pick up due to small size (beads, spearheads, etc.).[27,31]

However, **taphonomic staining on skeletal material** can help overcome the limited interpretation for reopened graves. Numerous examples of patina staining on bones can be seen in skeletal material, especially in situations where archaeologists were unable to locate the corresponding items, which supports the idea that artefacts were stolen. These examples have been verified on the skeletons of adults and non-adults (temporal bones, wrists, fists, vertebrae, ribs, pelvic bones or legs). In these circumstances, the patina's position suggests that this might be proof of the previous jewellery. For example, patina staining was discovered on temporal and frontal bone and left hand of female adult from grave no. 9 at Šajkaš-Mošorin site (completely disturbed) (Figure 35a), while in the grave only beads and vessels were found. Another two cases were identified at Futog Klisa E-75 site (g. 8, child) and Orlovat-Vodica (g 2. adult, unknown sex), both reopened in the upper body section. In the case of Futog grave, patina staining was detected on temporal bone with no evidence of necklaces (only beads, fibulae, medallion, coins, bracelet). In Orlovat, patina was traced on radius and ulna bones (Figure 35b) without bracelet or any objects surrounding the arm (items found in the grave are beads, clasps, pot and spindle whorl).

Figure 35. Patina staining on bones from reopened graves suggesting previous position of taken grave items: (a) Patina on the left side of frontal bone from grave completely disturbed, grave no. 9, Šajkaš-Mošorin (Female, adult); (b) Patina staining on both ulna bones and radius bone from grave reopened in the upper part, grave no. 2, Orlovat-Vodice (Adult, indeterminate sex)

The authors usually contend that acts of grave reopening may have a variety of motivations, including religious, political, and other motivations in addition to materialistic one.[31] Nonetheless, there is no chronological or regional variation in the types of grave disturbance in a broad chronological framework, indicating once again a systematic phenomenon of grave reopening. Furthermore, it should be remembered that during Late Antiquity and the Early Middle Ages, the Great Hungarian Plain witnessed a great deal of migration (Sarmatians, Germanic tribes, Avars), warfare (Dacian wars, Marcomannic wars, Hunnic conquest, etc.) and raiding.[12-14] In such an environment, the occurrence of grave reopening can have both materialistic and political motives.

In many cases, models of skeletal disturbance demonstrated that the skeletonisation process was completed prior to the reopening period, indicating that graves were disturbed at least a few years or perhaps many years after the burial. Researchers point to the fact that Sarmatian cemeteries in the Great Hungarian Plain were opened several times, during the Hunnic conquests (from beginning of 5th century AD) and once again with the arrival of the Avar population.[13]

Since the study's sites date from the 2nd to the 5th century AD, robberies occurring hundreds of years later, when Huns or Avars arrived, would only be feasible if the overground marks were still present. This would enable robbers in any subsequent era to identify the grave and approximate the location of the body without having exact knowledge of the position of the deceased. According to several explanations from the literature, Sarmatian graves have been marked with wooden structures or stones that could be useful for robbers to indicate area of interest but in later periods.[14]

However, it is thought that the early Sarmatian graves (the middle of the 1st century AD to the 2nd century AD) were not marked in the field (ditches, barrows, or other such structures).[83] Thus, when new populations arrived a few centuries later, graves would not be visible on the field. Conversely, burial markers are well-known in later cemeteries (mounds, circular ditches).[83] In the study sample, such structures were rare, and were only identified at Verušić site.[39] However, even though there were not many mounds in Vojvodina, their presence should be expected on a much larger scale based on the discoveries in other territories.[84] This could mean that certain later cemeteries in the sample (Melenci-Kentra, Vojlovica, Orlovat, Vršac, Cerba-Mihajlovo, Verušić, Futog-Klisa, Klisa E-75, Šajkaš) could have been marked and recognized by Huns or Avars robbers. Another explanation might be that, as in the Čik cemetery, the Sarmatian and Avar groups used the same burial area at separate times, which allowed them to acquire knowledge about Sarmatian burial rituals. The most direct participation of the Avars in the reopening of Sarmatian graves can be seen in the region, where researchers found Roman artefacts (coins, beads, pendants, arrowheads, etc.) in Avar graves, assuming that many of them may have originally come from the reopened graves.[85]

In order to more precisely date some cemeteries in the sample, **AMS radiocarbon dating** was performed, which also helped in the reconstruction of the reopening period in some cases. Namely, AMS radiocarbon dating shows the approximate date when the individual died, and thus represents the postmortem interval - the time frame in which grave reopening and robbery happened. This was possible for a few graves in the sample (Verušić-Azotara g. 77; Vojlovica-Rafinerija g. 5, 13, 32; Vršac-Neuropsihijatrija g. 4 and 9; Šajkaš-Mošorin g. 9). If these data are incorporated into the bioarchaeological and archaeothanatological results, a more precise reconstruction of the period in which some graves were opened, and thus the identity of the robbers according to historical data, can be obtained.

Few examples in the study illustrate such possibilities. Grave no. 4 (adult male) at the Vršac site was robbed in the upper body with minimal bone disturbance (only the right shoulder and cranium were displaced) and some of the items were left intact in the grave (iron brooch, vessel). Skeletal displacement suggests that at the time of the robbery the skeletonisation process was finished (bone fragments in all of the top layers), yet with coffin structure being present and intact (minimal bone dislocation, coffin wear changes). According to archaeothanatological principles, this grave could be reopened between 10 and 35 years after death (open space from coffin, skeletal displacements, intact objects in the grave). The calculated AMS date for this grave is 409 AD, meaning that grave reopening occurred sometime in the first half of the 5th century AD. In a historical context, this would mean that the Huns or some other population could have robbed this grave, but not the Avars. Similar situation could be followed in the case of grave no. 5 (male, adult) from Vojlovica. The grave was reopened according to the same model (upper body disturbance), yet with more bone disturbance. In this case too, it can be concluded that the grave was opened after the skeletonisation process was completed and that the deceased was buried in a coffin (fragments of bones and wood in top layers, intact lower body portion and items around legs, coffin wear changes on the femora, length of 2.90 m). The AMS date for this grave ranges from 230 to 235 AD. Considering the archaeothanatological findings, this grave could have been opened in the period of 10 to 35 years after the death, which means that it was opened in the second half of the 3rd century AD, ruling out the possibility that Huns or Avars were responsible for this robbery. However, for another grave from the same site (grave no. 13), reopened by the same model, the AMS date suggests 420 AD, which could be related to the Huns. These two cases from the Vojlovica site indicate that these graves were opened in different time periods (in 3rd and 5th century), meaning that robbery activity occurred a minimum two times. Given that there is a substantial temporal difference between those reopenings, this would suggest that one population could not have opened these graves, and that the theory that the Huns and Avars were the only plunderers of these Sarmatian cemeteries is not valid.

Other graves with determined AMS dates (Vojlovica g. 32; Vršac g. 9; Šajkaš g. 9) belong to the models of graves entirely opened and without physical evidence of coffin structure (neither coffin wear changes, wood traces, clamps, nails, etc.). Absolute AMS dates for those graves range from 334 AD to 418 AD, but the more precise time of the grave opening according to archaeotanatological or taphonomic evidence could not be reconstructed. Grave reopening could have happened in a later period in these cases, which could be related to Huns and Avars or other communities.

Overall, these findings reveal that Sarmatian graves, apart from Huns and Avars, had to be opened by some other populations, maybe even local ones. It should be borne in mind that the area of Banat and Bačka was inhabited by different Sarmatian tribes, where Jazygi lived in the present day territory of Bačka, while Roxolans, lived in the present day Banat region, supporting different alliances[86], and thus becoming each other's enemies. In such a context, it could be possible that the Sarmatian tribes plundered each other, which could explain the good knowledge of the burial complex and therefore the precisely chosen model of grave reopening. Moreover, historical sources mention the Roxolani tribe as being more interested in looting than fighting during attacks on the Roman provinces on the Danube in the 1st century AD, which testifies about the character of the events during turbulent times and adds a new dimension to understanding the context of general wartime plundering.[87]

Furthemore, the presence of a local community in the opening of graves can be seen through the very phenomenon of grave reopening. For example, researchers dealing with reopening phenomena of Merovingian graves stated that it would take a long time to excavate deep graves, which would make it impossible to do so covertly. This suggests that the community either approved or accepted this phenomenon in general.[31] The same may be stated for Sarmatian cemeteries, where a large percentage of reopened graves and their sizable proportions make it difficult for this action to go unnoticed, particularly considering the proof of bone weathering, which again supports the idea that graves were left open for a long duration after they were reopened and that cemeteries' layout changed (reopened graves, mounds, dispersed bones on the ground surface). Therefore, it appears that either Sarmatian cemeteries were robbed at the time when local community and descendants disappeared, or they somehow accepted this phenomenon, possibly even taking part in it. Conversely, early cemeteries were probably reopened by the local or contemporary people, who were either present for the burial or knew how the cemetery was laid out. The act of returning to the cemetery and removing burial goods after they had fulfilled their purpose during the funeral was recognized as the concept of the community robbing their own cemeteries.[21,24] Reopening graves immediately after burial implies that interment occurred when the cemetery was still in use or in proximity, and it would indicate a customary practice among Sarmatians.

6. CONCLUSIONS

In this thesis, we examined the relationship between the practice of reopening of Sarmatian graves in the past and the preservation of skeletal material. Additionally, we investigated the possibility that other factors may have contributed to the poor preservation of the skeletons.

1. The state of preservation of the skeletal remains from Sarmatian graves in Vojvodina is poor, particularly those from graves that were previously opened and looted. Skeletal remains from intact graves provide evidence that extra taphonomic agents, rather than systematic grave looting only, are responsible for the high degree of skeletal incompleteness and fragmentation.

2. Three models of grave robbery are identified by the skeletal incompleteness and spatial analysis of skeletal disturbance in robbed graves: complete opening of graves with intense skeletal disturbance; complete emptying of graves because of intense robbery; and opening of graves in the upper half of the skeleton with minimal or greater dislocation of bones. The archaeothanatological analysis shows that the graves were opened after the bodies had fully skeletonised, but possibly only a few years after the deaths.

3. Grave robbing directly affected skeletal preservation, which can be seen through bone scattering during grave content shovelling (cut marks, bone fragments in upper strata, broken bones *in situ*), as well as indirectly, leaving graves completely or partially open after the robbery. In these cases, taphonomic alterations on the bones point to extensive weathering of the skeletal material, which results from prolonged exposure to meteorological factors (snow, rain, sun, etc.) and varying seasons.

4. The Sarmatian burial ritual, placing the body in solid coffins made of tree trunks, further affected the degree of preservation of the skeletal material, as the bones were exposed to an acidic chemical reaction caused by the decomposition of the coffin, as evidenced by the findings of coffin wear changes. Also, violent crushing of coffin lid during act of plundering additionally damaged the bones.

5. The earlier conclusion that the Huns and Avars were only one responsible for the systematic looting of Sarmatian tombs was disproved when AMS results were integrated into archaeothanatological findings and demonstrated that some of the graves were opened between roughly 10 and 35 years after the death. The Huns and Avars may have been responsible for looting later necropolises, while graves from earlier periods were opened by other populations, local contemporary tribes, and possibly other Sarmatian tribes during turbulent times in the Great Hungarian Plain.

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Publications that originated from the work on this thesis

Research papers:

1. Pavlovic, T., Grumeza, L., Roksandic, M., & Djuric, M. (2022). Taking from the dead: Grave disturbance of Sarmatian cemeteries in the Banat region. *International Journal of Osteoarchaeology*, 32(3), 630–644. **IF 1.639 M22**
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3. Pavlovic T, Djuric M. 2024. Uticaj spoljašnjih tafonomskih faktora na skeletnu očuvanost - sekundarno otvaranje grobova na sarmatskim nekropolama. Medicinski podmladak, Vol. 75, br. 6. **DOI 10.5937/mp75-45142 M52**

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Tamara Pavlović was born in 1989 in Pančevo, where she finished elementary school and gymnasium. In 2016, she graduated from the Faculty of Philosophy, Department of Archaeology, University of Belgrade. Since 2010, she has been involved in the work of the Center for Bone Biology, where, as a student, she volunteers to analyse skeletal material from archaeological and forensic contexts. In the 2016–2017 academic year, she was enrolled in doctoral studies (course: Skeletal biology) at the Faculty of Medicine, University of Belgrade. Since 2017, Tamara Pavlović has been participating in several multidisciplinary scientific research projects funded by the Ministry of Education, Science, and Technological Development, Science Fund of the Republic of Serbia, investigating skeletal material from different periods and archaeological contexts in the territory of Serbia. She has also been actively participating in archaeological excavation projects led by the Faculty of Philosophy at the University of Belgrade. As a high school student, she became a participant in the Department of Archeology at the Petnica Science Center, where she actively researched archaeological material and published student papers. She later became a student associate and eventually the co-head of the Department of Archeology at the Science Center Petnica. The experience in pedagogic and educational work that she gained at SC Petnica is transferred to activities related to the promotion and popularisation of science, which is reflected in the participation and management of numerous projects at the Center for the Promotion of Science and events such as Museum Night, Researchers' Night, and the Science Festival. Today, she leads a non-governmental organisation, the Neozoik Foundation, which advocates for the education of young people and a wide audience in the field of protection and promotion of archeology and cultural heritage.

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